Prepared for Clallam County and the WRIA 20 Planning Unit

Water Resource Inventory Area 20
Phase II Technical Assessment

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WATER RESOURCE INVENTORY AREA 20 (WRIA 20)

FINAL DRAFT

PHASE II TECHNICAL ASSESSMENT REPORT

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&
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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

AET	annual actual evapotranspiration
AF	acre feet
ASCE	American Society of Civil Engineers
ASR	Aquifer Storage and Recovery
BMP	best management practices
BOR	United States Bureau of Reclamation
CARA	Critical Aquifer Recharge Area
CCC	Clallam County Code
cfs	cubic feet per second
CIG	Climate Impacts Group
CWA	Clean Water Act
DEM	Digital Elevation Map
DO	dissolved oxygen
DWAIN	Drinking Water Automated Information Network
Ecology	Washington Department of Ecology
EIS	Environmental Impact Statement
ENSO	El Nino/Southern Oscillation
EPA	Environmental Protection Agency
ESA	Environmental Species Act
ET	Evapotranspiration
FLIR	Forward Looking Infrared
GMA	Growth Management Act
gpdpc	gallons per day per capita
gpm	gallons per minute
GUI	groundwater under the influence
HCP	Habitat Conservation Plan
LFA	Limiting Factors Report
LWD	large woody debris
MCL	Maximum Contaminant Level
MOA	Memorandum of Agreement
mya	million years ago
NFP	National Forest Plan
NLCD	National Land Cover Database

NOAA	National Oceanic and Atmospheric Administration
NOAA/NWS COOP	NOAA/National Weather Service Cooperative
NOPLE	North Olympic Peninsula Lead Entity
NTU	Nephelometric Turbidity Units
NWS	National Weather Service
OFM	Office of Financial Management
ONRC	Olympic Natural Resources Center
OPGA	Olympic Peninsula Guides Association
PCHB	Pollution Control Hearing Board
PDO	Pacific Decadal Oscillation
PET	Potential Evapotranspiration
PRISM	Parameter-elevation regressions on independent slopes model
PWS	public water system
Qa	Annual withdrawal/discharge rate
Qi	Instantaneous withdrawal/discharge rate
QNR	Quileute Natural Resources
RCW	Revised Code of Washington
RM	River Mile
SADIE	System for Automated DWAIN Information Extraction
SASSI	State Salmon and Steelhead Stock Inventory
SDWA	Safe Drinking Water Act
SMP	Shoreline Master Plan
SNOTEL	Snowpack Telemetry
SOC	Synthetic Organic Compounds
SWSL	Surface Water Source Limitation
TMDL	Total Maximum Daily Load
TRS	Township Range Section
USDA	United States Department of Agriculture
USDI	United States Department of the Interior
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UW	University of Washington
VOC	Volatile Organic Compounds
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WDNR	Washington State Department of Natural Resources
WDOH	Washington Department of Health
WFPA	Washington Forest Protection Association
WRATS	Water Rights Application Tracking System
WOB	“WRATS on a Bun”
WRIA	Water Resource Inventory Area

1.0 INTRODUCTION AND BACKGROUND

1.1 Introduction to Phase II Planning

This Technical Assessment report summarizes the technical components of the Watershed Assessment for Water Resource Inventory Area 20 (WRIA 20). The technical components are intended to provide baseline information for development of management strategies in the Phase III Watershed Plan. The Watershed Management Act identifies one required element (water quantity) and three optional elements (instream flow, water quality, and habitat) of watershed planning. Based on direction of the WRIA 20 Planning Unit, this Technical Assessment includes the Water Quantity required element, as well as assessments of Water Quality and Habitat. The Instream Flow element will be included in the Phase III WRIA 20 Plan, to be produced in Fall 2005. Some background instream flow information is also included in this Technical Assessment.

The Water Quantity element of this assessment was conducted by Golder Associates Inc. (Golder), and includes a groundwater resources and geology, water allocation, water use, water balance, and land use component. Each of these components were presented to the WRIA 20 Planning Unit as draft Technical Memoranda for their review and comment. Each of the technical memoranda were revised, based on Planning Unit comments, and incorporated as Sections 2 through 5 of this report.

The Water Quality and Habitat elements for WRIA 20 were provided by the Olympic Natural Resources Center (ONRC), and are presented in their entirety in the *WRIA 20 Technical Assessment Level 1* (Hook, 2004). Relevant portions of the water quality and habitat assessments are incorporated into this Technical Assessment Report as Sections 7 and 9.

The Bureau of Reclamation (BOR) provided estimates of streamflow for all sub-basins within WRIA 20 with the exception of Sooes and Ozette. A report from BOR detailing the methodology for estimating streamflows is forthcoming and will be included as an appendix to this report. Streamflow data from BOR were used in the water balance (Section 5). Exceedance curves for five of the seven major sub-basins in WRIA 20 are also presented in Section 5.

This Technical Assessment Report contains specific elements that are intended to fulfill the requirements of RCW 90.82 for Watershed Planning, as summarized below.

Section	Requirements
Section 2.0 Groundwater Resources and Geology	RCW 90.82.070 (1a)(1b)(1f)(1g)
Section 3.0 Water Allocation	RCW 90.82.070 (1c)
Section 4.0 Water Use	RCW 90.82.070 (1d)(1e)
Section 5.0 Water Balance (Including exceedances curves for streams in the Watershed)	RCW 90.82.070 (1a)(1b)(1g)
Section 7.0 Fish Habitat & Distribution Section 8.0 Fish Plans and Policies	RCW 90.82.100
Section 9.0 Water Quality	RCW 90.82.090

1.2 Watershed Summary

The text of Section 1.2 is excerpted from the document written by Abigail Hook, submitted to the WRIA 20 Planning Unit on June 10, 2004 with minor changes made by the Planning Unit.

The 735,000 acre watersheds designated "WRIA 20" by the Washington Department of Ecology (Ecology) includes all rivers and streams that drain into the Pacific Ocean from Cape Flattery to Huelsdonk Ridge on the south side of the Hoh valley (Figure 1-1). The northern portion of the watershed lies within Clallam County, the slightly smaller southern portion within Jefferson County. The watershed includes the Usual and Accustomed Fishing Grounds and Stations for three Western Washington treaty tribes: the Makah, the Hoh and the Quileute Tribes. This watershed generally is characterized by streams that have headwaters in the Olympic Mountains upwards of 6000 feet in elevation and drain into lowland valleys. The largest basin in the WRIA is the Quillayute with four major sub-basins: the Dickey, Calawah, Bogachiel and Sol Duc. Other basins in the WRIA include the Hoh, Ozette, Waatch and Sooes as well as several independent streams that do not drain from the higher elevations of the Olympic Mountain core. Within the WRIA, there are 569 streams and 1,355 stream miles (Hook, 2004) with three major lakes, Ozette Lake (Ozette sub-basin), Lake Dickey (Dickey sub-basin) and Lake Pleasant (Quillayute – Sol Duc sub-basin). Annual rainfall in the basin is the highest in Washington State with an average of 80 inches near the coast to 240 inches in the Olympic Mountains. Streams flowing from much of the coastal lowlands are rain dominated while higher elevation streams are rain-on-snow dominated (i.e., mix of rain and snowfall). Several of the sub-basins on the eastern edge of the WRIA are glacially fed. The WRIA is often exposed to high winds and heavy rainstorms, which affect both vegetation and hydrology.

Undisturbed areas in WRIA 20 are naturally dominated by Sitka spruce (*Pincea sitchensis*) and western hemlock (*Tsuga heterophylla*) in the lowlands with silver fir (*Abies amabilis*) at higher elevations. Early successional species and riparian species often include hardwoods such as bigleaf maple (*Acer macrophyllum*) and red alder (*Alnus rubra*). Old growth stands are generally open canopied conifers; trees can reach up to 200 feet in height. As a result of logging and disturbance since the 1940s, much of the riparian tree diversity, size and abundance had been altered.

1.2.1 History

Before white settlement, the Quileute, Hoh, Ozette and Makah Tribes inhabited many areas of WRIA 20 in their numerous villages inhabited and used most of the land for hunting, fishing and gathering. The tribes today are on four separate reservations. However, the Ozette Reservation is under the treaty jurisdiction of the Makah Tribe and is currently managed for wilderness. All the tribes continue to use natural resources within their usual and accustomed places for sustenance, ceremonies, and commercial fishing. Many of the rivers are sites of ceremonial and cultural importance.

White settlement began in the mid 1800s in the Ozette, Sol Duc, Dickey, Calawah and Bogachiel watersheds. Much of the initial settlement was located on the Forks prairie where topography was conducive to farming. Both natives and early settlers used fire to clear the way for homesteads, farming and primitive roads. With the arrival of the railroad in the 1920s, commercial timber harvesting swept across the area and billions of board feet were exported. Extensive road networks accompanied the logging efforts except in Olympic National Park (protected as a National Park in 1938), which has remained relatively undisturbed. Logging continued through the 1980s but has slowed in scale and economic growth due to world timber markets, corporate agglomeration, and state and federal legislation.

1.2.2 Land Management

Limited riparian protection began in the 1970s and buffers of 50 feet were required on type I and II streams (i.e., large fish bearing streams). By 1982, streamside buffers of 50 feet were to be left on all non-federal fish bearing streams (i.e., type I to III). In 1990, a 200 feet minimum disturbance buffer with no clearcutting within 100 feet of Type I and II steams was required on national forest lands. In 1994, The Northwest Forest Plan was instituted in the Olympic National Forest. This plan has halted commercial harvests on federal land within the WRIA with the exception of occasional commercial thinning sales.

The Washington State Department of Natural Resources manages Trust Lands of the State and Clallam County under a Habitat Conservation Plan (HCP). The HCP was negotiated with the federal agencies that regulate DNR's timber harvest and associated impacts for species that are or could conceivably come under Endangered Species Act (ESA) protection. The Trust Lands are also subject to state regulation of timber harvest and other activities under the Washington Forest Practices Act and Shoreline Management Act. Private timberland is also regulated under the Forest Practices Act and Shoreline Management Act. The Forest Practices Act now also includes provisions a regulatory HCP, which were negotiated among federal, state, tribal and industry representatives. Provisions of this HCP have been determined to meet requirements of the federal Clean Water Act. Treaty tribes participate in implementation of the Washington Forest Practice Act through significant planning, restoration, and implementation assistance (the role of the Tribes in land management activities in WRIA 20 is discussed below in Section 1.3.1). Under DNR regulations, tribal technical personnel are part of the "ID Team," with landowners and other applicable state agencies, when harvests are proposed.

With the slow down of timber harvest and an increase of urban centers in Washington State, the Olympic Peninsula communities have promoted the area as a destination for recreation in order to boost economic development. The undeveloped nature of the basins combine with abundant resources to make the area a natural choice for activities including hiking, sport fishing, biking, camping, and driving for pleasure. There has been little impact from these activities outside heavily used campsites, occasional heavy sport fishing, and mainstem river access points but as use increases, impacts from recreation will most likely increase.

1.2.3 Dominant Processes

Winds off of the Pacific Ocean have a major effect on WRIA 20. The most famous historical event occurred in 1921 when more than 8 billion board feet were toppled in a single storm. Between 20% and 40% of the stands in the Dickey sub-basin alone were blown down. Patterns in most watersheds in WRIA 20 suggest that the wind disturbance is frequent with return intervals averaging around 20 years. In the Hoh watershed, winds exceeding 100 mph disturb southern exposure slopes on the same return interval. As a result of the wind, across the watershed, the largest canopied trees are often in protected draws.

Fire is one of the dominant processes on the western portion of the Olympic Peninsula. Prehistorically, the fire regime was one of infrequent, very large, very intense events, which cleared entire stands (around 1 million acres) about every 200 years. A major fire is thought to have occurred in 1708, traveling from the east portion of the WRIA westward to the Pacific. The 1951 Forks Fire was the last major fire.

The historic fire regime includes most notably the Great Forks Fire of 1951. The fire began as a result of a clearing effort for the Port Angeles-Western railroad in the Sol Duc watershed. Within 8 hours, the fire burned 33,000 acres through the North Fork Calawah watersheds, and the northwestern portion of the Sitkum and South Fork Calawah watershed according to the 1998 North Fork Calawah Watershed Analysis. Though the fire "damaged" a large area, subsequent management practices worsened conditions. Within five or six years, the entire burn area had been roaded and salvaged logged, leading to a greater potential for mass wasting events and surface erosion.

Upper reaches of sub-basins on the western edge of the Olympic Mountains often have steep slopes with a surface layer of glacial till. This combination makes mass wasting a common natural event in the mountainous portions of the WRIA. Forest roads and clearcutting have accelerated mass wasting rates within WRIA 20. Lack of road maintenance activity associated with the implementation of the U.S. Department of Agriculture (USDA) Northwest Forest Plan has contributed directly to mass wasting as well on federal lands.

1.3 Tribal Management

Western Washington treaty tribes (the Makah, Hoh, and Quileute in WRIA 20) have unique treaties that reserve off-reservation rights to fish in "Usual and Accustomed Fishing Grounds and Stations," often abbreviated as "U&A." The drainage basins in WRIA 20 for treaty tribes are initially described in *United States v. Washington,* 384 F. Supp. 312 (W.D. Wash. 1974), although some refinements may appear in the sub-proceedings of this ongoing case or other federal decisions. *United States v. Washington* sets forth the tribal ownership of the fishery as 50-50 with the non-Indians for each U&A, and also qualifies the tribes as co-managers of the fishery within their respective U&A. Because of tribal shared ownership of the fish, and co-management with fisheries managers such as WDFW and USFWS, they have a major role in fish habitat management, which includes the waters which are the subject of this process. Every part of WRIA 20 addressed by this state watershed process (RCW 90.82) lies within at least one of the three tribes' U&A and in some cases, there is overlap.

1.4 Sub-Basin Descriptions

The text of Section 1.4 is excerpted from the document written by Abigail Hook, submitted to the WRIA 20 Planning Unit on June 10, 2004 with minor changes made by the Planning Unit.

For the purpose of this report, and the Phase III Watershed Management Plan, the watershed has been divided into the following sub-basins. These sub-basins are shown on Figure 1-1.

1.4.1 Hoh Sub-Basin

The Hoh watershed lies along the most southern edge of WRIA 20. The river system is fed by several glaciers on Mt Olympus and flows westward for approximately 60 miles to the Pacific Ocean, draining 299 square miles along the way.

1.4.2 Ozette Sub-Basin

The Ozette watershed is dominated by Lake Ozette, the third largest natural lake in the State of Washington. While the lake is large (11.4 square miles), the actual watershed is relatively small at 77 square miles. The total drainage area of the Ozette watershed at the confluence with the Pacific Ocean is 88.4 square miles. Several large, low elevation, low gradient streams drain into Lake Ozette, which empties through the Ozette River into the Pacific Ocean. With the exception of some headwaters and tributaries, the watershed is generally characterized by gentle topography with a maximum elevation of 1900 feet.

1.4.3 Quillayute Sub-Basins

The Quillayute drainage system consists of the 5.5-mile Quillayute mainstem, and the Bogachiel, Calawah, Dickey, and Sol Duc Rivers, which collectively become the Quillayute River at the Sol Duc/Bogachiel River confluence. The sub-basin in total drains 628 square miles into the Pacific Ocean (Fretwell, 1984). There is very little information on the Quillayute River mainstem. The entire area between the reservation boundary and the confluence with the Sol Duc and Bogachiel can be considered a data gap for both fish habitat and water quality.

1.4.3.1 Bogachiel Sub-Basin

The Bogachiel River is formed by the North Fork and South Fork Bogachiel Rivers that drain from the steep headwaters of the Olympic Mountains. Technically, the entire Calawah River is a tributary to the Bogachiel, but because of the size of the drainage, it is generally treated separately. The upper reaches of the Bogachiel River lie within the Olympic National Park while the middle and lower reaches are used primarily for timber production and farming. There is little information on the hydrology of the Bogachiel basin.

1.4.3.2 Calawah Sub-Basin

The South Fork Calawah and Sitkum Rivers lie on the eastern edge of WRIA 20, abutting the Olympic Mountains and flow 21 miles and 12 miles long respectively. Both rivers flow in a westerly direction with a combined drainage area of about 72 square miles. Within the watershed, elevations range from about 100 to 3,750 feet, most high elevation ridge tops reaching over 3,000 feet. The Sitkum River flows into the South Fork Calawah which in turn meets the North Fork to form the Calawah River. The Calawah River flows into the Bogachiel which eventually meets the Sol Duc to form the Quillayute River. The Quillayute drains westerly into the Pacific Ocean.

1.4.3.3 Dickey Sub-Basin

The Dickey River is a major tributary of the Quillayute River system. The Dickey mainstem is 22.8 miles long with a drainage basin of 108 square miles. The majority of the basin lies below 440 feet in elevation with the ridge tops ranging from 1,200 to 1,400 feet in elevation. Much of the area is within 10 miles of the Pacific Ocean. These conditions lead to high precipitation with little incident of snow or rain-on-snow events, as well as high winds, a factor that can adversely affect riparian buffers.

The Dickey basin contains three major tributaries (East, West and Middle Dickey), two major creeks (Skunk and Thunder) and a large lake (Dickey). The river sub-basins are very different in character.

1.4.3.4 Sol Duc Sub-Basin

The Sol Duc watershed is located in the northeast corner of WRIA 20 and lies completely within Clallam County. The watershed is comprised of 20 sub-watersheds and drains approximately 219 square miles. The upper portion of the Sol Duc is high country (elevations above 5,000 feet) meadowland with many glacier lakes. These meadowlands drain into steeply incised headwater tributaries and form the rugged Upper and North Fork Sol Duc sub-watersheds. The mainstem gradually broadens below Sol Duc falls and then adopts a lower gradient channel configuration typical of flat valley bottoms. Within the valley lowland reach, Camp, Lake, Bear and Beaver Creeks are all major tributaries with Shuwah Creek to a lesser extent (R. Lien, personal communication). Lake Pleasant lies between Upper and Lower Lake Creek. Finally, 64.9 river miles from the headwaters, the Sol Duc and Bogachiel Rivers meet to form the Quillayute River, a Pacific Ocean tributary.

1.4.4 Sooes/Waatch Sub-Basin

The Sooes River originates in the foothills of the Olympic and flows through mostly Crown Pacific timberlands until it reaches the Makah reservation at river mile (RM) 4.2. The mainstem is approximately 16 miles long with about 39 miles of tributaries. The Waatch River is located entirely within the Makah reservation and there is very little published information on the river.

2.0 GROUNDWATER RESOURCES AND GEOLOGY

2.1 Introduction

As a component of the Phase 2 Technical Assessment for the Sol Duc-Hoh Watershed (WRIA 20), Golder conducted an assessment of the groundwater resources in the WRIA. The primary objective of the assessment is to characterize the role of groundwater in each sub-basin by examining existing reports, geological maps, well logs, and other information.

2.1.1 Study Area

WRIA 20 comprises approximately 1,190 square miles of the western Olympic Peninsula in Washington State. The watershed is characterized by rugged and varied topography with lowland valleys containing coniferous rainforests, and craggy mountains containing alpine meadows and glaciers in the interior. Topographic elevation in WRIA 20 ranges from 7,965 feet on the summit of Mt. Olympus in the east to sea level at the Pacific Ocean in the west. WRIA 20 exhibits some of highest total annual rainfall in the United States, with an average annual rainfall total of greater than 240 inches in the vicinity of Mt. Olympus. Major rivers in WRIA 20 include the Sooes, Ozette, Dickey, Sol Duc, Quillayute, Calawah, Bogachiel, and Hoh Rivers.

2.1.2 WRIA 20 Geologic History

The geology of the Olympic Peninsula is unique and interesting. The peninsula contains a thick sequence of Tertiary submarine basalt (Crescent Formation - erupted 60 to 50 million years ago [mya]) that has been thrust over younger Tertiary marine sedimentary rocks (sandstones, siltstones, and shales deposited between approximately 50 and 24 mya). The sediments comprising the marine rocks were originally deposited in an oceanic trench created by the west-to-east subduction of oceanic crust. When the wedge of sediments reached a critical thickness, subduction could longer continue and the wedge began to push up the overriding coastal slab of oceanic crust that it was formerly subducting beneath. Tectonic uplift of the Olympic Mountains associated with overthrusting of the basalt began approximately 17 mya. Today, the Crescent Basalt can be observed forming a “crescent” shape, open to the west, of steeply dipping rocks that enclose the interior Olympic Mountains, which themselves are comprised of highly deformed marine sedimentary rocks.

As the uplift of the Olympic Mountains continued, streams became incised, creating an erosional landscape of steep, rugged valleys. During the Pleistocene epoch (beginning approximately two million years ago), global climate patterns shifted and a series of alternating cool and warm periods began, which resulted in glacial and interglacial episodes. The glacial intervals allowed ice from British Columbia to flow southward into Washington numerous times during the Pleistocene. The most recent glaciation in Washington is referred to as the Vashon Stade, which reached maximum advancement approximately 13,000 to 12,000 years ago. As the Cordilleran ice advanced into western Washington, it split into two lobes, with one lobe filling the Straight of Juan de Fuca and the other advancing southward into Puget Sound lowland.

As Cordilleran glaciation progressed, alpine glaciers in the interior mountains of the peninsula also grew, and advanced into the valleys previously formed by incised streams. The alpine glaciers, though much smaller than the Cordilleran glaciers, deeply eroded the landscape creating the rugged topography that characterizes the Olympic Mountains today. Remnants of the larger alpine glaciers remain in the peaks of the Olympic Mountains. Meltwater streams draining the alpine glaciers deposited sand and gravel that comprise the most important hydrogeologic units in WRIA 20. Glacial sediments form the primary aquifers from which groundwater is withdrawn today for drinking and other uses.

Glacial sediments also play a role in the surface water in WRIA 20. In addition to the valley sediments which contain most of the WRIA's major rivers, glacial sediments serve to impound several lakes. Ozette Lake is dammed by a glacial moraine, which forms a ridge on the west side of the lake. Dickey Lake and Lake Pleasant are both surrounded by glacial sediments. Crescent Lake (outside of WRIA 20) is dammed on its eastern side by landslide debris associated with the recession of the glaciers.

2.1.3 Previous Studies and Data Sources

There are few published reports describing the hydrogeology of WRIA 20. Those identified by Golder include:

- Two reports regarding the hydrogeology in the vicinity of the Hoh Indian Reservation (Luxton, 1995 and Lum and Nelson, 1986); and
- A report on the water resources of the Makah Indian Reservation (Dion, Walters, and Nelson, 1980).

Geologic map coverage and structural information are included in:

- Rau (1973 and 1979);
- Long (1975 and 1976);
- Tabor and Cady (1978a and 1978b);
- Thackray (1997);
- Gerstel (1999); and
- Washington State Department of Natural Resources (WDNR, 2001) - 1:100,000 scale digital coverage.

Because very few detailed data exist about the hydrogeology in WRIA 20, large-scale surficial geologic map coverage of WRIA 20 was examined in order to determine important hydrogeologic units. Using the WDNR digital 1:100,000 geologic coverage (WDNR, 2001), a geologic map was produced by consolidating the existing coverage into several groups which focused on outcrops of sedimentary rocks, basalt bedrock, and the distribution of glacial sediments in WRIA 20 (Figure 2-1). The consolidated geologic map provided a base on which to plot locations of well logs that describe subsurface conditions at a particular location (Figure 2-2). Plotting the surface and subsurface data together allows for a better understanding of the hydrogeologic conditions in WRIA 20.

Logs for water wells located within WRIA 20 (approximately 324 well logs) were downloaded from Ecology's online site (http://apps.ecy.wa.gov/welllog/textsearch.asp) and hardcopies of the well logs are stored in Golder's project files. A total of 295 (or approximately 91%) of the wells are located in Clallam County and 29 (or approximately 9%) of the wells are located in Jefferson County. The well logs on file at Ecology constitute a portion of the total number of wells actually drilled in WRIA 20. This discrepancy arises because submittal of well logs to Ecology was not required prior to 1971. Therefore, some wells drilled prior to 1971 likely do not have an associated well log available for review. It is unknown what the exact percentage of total wells the logs on file with Ecology represent, but it is likely that a majority of the wells in WRIA 20 have an associated log at Ecology.

A spreadsheet database was developed to catalog hydrogeologic information for selected wells located throughout WRIA 20 with the objective of providing spatial information on aquifer characteristics to use in conjunction with geologic maps. Information on location, geology and hydrogeology from 270 selected well logs was input into the database. This represents approximately

83% of all the water well logs in WRIA 20 currently on file with Ecology. Well logs were selected for inclusion in the Golder well log database using the following criteria:

- Adequate location description (Township, Range, Section [TRS]);
- Detailed geologic description (clear, plausible description of material encountered);
- Well testing information (test type, pumping rate, drawdown measurement, duration); and
- Sufficient completion information (screened interval, construction details, and/or abandonment details).

The following information was noted for each well log (where available):

- Well location (TRS ¼ ¼);
- Owner first/last name;
- Well county;
- Ground elevation (from well log or estimated from U.S. Geological Survey [USGS] 7.5-minute topographic quad);
- Water level depth below ground surface/water level elevation/date;
- Well diameter/Screen type;
- Surface seal depth;
- Top of screen below ground surface/top of screen elevation;
- Bottom screen below ground surface/bottom of screen elevation;
- Screen length/mid-screen elevation;
- Bottom of hole below ground surface/ bottom of hole elevation;
- Screened unit;
- Feet of material overlying screen;
- Depth to consolidated rock/type;
- Dry or abandoned wells; and
- Minimum thickness of screen unit.

Wells were not included in the Golder well log database if they did not have: sufficient geologic description, location information, or if one or more wells were already included from that ¼-¼ section. Figure 2-2 shows the location of all the well logs in WRIA 20.

2.1.4 Aquifer Parameters

Where well test information (i.e., pumping rate and drawdown) was available, the following hydraulic parameters were evaluated:

- **Specific Capacity (Cs)** is a measure of the performance of a well and is expressed as a flow rate per unit drawdown (gpm/ft). Specific capacity is a time dependant parameter until steady-state conditions are reached.

$$Cs = \frac{Q}{s}$$

Where:

Cs = Specific capacity (gpm/ft);

Q = pumping rate (gpm)

S = drawdown (ft)

- **Transmissivity** is a measure of the transmitting capacity of the aquifer and is expressed in units of L^2/T (e.g., ft^2/day). It is also often expressed as a volume capacity (gallons per day) per unit thickness of aquifer (ft). Transmissivity for an aquifer can be estimated from the specific capacity using the following empirical formula (Driscoll, 1986):

$$T = \frac{Q * x}{s}$$

Where:

T = transmissivity of the well (gallons per day/foot)

Q = yield of the well (gallons per minute)

s = drawdown in the well (feet)

x = 2,000 (assumed value for a confined aquifer)

A well efficiency of 70% was assumed for each well based on professional experience. As a result of a number of factors (e.g. design, construction, development), wells are typically less than 100% efficient. The assumption regarding efficiency means that if a well exhibited a drawdown of 10 feet during a pumping test, it was assumed that inefficiency related to well construction resulted in some of the drawdown observed in the well, as opposed to being fully attributed to the aquifer properties. In this example (e.g. 10 feet of drawdown in the well with 70% efficiency), the aquifer immediately surrounding the well likely experienced only 7 feet of drawdown. This correction yields a higher specific capacity and subsequently a higher transmissivity than the raw drawdown data. An efficiency of 70% was applied to all wells in the database.

Approximately 43 water wells in WRIA 20 (approximately 13% of the wells with recorded logs) contained information indicating that they are “dry” (Figure 2-3), and it is assumed that very little or no water could be pumped from these wells. Of these, approximately 79% were located in shale, 19% were located in the unconsolidated sediments, and 2% were located in basalt. Driller's notes on the well logs indicate that in many instances, the casing was removed from the borehole and the well was abandoned with concrete. The locations of dry wells are very approximate because the logs for dry wells commonly did not include ¼,¼ section in their location description.

2.2 Groundwater Resources

2.2.1 Principal Hydrogeologic Units

Aquifers

The glacial sediments (along with the fluvial sediments associated with the rivers draining the upland areas) comprise the principal aquifers in WRIA 20 because of their abundance and relatively shallow water table where they are saturated. The aquifers in WRIA 20 are expected to be limited in extent and are probably laterally discontinuous over large areas as a result of the topography and original glaciofluvial depositional environments.

Wells logs on file at Ecology were examined to gather information about the hydrogeology of WRIA 20 (see Section 1.1.3 for discussion). Using the information gathered from well logs, the productive hydrologic units of the WRIA were classified as follows:

Unlithified Sediments

Glacially deposited materials (drift [coarse-grained only], outwash)
Non-glacial deposits (alluvial and fluvial sediments)
-*Coarse-grained (sand, gravel, sand and gravel, with trace silt/clay)*

The most significant sediment type for water production in WRIA 20 is sand and gravel deposited on top of the consolidated marine sediments and basalt. Sand and gravel can be deposited by present day streams or by meltwater streams draining from glaciers. The most productive glacially derived deposits are advance outwash sand and gravel, which were deposited as the glacier advanced. Drift is an ambiguous term and can include both till and outwash. Till is a highly heterogeneous, often compacted mixture of clay, silt, sand, and gravel that was deposited directly beneath the glacier and is not commonly expected to produce a significant amount of water.

Non-water producing units

Rocks that are unlikely to produce significant amounts of groundwater in WRIA 20 include:

Unlithified Sediments
Glacially deposited materials (drift [fine-grained only], till)
Non-glacial deposits (lacustrine sediments)
-*Fine grained (clay, silt, fine sand)*
Marine Sedimentary Rocks
-*Fine grained (shale, siltstone)*
-*Coarse grained (sandstone, conglomerate)*
Igneous Bedrock
-*Volcanic rocks (basalt and other shallow intrusive rocks associated with the Crescent Basalt - e.g. gabbro and diorite)*

In some cases, rocks such as sandstone and basalt can yield significant amounts of water if they contain interconnected fractures, but on the Olympic Peninsula, this does not appear to be the case, as several wells completed in these units were reported as being dry or produce very small amounts of water. The low permeability of the sedimentary rocks and basalt in WRIA 20 likely precludes large-scale production of water from these units.

Minor constituents that have an insignificant hydrogeologic role in WRIA 20 include other igneous rocks (tonalite, andesite, and dacite) and metamorphic rocks (schist, metavolcanics, metasedimentary and tectonic breccias).

2.2.2 Distribution of Wells in WRIA 20

There are seven sub-basins in WRIA 20 that have a number of water wells and five sub-basins with very few or no wells. These areas have informally been classified in Table 2-1.

Figure 2-2 shows the location of these sub-basins and their proximity to major rivers in the WRIA.

2.2.3 Hydrogeologic Characteristics of Geologic Materials

The transmissivity values for the wells included in the database are shown on Figure 2-4 and summarized in Table 2-2.

The average values shown for transmissivity are geometric means. Geometric means were used because transmissivity values occur over a large range and typically have a log-normal distribution. Approximately 63% of the wells contained in the database are completed in the coarse, unconsolidated sediments (sand and gravel). This distribution indicates that much of the groundwater development that has occurred in the WRIA in the glacial and non-glacial sediments is located in valleys, usually in close proximity to a river (Figure 2-2).

Total thickness of the unconsolidated units is generally less than 100 feet, but may be up to several hundred feet thick in some places in WRIA 20. It is important to note that within the total thickness of unconsolidated sediments, there are likely zones of water that are capable of storing water (in pore spaces of sand and gravel) and transmitting the water to wells during pumping. The sediments above and below these zones may contain water, but may not be permeable enough to allow movement of the water on short time scales (e.g. minutes, hours). The length of screen used in a well can be indicative of the thickness of the water producing layers encountered during drilling. The productive layers of sand and gravel within the total thickness of unconsolidated sediments are typically thin, with the Golder well log database indicating that the median thickness of screened units listed on well logs was 9 feet.

Additionally, the Golder well log database shows that the median thickness of coarse unconsolidated sediments of material overlying the water-bearing unit was 45 feet. The thickness of the overlying sediments ranged from 5 to 369 feet. Because the wells in WRIA 20 are generally shallow and most are located in river valleys, the interaction between groundwater and surface water may be very important to management of water resources. Groundwater-surface water interaction will be discussed in Section 1.3 of this report.

In general, the unconsolidated sediments are present above sea level, but in 12 wells in the database, the interface between the bottom of the unconsolidated sediments and the top of the consolidated rocks is below sea level. With the exception of one well (well 267 in Golder database), all of the wells are located more than a mile from the Pacific Ocean. Well 267 (owned by the U.S. Department of the Interior) is located approximately 1/3-mile from the Pacific Ocean. Pumping of water from unconsolidated sediments from below sea level close to (e.g. less than 0.5 mile) the marine shore may cause saline intrusion. This usually results in long-term degradation of water quality in the affected portion of the aquifer. Water quality impairment from saline water WRIA 20 has historically been a result of completing wells in a freshwater-salt water zone of diffusion and not a result of groundwater pumping (Drost, 1986).

Thickness of the unconsolidated sediments in WRIA 20 was determined from approximately 93 well logs that recorded occurrence of underlying consolidated rocks (Figure 2-5). In wells where consolidated rocks were encountered, the median depth to the consolidated rock was 48 feet. The thickness of unconsolidated sediments ranged from 18 to 295 feet. The wells which encountered consolidated rocks are generally located:

- Along the length of the Sol Duc and Quillayute Rivers (various townships);
- On the Makah Indian Reservation (Townships 32N and 33N, R15W); and
- Along the Calawah River near its confluence with the Sol Duc River (T28N, R14W).

Some wells encountered consolidated rock in the vicinity of the Hoh River in T26N, R13W and north of Lake Ozette (T30N, R15W and T31N, Ranges 14W and 15W).

2.2.4 <u>Regional Groundwater Quality Concerns</u>

There are no published reports detailing the groundwater quality of WRIA 20. A query of the State of Washington Department of Health (WDOH) database for water quality reporting between 1970 and 2002 (WDOH, 2002) is summarized below:

- No synthetic organic compounds (SOCs) or volatile organic compounds (VOCs) were detected, with the exception of some chlorination by-products that are typically associated with disinfection of water for drinking. One detect of o-xylene (a common component in gasoline and paint thinners) was detected below its maximum contaminant level (MCL); and,

- All inorganic parameters were less than drinking water standards with the exception of iron, manganese and lead in some wells. These exceedances are included in Table 2-3. Exceedances occurred for iron, lead, and manganese in 25%, 9%, and 14% of the reported results for each parameter, respectively. The source of lead in drinking water is typically from solder used in plumbing systems and rarely occurs in detectable concentrations in naturally occurring groundwater or surface water.

It is important to note that occurrences of lead (particularly at concentrations exceeding the action level) can be caused by the plumbing of the distribution system rather than by the source water. However, groundwater sources can also contain lead. Additionally, the reported exceedance level for lead of 0.0015 mg/L is not a maximum contaminant level (MCL), but rather an action level that requires a Treatment Technique if more than 10% of tap water samples exceed this concentration.

Water quality from wells drilled for the Hoh Indian Tribe in T26N, R13W, Sections 20, 28, and 29 (Luxton, 1995) is summarized in Table 2-4. All of the parameters indicated on Table 2-4 have secondary drinking water standards, which are primarily associated with aesthetic concerns (e.g., taste, color, etc.) and are not health concerns. The iron level of 0.3 mg/L is equal to the secondary

MCL. The pH values reported in Luxton (1995) range from 5.5 to 6. While low pH itself is not a health risk, water with a low pH (acidic) can be corrosive to pipes and if untreated can result in increased metal content (for example, copper, lead, zinc and cadmium).

Although the extent of sea water intrusion in the coastal portions of WRIA 20 is unknown, limited data indicate that some wells in the WRIA are impaired by marine water. This is shown mainly by elevated chloride concentrations and specific conductivity values. Water quality from wells drilled for the Makah Indian Tribe in T33N, R15W Section 5 and T32N, R15W Sections 10, 14, and 16 (Dion, Walters, and Nelson, 1980) is summarized in Table 2-5.

Water quality from wells drilled for the Quileute Indian Tribe in T25N, R15W Sections 23 and 25 (Luxton and Bliemeister, 1989) are summarized in Table 2-6. Most of the parameters indicated on Table 2-6 have secondary drinking water standards, which are primarily associated with aesthetic concerns (e.g., taste, color, etc.) and are not health concerns. Nitrate is associated with a primary drinking water standard (10 mg/L), but measured concentrations were far below the standard. The iron level ranged from 0.03 to 0.7 mg/L. The secondary MCL for iron is 0.3 mg/L, indicating wells serving the Quileute Indian Reservation may have water quality problems associated with elevated iron concentrations (e.g. fixture staining, well encrustation, staining of clothes during laundering).

Dion, Walters, and Nelson (1980) note that the observed water quality impairment may be the result of the wells tapping brackish water that was trapped in aquifer materials when they were originally deposited (in a marine environment) rather than the result of sea water intrusion. However, the potential for sea water intrusion exists in WRIA 20 if groundwater development is focused in a coastal aquifer at or below sea level.

Both Jefferson and Clallam counties monitor critical aquifer recharge areas (CARAs). Jefferson County manages CARAs under JCC 18.15.240, which can be found online at http://search.mrsc.org/nxt/gateway.dll/jfsnmc?f=templates&fn=jfsnpage.htm$vid=municodes:JeffersonCounty. Clallam County also manages CARAs under CCC 27.12.600, which can be found at http://search.mrsc.org/nxt/gateway.dll?f=templates&fn=cllmpage.htm$vid=municodes:Clallam.

2.3 Groundwater-Surface Water Interaction

2.3.1 Hydraulic Continuity

Hydraulic continuity is the degree to which groundwater is connected to a nearby surface water body. Pumping in a well can induce recharge from the surface water body (e.g. river or lake). Rivers may lose water to groundwater, or groundwater may seep to streams and increase their flow. The dominant condition in terrains similar to that of WRIA 20 is that streams gain from groundwater seeps, although short reaches of the stream may be losing.

The nature of the connection between rivers and shallow sediments in WRIA 20 is largely unquantified. There are no published studies that have focused specifically on the relationship between surface water and groundwater in WRIA 20. The Water Quality and Habitat Level 1 Assessment (Hook, 2004) mentions that there is a noticeable groundwater contribution in certain reaches of the Hoh and North Fork Calawah Rivers. In both cases, groundwater discharge to the rivers is evidenced by temperature variations along the channel. Data included with the East-West Dickey Creek Watershed Analysis indicate that there are fluctuations in stream temperature along the creek branches that may be related to groundwater discharge (Rayonier, 1998). The Washington State Department of Natural Resources (WDNR) North Fork Calawah Watershed Assessment

Module C Hydrologic Change Assessment (Jackson, 1997) notes that the river goes dry in the following locations:

- T29N, R12W Secs. 13, 14, 15, 24; and
- T29N, R11W Secs. 15, 16, 17, 18, 19, 20.

There are indications that seasonal water level fluctuations along the river channel can be considerable. According to Jackson (1997), the water table beneath certain reaches of the North Fork Calawah can be deeper than 40 feet beneath the river during some periods in the summer. The thickness of the unconsolidated sediments infilling the river valley in the drying reach of the North Fork Calawah ranges between 100 feet to over 350 feet, as extrapolated from the angle of valley walls at several locations (Jackson, 1997). If these thickness estimates are correct, there are sections of river valleys in WRIA 20 that are capable of transmitting large amounts of subsurface flow. There are no well logs located near the drying reach of the North Fork Calawah to independently verify the thickness estimates.

Lum and Nelson (1986) noted the presence of springs and spring-fed ponds near the Hoh Indian Reservation. Luxton (1995) noted springs outcropping along the northeast side of the Olympic National Park border that lies east of the Hoh Indian Reservation. In both cases, the springs are likely associated with the draining of upland areas and discharge of water to lower elevations near rivers. This configuration is likely common throughout the valleys of WRIA 20.

2.3.2 Regulatory Issues

There are 12 Group A systems in WRIA 20 with 20 wells, and 26 Group B systems with 26 wells listed in the WDOH database (Figure 2-6). Because of the configuration of the hydrogeologic units (i.e. unconsolidated sediments filling river valleys), a great deal of groundwater in WRIA 20 is likely to be hydraulically connected to surface water to some degree. As a well pumps, a cone of depression in the groundwater around the well will extend laterally into the surrounding aquifer. During the early part of the pumping, the water level in the pumping well will go down. However, when the cone of depression intersects a surface water body (e.g. a river channel), a hydraulic gradient develops between the groundwater in the aquifer and the water in the river. If the streambed is hydraulically connected with the aquifer, river water will percolate through the streambed material under the influence of the hydraulic gradient. Therefore, the river recharges the aquifer at an increasing rate, as the cone of depression around the pumping well grows larger. When the rate of recharge to the aquifer equals the rate of discharge from the well, the cone of depression and the water level in the pumping well become stable. This condition is commonly reflected as a horizontal line on a plot of water level drawdown versus time.

Public drinking water wells that have hydraulic connection with surface water bodies in Washington State are increasingly being regulated by WDOH. WDOH considers these wells as GUI (groundwater under the direct influence of surface water) and Federal Surface Water Treatment Rule requires that all Group A public water systems determined to be GUI treat their water. The GUI Program focuses specifically on drinking water sources that appear to be at risk of microbiological contamination associated with surface water. The program provides a means for identifying these types of sources (referred to as “potential GUI sources”), characterizing the degree of risk for microbiological contamination (through specific data collection requirements and methodologies), interpreting the results of the characterization, and determining appropriate follow-up contaminant risk mitigation actions.

The WDOH regional engineers for Clallam and Jefferson Counties were contacted in order to quantify the nature of groundwater-surface water interactions in public water system wells in WRIA 20. The engineers noted that there are no significant water quality issues in the WRIA. Additionally, no public drinking water sources have been identified as GUI, but several sites are being investigated for the possibility.

According to WDOH, water systems with GUI sources must achieve at least 99.9% removal or inactivation of *Giardia lamblia* cysts and at least 99.99% removal or inactivation of viruses. To accomplish this, systems must do all of the following:

- Filter water, unless certain source quality and site-specific conditions are met to avoid filtration;
- Disinfect water; and
- Be operated by qualified personnel.

Systems with GUI sources or sources identified by the department as being "potential" GUI sources have several compliance options to choose from, including:

- Modifying the groundwater source to eliminate direct surface water influence;
- Developing an alternate WDOH-approved source (for example, develop a protected groundwater source or purchase from a nearby approved public water system);
- Attempting to meet the source quality and site-specific criteria to remain unfiltered; and
- Installing filtration equipment.

2.4 Groundwater Availability - Summary and Recommendations

Groundwater development in WRIA 20 is limited by the productivity of aquifers. The locations of wells in WRIA 20 are concentrated mainly in river valleys. Most wells in the WRIA are shallow (i.e., median well depth in the Golder well log database was 62 feet) and are completed in unconsolidated sediments, which lie on top of low permeability consolidated rocks (marine sedimentary rocks and basalt). Where fully penetrated by boreholes, the unconsolidated deposits are generally less than 100 feet thick. The low transmissivity of the underlying consolidated rocks preclude their use as aquifers on a large scale in WRIA 20.

Despite having annual rainfall totals of over 240 inches in some areas of the WRIA, there are still many wells drilled that do not produce sufficient water for domestic use (approximately 13% of the well logs on file with Ecology indicated that the well did not produce sufficient water). Additionally, wells located near rivers may be hydraulically connected to the surface water which requires that in order for water resource management to be successful, development of groundwater must be directed in a manner that does not impair instream flows.

2.4.1 Quantifying Water Present

Because very little information is currently available to determine the amount of groundwater present in WRIA 20, the amount of water currently available and available for future appropriation cannot be accurately quantified at this time. Accurate quantification of the water present requires collecting and analyzing a significant amount of data about a selected area. Although WRIA 20 is large, groundwater development has historically occurred in focused areas; in particular, the lower reaches of the WRIA's major river valleys. Because groundwater development is geographically constrained, hydrogeological studies should focus on a particular area in order to characterize an aquifer and in turn, the amount of water present. Information helpful to characterize an aquifer and the water present includes:

- thickness and extent of aquifer;
- aquifer boundaries;
- aquifer recharge and discharge zones;
- annual well production records;
- aquifer parameters (storativity, transmissivity, response to pumping); and
- hydraulic head data (water level information with adequate spatial distribution and seasonal record).

Because the hydrogeologic conditions of the WRIA are likely to be highly variable not only between valleys but also along valleys, hydrogeologic studies specific to a particular area are recommended rather than a generalized study covering large areas.

2.4.2 Quantifying Available Water

The amount of water stored in the aquifers can be determined only by compiling and analyzing the data described above. Additionally, identifying the degree of hydraulic continuity between surface water and groundwater will help determine how much water is available for use without impairing instream flows. Establishing minimum instream flows in creeks in the WRIA will also guide the determination of the amount of groundwater available for pumping.

2.4.3 Quantifying Water Available For Future Allocation

Once the amount of available water has been determined, the amount available for future allocation should be estimated. This requires a detailed evaluation of how much water is currently being used and an estimate of additional future water demand (if any) in the WRIA. The Water Use technical assessment (Section 4) addresses current and future water use. The Planning Unit could choose to characterize available groundwater in areas of WRIA 20 that are likely to face future groundwater development pressures. Using the estimated locations of future development, information could be extracted from the Golder well log database regarding aquifer characteristics found in these regions (e.g., transmissivity, depth of unconsolidated sediments, estimated depth of productive zones, location of dry wells).

2.4.4 Other Recommendations

The supply of shallow groundwater is susceptible for a number of reasons: seasonal fluctuations in water level, contamination from surface sources, and potential GUI. In order to protect the water supply, shallow groundwater requires careful management. Several options to protect and develop shallow groundwater that can be incorporated into Watershed Planning are summarized below. There is no fixed depth that defines a shallow well and wells at any depth may be susceptible to certain impairments such as contamination and declining water levels. The term shallow, as it is used here can be thought of as wells less than about 150 feet deep.

Groundwater/Surface Water Interaction

Because of the proximity of wells to rivers in WRIA 20, there is a need to understand the degree of hydraulic continuity between groundwater and surface water. In the absence of any published data, some options for increasing the understanding of groundwater/surface water interactions include:

- Compiling anecdotal evidence (e.g., location of springs and seasonally dry reaches of dry river beds);
- Developing a stream gaging program (long term - continuous) or study of instream flows (short term – seasonal) to identify gaining/losing reaches (a.k.a. seepage reaches) of streams on selected rivers;
- Performing pumping tests on wells sited near rivers (e.g. distance from river dependent upon local conditions) and measuring streamflow and water quality (e.g. temperature, conductivity, microscopic particulate analysis); and,
- Intensive streambed studies (similar to USGS in Lower Dungeness River; Simonds and Sinclair, 2002).

These options range in cost and level of technical effort required and could conceivably be accomplished as supplemental assessments as part of the watershed planning process.

Wellhead Protection

The Planning Unit may decide to develop a program to assist public water systems in developing wellhead protection plans. Group A wells located near surface water bodies must comply with guidelines set forth by WDOH and wellhead protection plans can help identify and protect aquifer recharge areas for water supply wells in the WRIA. A program of developing uniform wellhead protection plans in the WRIA will help smaller system wells share a similar degree of water quality protection as larger systems. According to the WDOH database, there are currently 12 Group A systems in WRIA 20 with 20 wells (and 26 Group B systems with 26 wells). The first step to developing a wellhead protection plan program may be to survey the public water systems and compile the results to rank the systems and determine where the most effort is needed to update the wellhead protection plans.

Informed Groundwater Development

Because of the cost associated with drilling a dry well, particularly to a private homeowner, future groundwater development in WRIA 20 should utilize techniques that give insight into the hydrogeologic conditions expected at a site before drilling begins. Examining well logs and extracting information from the Golder well log database is one method to increase the understanding of the hydrogeology of an area. Another means to identify favorable hydrogeologic conditions for siting a well are geophysical techniques (e.g. electrical resistivity, ground penetrating radar, and seismic refraction) that provide information on subsurface materials of an area without installing a well. Depending upon the parameters measured and the size if the area investigated, a geophysical study may be comparable in cost to installing a well at a site where subsurface conditions are unknown.

Aquifer Storage and Recovery

Aquifer storage and recovery (ASR) entails the use of wells to recharge treated water directly to an aquifer unit, for recovery at a later time. Implementing a successful ASR program entails considerable knowledge of the hydrogeologic conditions of an area. The type of aquifer information required is similar to that obtained from in-depth hydrogeologic studies (Section 1.4.1) and also includes: porosity, specific yield, storage coefficient data, as well as aquifer pressure conditions/response to changes. In order for ASR to be successful, aquifer materials must have sufficient storage and have boundaries which inhibit the movement of water. Because of the limited thickness of most of the aquifer zones in WRIA 20 and the proximity to surface water bodies, identifying a site suitable for ASR is likely to require a site-specific hydrogeologic investigation complete with pumping test(s) and perhaps computer modeling. Future hydrogeologic investigations may identify areas in the WRIA where ASR programs should be explored in greater detail. Guidelines for planning and designing typical ASR projects can be found in the Standard Guidelines for Artificial Recharge of Ground Water (ASCE, 2001)

Infiltration to aquifer units exposed at the surface entails impounding and spreading water over a wetted area for recharge. Surface infiltration may be successful in areas of WRIA 20 where water (e.g. stormwater runoff) can be captured and directed to areas where groundwater flow paths allow for a delayed release back to surface water bodies. Recharge to shallow aquifer units may not provide long-term storage of water (e.g. months) but instead may allow groundwater production to be more sustainabe by augmenting stream baseflow.

3.0 ALLOCATED WATER RIGHTS

This section provides an assessment of the degree of allocation of water in the WRIA 20 Watershed estimated from claims and administratively issued water rights (applications, permits and certificates). Ecology maintains a database to track and store water rights information, called the Water Rights Application Tracking System (WRATS) database (Ecology, 2003a). An abbreviated version of the WRATS database, called "**WRATS**-**O**n-a-**B**un," or WOBS, that is current as of December 2003 is used for the assessment of allocation in the WRIA 20 Watershed. Information on applications for new water rights and change applications was also obtained (current as of June 2004) from Ecology (http://www.ecy.wa.gov /programs/wr/rights/tracking-apps.html) to assess the current degree of water rights activity in the watershed. Finally, instream flow regulations are reviewed.

3.1 Water Rights in Washington

3.1.1 State Administered Water Rights

Administrative water rights issued by Ecology or predecessor agencies have existed in Washington State since 1917 for surface water and 1945 for groundwater. These take the form of permits and certificates and are collectively referred to as administratively issued water rights. With exceptions made for some groundwater exemptions discussed below, legal water use since these dates requires application to and approval from Ecology. A groundwater right for the withdrawal of up to 5,000 gallons per day of groundwater for prescribed uses may be established without application to Ecology with a priority date of first beneficial use, and are referred to as "exempt wells." Exempt well use is addressed in the section assessing actual use. Water rights are valid only as long as they are used, and except under specific conditions, cease to exist if they are not used for a continuous period of five years (i.e., they are relinquished and/or abandoned).

A water right claim is a possible water right based on the statement of a claimant that a beneficial use of water was established before the establishment of water code for surface water in 1917 (RCW 90.03), or before the regulation of public ground waters in 1945 (RCW 90.44). Water use before 1917 (for surface water) or 1945 (for groundwater) is "grandfathered" in and establishes a water right, subject to conditions (e.g., the water must be applied to beneficial use, must not have been relinquished, etc.). Such rights are referred to as claims, and must have been registered with Ecology. Since the establishment of the surface and groundwater codes, there have been four claim registration periods. Claims for water use may have been registered multiple times resulting in duplicate, triplicate, or possibly quadruplicate records in Ecology's database for what is intended to be a single water right claim. Claims do not necessarily represent a valid water right. Their validity can only be determined through an adjudication, although Ecology may make a tentative determination as to their validity.

Approximately 177,000 claims were filed statewide in the initial opening to the water right claims registry (July 1, 1969 through June 30, 1974) in response to RCW 90.14.041. A list of the information that the claimant had to provide was specified in RCW 90.14.041. In 1973, RCW 90.14.041 was amended to allow a less extensive list of information – a "short form" filing. The short form only requires inclusion of sufficient data to identify the claimant, source of water, purpose of use and legal description of the land upon which the water is used and is of limited evidentiary value in adjudications. With the amendment to RCW 90.14.051 in 1973, there are long forms (exclusively used prior to 1973, and selectively used after 1973) and short forms.

The intent was that short forms were supposed to be used only by those who were withdrawing water pursuant to RCW 90.44.050 (exempt wells), but that is not what happened in practice. The language in RCW 90.14.051 is as follows: "Except, however, that any claim for diversion or withdrawal of surface or groundwater for those uses described in the exemption from the permit requirements of RCW 90.44.050 may be filed on a short form to be provided by the department." This language is confusing because there is no exemption for the diversion of surface water under RCW 90.44.050.

The second opening was from July 1, 1979 through December 31, 1979, and was created by RCW 90.14.043.

That section of the code was amended in 1985 to allow a third opening was July 1, 1985 through September 1, 1985. In those cases the claimant first had to petition the Pollution Control Hearings Board for a certificate and make a showing to the PCHB regarding their water use. A certification was issued by the Pollution Control Hearings Board if, upon petition to the board, it was shown to the satisfaction of the board that:

(a) Waters of the state have been applied to beneficial use continuously (with no period of nonuse exceeding five consecutive years) in the case of surface water beginning not later than June 7, 1917, and in the case of groundwater beginning not later than June 7, 1945; or,

(b) Waters of the state have been applied to beneficial use continuously (with no period of nonuse exceeding five consecutive years) from the date of entry of a court decree confirming a water right and any failure to register a claim resulted from a reasonable misinterpretation of the requirements as they related to such court decreed rights.

If the claimant received a certificate from the Board, then Ecology accepted the filing of the claim and entered it into the claims registry.

The fourth opening from September 1, 1997 through June 30, 1998 was created by a new section of the code, RCW 90.14.068. These claims are commonly entered into the WOB database without designation as to whether they are long or short form claims.

Each of the openings came with limitations and differences from the other claim openings and most of that information can only be gleaned by reading the various laws that created/limited the openings. For example, filings in the September 1, 1997 through June 30, 1998, opening have a water right priority date of as of the date the statement of claim is filed with Ecology – even though to be a valid claim the water use needed to start prior to 1917 for surface water and 1945 for groundwater.

An adjudication must be conducted to determine the validity of claims, and to resolve conflicts between water rights holders. An adjudication is a court process that may be initiated by petition by a person claiming a right to water, by Ecology, or by planning units. There have been no adjudications in the WRIA 20 Watershed.

When applications are made to Ecology for a new water right, Ecology (or their predecessor agencies) is required to consult with the Washington Department of Fish and Wildlife (WDFW, or their predecessor agencies, such as the Department of Game and Fish). If WDFW replies with a letter recommending to deny or limit the exercise of a water right for the protection of aquatic habitat under the authority of the Fisheries Code (RCW 75.20), such letters are called Surface Water Source Limitation (SWSL) letters and effectively establish a regulatory minimum instream flow with an associated priority date.

Water rights may also be established for instream flow values under the Water Resources Act of 1971 (WAC 173-500). Regulated instream flow quantity is a water right with a corresponding priority date and period of use. The purpose of establishing such flows is typically for the maintenance and/or protection of aquatic biota/fish, although other values may also be considered, such as water quality and recreational uses. Water may also be reserved or set aside for future use. Ecology must initiate a review of such regulations whenever new information, changing conditions, or statutory modifications make it necessary. No instream flows or closures have been set in the Sol Duc-Hoh Watershed.

Other than tribal water rights, no other forms of water rights are addressed in this section (e.g., other federally reserved water rights).

3.1.2 Tribal Water Rights

There are three tribes within WRIA 20, the Hoh, Makah, and Quileute Tribes. There are four Tribal reservations, however the Ozette Reservation is under treaty jurisdiction of the Makah Tribe and is currently managed as wilderness. Land within WRIA 20 is included within land ceded by the Treaty of Neah Bay (1855), and the Treaty of Olympia (1856). Tribal water rights are a type of federal reserved water right. These rights are reserved whenever the United States sets aside land for some federal purpose, including an Indian reservation. These rights are outside the state system and cannot be adjudicated in state court without the tribe’s consent, unless there is a general water rights adjudication involving every water right holder.

Tribes generally have two types of water rights. The first is a right to water to meet the primary purposes of the reservation and has been broadly interpreted by the courts. The protection for water on reservations is first cited in *Winters v. U.S.*, a U.S. Supreme Court case [Winters v. United States, 207 U.S. 564, 565 (1908)]. In 1984 the 9th Circuit Court of Appeals finalized its 1981 decision after rehearing *U.S. v. Adair* (723 F.2d 1394 (9th Cir. 1983). That court cited the Winters Doctrine (that creation of a reservation also implied continued supply of necessary waters to it) and also, described aboriginal water rights of tribes since time immemorial to the treaty area, including off-reservation water rights within the lands known as the Usual and Accustomed Area, for each applicable treaty. This right has a priority date of treaty signing and is not subject to continuous beneficial use provisions or a particular withdrawal point.

The second type of right is off-reservation and is for water for instream flows to protect fish and fish habitat. The right to fish was defined in treaties and reaffirmed in the Boldt decisions [U.S. v Washington 1974, 384 F. Supp. 312 (W.D. Wash. 1974), aff'd, 520 F.2d 676 (9th Cir. 1975)]. Implicit in that fish right is a right to sufficient water in the streams to sustain a productive fishery. The priority date of this water right falls either at “time immemorial” or the date of the Treaty signing, depending on the court involved.

The Tribal right to instream flow to protect fish and fish habitat is independent of the state system of establishing minimum instream flows. The Tribal right generally predates any other water right, while the state minimum instream flow has a priority date based on the time the State law was codified. These State rights are junior to many other water rights.

3.2 Assessment of Water Allocation

This section describes water rights allocated by Ecology in the WRIA 20 Watershed and by sub-basin. The characterization of water rights was based on:

- Source type (groundwater or surface water);
- Document type (certificate, permit, claim, etc.);
- Purpose of use (irrigation, domestic, municipal, etc.); and,
- Sub-basin.

The WOB database was initially queried to exclude those documents listed in the database as inactive. The extracted data were placed in a new database for further analysis. A total of approximately 560 records were extracted from the WOB database for WRIA 20, and are summarized in the following table:

Document Type	**Number of Documents**	
	Groundwater	**Surface Water**
Applications	3	18
Certificates	38	135
Claims (last registration period)	1	8
Long Form Claims	115	77
Short Form Claims	84	71
Permits	1	5
Subtotal	**242**	**314**
Total	**556**	

Information from WOB database (Ecology, 2003a).

Also included in the database are two reservoir certificates and one short form claim with a “B” number, indicating uncertainty in the source (i.e. groundwater or surface water).

3.2.1 Characterization by Purpose of Use

For each sub-basin, the database was queried to extract the distribution of documents by purpose of use for both groundwater and surface water. The order of extraction was as follows:

- All documents including the “MU” (municipal) purpose of use;
- Remaining documents including the “CI” (commercial-industrial) purpose of use;
- Remaining documents including the “IR” (irrigation) purpose of use;
- Remaining documents including the “D*” (domestic) purpose of use;

- Remaining documents with non-consumptive or infrequently used purposes of use (power, fish propagation, and fire); and,
- All other documents including all other purposes of use (mining, recreation, stock, etc).

After each query, the records are removed from the database before applying the next query. This characterization is based solely on the number of records. The results of the analysis by purpose of use are summarized on Table 3-1. The approach for an assessment of allocation based on the volume of water is presented in the next section.

Non-consumptive (e.g., fish hatchery or hydropower production) or infrequently used (e.g., fire suppression) water rights contributed less than one percent of all documents. Because annual quantities are usually not listed in the WOB database for these types of water rights, they are not further characterized with respect to associated annual quantities following initial extraction from the database. The surface water diversions for non-consumptive or infrequently used purposes of use are summarized as follows:

- Two certificates totaling 0.23 cubic foot per second (cfs) for fire protection;
- Ten certificates totaling 135.11 cfs for fish propagation;
- One permit for 3 cfs for fish propagation; and
- One reservoir certificate for 20.2 acre-feet (AF) for propagation..

3.2.2 Assignment of Annual Withdrawals or Diversions

Water rights are assigned with a variety of properties among which are an instantaneous withdrawal/diversion rate (Qi; in gallons per minute [gpm] for groundwater and cubic feet per second [cfs] for surface water), and an annual withdrawal/diversion rate (Qa; acre-feet per year for both surface and groundwater). (Groundwater is typically described with the term “withdrawal” while surface water is generally described with the term “diversion.” The terms withdrawal and diversion may be used interchangeably in this report.) Assessment of allocation on a watershed scale is appropriately considered by examination of the annual permitted quantities, which may then be seasonally distributed.

The WOB database includes instantaneous withdrawal rates (Qi) for almost all administratively issued rights (permits and certificates). However, annual withdrawal rates (Qa) are missing for many administratively issued rights and almost all claims. Surface water permits and certificates generally have a higher percentage of records with missing annual withdrawal rates than groundwater permits and certificates. For records that do not include annual withdrawal rates (Qa), the Qa is assigned to allow an assessment of allocation. The method of estimating assigned Qa is described below.

3.2.2.1 Certificates and Permits

Within each group of purpose of use, the ratio of Qi/Qa of water rights was calculated for both surface water and groundwater for rights for which both parameters are defined (Table 3-2). The mean and median Qi/Qa was calculated for each purpose of use. For certificates and permits for non-irrigation use without Qa, the Qa was estimated by multiplying the Qi by the median Qi/Qa ratio. The median Qi/Qa is considered most representative, as outliers in the Qi/Qa ratio do not skew it. For surface water certificates and permits for the “other” purpose of use, there was only one certificate with Qi and Qa defined. Therefore, for those certificates and permits without Qa, the Qa was calculated using the median Qi/Qa from groundwater certificates and permits for the “other” purpose of use.

For irrigation rights without Qa, the Qa was calculated by multiplying the irrigated acreage for each right by the median duty for either surface water or groundwater (Table 3-2). The median duty for irrigation rights was calculated to be 2.0 ft/yr per acre for surface water and 1.8 ft/yr per acre for groundwater (Table 3-2). Typical irrigation duties in other parts of the state are on the order of 4 ft/yr per acre in eastern Washington, and 2 ft/yr per acre in Puget Sound. Therefore an irrigation duty of 2.0 ft/yr per acre was used for WRIA 20.

3.2.2.2 Assignment of Qa to Claims

Long and short form claims generally do not contain complete information on Qa, Qi, or irrigated acres, and therefore require an assignment of Qa. New claims filed during the last claim registration period (September 1, 1997 through June 30, 1998) have Qa and Qi information.

Short form claims are generally equivalent to exempt wells as defined in RCW 90.44.050, such as for domestic water use and limited irrigation (i.e., less than 0.5 acre). Short form claims were assigned a Qa of 0.5 AF/yr, regardless of purpose of use, consistent with domestic, stock, and limited irrigation use. Long form claims with a domestic purpose of use were also assigned a Qa of 0.5 AF/yr.

For long form claims with irrigated acreage information, the duty calculated from water rights was applied to obtain a value for Qa.

Long form claims for irrigation use without a defined number of irrigated acres were assigned a Qa based on the median number of irrigated acres for groundwater or surface water rights, and a corresponding duty calculated from water rights.

For the remaining long form claims, the purpose of use is stock, or no purpose of use is listed. A Qa of 2 AF/yr was assigned to all of these remaining long form claims.

3.3 Allocation by Sub-Basin

The WOB database lists the location of water rights and claims by Township, Range, and Section (TRS). Sections and associated water rights and claims were assigned to sub-basins based on the sub-basin in which the centroid of the section was located. If the centroid of a particular section fell within the defined sub-basin boundary, all water rights in that section were included in that sub-basin regardless of whether portions of that section were located in other sub-basins. It is therefore possible that some water rights that were located within a particular sub-basin were assigned into a different sub-basin as the centroid of that section was in the different sub-basin.

A number of water rights and claims have a place of use that covers multiple sections. For these documents, the Qa was allocated between sections by dividing the total Qa by the number of sections and distributed accordingly.

3.4 Results

A total of 3,413 AF/yr (equivalent to 4.7 cfs) is estimated to be allocated and claimed in WRIA 20. The allocation of water in WRIA 20 is summarized by source (groundwater or surface water), purpose of use, and document type in Table 3-3.

Surface water accounts for 1,377 AF/yr, or 40% of the total estimated claimed and allocation water. Surface water certificates and permits account for 773 AF/yr, or 56% of the total estimated claimed and allocated surface water (Figure 3-1). Claims make up 606 AF/yr of estimated claimed and allocated surface water, or 44% of the estimated claimed and allocated surface water (Figure 3-2). Groundwater accounts for 2,042 AF/yr, or 60% of the total estimated claimed and allocated water rights. Groundwater certificates and permits account for 1,498 AF/yr, or 70% of the estimated claimed and allocated groundwater (Figure 3-3). Claims account for 613 AF/yr, or about 30%, of the total estimated claimed and allocated groundwater (Figure 3-4).

The largest allocation of water in WRIA 20 is for municipal use, accounting for 35% of the total claimed and allocated water, all of it from groundwater (1,182 AF/yr). Of the 1,182 AF/yr of water allocated for municipal use in WRIA 20, 950 AF/yr is groundwater for the City of Forks. The City of Forks also has supplemental certificates for 968 AF/yr. The remaining 232 AF/yr of groundwater allocated for municipal use is for the Quileute Tribe. Domestic use is divided almost equally between groundwater and surface water. The distribution of surface water claimed and allocated for domestic use is shown on Figure 3-5. The distribution of groundwater claimed and allocated for municipal and domestic use is shown on Figure 3-6.

Irrigation use is the next largest volume of claimed and allocated water in WRIA 20. About 60% of the irrigation allocation is from surface water. The distribution of surface water claimed and allocated for irrigation is shown on Figure 3-7. The remaining 40% of water allocated for irrigation is from groundwater. The distribution of groundwater claimed and allocated for irrigation use is shown on Figure 3-8. Other uses of water account for 5 AF/yr, or less than one percent of the total claimed and allocated water in the watershed.

The Sol Duc and Bogachiel sub-basins have the largest amount of claimed and allocated water in WRIA 20, each with approximately 40% of the total claimed and allocated water (Tables 3-4 and 3-5). The Calawah and Hoh sub-basins each have approximately 5% of the claimed and allocated water. Most of the water withdrawals and diversions are in the vicinity of the Highway 101. Most of the water withdrawals and diversions in the Bogachiel sub-basin are in the vicinity of the Town of Forks. Together, the Sol Duc, Bogachiel, Hoh, and Calawah basins account for about 3,279 AF/yr, or about 96% of the water allocated in WRIA 20.

Pacific sub-basins 2, 3, 4 and 5 do not have any water rights or claims.

There are 21 pending applications in WRIA 20, including 20 applications for new water rights and one change application (Figure 3-9). There are three applications requesting a total of 357 gpm of groundwater for domestic use. There are also 17 applications requesting a total of 1,008.36 cfs of surface water, including one application for 1,000 cfs for power generation and 7 cfs for fish propagation.

3.5 Administrative Status of Instream Flows

Minimum Instream Flows or closures for the WRIA 20 Watershed have not been set at this time. Ecology provided a list of Surface Water Source Limitation (SWSL) letters associated with water right applications. The SWSLs are summarized in the following table:

Water Body	Priority Date	Recommendation
Beaver Creek (tributary to Sol Duc River)	December 9, 1992	Recommended denial of application for 0.6 cfs, recommended no diversions when flow < 215 cfs October-June or flow <145 cfs July-September
Bogachiel River (tributary to Quillayute River)	September 12, 1991	Denial of application, concerns for Coho salmon
Lake Pleasant (tributary to Sol Duc River)	March 31, 1993	Denial of application, concerns for Coho salmon
Sol Duc River (tributary to Quillayute River)	February 27, 1992	Denial of application, concerns for Coho salmon
Sol Duc River (tributary to Quillayute River)	May 5, 1989	Recommended low flow provisions of 250 cfs October-June and 145 cfs July-September measured at Snider Creek Sanger Station Gage
Snider Creek (tributary to Sol Duc River)	January 11, 1993	Recommended low flow provisions of 215 cfs October-June and 145 cfs July-September measured at Snyder Creek Sanger Station Gage (Sol Duc River)

3.6 Discussion and Recommendations

The following are observations concerning water allocation in WRIA 20:

- Claimed and allocated water accounts for an annual average of about 4.7 cfs of water. This is a small portion of the total water budget of WRIA 20. Although claimed and allocated water represents a small portion of the WRIA 20 water budget, most of the claims and allocations occur in limited areas along rivers such as the Sol Duc River and major transportation corridors such as Highway 101. Therefore, claimed and allocated water can be a larger portion of a sub-basin water budget.
- Claims account for approximately 64% of the documents in the WOB database for WRIA 20. However, the volume of claimed water accounts for approximately 36% of the total claimed and allocated water in WRIA 20. Certificates and permits account for about 32% of the documents in the WOB database, but account for about 64% of the claimed and allocated water.
- Municipal and domestic use accounts for about 48% of the claimed and allocated water in WRIA 20. All water allocated for municipal use is from groundwater. Water allocated for domestic use is from both groundwater and surface water.
- There is little crop irrigation in WRIA 20. However, this assessment of water allocation indicates that water rights and claims specified to have an “irrigation” purpose of use account for about 42% of the claimed and allocated water in WRIA 20. Certificates and permits account for about 25% of the water claimed and allocated for irrigation use. Many of the water right and claim documents that were included in the “irrigation”

purpose of use in this assessment also include purposes of use such as domestic supply or stock watering in addition to irrigation. Therefore, some of the water claimed or allocated for irrigation in this analysis is likely used for other purposes.

The following are recommendations concerning water rights in WRIA 20:

- Although minimum instream flows have not been set in WRIA 20, the Washington Department of Fish and Wildlife has recommended denial of water rights, low flow provisions, or no diversion when streamflow rates drop below certain levels for several surface water right applications in WRIA 20. Instream flows and sub-basin water balances should be evaluated, and minimum instream flows adopted, to guide future water right decision making in the basin.
- Better understand the actual uses associated with rights and claims that have a “irrigation” purpose of use and a “domestic” purpose of use associated with the right or claim.

4.0 OUT-OF-STREAM WATER USE

Water use estimates for current and future conditions are a required element of watershed planning under RCW 90.82.070 (1d) (1e), and provide baseline information for development of management strategies in a watershed plan. This chapter addresses out of stream, human-related water use. Naturally occurring water use, such as forest-related consumptive use and evapotranspiration losses are described in the context of the overall water balance in Section 5. Non-consumptive uses, including fish, wildlife, and recreation, are not discussed in this document. However, it is important to recognize that these in-stream uses are critical to the watershed system as a whole. A discussion on fisheries habitat in the WRIA is included in Section7.

Types of human-related water use in the WRIA 20 watershed are characterized in this section according to the following categories:

- Municipal Purveyor withdrawals (residential and commercial uses);
- Exempt well withdrawals (rural residential uses);
- Agriculture/Irrigation;
- Forestry;
- Tribal
- Other combined uses.

Current and future water use in WRIA 20 is aggregated according to the seven sub-basins. Water use in WRIA 20 is relatively small compared with many other WRIAs. This is due to factors such as the small population and the lack of significant irrigation in the WRIA. The five Pacific sub-basins (Pacific 1-5) were excluded from this analysis. The majority of primary water uses in the watershed were quantified using existing data.

Watershed planning typically focuses on the water balance and the way that humans affect it through the water use component of the water balance. Water use can be broken into two components, consumptive use and non-consumptive use. The non-consumptive use component is characterized by water that, after being put to beneficial use, is returned to the hydrologic system via mechanisms such as wastewater treatment plants, septic systems, and infiltration of excess domestic and agricultural irrigation water. Consumptive use is water that is not returned to the WRIA 20 basin hydrologic system after use. Examples of consumptive water use include evapotranspiration from forestland and agricultural crops, evaporation of open water, and evapotranspiration of water used for landscaping and home gardening. Most of the data available for this water use analysis do not break total use into consumptive and non-consumptive components.

4.1 General Water Use Assumptions

The general approach to determining total current and future residential water use in WRIA 20 in this assessment uses a per capita water use based on Forks Water System data, which is applied to population data from the U.S. Census (to estimate exempt well use) and to Washington Department of Health (WDOH) service connection data (to estimate Group A and B water system use). This method is applied at both the watershed and individual sub-watershed level. Several key assumptions are necessary to calculate overall water use in the WRIA. These include the following:

Per Capita Water Use

An average daily per capita water use factor of 121 gallons per day per capita (gpdpc) is used for the following analysis. This factor is derived from City of Forks pumping data (May 2002 through June 2004), and a population served by the Forks water system of 5000 people (reported in the WDOH Compliance Monitoring Database [2002]). This per capita water use factor is assumed to apply over the entire watershed and to both residential use from municipal systems and exempt well use. This per capita water use factor is used in this assessment to obtain current and future population-based exempt well annual water use quantities. Forks municipal water use was divided by the population serviced by the Forks Water System to determine an average daily per capita water use for each month, which were then averaged to obtain a per capita use of 121 gpdpc. R.C. Lane reports a per capita use factor of 100 gpdpc for Clallam County (Lane, 2004). This estimate appears quite low when compared to the calculated value for the City of Forks.

Average Number of Persons Per Household

Estimates of total population utilizing purveyor water were made assuming an average of 2.75 people per connection served by a public water system (PWS) (Clallam County Western Regional Comprehensive Plan, 2002). Estimates of the number of residences served by exempt wells were also made assuming 2.75 persons per residence.

Washington Department of Health Compliance Monitoring Database

The WDOH compliance monitoring database contains the water quality information and well data for public drinking water systems throughout the state. This database was queried to obtain information on public water system wells located within WRIA 20.

The WDOH database is comprised of several information management systems, including SADIE, DWAIN, and SENTRY systems. The WDOH Drinking Water Division Information Technology Project Section is responsible for analysis, design, development and deployment of two information management systems for public water systems, including water system operators and water sample results. The two systems are the Drinking Water Automated Information Network (DWAIN) and the System for Automated DWAIN Information Extraction (SADIE).

4.2 Current Water Use

This section summarizes current water use and the data used to summarize each type of use in WRIA 20. This summary is limited to readily available, existing information. Tables 4-1 through 4-7 provide detailed breakdowns on water use. A summary of annual water use by category and sub-basin is presented in Table 4-6. Data presented in this section are used in the annual and monthly water balance presented in Section 5.

4.2.1 Municipal Purveyor Water Use

Purveyors are entities that provide water to the public and private sector. For the purposes of this analysis, the term purveyor is defined as all public water systems (PWS), including municipalities, water districts and privately owned public water systems that provide water to two or more service connections. A PWS is defined by the WDOH as any domestic water supply serving more than a single-family residence. The WDOH regulates public water systems under two main categories. Group A systems are those systems regulated under the Federal Safe Drinking Water Act (SDWA). Group B systems are regulated under state law, but not under the SDWA.

The PWS identified in the WDOH database are listed in Table 4-1, and are defined as follows:

- Group A, Community Water Systems, provide water to 15 or more service connections used by residents for 180 days or more per year, or provide water to less than 15 connections that serve at least 25 year-round residents. There are 9 active Group A Community Water Systems located within the 7 primary sub-basins of WRIA 20 (Table 4-1).
- Group A, Non-Community Water Systems provide water to the public, but not to residential communities. There are two categories: transient and non-transient. Examples of WRIA 20 non-community uses include campgrounds, motels, restaurants and those relating to commercial forestry. There are 13 active Group A Non-Community Water located within the 7 primary sub-basins in WRIA 20 (Table 4-1).
- Group B systems include systems that serve smaller communities and subdivisions ranging from two to 14 residential service connections. There are 27 Group B systems located within the 7 primary sub-basins in WRIA 20 (Table 4-1).

Figure 2-6 shows the location of Group A and B systems in the watershed.

Table 4-2a summarizes total current domestic water use in the WRIA. This domestic use is comprised of both municipal purveyor use and exempt well use (exempt well use is discussed in the following section). Municipal purveyor water use estimates were developed using service connection information provided in the WDOH database.

The WDOH database indicates that 1,450 connections and 5,000 people are currently served by the City of Forks PWS. These figures were applied to water use data for the City of Forks. It should be noted that the U.S. Census reports a total Forks population of 3,120 for the year 2000. The City of Forks public water system service area extends outside of the City of Forks incorporated area.

The footprint for the City of Forks is distributed between three sub-basins, with approximately 26% of the Forks' land area within the Bogachiel sub-basin, 70% within the Calawah sub-basin and 4% within the Sol Duc sub-basin. These percentages were applied to the WDOH reported number of connections for the Forks PWS (along with other connections in those sub-basins) to calculate the number of connections within each of the three sub-basins. It should be noted that even though Forks Public Water System services connections outside of the city's footprint, using the land area within the city's boundary was the best method available with the existing data for determining the connection and population distribution amongst the three sub-basins.

The connection use factor of 2.75 people per connection was obtained from the Clallam County Western Regional Comprehensive Plan, but was originally reported in the 1989 City of Forks Comprehensive Water System Plan. The Forks Plan is outdated and the City of Forks has plans to make updates in the near future. For the purposes of this assessment and until further data are made available, it is assumed that the per connection use factor is relatively accurate and applicable to WRIA 20.

Table 4-2b summarizes water use by non-community public water systems. Non-community water use is assumed to occur for approximately half the year and at half the rate of domestic use.

Base and Peak Use

In general, purveyor water use is comprised of two components: a low base use component characterized by water that is used consistently over an annual cycle, a significant portion of which is returned to the hydrologic system through wastewater treatment plants and septic systems; and a high peak (consumptive) use component usually occurring during drier warmer months, in the form of landscaping and home garden irrigation. Purveyor water use is typically expressed on a per capita basis and a peaking factor is commonly used to represent the increase in outdoor watering during the summer. Table 4-3 presents the City of Forks monthly withdrawal records. These records indicate that there does not appear to be a large difference in water use during winter and summer months. This is likely due to high rainfall and the lack of a need for significant lawn irrigation during the summer months in WRIA 20.

Table 4-3 indicates that base water use ranges between 108 and 123 gallons per day per capita (gpdpc). Maximum summer water use is on the order of 158 gpdpc, which is equivalent to a peaking factor of approximately 1.4, a factor that is significantly less than typical peaking factors found elsewhere in the state.

Discharges from the City of Forks wastewater treatment plant in 2004 are presented in Table 4-3. These data are compared to 2003 water use data for the City of Forks to evaluate consumptive water use. Discharge volumes have relatively low variability throughout the year, with per capita discharge rates ranging between 91 and 117 gpdpc for an annual average discharge of 101 gpdpc.

Consumptive and Non-Consumptive use

The consumptive and non-consumptive components of residential water use in WRIA 20 can be estimated by comparing the City of Forks per capita water withdrawals and wastewater discharges over a specified time period. Although the water system and the sewer system service areas are different, comparison of per capita water use to per capita wastewater discharge can be used to approximate consumptive water use. The difference between wastewater discharge and water supply withdrawal is equivalent to municipal consumptive use. Table 4-3 presents the total water use and the amount of that water returned to the hydrologic system from City of Forks pumping and discharge data, respectively. Comparison of these data show that approximately 85% of the water withdrawn by the City of Forks is returned to the natural system via wastewater discharge or septic system infiltration on an annual basis. Consumptive use estimates can be used for purposes of the overall water balance.

An annual estimate of 85% consumptive use is relatively high. Because the sewer and water service areas for the City of Forks are different, a direct comparison of water use and wastewater discharge is difficult. It should be noted that a larger proportion of Fork's water service area serves single family residences, and that the per capita wastewater estimates may be skewed by the larger portion of commercial hookups in the sewer service area that the water service area. We were unable to obtain a breakdown of residential versus commercial waste water hookups from the City for purposes of this analysis.

4.2.2 Exempt Well Use

Single domestic water supplies in WRIA 20, if not provided by a municipal or purveyor system, are typically drawn from either exempt wells or permitted surface water sources. Domestic exempt well withdrawals are defined as "any withdrawal of public ground waters for stock-watering purposes, or for the watering of a lawn or of a noncommercial garden not exceeding one-half acre in area, or for single or group domestic uses in an amount not exceeding five thousand gallons a day, or for an industrial purpose in an amount not exceeding five thousand gallons a day" (RCW 90.40.50).

Exempt wells are an important factor in watershed planning and they can comprise a significant portion of water use within a WRIA. However, the total number of wells and quantity of water withdrawn by exempt wells is not well known. Wells described as exempt wells are exempt from the requirement to obtain a water right from Ecology under RCW 90.44. RCW 90.44.050.

Individual household water supplies from surface water sources are not exempt from the requirement to obtain a water right, and as such individual household surface water uses should be included in Department of Ecology water right/claims records, as described in Section 2.

Although exempt wells are allowed to use up to 5,000 gallons per day, which is equivalent to a maximum annual use of 5.6 acre-feet per year (0.0077 cfs), individual household use is usually a much smaller annual amount. Exempt well water use patterns typically mirror that of the municipal system, but may be higher or lower, depending on a number of factors.

Variables contributing to higher water use from exempt wells include:

- There is no meter charge for exempt wells as there is for water supplied by municipal purveyors, therefore there is less incentive to conserve water (aside from the electrical bill associated with pump operation);
- Exempt wells occur in rural areas with larger lot sizes. Therefore landscaping and garden use can be higher than in more developed areas; and
- Exempt wells occur in rural areas that commonly support livestock with wells.

Variables contributing to lower water use from exempt wells include:

- Exempt wells may be installed in less productive aquifers which limit the volumes of water that can be withdrawn.
- Exempt wells may support homes in rural areas that do not have any landscape water needs.
- Some exempt wells support seasonal vacation homes that are not regularly occupied.
- Exempt wells are sometimes located on vacant lots with no actual water use.
- Properties with irrigation rights would only use their exempt wells for indoor use, resulting in lower consumptive use of the exempt well.

<u>Number of Exempt Wells</u>

A detailed study to identify, locate and map exempt wells in WRIA 20 has not been conducted. The residential population served by exempt wells in each sub-basin was calculated using 2000 U.S. Census (2000) data and subtracting the number of residents served by PWS. The total 2000 population of full time residents in the 7 major WRIA 20 sub-basins is 7,181. The total population served by PWS is 4,334. The remaining resident population of 2,847 is serviced by exempt wells. This assumes that the number of single households being served by permitted surface water withdrawals is negligible.

Table 4-2a summarizes the estimated number of permanent resident exempt well users and exempt well water use in each sub-basin. The Clallam County Western Regional Comprehensive Plan reports an average household size of 2.75 people per residence. Using this factor, we estimate that 1,035 permanent residences are serviced by exempt wells in WRIA 20. Total water use by persons on exempt wells in WRIA 20 is 386 AF/yr or 0.53 cfs averaged over the year.

Actual exempt well water use may vary depending on whether a secondary irrigation source is available to a household with an exempt well. Existing data estimating per capita exempt well water use for homes with a secondary irrigation supply are not currently available.

4.2.3 Agricultural Water Use

Based on National Land Cover Database (NLCD) land coverage data, agricultural lands comprise approximately 2355 acres within WRIA 20, accounting for 0.3% of the total land cover. This small percentage of agricultural land in WRIA 20 was confirmed through conversations with representatives from both the Clallam and Jefferson County Conservation Districts, who agreed that agricultural consumptive uses are probably negligible in WRIA 20.

The land cover data set used to calculate agricultural water use was obtained from the NLCD and is interpreted from 1992 LANDSAT Thematic Mapper satellite images with 30 meter resolution. Because of the scale of these satellite images, the land cover information presented here is effectively the average of the land cover per 30 square meter pixels across the watershed. Users accuracy for the data set is estimated to be between 57% and 93% for aggregated land use classes with overall average accuracy of 83%. This land cover information can be used to provide an understanding of overall land cover distribution in the watershed in 1992, but is not expected to be accurate at a small scale (i.e., land cover distribution within one mile of Forks).

Agricultural consumptive use can be divided into two general categories, irrigation and stock watering. Irrigation water constitutes water applied to crops, which includes conveyance losses, application losses and evapotranspiration by the crop. In order to estimate water use for agricultural irrigation, the amount and location of irrigated acreage must be identified. There is little irrigable acreage in WRIA 20. Stock water use refers to the amount of water used by farmers to maintain stock. Much of the agricultural land in the watershed is used as pasture for livestock, and there may be some livestock-related water consumption (Personal Communication, Al Latham, Jefferson County Conservation District, 6/1/2004). However, total stock water use is not precisely known and in comparison to other water uses in the watershed, is not considered significant and has therefore been excluded from further analysis.

USDA 2002 Agricultural Census data for Clallam and Jefferson Counties confirm that there is very little irrigated agriculture in either of these counties, comprising approximately 0.4% of all lands within Clallam County and 0.06% of all lands in Jefferson County. This data source reports total cropland, (including harvested, failed, fallow and idle croplands as well as lands used for pasture, grazing and cover crops) and the total number of irrigated acres by county. Clallam County is shown to have a total of 13,469 acres of cropland and of this, 4,691 acres are reported as irrigated acres. Jefferson County is reported as having 5,640 acres of agricultural land, of which 754 acres are reported as irrigated. Using these data, irrigated agriculture comprises approximately 34.8% of the total agricultural lands in Clallam County and approximately 13.4% of the total in Jefferson County. The majority of agricultural irrigation in Clallam County occurs in the Dungeness Valley, which is not a part of WRIA 20 (personal communication, Joe Holtrop, Clallam County Conservation District 6/1/2004), therefore 34.8% is likely an overestimate of irrigated acreage in WRIA 20. Based on conversations with representatives from the local conservation districts and the high rate of precipitation known to occur in WRIA 20, the irrigation estimate of 13.4% for Jefferson County more likely reflects conditions within WRIA 20 and will therefore be applied to the NLCD total agricultural lands data to obtain the number of irrigated acres in WRIA 20.

To estimate irrigation water use in each WRIA 20 sub-basin, an irrigation duty of 1.5 feet per year, reported for Jefferson County (Lane, 2004), was applied to the irrigated acreage within each sub-basin. As described above, irrigated acreage for each sub-basin was calculated by assuming that 13.4% of the total agricultural lands reported by NLCD are irrigated (Table 4-4). This estimate indicates that approximately 473 acre-feet per year (or 0.65 cfs) of water is used for irrigation in WRIA 20. In light of the high precipitation rates and the likelihood that pastures are only watered during summer months, this is likely an overestimate of water use related to agricultural activities. However, no data are available, specific to WRIA 20 (and western Clallam County) that can provide more accurate estimates of irrigation water use in the WRIA at this time. Based on the reported overall accuracy of the NLCD data (83%) used to calculate agricultural water use, we can assume that at a minimum, this level of error is also present in the agricultural water use calculations. Using the accuracy estimate provided by NLCD, actual agricultural water use can be assumed to range between 393 acre-feet per year (0.54 cfs) and 554 acre-feet per year (0.77 cfs) in WRIA 20.

As described in Section 3, water rights and claims specified to have an “irrigation” purpose of use account for about 580 acre-feet of water per year from groundwater, and 847 acre-feet per year from surface water. The water rights for irrigation purposes are well above the estimated water use for irrigation (473 acre-feet per year), and may be used to represent an upper bound of potential irrigation water use. It should be noted, however, that the assignment of an “irrigation” purpose to a water right may also include other purposes such as domestic supply, and therefore the estimate of water allocated for irrigation is also likely overestimated.

4.2.4 Forestry-Related Use

Based on conversations with forestry representatives from the U.S. Forest Service (USFS), the Washington Department of Natural Resources (WDNR) and private timber industry, there is no significant water use associated with the forest industry in WRIA 20 (personal communication, Sue Trettevik, June 18, 2004; Vern Ferrell, June 18, 2004; and Bill Peach, July 8, 2004). There may be forest fire-related water use during the summer months, but these uses are also believed to be insignificant (personal communication, Bill Peach, July 8, 2004).

4.2.5 Tribal Water Use

There are three tribes within WRIA 20; the Hoh, Makah, and Quileute Tribes. There are four Tribal reservations, however the Ozette Reservation is under treaty jurisdiction of the Makah Tribe and is currently managed as wilderness. Water use data for the Hoh and Makah Tribes are not included in this water use assessment by request (personal communication, Jim Jorgensen, July 12, 2004; and Jeff Shellberg, June 9, 2004, respectively). The Quileute Tribe draws its water from two wells located in the Three Rivers area (the confluence of the Bogachiel and Sol Duc Rivers, which form the Quillayute River). The wells are approximately 60 feet apart and pump in an alternating manner (Schuch, 2003). Water use data for the Quileute Tribe are summarized in Table 4-5 and were calculated using monthly production data for 1995, 1997, 2000 and 2002, provided by the Three Rivers Water Plant. Based on these data, total annual water use for the Quileute Tribe is approximately 148 acre-feet per year, or 0.20 cfs. The Quileute Reservation is located in Sol Duc sub-basin and this water use is therefore applied to the total water use estimate for this sub-basin.

4.2.6 Total Annual Water Use

Table 4-6 presents a summary of the total annual water use for each of the categories discussed above. The water usage estimated for each category is totaled by sub-basin. Total water use for all categories in WRIA 20 equals 1,594 AF/yr, or 2.2 cfs. Residential water use, including both municipal use and use of exempt wells, comprises the largest overall water use in the watershed. Agricultural water use (irrigation) also comprises a significant portion of the total annual water use. However, the lack of data regarding irrigable acreage leads to an overly conservative estimate of irrigation.

4.3 Future Water Use

Estimates of future water use are a required component for Phase II Watershed Planning under HB2514. Agricultural water use appears to be a significant water use, however this use is likely over-estimated, as discussed in Section 4.2.3. The primary water use in WRIA 20 is for domestic purposes. Therefore, domestic water use is the only projected future water use that will be determined for this assessment.

4.3.1 Future Municipal (Purveyor) and Domestic Exempt Well Use

Projected water use for municipal and domestic purposes was calculated by determining the projected 2025 population in each sub-basin based on observation of the population trend from 1990 to 2000. The projected future water use was calculated assuming that projected water use rates are equivalent to the current water use rates, and that the population trend observed from 1990 to 2000 is linear through 2025. The exceptions are the Bogachiel, Dickey, and Sol Duc sub-basins, where populations have decreased by 34%, 51%, and 4% respectively between 1990 and 2000. In the cases of decreasing populations, it was conservatively assumed that populations (and thus water use) will remain the same through 2025.

Population data were obtained from the U.S. Census Bureau for the 1990 and 2000 U.S. Census and were distributed by census block for each sub-basin. Where census blocks straddle sub-basin boundaries, the population of the census block was distributed between the sub-basins proportional to the area of the census block in each sub-basin. This assumes the population to be evenly distributed within the block. In actuality, this may not be the case. However, the error is considered acceptable for the purposes of this study given the size of the population being examined.

The projected water use estimate is based only on population estimates. Growth or declines in water use is not broken out between municipal and exempt wells because it is difficult to determine where growth will occur within a sub-basin, if the growth will occur on purveyor systems or exempt wells and how the water supply system would choose to accommodate growth demands. It is anticipated that any significant future growth would likely be served by public water systems instead of exempt wells. In addition, water use savings as the result of conservation was not investigated or incorporated into the projected water use estimate.

Residential water use in the year 2025 was estimated using the projected 2025 watershed population of approximately 9,093 people, as shown in Table 4-7. Total residential water use (PWS and exempt wells) in 2025 is estimated at 1,232 AF/yr, or 1.7 cfs, slightly more than the estimated current water use of 973 AF/year or 1.34 cfs (for PWS and exempt wells).

The OFM (Office of Financial Management) provides high, medium and low growth estimates for Clallam County. The high estimate is 35%, the medium is 21% and the low estimate is 5%. This approach, utilizing Census data, assumes that growth will be even less than the low estimate by OFM. Growth in Clallam County is primarily occurring in the northwestern portion of the County which does not encompass WRIA 20. Population trends within the actual sub-basins are likely more representative of future growth.

4.4 Summary

The generally low population density and lack of commercial and industrial facilities that characterize WRIA 20 result in relatively small quantities of out-of-stream beneficial water use in the watershed as compared to other WRIAs. The following is a summary of primary findings regarding water use in WRIA 20:

- The primary consumptive water use in the watershed is from individual households on public water supply systems or individual households on self-supplied systems;
- Future (2025) household water use is not expected to increase significantly in WRIA 20 due to low projected population growth.
- Water use demands outside of WRIA 20 are expected to increase, and may result in an increase in the use of WRIA 20 water for outside entities. There is concern that these projected demands may outweigh the low population growth projections within WRIA 20 and result in net increase in water use. For example, increasing population and water use demands from outside areas (such as Port Angeles) may result in increased development of water supplies in areas such as WRIA 20. Therefore, relying on population estimates within the WRIA 20 boundaries may not reflect actual or potential water supply demands.
- Many individual households are not serviced by public water supply systems and use exempt wells as a water source. There is no single database that summarizes the location and extent of exempt wells in the watershed. To better understand the effects of exempt wells on both the groundwater resource and instream flows, an estimation of their number, their spatial distribution and depth, and the actual amount of water consumptively used needs to be made.
- Some individual households may use surface water or groundwater for which they hold a certificate or permit. Single residential water use by water right holders is not addressed as it is assumed to be quite small. Further discussion about surface water rights for domestic use are included in Section 3.
- Forested lands (as compared to residential and agricultural land) encompass the greatest percentage of land cover in the basin. It has been indicated that human water use resulting from forest practice activities is negligible (personal communication, WDNR, USFS, Bill Peach, July 8, 2004). However, evapotranspiration losses through forest vegetation comprise a large and significant component of the overall consumptive water use in the basin. This consumptive water use associated with forested lands is addressed in the water balance in Section 5.
- There are other types of water use including self supplied use for commercial or industrial purposes (i.e., not supplied by a water purveyor), however since there are no existing data available to estimate actual water use for these purposes, this category of water use has not been evaluated.
- There are substantial volumes of surface water rights allocated throughout WRIA 20, particularly in the Sol Duc sub-basin. The majority of the surface water rights are

designated for commercial/industrial purposes, such as shingle operations and timber companies. A large water allocation is also noted for the National Forest for domestic purposes. These rights represent the volume of surface water that may be withdrawn, but do not reflect the actual water use, as a significant portion of the allocated water may not be put to use. Personal Communication with forestry representatives from the USFS, WDNR and private timber industry have stated that there is no significant water use associated with the forest industry in WRIA 20 (June 18 and July 8, 2004).

5.0 WATER BALANCE

This section in the Technical Assessment report brings together all the water related processes in WRIA 20 that have been addressed in previous sections of this report or in studies conducted by the Bureau of Reclamation. Information regarding precipitation, streamflow, water use and groundwater are brought together to further the understanding of how water is apportioned in the watershed and in individual sub-basins within the watershed. Given the size of the watershed, the generally low volume of water use and high proportion of forest evapotranspiration, a water balance approach was selected that assumes no net change in annual groundwater storage. Because the groundwater component of the water balance is anticipated to be small, errors associated with estimating larger components of the water balance (e.g., evapotranspiration and streamflow) do not justify the use of a watershed scale water balance to calculate available groundwater. Instead, groundwater availability and use are discussed separately in Section 2.

The hydrologic cycle forms the technical basis for watershed planning. The traditional method for characterizing the hydrologic cycle at a watershed scale is through a water balance. A physical water balance uses measured data or scientific methods to estimate current and future water use and availability. This section discusses the methodology used to create a physical water balance for WRIA 20, what the balance can illustrate data used and results, and the accuracy and sensitivity of this information.

5.1 Study Area

WRIA 20 has been divided, for purposes of the water balance, into seven primary sub-basins and five small sub-basins, shown in Figure 5-1. Of the seven larger sub-basins, the Sol Duc, Calawah, Bogachiel, and Dickey drain towards a single river - the Quillayute River, close to its mouth at the Pacific Ocean. Of the remaining three larger sub-basins only the Hoh and Ozette River drain primarily to a single outlet. The Sooes River, as well as the remaining grouped sub-basins (noted as Pacific 1 through 5), consist of many smaller drainages with rivers and creeks originating in the lowlands and draining directly into the Pacific.

Precipitation in the form of rain and snow is the primary source of water in WRIA 20 with the only other identified source being fog-drip (Harr, 1982). Much of the watershed is in lower elevation areas and receives precipitation in the form of rain with snow pack only existing for brief periods (generally several days). Portions of the Sol Duc, Bogachiel, and Hoh contain higher elevation areas where snow may exist over a period of weeks or months. Precipitation occurs year-round but the greatest precipitation generally occurs between November and January and the least precipitation occurs between June and August.

Water balances were completed for the Bogachiel, Calawah, Dickey, Hoh, Sol Duc, Ozette and Sooes sub-basins (Figure 5-1). Water balances were not performed for the five smaller sub-basins referred to as Pacific 1 through 5 because:

- Numerous smaller creeks draining sub-basins along the shore are not gauged;
- These areas are expected to act as natural systems due to their remote location and existence within National Park Boundaries;
- Water use was not calculated for Pacific sub-basins 1 through 5 and is not expected to be significant now, or in the future; and

- Streamflow estimates provided by the Bureau of Reclamation (BOR) did not include Pacific sub-basins 1 through 5.

5.2 Previous Studies

Several studies specific to the watershed were used to provide background, data or methods in the water balance. These include:

- *Watershed Analysis Studies completed for the Sol Duc, East and West Dickey and North Fork and South Fork Calawah sub-basins (USDA Forest Service 1995, Rayonier, 1998, USDA Forest Service 1996, and USDA Forest Service 1998).*

These reports were completed by varying groups of private/public partnerships and are intended to serve as the basis for forest practice prescriptions on State and private lands, and as guidance for site specific activities and long range land management planning on federal lands. Most of the analyses were completed using the Standard Methodology for Conducting Watershed Analysis Manual, Version 4.0 (Washington Forest Practices Board, November 1997), as well as the Ecosystems Analysis at the Watershed Scale: Federal Guide for Watershed Analysis [the Federal Guide; USDA Forest Service and U.S. Department of the Interior (USDI) Bureau of Land Management, 1994]. Hydrologic analysis conducted under these studies generally evaluated whether forest practices impacted peak flow through modification of rain-on-snow and spring snow melt processes.

- *Overview of Watershed Conditions and Seasonal Variability in Streamflow for Select Streams within WRIA 20, Olympic Peninsula, Washington (BOR, in Draft).*

The Bureau of Reclamation report provides a "comprehensive appraisal level overview of watershed conditions within WRIA 20". The BOR uses a method termed the watershed characteristics method to calculate the range of flow variability and monthly discharge for natural, undisturbed watershed conditions at ungaged locations along each selected stream. This method involves the transference of of flow characteristics from gaged watersheds to ungaged watersheds. An appendix (this report is still in draft) describing the application of this method to WRIA 20 will be included in the final report. In addition, these reports include a discussion of watershed responses to changes in watershed conditions.

- *U.S. Geological Survey, Low-Flow Characteristics of Streams on the Olympic Peninsula, Washington. Open-File Report 77-812.*

This report provides estimates of the magnitude, frequency, and normal period of occurrence of low flows on certain streams on the Olympic Peninsula based on measured data.

5.3 Background Issues

5.3.1 <u>Streamflow Estimates</u>

Naturalized monthly average streamflow estimates, developed by the Bureau of Reclamation (BOR), were used to calculate the streamflow (referred to as runoff) component of this water balance. It is assumed, based on conversations with BOR, that their streamflow estimates represent flows that would occur if no water was withdrawn from the system. These BOR synthesized flows are not adjusted for vegetation maturity. The streamflow (runoff) component of this water balance was calculated using the BOR streamflow estimates and subtracting actual residential and irrigation water use (both surface and groundwater use) from them (see Section 4, Water Use). This document does not include an analysis of the BOR methodology or a comparison of their results with measured data. The methodology used by the BOR to develop streamflow estimates is included in Appendix B.

5.3.2 Fog Drip

Fog-drip is water that drips to the ground from trees or other objects that have collected moisture from drifting fog. Some studies have estimated fog-drip to account for as much as 20-50% of total water input to the basin (Harr, 1982; Dawson, unpublished). Water input from fog drip is not quantitatively addressed in this water balance. Fog drip data are not captured by standard climate station measurements and well accepted methods do not exist to estimate fog drip.

5.4 Hydrologic Cycle

The hydrologic cycle forms the technical basis for water resource decision making at multiple scales. At a global scale, the hydrologic cycle describes the circulation of water between the oceans, atmosphere and land. At the watershed scale, the hydrologic cycle focuses on the land-based hydrologic system that is bounded by surface water divides.

A watershed must be viewed as a combination of both the surface drainage area and the subsurface materials that underlie the watershed. A clear understanding of the hydrologic cycle at the watershed scale involves an inventory of the water inputs, outputs and storage within the watershed. Knowledge of the dynamic processes that occur within a watershed hydrologic cycle provides an understanding of what effects various resource management approaches will have on the natural system.

The hydrologic cycle, illustrated in Figure 5-2, is a network of inflows and outflows that may be expressed as a water balance or water budget by equating the primary variables (input, output and change in storage):

$$\text{Input} = \text{Output} +/- \text{Change In Storage}$$

This equation is a conservative statement that ensures that all the water within the watershed is accounted for and that water cannot be lost or gained.

The main input to the hydrologic system is precipitation falling as rain or snow. The amount of precipitation is the primary control on the amount of water that may be available within the watershed. Additional inputs to the hydrologic system may include fog-drip captured in vegetation and groundwater inflow from adjacent watersheds.

Outflow from a watershed occurs naturally as streamflow or runoff, groundwater discharge, and as evapotranspiration. Evapotranspiration is the combination of evaporation from open bodies of water, vegetation and soil surfaces, and transpiration from vegetation. Outflow from a watershed also occurs as a result of human consumption and redirection of flows.

Movement of water within a watershed occurs naturally through a number of processes. Overland flow delivers precipitation to stream channels. Infiltration results in movement of water at the land surface downward into the subsurface. Groundwater flow results in movement of water within the subsurface either to streams (baseflow) or other outlets. The nature of the land surface and subsurface controls run-off, infiltration rates and groundwater flow rates. Infiltration rates and groundwater flow rates in turn influence the timing and spatial distribution of surface water flows. Groundwater flows and surface water flows are linked by the relationships between infiltration, groundwater recharge, baseflow and streamflow generation.

Movement of water within a watershed is also impacted by a number of anthropogenic factors including groundwater pumping, extraction of surface water, stormwater generation and discharge, wastewater generation and discharge, and agricultural, land use and forest management practices, as well as by climate variability and climate change. These factors are discussed below.

5.4.1 Anthropogenic Changes

Anthropogenic changes associated with increasing population and population densities can have varied impacts on water resources. Water use includes elements such as water withdrawal from surface- and ground-water sources, water delivery to homes and businesses, consumptive use of water, water released from wastewater-treatment plants, water returned to the environment, and instream uses, such as using water to produce hydroelectric power.

Water use for domestic purposes can change the timing and location of water delivery in the hydrologic cycle. For example water that would normally be under ground may be pumped to the surface and applied to the ground to water lawns. Additionally, water use is typically at its peak when water availability is lowest. Urbanization is accompanied by accelerated drainage of water through road drains and city sewer systems, which can increase the magnitude of urban flood events. Urbanization can also alter the rates of infiltration, evaporation, and transpiration that would otherwise occur in a natural setting.

5.4.2 Climate Variability and Climate Change

Information on climate variability and climate change is the focus of studies by the University of Washington Climate Impacts Group (UW CIG, 2004). The following information is excerpted from a memo distributed by that group dated April 15, 2004.

The El Niño/Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO) are important sources of natural climate variability affecting the Pacific Northwest. ENSO and PDO are natural cycles in Pacific Ocean sea surface temperatures and related ocean/atmosphere dynamics that influence climate globally. ENSO phases, also known as El Niño (the warm phase of ENSO) and La Niña (the cool phase of ENSO), are a major source of year-to-year climate variability, typically lasting 6 to 18 months and reaching peak intensity in December. The PDO, which is also categorized as warm phase or cool phase, is a major source of decadal-scale (approximately 10 to 30 years) climate variability. Figure 5-3 shows the general trends of the PDO cycle between 1900 and 2003.

The changes in regional temperature and precipitation associated with warm and cool ENSO/PDO phases affect many aspects of the Pacific Northwest environment (Table 5-1). For example, the warmer and drier conditions that typically occur with warm phase ENSO and PDO increase the potential for reduced snowpack, lower streamflows, degraded coastal and near-shore ocean habitat quality, reduced salmon runs, drought and forest fires. Cool phase ENSO and PDO conditions increase the potential for the opposite effects. The 20th century ENSO/PDO phases are listed by year in Table 5-2.

In addition to the interannual effects of natural climate variability, water resources in WRIA 20 will also be affected by global climate change. An evaluation of seven 21st century climate change scenarios for the Pacific Northwest shows that, in general, the region is expected to get warmer and wetter as a result of climate change. These climate change scenarios are based on assumptions about (1) future greenhouse gas and aerosol emissions, and (2) modeled sensitivity to those changes. Both are imperfectly known but the scenarios produced provide valuable insights into likely future conditions.

Based on the evaluation of seven global warming scenarios, the CIG projects increases in average annual temperature on the order of 2.5°F by the 2020s and 3.8°F by the 2040s (Table 5-3). Pacific Northwest winters are also projected to get wetter on average (+8%), but the range of uncertainty in precipitation change is much larger than that associated with temperature change. Projected increases in summer precipitation are negligible given how little rain falls in the summer and may be lost if evapotranspiration rates increase. All of these changes are expected on top of the 1.5°F warming (average) already experienced throughout the region during the 20th century.

Streamflows in low elevation "rain dominant" basins respond directly to precipitation events and generally peak in mid-winter with the Pacific Northwest wet season. Climate change impacts in rain dominant basins, therefore, depend primarily on projected changes in winter (October-March) precipitation, which are less certain than projected temperature changes.

If total winter precipitation increases as projected and/or precipitation intensity in individual storms increases, annual flow volumes in rain dominant basins should increase. The severity of floods and flood-related impacts, including erosion, infrastructure damage, and loss of salmon nests ("redds") to high flow riverbed scouring events, may also increase. The opposite effects would be experienced if total precipitation in winter decreases and/or the precipitation intensity in individual storms decreases. On the positive side, increases in spring precipitation could increase summer water availability if storage is available. Changes in the seasonality of streamflow are expected to be minimal in rain dominant basins unless the seasonality of precipitation is significantly altered by climate change.

Although most of WRIA 20 can be considered to be a "rain dominated" basin, portions of the Sol Duc and Hoh sub-basins can be considered "transient snow" basins. Transient snow basins are located near the current mid-winter snowline and as such, receive a mix of winter precipitation dependent on elevation. Lower portions of the basin will receive rain throughout the winter season. Mid-elevation portions of the basin will receive rain in autumn and early winter with a transition to snow in late winter. The highest elevations of the basin may accumulate snow throughout the winter season. Because of these characteristics, hydrographs for transient basins are noted by two seasonal runoff peaks: the first runoff peak occurs in mid-winter with the peak in fall rains (November-January) while the second runoff peak occurs during the period of spring snowmelt (May-June).

Of the three hydrologic basin types (rain dominant, transient snow, and snowmelt dominant), transient basins are the most sensitive to climate change because average winter (October-March) temperature in large portions of these basins is near the freezing threshold. A few degrees of warming in transient basins is enough to shift temperatures above freezing for longer periods over more of the basin, resulting in more winter precipitation falling as rain rather than snow and reducing the amount of water stored as snow in mid-winter. This combination of effects also results in higher winter flows and increased risk of winter flooding.

Climate change impacts on winter precipitation and snowpack accumulation have important carry-over effects on the volume and timing of spring and summer streamflow. Temperature-induced reductions in winter snowpack reduce the volume of spring and summer streamflow in transient basins. In a simulation of climate change impacts on a west Cascades transient basin, for example, a 4.5° F warming scenario resulted in a 35% reduction in April-September inflows.

Changes in the timing of spring streamflow are driven by the influence of warmer winter/spring temperatures on the timing of snow melt. Warmer temperatures earlier in the snowmelt season induce earlier snow melt, potentially shifting the peak of spring runoff earlier into the spring season by as much as four weeks by 2040. This shift in streamflow timing may affect a transient basin's ability to meet water demands during the driest time of the year by lengthening the time between peak spring runoff and the onset of fall rains.

For both rain dominant and transient snow basins, warmer summer temperatures may reduce late summer base flows if net evapotranspiration increases. Changes in cloud cover and wind (which are difficult to model reliably) can have significant mitigating effects on evapotranspiration losses, however. Decreased base flows in late summer and higher water temperatures may pose threats to cold water fish, including salmon. On the demand side, warmer summer temperatures are projected to increase summer water demand.

5.4.3 Forest Management

In forest ecosystems, the underlying processes that control water movement are: evaporation, transpiration, snow pack energy balance, infiltration, percolation, and lateral subsurface flow (Waring and Schlesinger, 1985). Most of these processes are not easily quantified through direct measurement. Estimation of these processes requires measurement of parameters such as seasonal canopy leaf area, wind, humidity, solar radiation, canopy height and soil hydrologic characteristics, parameters that are not readily available and vary widely spatially. Computer simulation models can often be the most effective method for predicting the interaction of these parameters in a forest ecosystem as well as their relative importance.

As a result of the complexity of the forest hydrologic cycle and process understanding, determining the overall response of a watershed to forest management practices is difficult. There have been few well-controlled paired-watershed experiments and, of those, the variability of climate and lithologies among studies results in inconsistent and unsupported findings that may not be applicable to varied areas. However, there are several hydrologic responses to forest management practices that are well accepted. Table 5-4 summarizes generally accepted hydrologic responses to deforestation. In general, the opposite response would be expected from afforestation. The magnitude of the components response as well as the length of time the response can be observed can be expected to vary from basin to basin depending on basin characteristics and magnitude of forest change. A further discussion o fthe effects of land use on water resources, and specifically for forest lands, can be found in Section 6.3.2.

5.5 Water Balance Objective and Level of Detail

The watershed planning process is designed to bring stakeholders together as a group to determine the future of water management in their basin. The water balance is an important part of this process because it represents the integration of each watershed study component. Therefore, the objective of this water balance is to provide a tool that can easily be understood and utilized by a diverse group of people for assessing allocation of water within WRIA 20 sub-basins.

The level of detail for this study is a monthly and annual water balance at the sub-basin scale. The seven sub-basins used in the analysis are described in Table 5-5 and shown in Figure 5-1. The water balance was created using a spreadsheet that clearly displays each component and its relative influence on the water balance. Several issues should be noted when applying this water balance for purposes of watershed planning.

- The relative magnitudes of each hydrologic parameter are aggregated at a sub-basin geographic scale and a monthly time scale. This format can be easily implemented in a spreadsheet, but lacks the fine scale necessary for site-specific studies. Therefore, it provides a basis for management strategies that will affect hydrologic features at a comparable scale.
- The water balance provides a basic assessment of groundwater/surface water interaction at a sub-basin scale. Most hydrologic parameters in a water balance are directly measured (precipitation, water use, etc.), while others, such as groundwater recharge or discharge, are calculated as a "residual" in the water balance equation.
- The water balance provides only a very basic assessment of water availability for habitat needs. Habitat management issues may require additional "fine scale" assessment (both spatially and temporally) to quantify water availability for habitat purposes.

5.6 Water Balance Approach

Watershed water balance refers to the balance between the inflow of water to a watershed as precipitation, any changes in storage, and the outflow of water from the watershed as evapotranspiration, ground water discharge, and streamflow. Basically, a watershed water balance is an accounting tool to keep track of the inputs and outputs of the hydrologic cycle in a watershed over time.

The units used in a water balance are, by convention, inches and acre-feet. Values expressed in inches are typically used to compare the relative magnitude of the components of the water balance within a sub-basin. Values expressed in acre-feet are typically used to compare the relative magnitude of the components of the water balance between sub-basins. This is an important distinction. An inch of water in a large sub-basin represents more water than an inch of water in a small sub-basin. The water balance is analyzed over the water year, defined as the October 1 through September 30 (i.e. the beginning of autumn through to the end of summer).

The following components are incorporated for each sub-basin water balance on both a monthly and annual time step. Sources of data used for each component are discussed in the subsequent section (Section 5.7 Water Balance Data Sources).

1. *Precipitation*: Total monthly precipitation that falls as rain or snow within the sub-basin.
2. *Snow accumulated*: The proportion of precipitation that accumulates as snowpack reported as a cumulative amount of snow water equivalent.
3. *Rainfall + Melt*: The amount of water released from snowpack plus the amount of precipitation falling as rain. Water released from snowpack is calculated using a simple temperature model based on degree-day melting rate.
4. *Observed Run-off*: Mean monthly run-off (streamflow) developed by the BOR and corrected by subtracting water use estimates for that sub-basin from the BOR estimates.
5. *Irrigated Net Use*: Agricultural irrigation is considered a minor water use component within WRIA 20. It is assumed that all irrigated water use is consumptive.
6. *Residential Net Use*: Residential use is incorporated through monthly water use data obtained from the City of Forks and applied to the entire population of the WRIA (through either municipal water systems or exempt wells). It is assumed that all residential use is consumptive use.
7. *Predicted Run-off*: Rainfall + Melt minus water use + actual evapotranspiration estimates in the basin.

8. *Net Residual*: This component can represent several processes including sub-surface flow (groundwater and irrigation return flows), sublimation from snowpack, water storage in the unsaturated zone and evaporation from water surfaces. For this model net residual is only relevant on a monthly scale because on an annual basis it is assumed that the net residual is zero. This means that its assumed no inter-annual storage exists in snow or glaciers, soil moisture, canopy storage, etc.

5.6.1 Annual Water Balance

The general approach for the annual water balance on a sub-basin basis is:

$$P = RO + CU + NR + \Delta S \qquad [1]$$

Where

P = Precipitation, an externally modeled component, based on measured data.
RO = Runoff, derived data developed by the BOR.
CU = Consumptive use, a calculated component, based on measured data.
NR = Net residual can be calculated or estimated, the annual net residual is assumed to be zero in this approach.
ΔS = Change in storage, measured variable, currently managed inter-annual storage does not exist in WRIA 20.

All units are in inches. The annual water balance is applied for a water year, beginning in October and ending in September.

5.6.2 Monthly Water Balance

Snow accumulation and melt must be addressed in a monthly water balance because precipitation falling as snow in one month may not be released as snowmelt until several months later. The general monthly water balance equation is as follows:

$$R + M = RO + CU + NR + \Delta S \qquad [2]$$

Where:

R = Rainfall, an externally modeled component, based on measured data.
M = Snowmelt, a calculated component.

All units are in inches. Note that by the end of the water year, cumulative rainfall plus melt is equal to total precipitation, assuming sublimation from snow is negligible. Thus, the monthly and annual water balance approaches are compatible.

The methods used to estimate all components in the water balance are described below.

5.6.3 Rainfall and Snow Accumulation/Melt

Snow accumulation (A) and melt (M) can be estimated on the basis of mean monthly precipitation and temperature. When mean monthly temperature (T) is below a base temperature, a fraction of the monthly precipitation (P) is added to the snowpack. The remaining fraction of the precipitation is added to rainfall (R):

For $T \leq T_b$:

$$A = P * P_x \quad [3a]$$
$$R = P * (100\%-P_x) \quad [4a]$$
$$M = 0 \quad [5a]$$

Where:
T_b is the base temperature, set to 2°C for this study.
P_x is the fraction of precipitation, which becomes snow, set to 85% for this study.
A, R, and M are in units of inches in the above equations.

By using $P_x < 100\%$, the model allows for rainfall and snow accumulation to occur in the same month (rain on snow).

When temperature exceeds the base temperature, all precipitation is added as rainfall and the snowpack is melted according to the degree-day approach:

For $T > T_b$

$$A = 0 \quad [3b]$$
$$R = P \quad [4b]$$
$$M = C_x * (T-T_b) \quad [5b]$$

Where:
C_x is a degree-day factor in units of inches/(^{0}C·day), set to 0.97 in this study.

5.7 Water Balance Data Sources

The data used to complete the water balance were obtained from a variety of sources. Each data source and its use in the water balance are discussed below.

5.7.1 Precipitation

Monthly gridded precipitation data were obtained through the Oregon Climate Surface PRISM modeled results. The Parameter-elevation Regressions on Independent Slopes Model (PRISM) provides an integrated basin-scale analysis of climate. PRISM is a model developed by Oregon State University that uses measured point data and digital elevation model (DEM) data to generate grid-based estimates of climate parameters (Daly et al., 1994). Unlike other statistical methods used today, PRISM was written by a meteorologist specifically to address climate variability. PRISM is well suited to mountainous regions because the effects of terrain on climate play a central role in the model's conceptual framework. Data input to the model consisted of 1961-1990 mean monthly precipitation from over 8,000 National Oceanic and Atmospheric Administration (NOAA) Cooperative sites, Snowpack Telemetry (SNOTEL) sites, and selected state network stations. PRISM is used to estimate mean annual, mean monthly and event-based precipitation, temperature, and other variables. The model grid resolution is 4-km (latitude and longitude). The outputs used in this study are re-sampled to 2-km resolution using mathematical filtering procedures (Daly et al., 1994). Figure 5-4 presents average annual precipitation data obtained from PRISM model output.

The Washington Forest Practices Board Watershed Analysis Manual defines five distinct precipitation zones on the basis of elevation. These five zones, delineated by elevation, include: lowland (<800 feet), rain dominated (800-1,700 feet), rain on snow (1,700-3,000 feet), snow dominated (3,000-4,500 feet) and highland (>4,500 feet). For the purposes of this study, the lowland zone has been included with the rain dominated zone and the highland zone has been grouped with the snow dominated zone. Figure 5-5 shows the distribution of the three major precipitation zones within WRIA 20. Table 5-6 presents PRISM average monthly precipitation by precipitation zone and sub-basin for each of the seven major sub-basins.

The NOAA and National Weather Service (NWS) co-operative (NOAA/NWS COOP) maintain several continuous climate stations within the basin. The locations of these stations are shown in Figure 5-6. For purposes of the water balance, point measurements of climate variables are of limited use because these variables vary widely over a sub-basin. Therefore, these point measurements within the watershed were used to check the accuracy of PRISM modeled annual precipitation. A summary of existing stations and a comparison, where possible, of those gages with PRISM annual precipitation at that point is shown in Table 5-7. Based on average annual precipitation data from climate stations within the watershed the PRISM modeled precipitation results appear to adequately represent precipitation in the basin.

5.7.2 Streamflow

As described in Section 5.3.1, this water balance uses naturalized monthly average streamflow estimates, developed by BOR, to estimate runoff. Table 5-8a presents the monthly average flows used in this water balance. In order to present water balance results on a sub-basin scale, streamflow for a single sub-basin cannot include flows from tributaries that are also defined as major sub-basins (sub-basins are outlined in Figure 5-1). Therefore, flow presented for this analysis in the Bogachiel River sub-basin does not include Calawah River inflow and flow presented for the Sol Duc River sub-basin does not include inflow from the Bogachiel, Dickey and Calawah sub-basins. These altered monthly values, utilized in the water balance calculations (in units of inches), are presented in Table 5-8b.

The BOR also produced 10%, 51% and 89% exceedance probability results for sub-basin outlets. Exceedance probability plots are used to understand how often, or how probable it is that a certain flow will be equaled or exceeded in a specified time frame. Exceedance probabilities are also called recurrence intervals, or, more generally, frequency analysis. Frequency analysis techniques were primarily developed by civil engineers, who needed to determine design criteria for hydrologic structures, particularly during hydrologic extremes (e.g. floods and droughts). The data used in these types of analyses are purely historical and the “reliability” of frequency analysis increases with the length of the historical period of record. The occurrence of a certain exceedance probability flow in one month does not mean that the same exceedance probability will occur in the next month. Therefore, frequency analysis is useful in setting design criteria, but less useful for deciding how to respond to observed conditions. Figures 5-7a through 5-7h present the 10%, 51% and 89% exceedance curves at the outlets of each of the major sub-basins using BOR produced streamflow data. Appendix B presents the methodology used by the BOR to estimate these exceedance values. Mean annual flows as estimated by the BoR in WRIA 20 sub-basins ranges from 264 cfs in the Sooes River to 4638 cfs in the Sol Duc River.

5.7.3 Temperature

As with precipitation, monthly temperature data were obtained through Oregon Climate Surface PRISM model results. PRISM is described in Section 5.7.1. Table 5-9 presents PRISM annual and monthly temperature for each sub-basin and precipitation zone. Mean annual temperature in WRIA 30 sub-basins is estimated to range from 8.2 °C in the Hoh to 9.9 °C in the Dickey.

5.7.4 Water Use

Water use information was obtained through a number of sources, each of which is discussed in detail in Section 4. Tables 5-10 a-c summarize current annual and monthly domestic, agricultural and total water use by sub-basin. Note that the industrial/commercial water use is not included in this analysis.

Monthly domestic water use is presented in Table 5-10a and was obtained using the monthly per capita water use factors presented in Table 4-3 and 2000 U.S. Census data presented in Table 4-2a for each sub-basin. These per capita water use factors are assumed to apply over the entire watershed and to both residential use from municipal systems and exempt well use. The Quileute Tribe's monthly water use data are included as part of domestic water use in the Sol Duc sub-basin. Quileute annual and monthly water use is summarized in Table 4-5. Total annual domestic water use ranges from 8.9 AF/month in the Sooes to 509.9 AF/month in the Calawah.

Monthly agricultural (irrigation) water use was calculated using the annual values presented in Table 4-4. Section 4 describes the data sources and methods used to obtain these annual values. In determining monthly agricultural water use, it was assumed that water use relating to agricultural purposes typically occurs during the growing season, from April 15 through October 15. The total annual agricultural water use values presented in Table 4-4 were evenly distributed over the growing season to obtain monthly agricultural water use values for each sub-basin, which are presented in Table 5-10b. It was assumed that water use for stock is negligible on a watershed scale in WRIA 20. Total annual agricultural water use is estimated to range from 10.1 AF/month in the Sooes to 637.8 AF/month in the Calawah.

5.7.5 Evapotranspiration

Evapotranspiration includes water that evaporates from the soil and plant surfaces as well as water transpired by plants. At a small scale, estimates of evapotranspiration take into account vegetation type, maturity, the way wind moves through a canopy, and stomatal conductance, among other factors. However, it is not practical to perform such a detailed characterization of evapotranspiration at a watershed scale. For purposes of a watershed-wide water balance, techniques that apply at a watershed scale, rather than a laboratory or small experimental forest scale are appropriate.

Evapotranspiration is often described using two terms: potential evapotranspiration and actual evapotranspiration. Potential evapotranspiration or PET is a measure of the ability of the atmosphere to remove water from a surface through the processes of evaporation and transpiration assuming no control on water supply. Actual evapotranspiration or AET is the quantity of water that is actually removed from a surface due to the processes of evaporation and transpiration.

In the WRIA 20 water balance, annual actual evapotranspiration (AET) is estimated as the difference between precipitation and runoff (streamflow) at the multi-year timescale. Therefore, for the purposes of this water balance, the evapotranspiration component represents water transpired by plants, from soil, and plant surfaces, and also from open water (such as lakes). This method assumes there is no net change in groundwater, soil, snow, or canopy storage on an annual basis. Annual AET was calculated using average annual streamflow from the BOR (less water use estimates) and average annual precipitation output from PRISM for each sub-basin.

In order to distribute AET annual data to a monthly time step for the water balance, the temperature based Blaney-Criddle method (Dunne and Leopold, 1978) was used. The Blaney-Criddle method calculates potential evapotranspiration (PET) using longitude and latitude, average air temperature, the monthly fraction of annual day light hours and an empirical crop coefficient. Table 5-11 summarizes monthly and annual AET values for each sub-basin.

The Blaney-Criddle formula is:

$$PET = (0.142Ta + 1.095)(Ta+17.8)kd$$

Where:
PET = Potential Evapotranspiration (cm/mo)
Ta = average air temperature (C) when Ta is less than 3°C the first term is set to 1.38
k = empirical crop factor that represents the crop type and stage of growth (taken from a reference table) d = the monthly fraction of annual hours of daylight (reference table available based on latitude)

The crop factor is generally taken from a reference table, and is usually more applicable to farmed crops than to forests. In this case the Blaney-Criddle formula for PET is being used solely to determine the portion of annual evapotranspiration (ET) that occurs in any one month. Therefore a crop coefficient for the land cover of WRIA 20 is not used.

Total annual ET in WRIA 20 is estimated to range from 11.40 inches in the Calawah sub-basin to the 48.48 inches in the Ozette sub-basin. The Sooes and Ozette sub-basin are estimated to have significantly higher (approximately 12 to 23 inches higher, respectively, than any other sub-basin) total evapotranspiration than other sub-basins in WRIA 20. The higher total ET in the Ozette sub-basin can be explained by the presence of Lake Ozette, a large body of water, that would contribute high rates of evaporation. The high total ET in Soess is less understood. It may be due to climatic conditions that occur in the lowland, sub-basins, in northern WRIA 20 especially. Assessment of measured rainfall from Neah Bay and measured Sooes River flows corroborates the presence of a potentially higher total annaul ET.

There are many methods available for calculating AET and, as was mentioned previously, most of these either require parameters that are not readily available or use empirical equations developed for crops. Because the method chosen for this water balance utilizes other parameters that are also part of the water balance, it inherently will result in a "balanced" water balance on an annual timescale. Therefore, it is logical to explore what range of AET may exist if it is calculated independently of other water balance parameters. Table 5-12 compares three methods for estimating actual evapotranspiration in WRIA 20 with water balance AET values. Annual AET estimates from these three methods range from 20.9 to 26.8 inches, which is a relatively narrow range. Waring and Schlesinger (1985) report that, under ideal conditions, 6mm/day is the maximum evapotranspiration that could be seen from a forest on any one day. If this amount of ET were to occur year round, it would result in 86 inches of water lost to evapotranspiration. This could be considered a possible upper bound, but would only occur under ideal climatic conditions and ample water availability. In the Watershed Analyses completed within the WRIA per the Washington Forest Practices Board Watershed Analysis Manual, annual evapotranspiration was set to 20 inches for hydrologic analysis; this value is also within the range of calculated values used for this water balance.

5.8 Summary of Results

The results of the annual water balance for each sub-basin and WRIA 20 as a whole, excluding the small "Pacific" sub-basins, is shown in Table 5-13 and illustrated in Figures 5-8 and 5-9. Total volumes for the WRIA are displayed in both acre feet and cfs units in Table 5-13. This table also reports the partitioning of water as a percentage of total annual precipitation that falls in the basin. Figure 5-8 presents the annual water balance by sub-basin for WRIA 20. This figure illustrates that between 55% and 91% of water in each sub-basin runs off as streamflow, and that between 9.3% and 45% of water leaves the watershed as evapotranspiration. The quantity of water for human use, and the amount of water allocated through permits, certificates and claims are also shown.

In general the results show that there is not a significant amount of water use in the basin, and that the majority of precipitation that falls in the basin flows out of the basin as streamflow. Figure 5-9 shows that for the watershed (excluding Pacific basins and Ozette and Sooes) the majority of precipitation that falls in the basin, approximately 83%, leaves the basin as streamflow. The next largest parameter in the annual water balance is evapotranspiration at approximately 17%. Water use for both irrigation and domestic purposes are less than 0.03% of total inputs. The method used for calculating evapotranspiration assumes there are no inter-annual storage changes therefore groundwater and surface water storage do not factor into the annual water balance.

Results of the monthly water balance are displayed in Tables 5-14 through 5-20 for each sub-basin, respectively. All numbers are reported in inches of water, for intra-basin comparison.

Results of the monthly water balance show a pattern similar to that of the annual balance; the majority of precipitation runs off, with evapotranspiration from non-irrigated lands accounting for the next largest component. Water use for human needs makes up a very small portion of the total. Additionally, snow accumulation and melt is estimated to be a minor factor in the seasonal availability of water for streamflow, only the Hoh and Sol Duc have any significant snow accumulation. The seasonal nature of streamflow in all sub-basins mimics that of precipitation because there is not significant inter-monthly storage, such as snow. Figure 5-10 shows the water balance for the entire WRIA and for the Calawah sub-basin during the dryer summer months of July, August and September. The relative proportion of water leaving the watershed as ET increases significantly during the summer months, while the percentage as streamflow decreases. Figure 5-11 illustrates the actual water volumes of each component for each sub-basin estimated to occur during summer months.

The net residual in Tables 5-14 through 5-20 indicates water that is unaccounted for on a monthly time scale. Generally, this value is used to indicate groundwater interactions with surface water within a sub-basin. When negative, the net residual represents water that would be available to recharge groundwater; when positive it represents groundwater discharge to streams. In general, recharge occurs from fall to early spring, with discharge to streams occurring in the summer

5.9 Discussion of Results

The Hoh and Sol Duc both show brief periods in the late winter when groundwater discharge to streams is calculated to occur (net residual is positive). This is either due to variations in methods used by the BOR and Golder to estimate run-off, or it represents some temporary storage in the system that is not captured explicitly in the water balance. The BOR streamflow appears to show a higher winter peak and faster descending limb that that modeled by Golder, which results in a positive net residual during the late winter.

Long term variations in temperature from global warming should be considered in watershed planning discussions. Under several global warming scenarios, average annual temperature has been projected to increase by about 2.5°F in the next 15 years, and 3.8°F in the next 35 years. Increased precipitation may occur as a result of global warming, however there is too much uncertainty to determine the effects of this at this time.

In areas where heavy fog is common, large trees can capture the moisture in the fog. This moisture is reported to be both evapotranspirated by trees and condensed and dripped off the trees. Fog-drip has been found to be an important contributor to total effective precipitation in the redwood forest zone of the northern California Coast range and in one location in the Oregon Cascades (Dawson, unpublished). In the Bull Run watershed, Oregon Cascades, Harr (1982) estimated fog drip could increase water input by 20 inches, or 25 percent, relative to about 80 inches of rain measured in clearcuts. Fog does occur on the peninsula. Mean data for heavy fog visibility from the Quillayute Airport show that heavy fog (visibility of ¼ mile or less) occurred on average between 2.3 and 7.0 days per month, with 53 days per year of heavy fog on average (based on 28 years of record) and that the late summer and early fall experience the greatest number of days of heavy fog. Therefore, fog-drip could be a significant input to the watershed that is not captured in this water balance.

6.0 LAND USE

This section discusses land uses in WRIA 20 and the potential effects of these various land uses on water quality and quantity in the watershed. Often, the effect of a land use on water quality is determined by the management practices and policies in place and the current and historical land cover in the area. Also, historic land uses have a significant impact on the landscape and the surface process that occur today.

Land cover (what is physically covering the ground) in WRIA 20 provides the basis and context for this assessment. Land use (how that land cover is managed) is also discussed. Land use practices and related effects on water quality and quantity reported in studies that have been conducted in the watershed are presented, as well as a brief discussion of plans and policies affecting land use in WRIA 20. This Phase II land use assessment is intended to be used as a tool to develop and prioritize strategies for maintaining water quantity and quality in the WRIA 20 Management Plan, and also to understand the effects of land use on watershed hydrologic function.

6.1 Land Cover in WRIA 20

Land cover describes the status and type of vegetation and other ground cover on the land in an area. Land cover is the result of natural processes and vegetation combined with current and historical land use practices. Land cover is presented in this report to paint a picture of the current state of the watershed, and to indicate the general land cover types (trees, grasses, houses, etc.) that characterize the watershed. Although these data indicate the structure or vegetation that exists on the ground, they do not indicate the current or planned activities for an area, or how the area is being managed.

Land cover in WRIA 20 is illustrated in Figure 6-1. This land cover data set was obtained from the National Land Cover Database (NLCD) and is interpreted from 1992 LANDSAT Thematic Mapper satellite images with 30 meter resolution. Because of the scale of these satellite images, the land cover information presented here is effectively the average of the land cover per 30 square meter pixels across the watershed. Users accuracy for the data set is estimated to be between 57% and 93% for land use classes with overall average accuracy of 83%. This land cover information can be used to provide an understanding of overall land cover distribution in the watershed in 1992, but is not expected to be accurate at a small scale (i.e., land cover distribution within one mile of Forks).

Land cover from the NLCD is presented in nine categories. The transitional category contains areas with disturbed land cover, and can be used in the forest regions to indicate areas where the forest has been clearcut and not yet regrown to maturity. Selective logging practices are not likely to be apparent in the transitional land cover category. Developed land cover categories can include agriculture/orchards, transitional, and residential/commercial. Other land cover categories presented are forested uplands, water, barren, shrublands, and wetlands; these categories may or may not show effects of human land use. It should be noted that the “forested upland” classification provided by USGS designates lands that are elevated such that they are not wetlands.

Table 6-1 presents the number of acres in each land cover category by sub-basin and for the entire WRIA. Table 6-2 shows the percentage of each land cover category by sub-basin and by watershed (last column). “Pacific Sum” represents the land area contained in the five small sub-basins that drain directly to the Pacific Ocean.

According to the NLCD data, the majority of WRIA 20 (88%) and of most sub-basins (81%-93%) is forested upland. Because such a large proportion of the watershed is forested, the land uses in forested areas will be the focus of this land use discussion. The transitional land cover class illustrates that the highest proportion of clearcuts are likely found in the Dickey (12.6% of sub-basin, or 8,544 acres), Pacific Sum (8.5% of sub-basin or 6,341 acres), Hoh (5.1% of sub-basin, or 9,740 acres), and Sol Duc (4.9% of sub-basin or 7,247 acres) sub-basins.

Other developed land covers throughout the watershed make up a very nominal percentage of the entire watershed. According to the NLCD data, residential/commercial and agriculture/orchards together make up less than 1% of WRIA 20, or less than 4,000 acres. Local non-point sources related to these land covers are not expected to have a large scale impact on the watershed as a whole. This report does not address local point source water quality issues that may be associated with these land covers.

6.2 Land Use in WRIA 20

General land use in WRIA 20, as classified by Clallam and Jefferson County Comprehensive Plan zoning, is illustrated in Figure 6-2. In WRIA 20, land cover is very strongly dominated by forest lands, which are utilized for a variety of purposes including, predominantly, national park (35% of watershed) (conservation), national forest (17% of watershed) (forest agriculture and conservation), and state and private forest lands (40% of watershed) (forest agriculture and conservation). Percentages of land represented by these land ***uses*** are not necessarily equivalent to the percentages of land within the NLCD upland forest land ***cover*** classification because other land cover types (eg., water, barren, transitional, and grasses) are also included within the land use category. Conversely, low density residential areas may be classified in the NLCD dataset as having upland forest land cover if trees are predominant.

Much of WRIA 20 is made up of publicly owned lands, managed by the Washington Department of Natural Resources (WDNR), the US Forest Service (USFS), and the National Park Service (NPS). Public lands in WRIA 20 are illustrated in Figure 6-3.

6.3 Effects of Land Use on Water Resources

Watershed hydrology can be modified by land cover changes in the watershed, such as land clearing, agriculture, urbanization, or construction of infrastructure. Anthropogenic land cover changes due to different land uses can also increase or decrease the rate at which surface geomorphologic and hydrologic processes take place or change the impact of the forces of these processes relative to each other.

Watershed hydrology is driven by the way that precipitation, surface water, and groundwater move through the watershed system. Water generally enters the system as precipitation, which may then be infiltrated to the soil, intercepted by vegetation, evaporated, or moved across the landscape as surface runoff. Watershed land cover drives the percentage of water that moves through the landscape in each of these processes. In areas with dense vegetation, more water is intercepted or infiltrated than moves across the surface as runoff. In areas with less vegetation, a higher percentage of the water becomes surface runoff. The change in hydrologic regime due to land cover change has repercussions in the geometric shape of the stream channel, instantaneous rate of flow, the annual hydrograph, and the stream ecosystem itself.

The effects of land use on water quality and quantity in WRIA 20 have been discussed in assessments conducted by the Washington State Conservation Commission, USFS, WDNR, and other agencies. These effects are discussed in the following sections.

6.3.1 Overall Watershed

The WRIA 20 Limiting Factors Analysis (LFA) discusses general habitat problems for salmonids in WRIA 20 (Smith, 2000). The habitat problems cited in the LFA can provide insight into land use impacts that have historically or are currently occurring in the watershed, as the same factors that create salmonid habitat problems are also likely to impact water quality, and may also affect water quantity. The LFA represents a snapshot in time, and was published before many assessments were completed. Assessments that were completed subsequent to the LFA have been recognized in ranking projects.

General changes to the natural system are outlined below, along with factors that limit salmonids, and are summarized by sub-basin:

Ozette – Lack of large woody debris, invasive plants, sediment (no cause cited), incised banks and reed canary grass, general poor large woody debris and riparian habitat, also warm waters, altered estuary from dredging and diking, and poor hydrologic maturity.

Quillayute Estuary – Dredged and diked estuary, increased sediment, and increased flow problems. A four-year assessment of this watershed was initiated in 2000, therefore the results of that assessment were not reported in the LFA.

Dickey – Sediment from roads, riparian windthrow at logging buffers, warm water, culverts, low flows made worse by loss of fog drip, large woody debris reduced due to flooding, riparian roads are problems in isolated areas.

Sol Duc – This sub-watershed is in good condition inside the Olympic National Park. Outside the Park, sedimentation is a problem from landslides and roads, inadequate amounts of large woody debris, wetland habitat reduction, warm water, overallocation has created low flows, and some creeks suffer from blockages.

Bogachiel – This sub-watershed is in excellent condition inside the Park. Outside the Park, problems include fish passage issues, loss of riparian area, lack of large woody debris, and collapsed banks.

Calawah – Landslides from roads and sedimentation are the two main problems in this sub-basin. Other problems are dewatering, channel instability, riparian roads, lack of large woody debris, and warm water.

Hoh – This sub-watershed is in excellent condition inside the Park. Outside the Park, problems are debris flows that lead to streambank scour, incision, high sediment loads from mass wasting and road erosion, loss of important floodplain complexes, riparian roads, and loss of fog drip.

Smaller independent streams – Limited data are available but sedimentation and riparian area development are a general problem.

6.3.2 Forest Lands

The vast majority of land in WRIA 20 is made up of either managed or preserved forest lands under federal, state, or private management. Overall, the forest lands in WRIA 20 experienced a period of widespread forest harvest from about the 1940s to the 1980s. Widespread timber harvest was reduced significantly after 1994 with the adoption of the Northwest Forest Plan. Timber harvest data reported in the Washington Timber Harvest Report (WDNR, 2002) detail the quantity of timber harvested per County in Washington State. These data are not available per WRIA, but can be used to estimate the amount of timber being harvested in the area of WRIA 20. Figures 6-4 and 6-5 present annual timber harvests between 1965 and 2002 in Clallam and Jefferson County by land ownership. Land ownership types are defined as the following:

- Tribal – Tribal and allotted lands held in trust by the federal government;
- Forest Industry – Companies and individuals operating wood-using plants;
- Private Large – Non-industrial companies and individuals not operating wood-using plants but with statewide holdings totaling 1,000 or more acres;
- Private Small – Non-industrial companies and individuals not operating wood-using plants and having statewide holdings totaling less than 1,000 acres;
- State – State owned lands managed by the Department of Natural Resources and the Parks and Recreation Commission for a variety of trust beneficiaries; and
- National Forest – Lands managed by the USDA – Forest Service.

It is important to note the different scale of the Y-axis on the two graphs; significantly more timber is harvested in Jefferson County than Clallam. In both Counties, timber harvest on Federal lands was reduced significantly in the early 1990s with the implementation of the Northwest Forest Plan. In Jefferson County, harvest on lands other than federal was reduced in the early 1990s as well. In Clallam County, harvest on private and state lands does not show the same pattern of reduction that it does in Jefferson County.

The Northwest Forest Plan and the Forest and Fish Rules contain many provisions for protecting water quality; many of the practices discussed in this section that are damaging to water quality and quantity are no longer allowed or have been significantly curtailed. Forest practice rules have been modified as recently as 2001. The effects of this most recent management approach, once it is fully implemented, should result in improved water quality. Land clearing and road building on steep slopes during the years of widespread timber harvest in the watershed provoked a host of environmental problems including landslides and sedimentation. When conducted adjacent to streams, these activities reduced large woody debris input, increased sediment input, and allowed more sunlight to enter the stream, increasing stream temperature. Although forest harvest in the watershed has slowed significantly, and new forest practice rules are in effect that are likely to reduce the impacts to the watershed system, the watershed continues to exhibit symptoms of the historic forest practices. The overall improvements resulting from recent rule changes are not expected to be reflected in measurements of water quality and watershed function for some time.

Effects of land use practices on water quantity and quality specifically in forested areas are discussed in watershed assessments and analyses completed by the State Department of Natural Resources, the USGS, the USFS, and the Hoh, Makah, and Quileute Tribes. Generally, land use activities in forested areas that affect water quantity and quality are harvest (particularly clearcut harvest), land clearing in the rain-on-snow zone, riparian development and clearing, road building, and, to a lesser extent in WRIA 20, pavement and urbanization.

It is important to note that the following effects of forest practices are the repercussions seen in the watershed today from past road building, harvest, and management practices. After or at the time that the data for the reports cited below were written, rules and policies were put into effect that significantly changed the way forest land is managed in WRIA 20. These are the 1994 Northwest Forest Plan, the 1997 Forest Practice Act, the 2001 changes to the Forest Practice Rules, and WDNR’s 1997 Habitat Conservation Plan. These rules and policies are discussed in more detail in Section 8.

Clearcut Harvest

In a landscape devoid of vegetation, the rate of surface runoff is greater than in a forested landscape. Higher rates of surface runoff increase the erosion capability of water as it moves across the land surface, and yields more water in the stream at any one time, making streamflows “flashy.” These flashier flows result in more water in the stream channel that moves faster, increasing the scouring capability of streams. Flashier flows also result in less time and capacity for streams and floodplains to dissipate high intensity flows, increasing the frequency of high magnitude floods. Land clearing can also yield other problems including increased sedimentation, and reduction of the filtering ability from the landscape that would improve water quality.

In a discussion of the effects of land clearing on watershed hydrology, the Department of Natural Resources’ Habitat Conservation Plan (WDNR HCP, 1997) states that, “through the process of evapotranspiration, plants move water from the ground to the atmosphere. Evapotranspiration affects water table and soil moisture levels, and consequently timber harvest in and around a wetland can affect the hydrologic regime of the wetland. The principal organs of evapotranspiration are leaves, and a minimum [quantity of] leaf area per acre is necessary to maintain the hydrologic regime of a forested wetland.”

Watershed Analyses were conducted in the East/West Dickey, South Fork Calawah, North Fork Calawah, and the Sol Duc watersheds (Rayonier, 1998; USFS, 1998; USFS, 1996; and USFS, 1995). The watershed analysis of the Sol Duc sub-basin (USFS, 1995) found that effects of historical clearcut harvest practices include increased landslide frequency, more rapid runoff, higher stream peak flows, and greater stream erosion. Additionally, the practice of burning logging slash and understory vegetation further reduced the forest’s ability to resist against debris flows, snow avalanches, and other mass wasting events.

The Salmon River watershed is located in the drainage network just south of WRIA 20. The USGS completed a qualitative assessment of the manipulation of vegetation and how this might affect changes in hydrologic response in this watershed (Bidlake, 2003). Among other things, this assessment looked at how forest harvesting and road construction have altered frequency and magnitude of peak and low flows. This assessment was primarily a literature review where the USGS provided examples of documented effects of harvest on water quality and quantity in the Pacific Northwest.

The literature review reported that water yield (unit area discharge from a given catchment) increases after extensive harvest of dense forests. This effect is attributed to reduction in evapotranspiration. Generally, this increased water yield decreases through the decade following harvest, and recovery is attributed to vegetative regrowth. The removal of trees may also reduce water yield by reducing the amount of water available as fog drip. Overall, the literature reviewed as a part of the Salmon River

Watershed Assessment found that peak flow effects from timber harvest are difficult to interpret, as the effects depend on the variations in composition of the pre-harvest forces, as well as the extent and type of harvest, roads, and local soils, geology, and climate.

The 2001 Forest Practice Rules do not prevent clearcut harvest, but do impart significant constraints on the way that forest harvest is conducted. The current, more protective harvest practices have not been in effect long enough to evaluate long term changes to watershed-wide processes.

Land Clearing in the Rain-on-Snow Zone

The rain-on-snow zone is defined by WDNR as an area (usually an elevation zone) where it is commonplace for snowpack to be partially or completely melted during rainstorms several times during the winter. In the Olympics, this area ranges from approximately 1,700 to 2,600 feet in elevation. The problem of increased runoff and increased peak flows associated with land clearing is exacerbated in the rain-on-snow zone. "In forest openings, the amount of snow that accumulates and the turbulent-energy exchange between the air and the snowpack surface are greater than in forest stands" (Berris & Harr, 1987). "The greater accumulation of snow available for melt and the greater turbulent-energy exchange to melt snow may increase the amount of water available for runoff during rain-on-snow events in forest openings and worsen downstream flooding and erosion by increasing peak flows. These openings may result from wildfire, insect attack, blowdown, and timber harvest. Of these, timber harvest is the only process that can be planned to help mitigate the potential effects of increased water available for runoff during rain on snow events.

In Oregon and Washington, much of the timber harvest occurs at mid-altitudes of the western Cascade Range in the transient-snow zone" (Van Heeswijk, et al, 1996). "Additional snow accumulation and more rapid melt in young forest stands can increase the depth, velocity, and erosive power of streamflow during rain-on-snow events." (USFS, 1995, Sol Duc Watershed Analysis) Section D - Riparian conservation strategy for the Five west-side planning units, of the WDNR HCP (1997) states that, "A sub-basin in western Washington that is completely within the significant rain-on-snow zone is estimated to yield an additional inch of water during a 10-year 24-hour rain-on-snow event if one-third of the sub-basin is in an immature condition."

Riparian Development and Clearing

Riparian areas are the stretches of land area that are the margin between land and freshwater. They are the location where terrestrial ecosystems and watershed land uses meet and affect the stream ecosystem. Riparian areas serve many functions important to the watershed as a whole. Plants and moist soil filter nutrients, sediment, and toxins from runoff before they reach the stream channel (Manci, 1989). Root structures and ground cover decrease stream bank erosion and stream sediment load. Canopy cover shades streams and reduces water temperature, which is particularly vital for salmon. Streamside vegetation increases roughness, dissipating flood water velocity. Deep rooted trees increase ground porosity and capillarity, and improve infiltration (Tabacchi et. al, 2000). Riparian plants provide organic inputs (including large woody debris) to the stream which creates habitat, stores sediment and organic matter, and adds habitat complexity to the stream channel.

Riparian areas are often cleared to make way for human land uses, and benefits to the entire watershed system are lost. Any land clearing or land conversion activity including logging, agriculture, residential development, and general urbanization can result in riparian area degradation if the area is not protected from clearing and subsequent development.

In WRIA 20, impacts of land use on riparian areas were assessed in the Sol Duc Watershed Analysis (USFS, 1995), the South Fork Calawah and Sitkum Watershed Assessment (USFS, 1998), and the East and West Dickey Watershed Assessment (Rayonier, 1998). In the Sol Duc sub-basin, "both LWD [large woody debris] recruitment and shade situations are a result of past land clearing and logging and on-going land use for agricultural and urban purposes which have either eliminated trees or left fewer and smaller trees for LWD recruitment and stream shading in riparian areas." (USFS, 1995, Sol Duc Watershed Analysis). In the South Fork Calawah and Sitkum sub-basin, "As a result of past timber harvest, fire, broadcast burning, slash cleanout, and selective removal of conifers from riparian areas since the 1940s; the riparian area forest species, diversity, abundance, and size have been reduced." LWD has been reduced in the East/West Dickey sub-basin from 1950s logging practices that did not protect stream channels (East/West Dickey Watershed Assessment, Rayonier, 1998).

The 2001 Forest Practice Rules contain a riparian buffer strategy which creates 90-200 foot buffer zones beside fish-bearing streams. The intention of these buffers is to provide shade to streams at levels that approach or exceed the amounts provided by mature conditions (WFPA, 2003). Additionally, the Forest Practice Rules riparian buffer strategy promotes retention of mature trees alongside streams to allow for LWD input and provides incentives to landowners who voluntarily place LWD in streams (WFPA, 2003). These and other recent changes in the way the forest is managed are expected to significantly improve the problems cited in the watershed analyses.

Road Building

Roads built in certain areas can pose water quality risks. Often, roads are built along streams because topographically road construction is easier in these flatter areas. Impacts to the stream channel from roads can range from no-impacts to potentially significant impacts. When roads are not paved, fine grained sediments may wash off roads and into the stream, impacting habitat resources. Additionally, roads alongside streams can affect channel conditions by potentially limiting the ability for the channel to move. For example, if the channel were restricted along a particular reach by a road (or other corresponding structures like riprap, revetments, bridges, culverts, etc.) on one or both sides of the stream, the channel may respond by changing course and/or changing geomorphologic parameters such as sinuosity, width/depth ratio, bank-full condition, etc., resulting in downstream impact and changes in channel conditions.

Additionally, forest roads in the watershed can be related to mass wasting events. The Sitkum and Calawah (USFS, 1998) and Sol Duc (USFS, 1995) Watershed Assessments both found forest road network development and timber harvest contributed to increased frequency and magnitude of peak flows. These roads also contribute to landslides and occasionally cause large debris flows. Roads that cross the same stream channel two or more times are particularly prone to causing these problems. The North Fork Calawah Watershed Assessment (USFS, 1996) found that, "The trend of sediment production has been decreasing since the 1960s, dramatically so since the 1980s, but is unlikely to decrease further without focused road maintenance efforts." Road building is one of the major sources of fine sediment in the Dickey sub-basin. Erosion from roads is a problem throughout the Dickey sub-basin, exacerbated by road surfacing material and the local high precipitation levels (Smith, 2000).

Forest Practice Rules require that "all existing forest roads be improved and maintained to provide fish passage to fish in all life stages, prevent landslides, and limit delivery of sediment and surface runoff water to streams and avoid capture or redirection of surface or ground water" (WFPA, 2003). To accomplish these goals, landowners have been given deadlines before which their roads must be maintained or repaired. However, Veldhuisen and Russell (1999) concluded that, "Present Forest

Practice Rules, designed as they were to prevent erosion within the roadway, were generally found to be ineffective at preventing erosion below drainage sites along monitored roads".

6.3.3 Pavement/Urbanization

When precipitation falls on paved areas it is generally forced to move through the landscape as runoff. In areas with high levels of urbanization, this can result in problems of increased flood flashiness and scour of the stream channel similar to those seen in clearcut areas. The specific effects of urbanization on a landscape depend on a number of variables including topography, soil type, and other vegetative cover. As there is a minimal amount of paved or urbanized land area in WRIA 20, current water quality or quantity effects are not expected at a watershed scale, although there may be some localized impacts.

6.4 Forest Land Management in WRIA 20

Land in forested areas in WRIA 20 is primarily managed by the National Park Service, National Forest Service, the Washington Department of Natural Resources, and private land owners. Land managed by public entities is shown in Figure 6-3.

6.4.1 Olympic National Park

Thirty-five percent of WRIA 20 watershed is in National Park management. This land is managed for conservation, and is expected to undergo hydrologic processes in a manner very similar to a pristine environment. The fact that this land area is in the headwaters of the watershed is particularly beneficial to water quality because this helps to ensure that water quality and quantity in these sensitive areas of the watershed is in near pristine conditions.

6.4.2 Olympic National Forest Lands

Seventeen percent of the WRIA 20 watershed is in National Forest management by USDA – Forest Service. These lands are managed according to the Northwest Forest Plan. Land uses are designated through a zoning system specified in the Northwest Forest Plan, and are illustrated in Figure 6-6. The land use categories are as follows:

- Timber Management Areas (72.7%)
- Private land within forest boundary (21.5%)
- River Corridor (general) 1-4 (3.9%)
- Visual Management Area (0.9%)
- Botanical Areas, Bald Eagle Management Areas (0.9%)
- Developed Recreation and Administration (0.09%)

Timber harvest may occur in portions of the Timber Management Areas designated as Adaptive Management Areas, however, widespread harvest has not occurred in WRIA 20 on National Forest lands since the 1994 adoption of the Northwest Forest Plan, as was illustrated in Figures 6-4 and 6-5. Any harvest conducted in these adaptive management areas is implemented using an adaptive management approach of development and testing of harvest methods which meet ecological, economic, and social objectives. This approach has significantly limited timber lands available for harvest. Typically, harvest under the Northwest Forest Plan is conducted on lands designated as "Matrix." No lands within the Olympic National Forest have been given this designation.

The age of tree stands in the National Forest gives some indication of the amount of time that has passed since the area was last harvested. Generally, older tree age classes provide better canopy cover, tree species diversity, and more consistent beneficial water quality and quantity effects. GIS data were obtained from the Forest Service that depicts the age class of trees in the Olympic National Forest. These data are illustrated in Figure 6-7.

6.4.3 State and Private Commercial Forestry

Many state and private forest lands in WRIA 20 are managed for commercial forestry. Management on these lands is directed by the State Forest Practice Rules, written according to the direction of the Forest and Fish Report. Forest Practice Rules impose many constraints on forest practices including best management practices (BMPs) for road construction and maintenance, restoration and maintenance of riparian habitat, and restriction of harvest in sensitive areas. These are intended to minimize the effects of roads and road failure on water and fish habitat quality. These rules were updated in 2001 by the Forest Practice Board to further improve standards and guidelines for riparian buffers and forest road maintenance. The Forest Practice Rules provide provisions for monitoring the rate of timber harvest, but they do not impose significant limitations on harvest rate. These rules have only been in effect a relatively short time, and the effects of the revised management strategies have not been fully realized, however it is expected that harvest under the current regulations will have less impact on water quality and quantity than those activities that were conducted before the Forest and Fish Act.

The Forest Practice Rules also contain regulatory mechanisms for mitigation of past practices, including guidelines for Road Maintenance and Abandonment Plan implementation that set deadlines for corrections of problem roads (WAC 222-24). The goals for road maintenance establish that all forest roads must be maintained to prevent potential or actual damage to public resources. Fish passage must be addressed by December 2016. Replacement will not be required for existing culverts functioning with little risk to public resources or for culverts that were installed under an approved forest practices application or notification, and are capable of passing fish, until the end of the culvert's functional life. Corrective, rather than reactive, provisions such as these are working to correct legacy impacts from past forest practices.

A multi-species Habitat Conservation Plan (HCP) is implemented along with the Forest Practice Rules on State lands. The HCP is intended to fulfill Endangered Species Act (ESA) requirements for forest practices on state lands for a number of endangered and threatened species. The HCP generally requires more stringent environmental protection constraints than the Forest Practice Rules. The HCP has a Riparian Conservation Strategy which limits road building in riparian areas, and harvest in riparian areas, on unstable slopes (which are often adjacent to streams), in rain-on-snow zones, and in wetlands. Additional procedures are defined for preventing road failure and erosion. The HCP generally has more stringent buffer requirements for state lands than the Forest Practice Rules set forth for private lands.

6.5 Management of Non-Forest Lands in WRIA 20

This section discusses land uses outside of national and state forests in WRIA 20.

6.5.1 Clallam and Jefferson County Zoning Designations

Land use within WRIA 20 as designated by Clallam and Jefferson County zoning is illustrated in Figure 6-2. County Land Use is determined through comprehensive planning that takes into account the protections of some areas through the Growth Management Act and the Shoreline Management

Act. Acreages in each land use category are shown in Table 6-3 for Jefferson County and Table 6-4 for Clallam County. The vast majority of the County land is in forest land uses. Other significant land uses are National Park and low density residential. As discussed above, land uses other than those that are forestry related do not make up a significant portion of the watershed and therefore are not expected to have watershed-wide effects on water quality and quantity. Localized impacts on water quality are possible particularly in the local drainage area of land uses including agricultural, residential, commercial, and other more intensive human uses. Some sensitive areas within these land uses, such as riparian areas, are protected through the County's Critical Areas Ordinance (Clallam County Code Section 27.12, and Jefferson County Unified Development Code Section 3.6.4). The potential for significant future residential and commercial growth in the watershed is generally limited to Urban Growth Areas defined in Comprehensive Plans. The City of Forks Urban Growth Area is the only one in the WRIA.

Agriculture

USDA Agricultural Census data were consulted for this report for a summary of agricultural practices in the watershed. The Agricultural Census reports agricultural use by County, not by watershed. According to the Agricultural Census, in Clallam and Jefferson Counties as a whole, 19,109 acres of land was in agricultural use in 2002. According to NLCD data, 2,362 acres within WRIA 20 had agricultural land cover in 1992. Because of the limited accuracy of the NLCD data at a small scale and the county-wide scale of the Agricultural Census these agricultural land cover and land use numbers are considered rough estimates. Land in these areas is managed under Clallam and Jefferson County governance.

6.6 Summary

Overall, the land in WRIA 20 is heavily forested with small areas of residential, agricultural, and commercial land uses. Forest land in WRIA 20 has been used for conservation, recreation, timber harvest, and other land uses. Generally, historic (prior to 1994) timber harvest and road building practices were conducted in a manner that was likely to increase the frequency of mass wasting events, increase in-stream sedimentation, and generally decrease water quality in the watershed. However, since that time, timber harvest has been reduced significantly on federal lands in the watershed and on all lands in Clallam County. Most timber harvest in the watershed is currently occurring on State and private lands and is subject to the 2001 Forest Practice Rules as mandated by the Forest Practices Act. Harvest conducted on State lands is also subject to the WDNR Habitat Conservation Plan (1997). Timber harvest conducted under these practices is anticipated to improve water quality and have less overall impact on watershed hydrologic processes. However, it is too soon to realize the full outcome of these new practices. Intensive land use in specific areas (such as agriculture or residential) and point source water quality threats from industrial and other discharges were not assessed in this technical assessment of land use impacts in WRIA 20, and effects on local water quality and quantity are unknown at this time.

7.0 FISH DISTRIBUTION AND HABITAT

The following information about fisheries habitat in WRIA 20 is as reported in the Level 1 Technical Assessment by Abigail Hook.

7.1 Bogachiel Sub-Basin

7.1.1 Fish Distribution

The Bogachiel River and many of the major tributaries provide spawning and rearing habitat for summer and fall Chinook (*Oncorhynchus tshawytscha)*, coho (*Oncorhynchus kisutch)* and chum salmon (*Oncorhynchus keta),* and summer and winter steelhead *(Oncorhynchus mykiss*). Small numbers of sockeye salmon (*Oncorhynchus nerka)* have been reported in lower reaches of the Bogachiel River though these may be strays from other populations. Small numbers of pink salmon (*Oncorhynchus gorbuscha)* have been noted on the mainstem. Table 7-1 presents the stocks and status of Bogachiel salmon and steelhead.

Summer Chinook primarily use the Sol Duc; only a small component use the Bogachiel. This influences the appearance of the stock status (R. Lien, personal communication, May, 2004). Table 7-2 presents the run and spawn times for Quillayute/Bogachiel salmonids.

7.1.2 Habitat

7.1.2.1 Sedimentation and LWD

There was very little information on in-channel habitat on the Bogachiel and tributaries until 2000 (see below) when the Quileute Tribe began a four-year in-channel evaluation for the mainstem and the upper, middle and lower tributaries. This study was designed to re-assign stream types to the Bogachiel system. Though there was not detailed survey data, members of the 2000 Limiting Factors Analysis Technical Assessment Group noted that there are sedimentation issues in the mainstem. As in many of the other rivers in WRIA 20, problems with excessive sedimentation and low levels of LWD occur below mostly below Olympic National Park.

Levels of LWD on the mainstem are poor for the area from below the Highway 101 bridge to just below the confluence with Hemp Hill Creek. Levels of LWD in Maxfield, South Maxfield and Bear Creek range from fair to good. Riparian levels tend to mimic LWD levels within the Bogachiel watershed, ranging from poor on the mainstem to good within Olympic National Park (Smith, 2000). However, data are limited.

The lack of LWD on the mainstem has led to increased water velocity and sediment transport on the mainstem of the Bogachiel. This in turn has increased channel incision and exposed unstable clay layers. This incision has released sediment into the river and has resulted in a level of fines greater than 17% (Smith, 2000). Collapsing banks have been a problem from the Hemp Hill confluence to Highway 101 and have required local road relocation.

7.1.2.2 Barriers

In the year 2000, the Quileute Tribe surveyed the Bogachiel mainstem for fish habitat and fish passage blockages. In the basin, they found 37 blocked culverts but all cross drains were functioning. In 2001, the tribe surveyed the lower tributaries: Weeden, Maxfield and Murphy Creeks and found 123 impassable culverts and retyped several segments of the tributaries. Of the retyped streams, over

23 new river miles of fish habitat was discovered (Type 3 and 4). The most disturbing observation during these surveys was the blocked/perched culverts of the 3000 Goodman mainline over the South Fork of Maxfield Creek. This blockage blocked the most access in the entire Quileute usual and accustomed places. In 2002-2003, Rayonier and the Quileute Tribe cooperated in replacing these culvers with a bridge. In 2002, the tribe found 83 non-passable culverts in the middle tributaries: Mill, Grader, May, Dry and Bear Creeks. In these creeks, 30.4 miles of stream was reclassified from fish-bearing to non fish-bearing. In 2003, tribal surveys covered the upper tributaries, Dowans, Hemphill, Morganroth, and Kahkwa Creeks and discovered 18 impassable culverts. In these creeks, 23.76 miles of stream were upgraded. In Dowan Creeks, cedar spalts were recorded which block habitat and degrade water quality (Quileute Natural Resources [QNR], 2003).

7.2 Calawah Sub-Basin

7.2.1 North Fork Calawah Fish Distribution

The North Fork Calawah is home to substantial populations of Chinook, coho and steelhead. Stray (no lake for rearing) sockeye and chum are believed to be present though there is limited information on their locations. Resident cutthroat trout (*Oncorhynchus clarkia*) and mountain whitefish occur throughout the watershed as well as common sculpins and Pacific lampreys.

The North Fork Calawah watershed has 220 miles of perennial streams. Anadromous fish occur in 44 miles of the streams: 17.3 miles of the mainstem and 26.7 miles of the tributaries. During the summer, rearing on the mainstem is reduced by up to 47% due to the drying reach. Several tributaries to the drying reach flow year round and provide critical summer and winter rearing habitat.

The populations occurring in the North Fork Calawah are the same populations found in the South Fork Calawah and Sitkum Rivers. Currently, the Washington State Salmon and Steelhead Stock Inventory (SASSI) report (WDFW, 1992) rates the following major salmonid stocks as healthy native stocks: fall Chinook, fall coho, and winter steelhead. The lack of information available on summer steelhead and Chinook has resulted in an unknown stock status determination. McHenry (1996) however rates the summer Chinook and fall coho as threatened. Population trends over the last 20 years have been highly variable but there has been no consistent downward trend. The variability is though to be a result of ocean conditions and precipitation levels as opposed to habitat condition (Martin et al., 1996). Table 7-3 presents the run times for Calawah salmonids.

7.2.2 North Fork Calawah Habitat

7.2.2.1 Large Woody Debris

The habitat quality ratings for total LWD in the system ranged from fair to good for all tributaries, but poor for all but the upper mainstem. For key pieces of LWD, only Western Cool, Eastern Cool, Fahnestock, and Pistol Creek were rated as good, suggesting that key pieces were a concern for all other creeks and mainstem segments. Due to lack of LWD on the mainstem, the channel has incised significantly resulting in a degraded floodplain condition (Martin et al., 1996).

Much of the LWD currently in the stream is composed of alder. Due to the rapid rate of decay, alders are not considered desirable LWD. The loss of large conifer LWD is considered the most important concern for the formation of fish habitat in the watershed.

The majority of LWD inventoried recently is assumed to have originated from landslides and debris flows that deposited directly into the mainstem and from dam-break floods and fluvial transport from major tributaries because the riparian zone is too young to have provided such wood (Benda, 1996). The current LWD-recruitment potential in the North Fork Calawah basin is improving as riparian stands decimated in the Great Forks fire are approaching maturity (Springer, 1996). There is concern about deciduous dominated zones along the mainstem of the North Fork Calawah though it appears that this may reflect natural conditions in the flood disturbance zones (Springer, 1996).

7.2.2.2 Shade

Although there are exceedances for water temperature in the basin, this is not the primary concern for fish habitat. Most of the riparian zone has adequate shade cover as the hardwood stands have reached maturity since the Forks Fire. Areas without adequate shade are usually a result of naturally open conditions (Springer, 1996). Groundwater inputs are an important component in stream temperatures in this system, Though the drying reach acts as a barrier, it provides cold groundwater to the mainstem downstream (Jackson, 1996a).

7.2.2.3 Sedimentation

A majority of overall sediment contribution to the North Fork Calawah River is a result of roads and timber harvest (Dieu and Shelmerdine, 1996). The steep upper tributaries and mainstem deliver most of the sediment to the river. The upper segments are therefore dominated by coarse sediment while the lower gentler segments have more fine sediment deposition. Though sediment delivery has slowed since logging practices stopped in the late 1980s, it is not expected to continue to decrease without additional road restoration efforts. The sedimentation has contributed to embeddedness in spawning habitat.

The North Fork Calawah River, Pistol Creek and Albion Creek have all received poor channel stability ratings. In these areas, there have been significant debris jams resulting in channel aggradation. This in turn has led to a decrease in pool habitat and increase in fine sediment. The current lack of LWD in the mainstem increases the rate of sediment transport and worsens the fine sediment problem (Benda, 1996). Regardless of location, the average amount of fine sediments in low gradient spawning gravel across the basin is 14%.

7.2.2.4 Barriers

The majority of barriers in the North Fork Calawah drainage are naturally formed. Since the area is prone to mass wasting events, there are debris flows that are not passable for anadromous fish. High gradients and waterfalls are also common in the upper portion of the watershed. Finally, the drying reach of the North Fork mainstem acts as a barrier in summer months.

There a few barriers on small unnamed tributaries that are a result of perched culverts. The highest priority culvert replacement is on a tributary to the drying reach. This tributary is crucial as it provides rearing habitat during summer months when the mainstem is not available (Smith, 2000).

7.2.3 <u>South Fork Calawah and Sitkum River Fish Distribution</u>

The South Fork Calawah and Sitkum watersheds are heavily used by substantial populations of Chinook salmon, coho salmon, and steelhead trout, along with stray populations of river-run sockeye salmon and chum salmon. Pacific lamprey and mountain whitefish are present in the lower mainstem of both watersheds but information on their location and populations is very limited. Resident and anadromous cutthroat trout and sculpins are also found throughout most of the watersheds.

The Sitkum and South Fork Calawah stock health and status are reviewed in the North Fork Calawah section.

Within the South Fork Calawah and Sitkum watersheds, there are 50.6 miles of fish-bearing streams; 31.4 miles used by anadromous fish and 19.2 miles used by resident fish (Decillis, 1998). Natural barriers such as high gradients and falls limit all anadromous fish use. There are currently no unnatural barriers listed within the watershed.

7.2.4 South Fork Calawah and Sitkum River Habitat

7.2.4.1 LWD

Key pieces of LWD are currently rated “poor” throughout Hyas Creek, South Fork Calawah River, Sitkum River and Rainbow Creek. Total LWD was additionally rated as “poor” in Hyas Creek and sections of the North Fork Sitkum and Sitkum Rivers (Decillis, 1998). The rating “poor” overall in Hyas Creek can be attributed to the Great Forks fire of 1951 and subsequent salvage operation in the subwatershed (Decillis, 1998).

Within the South Fork Calawah watershed, Lost Creek, and the lower/middle/upper South Fork Calawah had the highest near term LWD recruitment potential. Hyas Creek had the worst potential with 99% of the area rated as low near-term potential. In the Sitkum watershed, the lower Sitkum, middle Sitkum and upper Sitkum had the highest potential while Rainbow Creek and the North Fork Sitkum River had 69% and 61% of their areas rated as low near-term LWD potential recruitment. Overall, 57% of the entire Sitkum/South Fork Calawah watersheds could be rated as high potential recruitment (Lasorsa, 1998).

7.2.4.2 Shade

Water temperatures in the mainstem of the South Fork Calawah and the Sitkum Rivers generally exceeded the upper limits recommended for migration. Due to run timing, fall Chinook, fall coho and winter steelhead should not be affected by elevated temperatures. Summer Chinook however are at risk due to their extended holding period during low flows in late summer.

Naturally low shade riparian cover may be to blame for some of the elevated temperatures found in these watersheds. The mainstem South Fork Calawah River, Lower South Fork Calawah River and Lower Sitkum River all have a majority of naturally low shade conditions. Though other subwatersheds, notably Lost Creek and Upper S.F. Calawah River, meet 100% shade targets, their management is of concern as they are upstream of areas with temperature concerns (Lasorsa, 1998).

7.2.4.3 Sedimentation

Dissolved oxygen (DO) levels in the South Fork Calawah and Sitkum River watersheds appear to be within optimal range as defined by Washington State. However, there are no data on inter-gravel DO levels which is the most important to certain salmonid life history stages. It is assumed that DO levels drop with increased stream temperatures as reflected by summer data.

Although current information is not available on fine sediment levels in gravels in these watersheds, there is concern that large mass wasting events in 1997 may have contributed to fines and therefore decreased intergravel DO. There is also aerial photo evidence that mass wasting in Hyas, Rainbow and N.F. Sitkum has increased in frequency following timber harvest and road building. Of the slides detected, 64% were a result of roads and harvests while 36% were due to natural causes (Dieu and

Shelmerdine, 1996). There is a high connectivity between hillslope and channel and a large percentage of sediment from mass wasting events delivers into the stream system (Wilson, 1998). Excessive sedimentation has contributed to dewatered sections of Hyas Creek and Sitkum River.

7.3 Dickey Sub-Basin

7.3.1 Fish Distribution

Tables 7-4 and 7-5 list the current stock statuses and run times as reviewed in the WRIA 20 Limiting Factors Report (Smith, 2000). Nearly all of the perennial streams in the Dickey watershed contain anadromous and resident salmonids. The Dickey basin produces an average of 19% of total fall coho, 2.6% of total fall Chinook and 4.1% of total steelhead productions for the entire Quillayute system. The Dickey is one of the most productive basins for coho in the entire state. This is likely due to low gradients and significant over wintering habitat. Steelhead and Chinook are found primarily in the East and Middle Dickey and Chinook are also located in the three tributaries in the lower East Dickey as well as the mainstem and its tributaries, such as Coal Creek. Chum occur sporadically in the system but there are little data on their existence.

Winter steelhead do not appear to be currently in “threatened” condition. Dickey fall Chinook reported numbers are more likely to reflect survey problems than of actual low numbers (R. Lien, personal communication, May, 2004).

7.3.2 Habitat

7.3.2.1 Off Channel Habitat

Side channels and wetlands are particularly important as the basin provides many square miles of this habitat (especially in the West Fork) that are used for rearing by salmonids, particularly coho. This report pre-dates the 2004 habitat study on the mainstem tributaries, but excellent wetlands and/or side channels may also be in those reaches (R. Lien, personal communication, May, 2004). As there were no buffers left on these areas during past logging practices (those that pre-date TFW or Forest and Fish rules by WDNR), many of these areas are now completely unshaded and have high temperatures and sedimentation. Though some were naturally unshaded, high moisture content of the soil has led to slow regeneration (Bretherton et al., 1998).

7.3.2.2 LWD

Current in-channel LWD is adequate within the West Dickey watershed where the low-gradient conditions tend to trap wood for long periods of time. Wood in this system is unlikely to be flushed out. LWD levels are also currently adequate on the Middle Dickey (Bretherton et al., 1998). This system however is more likely to lose wood in higher flows and therefore depends on continual recruitment. The East Dickey is extremely sensitive to jams and currently has a low count of LWD. The East Dickey has flows which regularly flush out jams and requires larger key pieces to secure wood. There are also local reports that fishermen may be clearing the channel of wood in order to float lower segments of the river. Most tributaries are in need of a continuous supply of coarse woody debris inputs and may be limited by the hardwood dominant riparian channels.

Most stands with LWD recruitment potential in the East/West Dickey watershed are less than 50 years old and are generally dominated by hardwoods. Though there is evidence of conifer regeneration in the undergrowth, future recruitment may be poor until stands mature (Bretherton et al., 1998). In the Middle and East Dickey, active recruitment by bank undercutting has been observed in pool-riffle reaches. There is also evidence of windthrow and bank erosion actively adding wood to the East Dickey. The West Fork does not actively recruit wood on the majority of the river and depends primarily on tree mortality. Though there are currently adequate LWD levels on the West Dickey, these levels will continue to decrease until the riparian stand matures (Bretherton et al., 1998).

7.3.2.3 Temperature

Most of the streams in the Dickey basin are vulnerable to high temperature as they either have shallow water, absence of riparian shading or microclimate controls. Only the West Fork glide habitat is not at potential risk as the river has deep cool areas and adequate LWD.

Currently, the average stand age in the Dickey basin does not provide adequate shading to streams with channel widths larger than 50 feet. The overstory spruce have long since been harvested and low-moisture terraces limit conifer regrowth. The tributaries generally have sufficient shading as hardwoods regenerate quickly along the floodplains, thereby shading smaller channels. In tributary channels lacking proper shading, windthrow has usually destroyed buffers left from logging practices (Bretherton et al., 1998).

Approximately 10% of the East and West forks of the streams in the Dickey watershed received a high hazard shade rating in the 1997 East/West Dickey Watershed Analysis. This analysis was based on the color 1996 aerial photographs. The areas most degraded include the mainstem of both East and West Dickey, Thunder Creek and Squaw Creek. There are also patches of high hazard shade areas on Middle Dickey and Pond Creek.

7.3.2.4 Sediment

Natural loads of fine sediment are naturally high in the Dickey watershed due to underlying geology, low gradients in the channel system and naturally low summer streamflows. Due to these factors combined with inner gorge deliveries and road erosion, fine sediments are one of the largest fish habitat concerns in the Dickey basin (LaManna et al., 1998). This concern relates only to areas in the Dickey watershed that have gravel-bedded channels with high spawning probability. An increase of fines in these areas could significantly reduce the quality of the habitat.

7.3.2.5 Barriers

There are no natural barriers in the Dickey watershed due to low gradients and gentle terrain. There were nearly 40 blocking culverts in the basin (as of the LFA of 2000), however resulting in a “poor” access rating in the 2000 Limiting Factors Report (Smith, 2000). Since the Dickey basin has the highest winter rearing habitat in WRIA 20 but low spawning habitat, these blockages are crucial. The majority of the blocking culverts are in the Ponds Creek area.

In addition to culvert blockages, the Dickey basin has several near riparian roads which act as dikes, blocking access to off channel habitat. The two most damaging roads are located in the Coal Creek and Colby Creek subwatersheds (Smith, 2000).

7.4 Hoh Sub-Basin

7.4.1 Fish Distribution

There are five native species of salmonids and three species of trout within the Hoh River Basin. Of the eight species of salmonids, the three that are most intensely managed are coho, Chinook and steelhead. The Chinook population consists of a spring/summer run, one of five remaining native spring Chinook stocks considered healthy in the Pacific Northwest. This run has typically used spawning grounds on the South Fork Hoh in the vicinity of Big Flat, the North Fork Hoh and Mt. Tom Creek. Owl Creek historically supported the run but habitat conditions have degraded to a level where few species are using the tributary at all (Smith, 2000). Recent observations by WDFW and Tribal staffs indicate that Chinook and steelhead utilization has fallen off considerably, partly because gravel substrate has become larger in the lower half of the anadromous reach and the number of stable LWD, LWD jams and channel stability has also decreased substantially (J. Jorgenson, personal communication).

Coho are the most abundant salmon population in the Hoh basin but there have been population declines since 1992 due to freshwater habitat decline. More severe declines were observed with the 1993, 1994, and 1997 returns, with ocean conditions being the largest factor affecting those years' runs. A recent set of more favorable ocean conditions and reduced Canadian fisheries led to large returns of coho in 2001 and 2002 and temporarily counteracted effects of any decline in freshwater production (J. Jorgenson, personal communication, 2004). Fall chum have never been numerous due to limited estuary area and have shown a long term population decline (McHenry et al., 1996).

The Hoh basin supports winter and summer steelhead. The stocks and status, and the run and spawn times of Hoh salmon and steelhead are presented in Tables 7-6 and 7-7, respectively. Quinault River steelhead are planted in the Hoh annually but have different run return timing and high exploitation rates resulting in limited interaction with wild fish. Though there has been a generally declining trend since the 1980s due to poor marine survival, winter steelhead stocks are described as stable. Less is known about the summer steelhead stock which has a smaller population and spawns in upper reaches.

Bull trout are present in the Hoh River Basin and have been listed as threatened by the US Fish and Wildlife Service. They are thought to use the Middle Hoh as a migratory corridor and they possibly spawn and rear in side channels of the mainstem (Erickson, 2001). The majority of the redds have been identified within the Olympic National Park boundary.

7.4.2 Habitat

7.4.2.1 LWD

The upper watershed mainstems and tributaries found within Olympic National Park generally have good ratings for LWD as there has been little management and old growth riparian areas still exist. In the rest of the watershed, LWD levels were generally poor. Some of these areas (Owl Creek) had many pieces of LWD outside the ordinary bankfull width, due to dam break floods, that were considered to be not functioning (McHenry, 2000). In Anderson, Elk, Braden, Lost, Nolan, Pins and Winfield Creeks, LWD ratings were low due to lack of large key pieces. The large wood loads of Winfield, Canyon and Dry Creeks are dominated by red alder which are unable to provide habitat and durability like conifers (McHenry, 2000). Streams with recent history of channelized landslides such as Spruce and Willoughby had almost no instream wood. The loss of wood in steeper streams results in the loss of step morphology and promotes incision (Kennard, 2001).

Near term LWD recruitment reflects current instream conditions in most cases. In the middle Hoh, 72% of the sub-watersheds have poor recruitment (Smith, 2000). This is due primarily to past logging efforts which often cleared land to the stream banks. Cedar spalts have worsened riparian conditions as areas with spalts on the bank cannot establish any vegetation.

The ability to physically recruit wood within the Hoh basin differs from sub-basin to sub-basin. In many areas, wood is delivered to streams either through mass wasting events or blow down. In a few creeks however (Alder and Winfield), wood is captured from within the channel migration zone when channel meanders. This process is extremely successful when riparian growth is fully mature. On the South Fork Hoh and North Fork Hoh below the Olympic National Park, the majority of wood is located on top of gravel bars and is hydraulically not functioning (McHenry, 2000). This shows the tremendous need for sufficiently key pieces within the bankfull width to trap the smaller wood during elevated flows. Another problem with recruitment on the mainstem is shallow reaches. On the South Fork of the Hoh (RM 6.2), the channel topography is so shallow and flat that the transport of wood is impossible (McHenry, 2000)

LWD has also been affected by channel morphology, namely dam-break floods and channelized landslides. Channelized landslides will remove all functional wood and reduce roughness and sinuosity, and increase bank and terrace erosion. Dam break events often happen on streams that were previously forced pool-riffle and often have fewer pools and larger substrate after events (Kennard, 2001).

7.4.2.2 Sedimentation

The quality of spawning gravels has been significantly reduced by excess sedimentation from mass wasting events and road erosion. High levels of fines have been measured in Iron Maiden Creek (57%) and Canyon Springs Creek (45%) following mass wasting events (Smith, 2000). There were also high levels of fines in Spruce, Bradenberry and Lost Creeks. Levels of fines between 11% and 17% were recorded in Alder, Elk, Split, Anderson and Braden Creeks (Smith, 2000). Cedar spalts often float up and down with flow and carve out banks and contribute to the delivery of fines. Channel incision in Owl and Nolan Creeks has exposed unstable clay layers and delivers fine sediments. In the upper watershed (within the Olympic National Park) there are few sedimentation problems and coho production has been 2-3 times higher than anywhere else in the watershed.

There has been discussion over the effects of sedimentation on the mainstem Hoh River. Because the river is heavily influenced by glaciers that release a tremendous amount of sediment (glacial flour), many argue that sediment produced by management activities is inconsequential. Lum & Nelson (1986) found that 60% of the mean fluvial sediments in the Hoh River originated upstream of the Olympic National Park Boundary. Kennard (2001) supports this finding by recording fine levels of 60% at Big Flats, an unmanaged mainstem segment. Though these levels exist naturally on the mainstem, they are a concern in steeper gradient tributaries (Kennard, 2001).

The greatest anthropogenic contributor to sediment in the Hoh basin is roads. Generally in the basin, roads were designed to high levels and are well surfaced. The major problem is the interconnection of the standard road ditch system with the channel system (Powell, 2000). The sub-basins with the largest percentage of sediment over background levels are South Fork Hoh (156%), Owl Creek (286%) and Winfield Creek (210%). The majority of the sediment in the South Fork Hoh and Owl Creek sub-basins is coming from the H-1000 mainline road while in the Winfield sub-basin, the majority of the sediment is delivered from the MLC-1000 road (Powell, 2000).

Sedimentation affects everything from temperature to off channel habitat. Excessive sedimentation is blamed for interfering with hydraulic connectivity within the floodplain. Since the Hoh is a basin largely dependent on in-channel springs, sediment will block the upwellings and deprive the channel of cooling water and nutrient rich, productive areas for salmonids.

7.4.2.3 Off-Channel Habitat

The Hoh River terrace is a complex system of springs, side channels, ponds and wetlands which provides critical habitat and refugia to fish and wildlife. Compared to the system within the Olympic National Park the downstream floodplains are extensively degraded (McHenry, 2000). Lack of wood and influence from riparian roads has changed sediment processes and been particularly damaging for the floodplain. The access road for the Olympic National Park, upper Hoh Road has been a problem and washed out continually resulting in a highly armored bank (Rot, 1996). Forest management practices have had an impact on the floodplain as the channel migration zone has not historically been recognized (McHenry, 2000). The floodplain at RM 19 and Elk Creek is exceptionally important as they support high levels of smolt production and a safe site for over wintering salmon (Rot, 1996).

Another important component of the channel migration zones are forested islands that form when LWD stabilizes gravel bars and allows for vegetation to establish. These bars encourage multiple channels and eventually serve as LWD banks (Rot, 1996). Lack of LWD combined with large coarse sediment loads prohibit the formation of forested islands thereby decreasing current and future floodplain complexity (Kennard, 2001).

In September 2000, the Hoh River was surveyed with FLIR (Forward Looking Infrared) to evaluate stream temperatures in the Hoh basin and develop longitudinal temperature profiles. Stream temperature patterns and the location of and range of cool water sources provided a better understanding of floodplain hydrology. This survey observed that many of the side channels started within the floodplain and were formed by cool subsurface flows. Since 79% of the surface inflows to the mainstem Hoh were found to be warmer than the Hoh River, it is believed that these subsurface floodplain inputs are an important part of the river systems thermoregulation (Watershed Sciences, 2001).

7.4.2.4 Barriers

Barriers are one of the largest concerns in the Hoh as they have not only blocked streams for anadromous fish but also are often the cause of degraded habitat and water quality. Cedar spalts, leftover waste wood from cedar shake and shingle-wood salvage operations, are blamed for increased temperatures, and sedimentation as well as a loss of access to more than 1,000 feet of stream in 18 sites (Smith, 2000, McHenry, 2000). In the Fullerton tributary alone, more 6,000 feet of stream are impacted. The streams with the highest cedar spalt impact include the Fullerton Tributary, Nolan, Cedar, and Sand Creeks (Smith, 2000).

There are also over 40 blocked culverts in the Hoh basin which are blocking coho, steelhead and cutthroat habitat (Smith, 2000). This number has decreased from estimates of 60 impassable culverts in 1997 (McHenry, 2000). In some cases these faulty culverts block up to 10,000 feet of free flowing stream while others block critical wetlands used for off-channel rearing.

7.5 Ozette Sub-Basin

7.5.1 Fish Distribution

The Lake Ozette watershed has one of the most diverse assemblages of freshwater fish species in the Pacific Northwest. Coho salmon, sockeye salmon and winter steelhead trout are currently found in the Ozette watershed, as are kokanee salmon and cutthroat trout. The area historically supported Chinook and chum salmon, though their current status is not known and believed to be extremely low or even extinct (Smith, 2000).

Of the salmonids in the basins, the Ozette sockeye has been listed as "threatened" under the Endangered Species Act. The Lake Ozette sockeye salmon is the only species currently listed on the ESA in WRIA 20. Comparing current numbers of fish with historical level estimates shows approximately a 75% drop in run size (Blum, 1988). The decline in the sockeye salmon is probably related to numerous factors including but not limited to over-fishing, predation by native and non-native fish and wildlife, and habitat degradation along the lake shoreline spawning habitat and in tributaries used for spawning (Meyer and Brenkman, 2001). Tributary spawning is currently limited to Big River, Umbrella Creek, and Crooked Creek and the spawning distribution along the lake shores has been significantly reduced.

Tables 7-8 and 7-9 list the current stock statuses and run times as reviewed in the WRIA 20 Limiting Factors Report (Smith, 2000). Ozette fall Chinook and fall chum are virtually absent in the system with only the occasional Chinook stray recorded since 1995. Chum salmon fry are occasionally observed at the Ozette River smolt trap, and adult chum have been observed attempting to spawn with sockeye on lake beaches (A. Ritchie, personal communication, 2004). Downward trends in all species have encouraged more intense spawner surveys since 1997 along shorelines and on all Lake Ozette tributaries. However, spawner surveys are not regularly conducted along the Ozette River mainstem due to difficult surveying conditions.

7.5.2 Habitat

7.5.2.1 Sedimentation

Though causes are undocumented, sedimentation is a major problem in Lake Ozette. Increased fine sediment in spawning gravels and native vegetation encroachment have severely degraded lakeshore spawning habitat. At some tributary mouths, and a few places along the shoreline, invasive species (reed canary grass, Japanese and giant knotweed) are exacerbating the problem. Degradation has occurred at Olson's Beach which is located near the mouths of Elk and Siwash Creeks and along Swan and Ericson's Bays (Meyer and Brenkman, 2001). Spawning gravels along the lower and middle reaches of the main tributaries average 18.7% fines by weight, well above the western Washington target of 11% (McHenry et al, 1994).

Roads and poor surfacing material, along with mass wasting are some of the major causes for excess sediment in the watershed (Dlugokenski et al., 1981). Road density in the Umbrella Creek sub-basin was 4.4 miles/mi^2 in the early 1980s (Dlugokenski et al., 1981) and densities averaged 3.78 miles/mi^2 in the Big River sub-basin (as reviewed in Smith, 2000). Though these road densities are not considered extremely high, estimates are conservative as 10.1 miles of new road have been added in the last 5-6 years (as reviewed in Smith, 2000).

7.5.2.2 LWD

From the 1950s to 1980s, active removal of LWD occurred on Ozette and Big Rivers (Kramer, 1953). This practice removed many (26 large jams on the Ozette River in 1952 alone) of the functioning wood in the systems and presumably interrupted the recruitment process, and the hydrologic and sediment regime. Loss of LWD in tributaries has undoubtedly destabilized channel morphology and potentially led to degraded water quality and spawning and rearing habitat (Haggerty, 2004). Currently, levels of LWD are “poor” on the lower Big River, most of Siwash Creek and in parts of South Fork Crooked Creek. Quantities of LWD were rated as “good” in Crooked Creek, North Fork Crooked Creek, parts of South Fork Crooked Creek, lower Siwash Creek, middle South Creek and the middle reaches of Big River (Smith, 2000).

7.6 Sol Duc Sub-Basin

7.6.1 Fish Composition and Distribution

The mainstem of the Sol Duc River is accessible to salmonids for almost 60 miles from the mouth of the river to Sol Duc Falls. Of all the streams in the watershed, 89 percent provide habitat for anadromous and resident fish species (Naughton and Parton, 1996). Table 7-10 presents the percentages of total salmonids in the Quillayute Basin for eleven distinct salmonid stocks in the basin.

Two hatcheries are currently operating in the Sol Duc watershed. WDFW operates the Sol Duc hatchery on the mainstem at RM 30 in cooperation with the Quileute Tribe. The hatchery produces and releases spring and fall Chinook, and summer and fall coho salmon. The spring Chinook stock is an introduced population, all other stocks are of local origin.

There is also a hatchery at on the Snider Creek confluence at RM 44, operated by WDFW and the Olympic Peninsula Guides Association (OPGA). This facility captures wild winter steelhead with the help of sport fishermen volunteers. The steelhead are spawned and incubated at other hatchery facilities and then released as smolts from the Snider Creek facility.

The status of the Sol Duc salmonids is listed in Table 7-11. In general, the Sol Duc stocks follow the same trend as other north coastal stocks and are mostly considered healthy.

The status of spring Chinook is considered healthy, but there will be a DNA evaluation conducted of spring/summer Chinook to determine if there is intermingling. All spring Chinook have been introduced to the Sol Duc artificially. Spring Chinook are an introduced run from the Dungeness and the Umqua River. The production of sockeye salmon is natural and healthy status. The Quileute Tribe does not survey for Cutthroat trout or chum (R. Lien, personal communication, 2004). Table 7-12 presents the run times for Sol Duc Salmonids.

7.6.2 Habitat

7.6.2.1 LWD

Throughout the Sol Duc channel network, LWD-jams in general were lacking and the condition of LWD in-stream was poor (Chesney, 1996). Areas that had adequate amounts of LWD included Goodman, Alckee, South Fork Sol Duc, Sol Duc (RM 52) and North Fork Sol Duc. Bear, Beaver, Lake, Shuwah and Bockman Creeks were all lacking in-stream LWD. The character of LWD is different form historical records in the Sol Duc system. Key-pieces of LWD in poor condition often trap smaller more mobile rafts of alder. While these rafts provide structure, they are likely to have a short residence time (Chesney, 1996).

Overall, near-term LWD recruitment in the Sol Duc watershed is good (60%). This is measured by the percentage of stream miles in which both sides of the channel can provide LWD (Christensen, 1996). Subwatersheds within the Olympic National Park and the upper watershed, the Upper Sol Duc River, the North Fork Sol Duc, and Alckee Creek have upwards of 94% of area with good recruitment. Kugel Creek has the worst recruitment potential with 70% of the area rated as “poor” (Christensen, 1996). The areas with poor recruitment are likely due to intense timber harvesting and salvage operations following fire and wind disturbances. There is also a distinct lack of cedar as a result of streamcleaning and the continual planting of common species such as Douglas fir and Western hemlock (Christensen, 1996).

7.6.2.2 Sedimentation

A history of fire, wind, and heavy precipitation and forest management activities has led to elevated sediment yields in parts of the Sol Duc drainage. Thirty two percent of the basin is unchanged from natural sediment yields and is located primarily in the headwaters of the basin. Twelve percent of the basin has elevated sediment levels recorded only in the past 20 years and will experience limited recovery in the near term. The rest of the basin (56%) has had elevated sediment yields for the last 40 years and is in recovery (Sasich and Dieu, 1996).

The basins that have limited recovery potential in the near term include the South Fork Sol Duc, Goodman, Upper Camp, Tom and Beaver Creeks. The South Fork Sol Duc, Goodman and Tom segments have the largest increases in sediment yield due to extensive clearcutting and harvesting (Sasich and Dieu, 1996). The road densities in these subwatersheds range from 3.05 – 3.73 miles/square mile. Two major debris flows in the Goodman and South Fork Sol Duc basins have contributed fine sediment to streams in the last 5 – 7 years (Sasich and Dieu, 1996). Beaver and Camp Creeks have experienced elevated rates due primarily to wildfires and subsequent harvesting activities.

7.6.2.3 Shade

In general, the upper portions of the Sol Duc watershed have good canopy cover with 77% of riparian areas providing adequate shade. Of the 23% of the area with low shade levels, 19% has natural low shade due to wide riparian corridors and only 4% is considered to have high impacts on water temperature as a result of lack of shade (Christensen, 1996).

Among areas that exceed state standards for temperature, the mainstem Sol Duc, North Fork Sol Duc, South Fork Sol Duc and Goodman Creek all have naturally low levels of riparian shade. Though these areas exceed 16°C, the duration of the exceedances is short term, lasting less than 7 days (Parks and Figlar-Barnes, 1996).

Tom Creek, Camp Creek, Upper Bear Creek, S.F. Bear Creek, Cold Creek, Shuwah Creek, Upper Lake Creek, Kugel Creek and Tassel Creek all have water temperatures well within current state standards even though the levels of riparian shade vary significantly. This suggests that shade is not the controlling factor for water temperature in these areas.

Lower Lake Creek and Bockman Creek have consistently high water temperatures and may be highly vulnerable to levels of riparian shade as they have naturally high levels of canopy cover. However, they are both fed by upper lakes which may compound high temperatures. Lower Bear Creek, Swanson Creek and Bockman Creek are all highly vulnerable to the removal of riparian canopy (Christensen, 1996).

7.6.2.4 Barriers

There were a few barriers present as a result of undersized or poorly engineered culverts primarily in Gunderson, Tassel and Bockette Creeks. The barriers blocked about 5 miles of anadromous fish habitat. The Quileute Tribe has replaced defective culverts in Bockette, Tassel, and Fossil Creeks since the watershed analysis was completed. Clallam County has been involved in a large culvert replacement at the downstream end of Tassel Creek. Due to the low levels of LWD in the streams and reduced numbers of natural barriers, there actually may be more habitat available than historically. This of course does not take habitat quality into account. Barriers in the area have been recorded and maintenance efforts are currently underway (Naughton and Parton, 1996).

7.7 Sooes/Waatch Sub-basin

7.7.1 Fish Distribution

There is very little documented information about the distribution and conditions of salmonids in the Waatch and Sooes basins, though McHenry et al. (1996) listed fall chum as critical. WDFW reports that historically there was (is) an impassable natural barrier at on the Sooes River at RM 13.8 and subsequently, salmonids only use about 14 miles of tributaries. The US Fish and Wildlife Service currently operates a hatchery at RM 3, which propagates and introduces coho, steelhead and Chinook to both the Sooes and Waatch Rivers. The hatchery facility partially blocks anadromous fish access to at least 10 miles of mainstem river and at least 14 miles of tributary areas (Zajac, 2002). Tables 7-13 and 7-14 list the current stock statuses and run times as reviewed in the WRIA 20 Limiting Factors Report (Smith, 2000).

7.7.2 Habitat

7.7.2.1 Sedimentation

Observations from 2000 show that the Sooes River can be characterized as having a dynamic, mobile bed with a coarse layer of gravel over a subsurface of coarse sand with little to no fine sand or silt (Zajac, 2002). This composition provides good spawning substrate but is easily mobilized (scoured) during high flows as there is little in-channel wood to dissipate hydraulic energy.

7.7.2.2 LWD

There are limited LWD data available within the Sooes and Waatch watersheds. Historically, wood jams were removed by the State of Washington and commercial landowners in misguided attempts to improve fish passage or reduce flooding in the Sooes and other streams, but documentation of this process is poor (Heckman, 1964) as compared to documentation in the Ozette (Kramer, 1953). Currently, few in-channel wood pieces or jams have been observed on the Sooes and immediate recruitment is considered poor due to past logging of riparian trees. Riparian stands are dominated by young alder with few conifers (Zajac, 2002). Due to lack of wood in these systems, high road density, which extends the drainage network, and the hydrologic immaturity of the upland stands coupled with the natural rain-dominated flow regime, these systems are thought to have an extremely "flashy" hydrologic pattern with brief, but frequent floods (Zajac, 2002).

8.0 FISH HABITAT-RELATED PLANS AND POLICIES

The major federal law that has shaped fisheries habitat related policy in the WRIA 20 watershed is the Endangered Species Act. The Endangered Species Act (ESA) provides protections for species meeting criteria to be listed as endangered or threatened. There are two fish species listed as threatened under the ESA in WRIA 20: Lake Ozette sockeye and bull trout. Another major fisheries habitat related policy is the 1994 Northwest Forest Plan, which governs federal forests. The Northwest Forest Plan Record of Decision details forestry management in the Olympic National Forest. (see Section 8.1.5, below.) The Olympic Experimental State Forest straddles this WRIA and others, and is an area of State study for forest management.

Additionally, a number of tribal, federal, state, county, and city plans, policies, and programs in WRIA 20 either directly or indirectly relate to fish habitat. The most significant of these are detailed in the following section. However, since fisheries habitat is indirectly related to most any watershed environmental attribute, this list is not intended to be exhaustive. A large proportion of the plans, policies, and programs detailed here are not regulatory, but are incentive programs or general policies that are implemented through voluntary actions.

8.1 Tribal and Federal Programs and Management

8.1.1 <u>Fisheries Co-Managers</u>

Streams in WRIA 20 are within the Usual and Accustomed fishing areas of three tribes: the Quileute, Makah, and Hoh. The treaty tribes have an active role in all ESA recovery processes that occur within their Usual and Accustomed fishing areas. In WRIA 20, ESA recovery applies to listed bull trout and Lake Ozette sockeye.

Along with the US Fish and Wildlife Service and the Washington Department of Fish and Wildlife, the treaty tribes play an integral role in management of the fishery for protection, restoration, and enhancement. The tribes survey a large number of index streams every year to count redds. In many cases they survey smolt numbers as well. These numbers are conveyed to the State and made a part of the negotiations to set the numbers for harvests in the following year. The tribes are also an integral part of the restoration process and work closely with land managers to determine the priorities and obtain funding for restoration projects. Makah and Quileute operate, and/or operate with the State and federal government, a number of hatcheries for salmonid enhancement when it is necessary to sustain fish populations.

8.1.2 <u>Bull Trout Recovery Plan</u>

The Olympic Peninsula Management Unit draft Bull Trout Recovery Plan was written by the US Fish and Wildlife Service, recovery teams, and State and Tribal agencies, and released by USFWS in May 2004. This document discusses recovery activities for bull trout on the Olympic Peninsula. There are two documented populations of bull trout in WRIA 20 in the Recovery Plan; both in the Hoh sub-basin. As more information on bull trout is collected, the number of populations identified in WRIA 20 may increase.

The objectives cited in the Bull Trout Recovery Plan are:

- “Maintain the current distribution of bull trout, particularly anadromous forms, and restore migratory life history forms in some of the previously occupied areas within the Olympic Peninsula Management Unit,

- Maintain stable or increasing trends in abundance of bull trout in the Olympic Peninsula Management Unit,
- Restore and maintain suitable habitat conditions for all bull trout life history stages and strategies, with an emphasis on anadromy, and
- Conserve genetic diversity and provide opportunity for genetic exchange to conserve migratory life history forms," (USFWS, 2004).

The two Hoh populations are targeted as a core population for restoration. The goal of the restoration plan is to increase abundance in the Hoh to 1000 spawning adults. The plan includes an implementation schedule which details prioritized activities needed for bull trout recovery to be completed over the next two to twenty-five years. Many of these activities are consistent with actions that may be proposed in the WRIA 20 Phase III 2514 Watershed Plan. Examples include:

- "Ensure adequate protection for bull trout at all life stages under Washington State Water Quality Standards,
- Identify and improve unstable or remove problem roads,
- Improve routine road maintenance practices,
- Implement measures to restore natural thermal regime,
- Monitor water quality and meet water quality standards for temperature, nutrient loading, etc.,
- Eliminate fine sediment sources from historical roads and railroads, and
- Identify, restore, and protect groundwater and hyporheic sources," (USFWS, 2004).

8.1.3 Lake Ozette Sockeye Recovery Working Group

The Lake Ozette sockeye was listed as threatened pursuant to the ESA in 1999. Recovery efforts are underway in the form of a working group that is developing a strategy to restore this species. Critical habitat for Lake Ozette sockeye includes the Ozette River, Lake Ozette, and the waterbodies and watershed that drains into the Ozette River and Lake. This working group is chaired by the Olympic National Park and the Makah Tribe. Other participants in the working group include WDFW, Quileute Tribe, Clallam County, timber interests, and land owners. The group is currently in the process of completing a limiting factors analysis for Lake Ozette sockeye. Some restoration work has been done with funding through the North Olympic Peninsula Lead Entity.

The Umbrella Creek hatchery, co-managed by the US Fish and Wildlife Service and the Makah Fisheries Management Department from 1983 to present, rears sockeye salmon specifically for release to supplement the Lake Ozette evolutionarily significant unit.

8.1.4 Clean Water Act

There are a number of streams in WRIA 20 listed as impaired on the 303(d) list under the Clean Water Act. The total maximum daily loads (TMDLs) of the listed pollutants in these waterbodies have not yet been established by Ecology. Most of these listings are related to temperature exceedances. These water quality impairments are further discussed in Section 9, Water Quality.

8.1.5 Northwest Forest Plan

Federal forest lands in WRIA 20 (the Olympic National Forest) are managed under the Northwest Forest Plan (NFP). The Northwest Forest Plan contains management strategies with a number of goals, including the protection of fish habitat. A central component is the Aquatic Conservation Strategy, which provides guidance for the management of aquatic and riparian habitat and maintenance and creation of ecosystem traits relevant to control of sedimentation problems associated with timber harvest and road building. For example, the NFP requires a riparian buffer along both fish bearing and non-fish bearing streams, with buffer widths ranging from 150 feet to more than 300 feet depending on the height of the adjoining forest stand.

The Northwest Forest Plan requires the creation and implementation of Road Maintenance and Abandonment Plans. A deadline for implementation of these plans is established through a Memorandum of Understanding between Ecology and the U.S. Forest Service and is discussed in section 8.2.6 of this chapter. The Northwest Forest Plan is also discussed in the Land Use section of this document (Section 6).

8.1.6 Olympic Coast National Marine Sanctuary

The Olympic Coast National Marine Sanctuary is managed by the National Oceanic and Atmospheric Administration (NOAA) under the authority of the National Marine Sanctuaries Act. The Olympic Coast National Marine Sanctuary will begin its next management plan review in 2005. There will be a public involvement process associated with this plan review. The current 1994 management plan protects the sanctuary by preventing activities that may threaten any part of the sanctuary, and acknowledges that activities outside the sanctuary boundaries may affect the sanctuary. That document is available online at:
http://olympiccoast.noaa.gov/protection/pubdocs/mgmtplan.pdf. (Accessed 10/04).

8.1.7 Olympic National Park

Thirty-five percent of the WRIA 20 watershed is a part of the Olympic National Park. This land is managed for conservation, with a goal of maintaining habitat conditions that are or are very similar to a pristine environment. This protected portion of the watersheds in WRIA 20 provides habitat and water quality benefits to fish species. The Olympic National Park area is unique not only in that there are many headwater areas protected by National Park boundaries, but also in that additional lowland areas are located along the coastline and at Lake Ozette, that are also managed by the National Park Service.

8.2 State Policies and Programs

8.2.1 Washington Department of Fish and Wildlife

The Washington Department of Fish and Wildlife (WDFW) works to protect, restore, and enhance fish and wildlife and their habitats in Washington State, and provide for sustainable fish and wildlife related recreational and commercial opportunities. WDFW is a co-manager of the fisheries resource on State lands, along with treaty tribes and the federal government (NOAA for salmonids and USFWS for bull trout). WDFW administers Hydraulic Project Approvals for the State, as required under the Hydraulic Code, RCW 77.55. Hydraulic Project Approval permits are required for any activity that will use, divert, obstruct, or change the bed or flow of State waters. The requirement for these permits helps ensure that fish species are considered before any instream work is conducted.

For all permit applications, the appropriate treaty tribe is consulted, and tribal comments are integrated into the permit.

WDFW also retains a State Endangered Species List, drawing special attention to species that are in peril in the State. On that list, bull trout and Lake Ozette sockeye are listed as species of concern, meaning that there is reason to consider them for State listing.

8.2.2 Growth Management Act

In 1990, Washington State's Growth Management Act (GMA) (RCW 36.70A) established a statewide program for local comprehensive planning. GMA requires local governments to balance competing societal goals with the intent of encouraging conservation, responsible use of lands and resources, and sustainable economic development. The GMA required the adoption of comprehensive land use plans to designate urban growth areas for concentrated development and growth, designate resource lands to preserve and plan for long term resource use (mining, forestry, and agriculture), and retain the integrity, character, and sustainability of these lands. These plans include an environment element, and provisions to protect fish habitat. Clallam and Jefferson counties and the City of Forks have Comprehensive Plans as well as provisions for Critical Areas.

The Growth Management Act requires that local governments designate and protect the following Critical Areas:

- Wetlands
- Fish and Wildlife Habitat Conservation Areas
- Geologically Hazardous Areas
- Frequently Flooded Areas
- Critical Aquifer Recharge Areas.

8.2.2.1 Clallam County Comprehensive Plan

The Clallam County Comprehensive Plan is recorded in the Clallam County Code (CCC) chapters 31.01-31.08. The Clallam County Comprehensive Plan has many policies that are relevant to fisheries habitat. The following policies are excerpted from Clallam County Code, but others exist throughout the Comprehensive Plan:

"(7) Habitat. (a) [Policy No. 18] Land use practices should protect and enhance habitat corridors, diversity and richness, and ensure protection of wildlife corridors and habitat for threatened and endangered species. Wildlife corridors and riparian areas should be maintained as important community infrastructure. (b) [Policy No. 19] Clallam County should protect, maintain and enhance fish and shellfish spawning, rearing, and migration habitat, and work to ensure harvestability of fish and shellfish. Damaged and degraded habitat should be identified, prioritized and restored. Recognize the various levels of government which have a vested interest in protection, maintenance and restoration of habitat. (c) [Policy No. 20] Clallam County shall recognize the large number of salmon and steelhead stocks that have been classified as critical or depressed. The County shall work toward prevention of these stocks from being listed as threatened and endangered through habitat restoration and land use practices which cause no further degradation to habitat needs."

<u>Clallam County Critical Areas Code, CCC Chapter 27.12</u>

Clallam County's Critical Areas Ordinance (CCC 27.12.070) provides protection for critical areas as required by the GMA. The purpose of this ordinance is to "…protect public health, safety, and welfare and maintain or enhance the biological and economic resources of the County while respecting legally established private property rights." Areas protected under the Critical Areas Ordinance that are relevant to fish are wetlands and wildlife and aquatic conservation areas. The Critical Areas Ordinance provides protection in the form of a 50 to 200 foot buffer between development and the protected area. Buffers that are in their natural state should be left alone or enhanced; those that are altered are encouraged to be restored.

Buffers for fish and wildlife aquatic conservation areas are intended to, "(1) Preserve natural flood control, storm water storage and drainage or streamflow patterns;(2) Control siltation, protect nutrient reserves and maintain streamflows and stream quality for fish and marine shellfish;(3) Prevent turbidity and pollution of streams and fish or shellfish bearing waters;(4) Preserve and protect habitat adequate to support viable populations of native wildlife in Clallam County," (Clallam County Code 27.12.300).

State law requires Critical Areas Ordinances to be updated based on the best available science by December 2004. Clallam County completed its update as of October 2004. The next changes to the Critical Areas Ordinance are expected with the next required update, in 2011.

8.2.2.2 Jefferson County Comprehensive Plan

The Jefferson County Comprehensive Plan for Growth Management was written in 1998 and has been updated almost annually. There are many areas of the Plan that are either directly or indirectly related to fisheries habitat, mainly the Environment Element. The plan states that, "the goals and policies of the Environment Element reflect the County's commitment to resource management based on watershed and fish habitat recovery planning." Within this element, the plan includes a watershed and fish habitat management strategy and a critical areas strategy, both of which are relevant to fish habitat and 2514 watershed planning.

<u>Watershed and Fish Habitat Management Strategy</u>

The Watershed and Fish Habitat Management Strategy component of the Jefferson County Comprehensive Plan supports a collaborative approach for integrated watershed management. Actions listed in this strategy include participation by the County in the 2514 watershed planning process.

<u>Jefferson County Critical Areas Code</u>

Jefferson County Critical Areas Strategy is discussed in the Environment Element of the Comprehensive Plan and is recorded in the Unified Development Code Section 3.6.4. The goal of the Environmental Element of the plan is to protect and enhance fish and wildlife habitat throughout Jefferson County. The Critical Areas Strategy includes a number of policies that benefit fish including: coordinated watershed and habitat plans, buffers and wildlife habitat corridors, support of best available science and best management practices, and coordination with agencies in approving development permits as to avoid impacts to fish habitat. Like the Clallam County Critical Areas Ordinance, the Jefferson County Ordinance requires buffers around wetlands, fish and wildlife habitat, and other sensitive areas.

8.2.3 Shoreline Management Act

The Shoreline Management Act was adopted in 1972 with the intent of preventing “the inherent harm in an uncoordinated and piecemeal development of the State’s shorelines.” It applies to shorelines of the State of Washington and the associated shorelands as designated in RCW 90.58.030. The Shoreline Management Act requires that cities and counties adopt Shoreline Master Programs, which combine plans and regulations and are a vision of how shoreline areas in the jurisdiction will be used and developed over time. Shoreline Master Plans are written by the counties, but must receive state approval through the Department of Ecology. There are three Shoreline Master Programs in WRIA 20: Clallam County, Jefferson County, and the City of Forks.

8.2.3.1 Clallam County Shoreline Master Plan

Clallam County’s Shoreline Master Plan provides protection for shorelines throughout the County. The rules governing shoreline development are included in Chapter 35.01 of the Clallam County Code. The purpose of these rules is to implement the Shoreline Management Act. These rules provide protection of lands that are within 200-feet of the ordinary high-water mark of a shoreline and any associated wetland, floodway, or 100-year floodplain where applicable.

8.2.3.2 Jefferson County Shoreline Master Plan

Jefferson County is currently using the 1989 version of the Shoreline Master Plan (SMP) in conjunction with the Critical Areas Ordinance in the Unified Development Code (UDC 3.6.4). There is a 2000 draft of the SMP, but it was never made final. The SMP is currently due for revision in December 2011; the County plans to have the update done between 2006 and 2008. The Shoreline Management Plan designates levels of development and protection in the area of shorelines in the County based on habitat and conservation goals. Shorelines are given a classification which defines the policies used to manage them. All streams under Jefferson County shoreline management in WRIA 20 are designated as “conservancy.” These streams are: Bogachiel River, Goodman Creek, Hoh River, Maple Creek, Mosquito Creek, Nolan Creek, Owl Creek, and Winfield Creek.

Conservancy areas are defined in section 4.103 of Jefferson County’s Unified Development Code as, “An area with valuable natural, cultural, or historical resources or environmental conditions that should be protected, conserved, and managed to the extent that a continual supply of those resources such as soil, water, timber, fish, shellfish, or wildlife are not degraded or depleted but are maintained. Also included are areas with sensitive environmental conditions that may limit the potential for development or use, including but not limited to steep slopes, flood prone areas, eroding bluffs, marshes, bogs, swamps, and accretion shore forms. Low density residential and recreational uses are permitted provided these activities do not significantly degrade or deplete resources and respect limiting environmental condition.” The same section of the Unified Development Code defines the policy governing management of these areas as, “to protect, conserve, and manage existing resources and valuable historical and cultural areas in order to ensure sustained resource stabilization and that sensitive natural conditions are not subject to inappropriate uses.”

8.2.3.3 City of Forks Shoreline Master Plan

The City of Forks also has a Shoreline Master Plan that provides protection for stream banks within the City’s jurisdiction.

8.2.4 Forest and Fish Rules

Many state and private forest lands in WRIA 20 are managed for commercial forestry. Management on these lands is directed by the State Forest Practice Rules, written according to the direction of the Forest and Fish Act. Generally, the Forest and Fish Rules and other associated regulations provide protection, but not restoration of fisheries habitat. Additionally, a multi-species Habitat Conservation Plan (HCP) is implemented along with the Forest Practice Rules on State lands. The HCP is intended to fulfill Endangered Species Act (ESA) requirements for forest practices on state lands for a number of endangered and threatened species. The HCP generally requires more stringent environmental constraints than the Forest Practice Rules. The HCP has a Riparian Conservation Strategy which limits road building in riparian areas and limits harvest in riparian areas, on unstable slopes (which are often adjacent to streams), in rain-on-snow zones, and in wetlands. The HCP generally has more stringent buffer requirements for state lands than the Forest Practice Rules set forth for private lands. These are also discussed in the Land Use Section of this report, Section 6.

8.2.5 Salmon Recovery Act

The Salmon Recovery Act, RCW 77.85, was passed in order to address the decline of salmon statewide. Statewide, local groups called lead entities were formed to prioritize salmon habitat restoration projects. In WRIA 20, the lead entity is the North Olympic Peninsula Lead Entity.

8.2.5.1 NOPLE Lead Entity Strategy

The North Olympic Peninsula Lead Entity (NOPLE) operates with a mission to, "develop a regional project strategy that when implemented will help to achieve genetically diverse, self-sustaining, salmon populations that will support healthy ecosystems and ceremonial, subsistence, recreational, and commercial fisheries." The lead entity strategy identifies and prioritizes restoration projects in the watershed for funding. These priorities are based upon a number of factors including geography, priority stocks and status, watershed assessment and limiting habitat features and watershed processes, actions necessary to address limiting factors, scientific and technical criteria and factors, and social and political consideration. Based on geography, the following sub-basins in WRIA 20 were identified as Tier 1, which means activities in these sub-basins have the highest priority for restoration: Hoh, Nearshore, Ozette, Quillayute Mainstem, Bogachiel, Calawah, Dickey, and Sol Duc. Activities prioritized by the NOPLE are presented to the Salmon Recovery Funding Board, which guides state spending for salmon recovery activities and projects. Examples of restoration activities recommended in WRIA 20 include: eliminate culvert blockages, remove cedar spalt blockages, road maintenance, large woody debris placement, general habitat restoration, and others.

8.2.6 USFS Water Quality Compliance

A 2001 Memorandum of Agreement (MOA) between the U.S. Forest Service (USFS), Region 6 and the Department of Ecology establishes responsibilities of these agencies under federal and state water quality laws and establishes the USFS and Ecology responsibility for implementation of the policies necessary for compliance with the Clean Water Act. The State Forest Practice Rules, codified in WAC 222 outline best management practices for forest management on non-federal forest lands. These strategies are recognized as a primary mechanism to prevent non point source pollution on federal lands, and federal land management is expected to meet or exceed requirements that apply to non-federal lands. Therefore, this MOA also outlines the USFS compliance with standards and Best Management Practices (BMPs) set forth in WAC 222. Specific rules from WAC 222 pertinent to road maintenance and water quality are as follows:

WAC 222-24 - The Forest Practice Rules (WAC 222-24) require forest roads to be brought up to state standards and maintained in a condition that will not cause damage to public resources. All forest roads must be improved and maintained to the state standards within 15 years of the effective date of these rules (2001).

WAC 222-24-051 – all forest roads must be covered under a road maintenance and abandonment plan within five years of the effective date of this rule or 2005. This includes all roads that were constructed or used for forest practices after 1974. Inventory and assessment of orphan roads must be included in the road maintenance and abandonment plans as specified in WAC 222-24-052(4).

The USFS and Ecology agree that roads can be a significant component for addressing water quality. Therefore, forest roads are addressed through the MOA, including a schedule for road maintenance and an implementation plan. In the MOA, the forest service commits to a number of responsibilities that are part of compliance with the CWA and other water quality laws. A sample of these responsibilities include:

- Implementation of site-specific BMPs,
- Stabilization and maintenance of all National Forest Service roads according to an included implementation schedule,
- Completion of an assessment of water quality effects generated by roads, and
- Pursue corrective action when water quality laws are violated on USFS lands.

Goals and milestones included in the MOA are a 5 year planning schedule (planning for which roads need to be maintained and to study water quality effects) and a 15 year implementation schedule (at the end of which all roads on USFS lands in the State of Washington will meet the level of protection specified in the Forest Practices Act, WAC 222.) The MOA also includes a list of road projects to be completed by specified dates.

8.2.7 Washington State Department of Transportation

The Washington State Department of Transportation maintains a number of plans and policies that could be relevant to fisheries habitat in WRIA 20. Corridor Master Plans guide development and maintenance of some highways in the watershed, including Highway 101. Corridor Master Plans are not regulatory documents and are intended to be consistent with any comprehensive plans completed pursuant to the Growth Management Act. A current restoration project along Highway 101 on the Hoh River will install engineered log jams in an effort to help prevent the River from washing out the road in a flood.

9.0 WATER QUALITY

The federal Clean Water Act requires states to assess water quality in their waterbodies and periodically prepare lists of waterbodies which are non-supporting of their assigned beneficial uses. This information is traditionally reported in a "303(d) list." In 1998, U.S. Environmental Protection Agency (EPA) policy was updated to better refine the water quality assessment process, requiring a complete Water Quality Assessment, as opposed to a listing of only waterbodies requiring a TMDL. In 2004, a draft of Washington's first, more detailed Water Quality Assessment list was completed, which highlights existing and potential water quality problems across the state in addition to listing the traditional "303(d) list" waterbodies. This draft Water Quality Assessment tells a more complete story about the condition of Washington's waters. Currently, the 2004 Water Quality Assessment list is still in draft form, so the most recent, approved 303(d) list is the 1998 list. However, the draft 2004 list can be used as an indication of what the final 2004 list will look like. The draft Water Quality Assessment is broken into the following categories:

- **Category 1** – Meets tested standards for clean waters.
- **Category 2 –** Waters of Concern. In these waters, there is some evidence that there may be a water quality problem, but not enough evidence to require a TMDL study at this time. (At least 10% of water quality samples must exceed the standard in order for a water body segment to be placed on the 303(d) list.) Category 2 waters are waters that Ecology will continue to test and watch closely.
- **Category 3 –** No data. This category functions mainly as a placeholder.
- **Category 4** – Polluted waters that do not require a TMDL either because the impairment is currently being dealt with through a TMDL, or because a TMDL process would not adequately address the water quality problem. Category 4 is broken down into the following sub-categories:
    - **Category 4a** – Has a TMDL.
    - **Category 4b** – Has a pollution control plan. Pollution control plans are not TMDLS, but they do have many of the same features as TMDLs and there must be some legal or financial guarantee that they will be implemented.
    - **Category 4c** – Impaired by a non-pollutant. The water quality problems in these waterbodies cannot be solved through the TMDL process. Examples of impairments that can cause Category 4c listing include low flows, stream channelization, habitat conditions, or dams.
- **Category 5 –** Polluted waters that require a TMDL (commonly called the "303(d) list") (Roughly 10% of water quality samples taken must exceed the standard in order for a waterbody to be placed in Category 5).

Waterbodies arrive on the list of impaired waterbodies by failure to meet state water quality standards for a percentage of times the station was monitored. After water quality data are analyzed by Ecology (data are submitted from many sources), water body segments are placed in one of the five categories. For waterbodies in categories 1 and 2, any changes in water quality parameter levels in subsequent study years may initiate movement of those waterbodies to categories 1, 2, 4, or 5. For waterbodies in category 4, TMDLs, pollution control plans, or other pollution mitigation plans will be implemented in subsequent years. These waterbodies may eventually move to category 1 or 2. For waterbodies in category 5, if the TMDL is approved by EPA, it will move to category 4. Otherwise, in subsequent water quality assessments, they may be placed in categories 1, 2, or 5 depending on changes in water quality parameter levels. It is possible for a waterbody initially placed in category 5 to be moved to category 1 or 2 without initiating the TMDL process if the water quality problem is sufficiently reduced before the TMDL process is initiated.

Although in 2003, the State of Washington adopted revised water quality standards (Section 4.1 of this report), these new standards have not yet been approved by the EPA. Therefore, the 1997 water quality standards are used to gauge water quality for the 2002/2004 water quality assessment.

The 2002/2004 draft 303(d) list was available for public comment in 2004. These comments will be incorporated, and the list will then go out for comment. The final list will then be approved as the 2004 303(d) list (Category 5) and the 2004 Water Quality Assessment. The 2006 303(d) list is expected to be the first to use the 2003 Washington State water quality standards, assuming they are approved by EPA.

9.1 Establishing TMDLs

Inclusion on the 303(d) list (Category 5) requires the setting of a Total Maximum Daily Load of certain pollutants in that waterbody. A TMDL is the identification of the maximum amount of a pollutant that can be released into a waterbody, while still allowing it to support its assigned beneficial uses. Establishing TMDLs is a time-consuming process. In 1997, Ecology and EPA signed a Memorandum of Agreement (MOA) which stated that waterbody segments on the 1996 303(d) list, and remaining on subsequent 303(d) lists, must have TMDL studies completed by 2014.

The order in which these TMDL studies are to take place is established through a prioritization process using criteria such as existing water quality management plans, threat to public health or other designated uses, public interest and support, technical feasibility, and other criteria. This work is done through Ecology's Water Quality Management Area (WQMA) approach to water quality management. WRIA 20 is within the Western Olympic WQMA, along with WRIAs 21 and 22. The WQMA approach addresses both point source and non-point source issues (NPDES permits and TMDL rules) on watershed scales throughout the State. The WQMA process allows Ecology to systematically issue permits, assess water quality conditions, focus staff effort, and develop an improved basis for decision making in each WQMA. Through this prioritization process, draft TMDL Priority lists have been created throughout Washington State.

TMDLs are required to be completed for all waters listed in 1996 unless they are de-listed, this delisting is approved by EPA, and is consistent with the requirements of Section 303(d) of the Clean Water Act. Ecology's MOA obligations for scheduling TMDLs are tied to the 1996 list. The agency intends to conduct TMDL prioritization and studies in the same manner for those waterbodies listed in 1998 and 2004.

One of the key provisions in the Forest and Fish Report (FFR) was a goal that the State's Best Management Practices (BMPs) for forestry meet requirements for water quality as stipulated under the Clean Water Act (CWA) and the Endangered Species Act (ESA). It was agreed upon by the Environmental Protection Agency (EPA) and the Washington Department of Ecology (Ecology) that the FFR would be crafted to ensure that forestry does not impair waters. Ecology and EPA have acknowledged that implementation of the Forest Practice Rules under FFR will significantly advance forest practices in Washington State, improve water quality in the short term, and it is hoped that these practices will allow water quality standards to be met in the long term. For this reason, Total Maximum Daily Load (TMDL) establishment and implementation on non-federal forest land in WRIA 20 have been deferred until 2009 to allow evaluation of the effectiveness of the current Forest Practice Rules. If these practices allow water quality standards to be met, TMDLs will not be developed for these waterbodies. If water quality standards are not met by 2009, establishment of TMDLs will be revisited.

9.2 1998 303(d) listings in WRIA 20

Water Quality information provided in section 9.2 below is as reported in the WRIA 20 Level 1 Technical Assessment by Abigail Hook. The draft 2002/2004 Water Quality Assessment List has been updated since this report was written, and the list has changed significantly, therefore references to the 2002/2004 Water Quality Assessment have been removed from the excerpt in section 9.2. Information about the most current 2002/2004 Water Quality Assessment is provided in section 9.3.

9.2.1 Bogachiel Sub-Basin

The Bogachiel is rated as Class AA by the Department of Ecology. There are several 1998 303(d) listings on the mainstem Bogachiel River for high water temperatures (Table 9-1). Those sites listed for just high temperatures include RMs 8.7, 9, 9.8, 12.6 and 15.7 and were submitted to Ecology by Quileute Natural Resources in 1996. Two segments (RM 0 and RM 20) have been listed by Ecology for both temperature exceedances and low dissolved oxygen. The exceedances on the mainstem of the Bogachiel cover the longest stream segments in WRIA 20. Maxfield Creek has also been listed for high temperatures (Ecology, 1998). There are tributaries within the upper watershed that have sites that exceed State water temperatures but since they are located in old growth, it is assumed that the conditions are natural (Smith, 2000). Table 9-1 presents a summary of the Bogachiel's condition on the 1998 303(d) list.

Turbidity is a problem on the Bogachiel mainstem and has resulted in a "poor" water quality rating in the Limiting Factors Report from RM 16 downstream to the mouth. This turbidity is a direct result of channel incision which has exposed unstable clay layers and contributed fines to the river (Smith, 2000).

9.2.2 Calawah Sub-Basin

The Calawah River and tributaries are all rated Class AA (extraordinary) by the Department of Ecology. The primary designated use requiring protection is anadromous fish production since there are no domestic water systems or hatcheries located within these watersheds. The following is taken directly from the North Fork Calawah Watershed Analysis Fish Module (Martin et al., 1996). Data were a compilation of Quileute Natural Resources and Sol Duc Ranger District monitoring from 1993 to 1995. The QNR and Ranger District collected instantaneous temperature, DO, and pH.

Mainstem Calawah

Table 9-2 presents water quality excursions for the North Fork Calawah River.

RM 0.0 – 9.0: Results along the mainstem downstream of the drying reach show a wide range of temperatures during the sampling period. Data suggest that there are several prominent areas of groundwater upwellings which result in localized cold spots. All sites upstream of Western Cool Creek and unaffected by groundwater inputs exceeded WA state water quality standards on 17 days in 1995. All sites were within state standards for pH and DO with the exception of one site that had minor exceedances.

RM 9.0 – 16.3: This reach of the river is dry from late spring to early fall.

RM 16.3 – 17.3: This section has the highest recorded temperatures during all the sample years. Temperatures exceeded state standards on 34 and 22 days in 1993 and 1995 respectively. Between RM 18 and RM 16.5, maximum stream temperatures increased by almost 4 C on the hottest days. This increase is probably due to the proximity of this reach to the downstream dewatered reach. This reach also had the highest number of DO exceedances (3) for the entire N.F. Calawah watershed. All measurements for pH were within WA state standards.

RM 18, 20: Temperature regimes for these two reaches were similar with a slight increase recorded at the downstream site. Slight temperature exceedances were recorded at RM 18 and one exceedance for DO was recorded. All measurements for pH were within WA state standards.

In Eastern Cool Creek, Devils Creek and Fahnestock Creek: Water temperatures exceeded state standards with the highest number of exceedances in Fahnestock and Devils Creek and minor exceedances in Eastern Cool Creek. Though all three streams currently have adequate riparian cover, low summer flows and low elevation increase their susceptibility to increased temperatures.

Albion Creek: Although riparian cover is below target goals, low flow temperatures are within target levels.

South Fork Calawah and Sitkum Rivers

All streams within the South Fork Calawah and Sitkum River watersheds are classified as class AA (extraordinary) surface waters. The primary designated use requiring protection is anadromous fish production since there are no domestic water systems or hatcheries located within these watersheds.

Water quality data for the Sitkum cover sites along the mainstem and major tributaries (Table 9-3). There is only one sampling site at the mouth of the South Fork of the Calawah. All water quality data summarized below were collected by the Sol Duc Ranger District, Olympic National Forest at selected sites in 1996 and 1997. Temperatures were recorded continuously from June to September at one hour intervals. Some sites were sampled throughout the year to detect seasonal variations in water temperature. DO measurements were only taken in 1996 (Table 9-4).

All sites sampled from the summer of 1996 show increased water temperatures as a result of the warm, dry summer. All reaches exceeded WA state water quality standards with the exception of Lost Creek which only had one day of temperatures over 16° C. Temperatures from 1997 have a marked decrease of water temperature that reflects the cooler, wetter summer. Temperatures from 1997 show dramatic decreases in exceedances, particularly with samples from Rainbow Creek and the South Fork of the Calawah. The Sitkum River is the only site that has an increase in temperatures between 1996 and 1997. There were no sites listed on the state 303(d) list in 1998.

Dickey Sub-Basin

The Dickey River and tributaries are rated as Class A by the Department of Ecology. The primary designated use requiring protection is anadromous fish production since there are no domestic water systems or hatcheries located within these watersheds. Within the Dickey watershed, parts of the West Fork, Middle Fork and East Fork Dickey are on the 1998 303(d) list for high water temperatures. In 1997, the maximum temperature recorded just above the confluence with the East Fork was 22.4°C. The seven day average temperature was continuously above 18°C for 27 consecutive days. Maximum temperatures in the East Fork just above the confluence were 21.3°C for the same period (Smith, 2000). The mainstems are thought to have elevated temperatures due in the most part to lack of riparian shade; due primarily to lasting effects from older logging practices and natural wetlands.

Water quality data sources for the Dickey watershed include Quileute Natural Resources historical data going back to 1971 (grab samples) and recent Dickey watershed water quality data (Table 9-5). The recent data are a result of the East/West Dickey watershed analysis effort. Eleven water temperature stations were monitored with data loggers stratified across the watershed in 1997. Grab samples were also taken in 1997 from the upper Pond's Creek wetlands complex. Coal Creek, a tributary to the lower Dickey River, is also on the 1998 303(d) list for elevated water temperatures (Ecology, 1998). Other areas with high water temperatures include Dickey and Wentworth Lakes, Skunk Creek, and Squaw Creek. These listings have resulted in temperature being the most outstanding problem in the Dickey watershed (J. Dieu, personal communication, 2004).

High levels of sedimentation and organic materials occur naturally in the channel of the East and West Forks Dickey system. During 1997, the watershed analysis identified mainline roads as a critical source of sediment delivery as it related to water quality and turbidity. That concern was dealt with by a collaborative effort of WDNR, Rayonier and the Quileute Tribe, and delivery was lowered by 50% as a result of the installation of a network of cross-drains and silt traps.

Sedimentation is a potential problem for Thunder Lake. The lake is fed by high gradient streams that drain from areas with an extensive network of logging roads. The lake's topography is shallow and flat which leads to a higher vulnerability for sediment inputs (LaManna et al., 1998).

Along with inputs from sandstone roads, clearcuts in the East/West Dickey basin have contributed to surface erosion events. Numerous field observations (LaManna et al., 1998) have shown that the inner gorges with southern aspects are particularly sensitive to any ground disturbance. While harvests on northern aspect slopes are able to revegetate quickly, southern aspect slopes are subject to winter raveling and cannot establish cover easily. The erosion from these inner gorges is directly contributing sediment to the channel networks and constitutes almost half of modern inventoried surface erosion events.

9.2.3 Hoh Sub-Basin

The Hoh River is rated as Class AA by the Department of Ecology. There are several sites within the Hoh basin on the 1998 303(d) list for high water temperature (Table 9-6). Most of the sites are located on the middle Hoh between Highway 101 and the confluence of the South Fork of the Hoh. The tributaries with slightly high temperatures include Fisher, Willoughby, Rock, Elk, Canyon, Anderson (lower Hoh), Alder, Line, Maple, Nolan (lower Hoh), Owl, Split, and Tower Creeks (Ecology, 1998).

In August 1999, temperatures in Winfield Creek were so elevated that extensive salmonid mortality occurred. This temperature spike and subsequent mortality was a result of a pile of road spoils collapsing into the creek. The channel was completely blocked and fines persisted for at least a season, contributing to extremely poor water quality overall and a complete change in channel structure (J. Dieu, personal communication, 2004).

From September to October 2002, DO measurements were taken for Alder, Anderson, Lost, Maple, Mosquito, Nolan, Owl, Rock, Tower, West Twin, Willoughby and Winfield Creeks. None of the sites were in compliance with state water quality standards for class AA waters (10,000 Years Institute, 2003).

One of the major contributors to poor water quality in the Hoh watershed is cedar spalts, leftover waste wood from cedar shake and shingle-wood salvage operations. The presence of these spalts leads to low dissolved oxygen, high acidity and high water temperatures. Dissolved oxygen in these areas falls considerably below the standard 9.5 mg/L with ranges between 3.5 mg/L to 6 mg/L. Water temperatures reportedly are 4 to 5˚C warmer above spalt dams than in free flowing reaches. Currently impacted streams include Winfield, Braden, Clear, Nolan, Red, Lost, Pins, Snell, Anderson and Willoughby Creeks in the Hoh basin (Smith, 2000). The majority if the spalts are found in regime channels where gradients are low, water velocities are low and streams may be susceptible to stream heating (McHenry, 2000)

Logging activity within the basin has also raised temperatures. When compared to unlogged areas, Hatten (1991) found that mean daily stream temperatures in logged areas (>65%) vs. unlogged areas (<10%) were 10.9% higher. The affected creeks (Willoughby, Owl and Split) in Hatten's 1991 study all *marginally* exceeded state water quality standards while the unaffected streams (Matson, Jackson and Rock) were cooler than critical levels. Logging activities were also to be blamed for major sediment pulses into tributaries. In 1989-1990, Logan et al. (1991) estimated that 243,000 yd^3 was mobilized off of the Huelsdonk tributary basins and more that 90% of the failures originated in clearcut areas. Roads and landings are also primary contributor to these tributaries and the Hoh River. Midslope failures commonly occur in affected areas where soils are less than 5 feet thick (75%) and gradients range from 26 to 46 degrees (Logan et al., 1991).

Murray et al. (2000) suggest that partial harvesting (7-33%) had little influence over temperature, chemistry and turbidity 11-15 years post-harvest. Though stream temperatures were increased by about 3°C, neither of the creeks measured (Rock and Tower) exceeded state water quality standards. Elevated nitrate levels were recorded and thought to be a result of the alder dominant riparian zones.

Though there have been no studies, there is suspicion that alterations to alluvial aquifers in the Hoh basin may be contributing to water quality problems. The Hoh watershed is highly dependent on groundwater upwellings to maintain baseflows and cool temperatures in the summer (Smith, 2000). Removal of upland vegetation prevents the infiltration of groundwater on hill slopes. Excessive sedimentation may also disturb the cool nutrient rich upwellings.

9.2.4 Ozette Sub-Basin

The entire Lake Ozette system is rated Class AA (extraordinary waters) by the Department of Ecology. The primary designated use requiring protection is anadromous fish production since there are no domestic water systems or hatcheries located within these watersheds. For the Lake Ozette system, there are no water quality excursions on the 1998 303(d) list. Temperatures cool after October with fall rains affecting the surface. The warm summer lake surface temperatures affect upper Ozette River at the lake's outlet. Upper river temperatures have been recorded as high as 23.7°C in the summer, well above the preferred range of sockeye salmon or other salmonids (Meyer and Brenkman, 2001).

Lake Ozette also experiences elevated water temperatures. In 1994, temperatures exceeded 20˚C on all sampled days from July to September from the lake surface to 6 m. (Meyer and Brenkman, 2001). Lake temperatures are probably naturally high, in part due to the color of the water (tannins absorb infrared very effectively) and to the low flows into the lake. The lake stratifies very strongly in the summer and suitable temperatures for salmonid holding and refugia are available deeper than 3 m (Crewson et al, 2002).

Summer dissolved oxygen levels range from poor to adequate in several tributaries, with levels ranging between 5.71 mg/L (Coal Creek) to 12.66 mg/L during 1994 (Meyer and Brenkman, 2001). Historically, low dissolved oxygen levels were also recorded during late summer (Bortleson and Dion, 1979).

Elevated turbidity levels are systematically a problem within the Ozette watershed. Turbidity is a surrogate measurement for suspended sediment. Tributaries to Ozette Lake, especially Big River and Umbrella Creek, deliver fine sediment under high flow conditions. The turbidity levels measured in Big River and Umbrella Creek were 161 and 185 NTU respectively during a storm event (Meyer and Brenkman, 2001). Without historical data, the State of Washington Class AA stream standards suggest levels should not exceed 5 NTU, which are consistently exceeded (Meyer and Brenkman, 2001). Tributary suspended sediment also causes visibility and turbidity problems in Lake Ozette. In December of 1999, storm conditions reduced visibility in the lake to less than one foot for 2 – 3 weeks (A. Ritchie, personal communication, 2004). Coal Creek also contributes sediment plumes to the lake and is considered to have poor water quality (A. Ritchie, personal communication, 2004).

9.2.5 Sol Duc Sub-Basin

All water quality data currently available are from Quileute Natural Resources (historical dating back to 1977) and the USFA Sol Duc Ranger District (Table 9-7). The ranger district completely assessed water quality in 1994 as part of the 1995 Watershed Restoration Strategy contained in the Record of Decision for the Northwest Forest Plan (USDA and USDI, 1994). All water quality data currently published are in the Appendix of the 1996 Sol Duc watershed analysis and include the following:

- Temperature data on 10 tributaries (USFS, 1994)
- Dissolved Oxygen and Temperature for Sol Duc RM 19.0 and 53.5 (QNR, 1992-1995)
- pH values for Sol Duc RM 6.5 (QNR, 1992-4), RM 23.4 and 44.9 (USFS, 1994), and RM 63.0 (ONF, 1993-4)
- pH values for Lower Lake Creek (QNR, 1992-4), Upper Lake Creek (QNR, 1992-4)
- Data for Lake Pleasant and Beaver Lake including temperature, secchi disk readings, fecal coliform, and dissolved oxygen (Fretwell, 1984)

Temperatures regularly exceed 20° C in some locations in July and August while annual lows around 5° C have been recorded in heavy rains in November and March. According to state water quality standards, Beaver Creek and Bockman Creek, both tributaries to the Sol Duc have temperatures exceeding 20° C, with Beaver Creek temperatures exceeding requirements 44 times out of 80 sampled in 1994 (Ecology, 1998).

There are few data on Sol Duc dissolved oxygen but most observations meet State water quality standards of 9.5 mg/L for class AA (extraordinary) waters. Instances where dissolved oxygen is low are usually due to high summer temperatures combined with low seasonal flows (Parks and Figlar-Barnes, 1996). The only area that exceeded state standards from 1992 – 1994 (measured by QNR) was RM 36 on the mainstem.

There is no continuous turbidity sampling currently done on the Sol Duc. However, instantaneous grab samples suggest that turbidity is extremely low (2 NTU) except for during elevated discharge during storm events. Data from tributaries seems to be more variable, ranging between 0.05 NTU and 87.8 NTU (Parks and Figlar-Barnes, 1996).

Water quality data for lakes in the Sol Duc sub-basin are limited to Beaver Lake and Lake Pleasant. Both lakes are thermally stratified. Data from QNR (1992) suggest that dissolved oxygen in Lake Pleasant is within state standards. Water temperatures in Beaver Lake (17.3° C) and Lake Pleasant (20-22° C) are well above state standards. As both lake outlets are discharge for streams, these elevated temperatures may have negative effects on the entire system (Parks and Figlar-Barnes, 1996).

9.2.6 Sooes/Waatch Sub-Basin

The Department of Ecology reported high temperatures and low dissolved oxygen in Sooes River in 1998 (Table 9-8). The Waatch River has exceeded state water quality standards for dissolved oxygen, pH and water temperature. The Educket River, a main tributary to the Waatch River and a water supply source for the Makah Tribe, had poor dissolved oxygen and pH samples.

9.3 2002/2004 draft Water Quality Assessment

The draft 2002/2004 Water Quality Assessment list was described in Section 9.1 of this report. Table 9-9 describes the number of listings in each category of that assessment in WRIA 20. Tables 9-10 through 9-17 shows streams in each WRIA 20 sub-basin listed in categories 2-5 of the assessment. The final version of this list is available for public comment November 3 through December 4, 2004, and can be accessed at the following website: http://www.ecy.wa.gov/programs/wq/303d/2002/2002-index.html.

10.0 PHASE II SUMMARY AND RECOMMENDATIONS

This technical assessment was compiled to provide baseline information for the development of management strategies in the Phase III Watershed Plan for WRIA 20. The technical assessment is comprised of one required element (water quantity) and two optional elements (water quality and habitat). Water quantity was assessed, per the requirements of RCW 90.82.070, by evaluation of groundwater resources and geology, water allocation, water use, streamflow, and a water balance. In addition, land use was assessed to understand the relationships between water quantity issues and human impacts to the land. Fish habitat and water quality assessments are incorporated into this report from the WRIA 20 Technical Assessment Report (Hook, 2004), per the requirements of RCW 90.82.100 and RCW 90.82.090.

These assessments are summarized below along with summaries of data gaps identified in each assessment, and recommendations for management strategies that may be incorporated into the Phase III Watershed Plan.

10.1 Groundwater Resources and Geology Summary

The availability of groundwater in WRIA 20 is dependent on the location and depth of productive aquifers. Most domestic water supply wells in WRIA 20 are shallow (less than 100 feet in depth), completed in glaciofluvial sand and gravels, and located in river valleys within the WRIA. Marine sedimentary rocks and basalt are unlikely to produce significant water.

Wells located near rivers may be hydraulically connected to surface water which requires that development of groundwater be conducted in a manner that does not compromise instream flows.

Water from shallow aquifers has the potential for susceptibility due to:

- Seasonal fluctuations in water level;
- Potential hydraulic continuity with surface water; and
- Potential contamination from surface sources.

<u>Data Gaps/Recommendations</u>

There are few data currently available to determine the amount of groundwater present in WRIA 20. Further hydrogeologic characterization at a local level is necessary to evaluate existing water supplies, to develop additional productive water supplies, and to understand relationships between groundwater withdrawal and instream flow. Hydrogeologic studies could include evaluations of:

- Aquifer thickness and extent;
- Aquifer recharge and discharge zones;
- Annual well production records;
- Aquifer parameters (storativity, transmissivity, response to pumping);
- Hydraulic continuity between surface and groundwater.

Additionally, hydrogeologic conditions in the WRIA are likely to be highly variable not only between valleys but also along valleys. Due to these constraints and conditions it is recommended that any further hydrogeologic characterization be conducted on a small scale within a particular area based on current needs or projected demands in that area.

Because of the proximity of wells to rivers in WRIA 20, there is a need to understand the degree of hydraulic continuity between groundwater and surface water. In the absence of any published data, some options for increasing the understanding of groundwater/surface water interactions include compiling anecdotal evidence, developing a stream gaging program, performing pumping tests on wells sited near rivers and measuring streamflow and water quality, and intensive streambed studies.

The degree of hydraulic continuity between surface water and groundwater will help determine how much water is available for use without impairing instream flows. Establishing minimum instream flows in creeks in the WRIA will also guide the determination of the amount of groundwater available for pumping.

Once the amount of available water has been determined, the amount available for future allocation may be estimated. This requires a detailed evaluation of how much water is currently being used and an estimate of additional future water demand (if any) in the WRIA. These evaluations should be conducted at a scale smaller than a sub-basin in select areas of WRIA 20 that are likely to face future groundwater development pressures.

The Planning Unit may decide to develop a program to assist public water systems in developing wellhead protection plans. A program of developing uniform wellhead protection plans in the WRIA will help smaller system wells share a similar degree of water quality protection as larger systems.

Because of the cost associated with drilling a dry well, particularly to a private homeowner, future groundwater development in WRIA 20 should utilize techniques that give insight into the hydrogeologic conditions expected at a site before drilling begins. This may be done by review of existing well logs, or using geophysical techniques that provide information on subsurface materials of an area without installing a well.

Aquifer storage and recovery (ASR) may be considered wherein existing wells are used to recharge water directly to an aquifer unit, for recovery at a later time. Hydrogeologic characterization is required to determine whether aquifer materials have sufficient storage capacities, and have boundaries which inhibit the movement of water. Because of the limited thickness of most of the aquifer zones in WRIA 20 and the proximity to surface water bodies, identifying a site suitable for ASR is likely to require a site-specific hydrogeologic investigation complete with pumping test(s) and perhaps computer modeling. Future hydrogeologic investigations may identify areas in the WRIA where ASR programs should be explored in greater detail.

Smaller scale hydrogeologic characterization will be completed as part of the Supplemental Water Storage study for WRIA 20. The Planning Unit has identified several areas for focused study of groundwater resources and aquifer storage potential.

10.2 Water Allocation Summary

An annual average of 4.7 cfs of water is claimed or allocated in WRIA 20, representing about 0.05% of the total amount of water entering the WRIA as precipitation. Most of the claims and allocations occur in limited areas along rivers such as the Sol Duc River and major transportation corridors such as Highway 101.

Claims account for approximately 64% of the documents in the WOB database for WRIA 20. However, the volume of claimed water accounts for approximately 36% of the total claimed and allocated water in WRIA 20. Certificates and permits account for about 32% of the documents in the WOB database, but account for about 64% of the claimed and allocated water.

Municipal and domestic use accounts for about 48% of the claimed and allocated water in WRIA 20. All water allocated for municipal use is from groundwater. Water allocated for domestic use is from both groundwater and surface water.

There appears to be little crop irrigation in WRIA 20. However, this assessment of water allocation indicates that water rights and claims specified to have an “irrigation” purpose of use account for about 42% of the claimed and allocated water in WRIA 20. Certificates and permits account for about 25% of the water claimed and allocated for irrigation use. These allocations likely list “irrigation” as a purpose of use along with several other purposes such as domestic supply or stock watering.

Data Gaps/Recommendations

The Department of Fish and Wildlife has recommended denial of water rights, low flow provisions, or no diversion when streamflow rates drop below certain levels for water rights applications in WRIA 20. Minimum instream flows have not been set within WRIA 20. Instream flows and sub-basin water balances should be evaluated to guide future water rights decision making.

The actual uses associated with rights and claims that have a “irrigation” purpose of use and a “domestic” purpose of use associated with the right or claim should be evaluated to provide a clearer understanding of the uses being implemented under the claims and allocations that list irrigation purpose of use.

10.3 Water Use Summary

The generally low population density and lack of commercial and industrial facilities that characterize WRIA 20 result in relatively small quantities of out-of-stream beneficial water use in the watershed as compared to other WRIAs. The primary consumptive water use in the watershed is from individual households on public water supply systems or individual households on self-supplied systems. Many individual households are not serviced by public water supply systems and use exempt wells as a water source.

Table 10-1 presents a comparison of water rights to water use quantities. This table includes an estimate of exempt well water rights based on 5,000 gallons allocated for each exempt well assumed to exist within WRIA 20 (based on U.S. Census 2000 population estimates). A total of 9,211 AF/yr (12.7 cfs) of water is allocated within WRIA 20 (including exempt wells), which represents about six times the quantity of estimated actual water use in the watershed (1,594 AF/yr, or 2.2 cfs). These rights represent the volume of surface water and groundwater that may be withdrawn, but do not reflect the actual water use, as a significant portion of the allocated water may not be put to use.

Future household water use is not expected to increase significantly in WRIA 20 due to low projected population growth. However, water use demands outside of WRIA 20 are expected to increase, and may result in requests for WRIA 20 water for outside entities. These projected demands may outweigh the low population growth projections within WRIA 20 and result in net increase in water use.

Data Gaps/Recommendations

Further research into the amount of water allocated throughout the WRIA and the amount actually used may be conducted to provide a clearer understanding on the purposes of use employed in the watershed.

More robust estimates of actual irrigation and stock water use could be made using methods that involve on-the-ground truthing.

Estimates of water use for commercial and industrial purposes have not been made. These data could be collected to further the understanding of overall water use in WRIA 20.

Further research into the number of exempt wells used as water sources in the WRIA could be conducted to identify the number of exempt wells that exist, their spatial distribution, and potential withdrawal rates. This may be used to understand the effects of the exempt wells on groundwater resources, instream flows, and the actual amount of water used consumptively in the WRIA.

10.4 Water Balance Summary

The results of the annual water balance indicate that there is not a significant amount of water use in the basin. For the watershed as a whole (excluding Pacific basins and Ozette and Sooes) the majority of precipitation that falls in the basin (approximately 86%) leaves the basin as streamflow (Figure 5-9). Evapotranspiration accounts for the next largest component of the WRIA 20 water balance (approximately 13.9%). Total consumptive and non-consumptive water use for both irrigation and domestic purposes are less than 0.03% of total precipitation in WRIA 20. On a sub-basin basis, between 77% and 91% of water in each sub-basin runs off as streamflow, and between 9.3% and 23% of water leaves each sub-basin as evapotranspiration (Figure 5-8). The quantity of water for human use in WRIA 20 is estimated to be 1,594 AF/yr (2.2 cfs). The amount of water allocated through permits, certificates and claims in WRIA 20 is 9,211 AF/yr (12.7 cfs). Table 10-1 shows a comparison of water rights and water use quantities in WRIA 20.

Results of the monthly water balance show a pattern similar to that of the annual balance; the majority of precipitation runs off, with evapotranspiration from non-irrigated lands accounting for the next largest component (Tables 5-14 through 5-20). The relative proportion of water leaving the watershed as ET increases significantly during the summer months, while the percentage as streamflow decreases. Water use for human needs makes up a very small portion of the total monthly water balance. Additionally, snow accumulation and melt is estimated to be a minor factor in the seasonal availability of water for streamflow, only the Hoh and Sol Duc have any significant snow accumulation. The seasonal nature of streamflow in all sub-basins mimics that of precipitation because there is not significant inter-monthly storage, such as snow. The relative proportion of water as ET increases significantly during the summer months, while the percentage as streamflow decreases.

This water balance indicates that on both a watershed-wide and sub-basin scale, out-of-stream beneficial use of surface and groundwater and total allocated water are quite small relative to precipitation and streamflow, even during summer months.

The net residual calculated on a monthly time scale in this water balance indicates the relationship between surface water and groundwater recharge/discharge. When negative, the net residual indicates that, on average, surface water is recharging to groundwater in that sub-basin during that month; when positive it indicates that groundwater is discharging to streams. In general, recharge to groundwater occurs from fall to early spring, with groundwater discharging to streams in drier summer months.

The Hoh and Sol Duc both show brief periods in the late winter when groundwater discharge to streams is calculated to occur (net residual is positive). This is either due to variations in methods used by the BOR and Golder to estimate run-off, or it represents some temporary storage in the system that is not captured explicitly in the water balance.

In areas where heavy fog is common, large trees can capture the moisture in the fog. This moisture is reported to be both evapotranspirated by trees and condensed and dripped off the trees. Fog-drip may be an important contributor to total effective precipitation in this watershed, but has not been considered in this water balance.

Data Gaps/Recommendations

The water balance brings together all the water related processes in WRIA 20 that have been addressed and/or quantified in the Technical Assessment Report or in studies conducted by the Bureau of Reclamation. Therefore there are no specific data gaps identified as part of the water balance. However, the results of the water balance have significant implications for the Phase III Watershed Management Plan. Some of these considerations are listed below:

- Given the size of the watershed, the generally low volume of water use and high proportion of forest evapotranspiration, a water balance approach was selected that assumes no net change in annual groundwater storage. Groundwater resources were addressed separately in this watershed assessment. As is often the case, the actual quantity of groundwater available in the WRIA is not known. Site or area specific studies addressing groundwater availability and potential for storage should be conducted in areas where future additional water supply availability is anticipated, rather than conducting additional watershed-wide or sub-basin wide studies to quantify groundwater or instream flows.
- This water balance indicates that the total water use and allocated paper rights in WRIA 20 are quite small in comparison to total water in the system. As such, data gaps such as identifying commercial and industrial use, and also refining estimates of water use for irrigation and stock may not be a high priority given the small portion of total water this use represents.
- Although there is a small out-of-stream beneficial use component in this water balance (both now and in the future), water quantity studies that include consideration of instream flow needs and instream flow setting may be warranted if requests for WRIA 20 water are made from outside the watershed.

10.5 Land Use Summary

Land use in WRIA 20 is comprised of heavily forested areas with small residential, agricultural, and commercial areas. Forest land in WRIA 20 has been used for conservation, recreation, timber harvest, and other land uses. Generally, historic (prior to 1994) timber harvest and road building practices were conducted in a manner that was likely to increase the frequency of mass wasting events, increase in-stream sedimentation, and generally decrease water quality in the watershed. However, since that time, timber harvest has been reduced significantly on federal lands in the watershed and on all lands in Clallam County.

Most timber harvest in the watershed is currently occurring on State and private lands and is subject to the 2001 Forest Practice Rules as mandated by the Forest Practices Act. Harvest conducted on State lands is also subject to the WDNR Habitat Conservation Plan (1997). Timber harvest conducted under these practices is anticipated to improve water quality and have less overall impact on watershed hydrologic processes than harvest conducted under previous rules. However, it is too soon realize the full outcome of these new practices. Intensive land use in specific areas (such as agriculture or residential) and point source water quality threats from industrial and other discharges were not assessed in this technical assessment of land use impacts in WRIA 20, and effects on local water quality and quantity are unknown at this time.

10.6 Fish Distribution and Habitat Summary

Although run sizes are lower than historical numbers, the current health of salmonids within WRIA 20 in generally good compared to the rest of the Northwest. However, bull trout and Lake Ozette sockeye are listed as threatened under the Endangered Species Act.

Run and spawn times for each salmonid species are listed by sub-basin in this report. This information is intended to alert managers as to when flows are particularly critical for fish. The rearing times are not listed as multiple species rear for over one year in freshwater.

In the upper elevation watersheds within the boundaries of Olympic National Park, riparian habitat is excellent. The area has been undisturbed with the exception of natural events such as fire or wind, and development of visitor access and facilities. Natural riparian conditions provide shade and potential recruitment for LWD. Sedimentation levels are generally low as there is a low road density and little timber production. This generalization does not hold true for the portion of the Olympic National Park surrounding Lake Ozette as there has been a greater history of anthropogenic disturbance.

In the mid and lower elevations of WRIA 20, the land has been more intensively managed for timber production and riparian stands are often hydrologically immature (i.e., forested stands in which root structure and canopy density have not reached the level of water use and influence created by mature stands, usually less than 30 years old). Though the maturation of the impacted stands will likely eventually lead to recovery, the areas currently have a lack of instream LWD as a result of riparian logging, decreased recruitment and historical stream clearing efforts. The immature stands have also led to a lack of riparian shade in WRIA 20 which in turn has affected stream temperatures. However, newer regulations that require modest buffer sizes will help slowly mitigate past disturbance.

Fish passage is a major concern in most of the sub-basins, particularly in the Dickey, Bogachiel, and Hoh. Most of the blockages are a result of collapsed, perched or undersized culverts. In the Hoh sub-basin and several other streams, cedar spalts are common blockages and lead to decreased water quality and habitat.

Invasive species are becoming an alarming problem in WRIA 20. In the Quillayute sub-basin in particular, but also in the Ozette and Hoh basins, Japanese knotweed has spread on mainstems and tributaries. The 10 feet or higher plant grows on river banks and out-competes native plants, leaving unshaded river edges and choked channels. Cutting the plant helps to spread the species; efforts are underway by counties and tribes to control the spread through the direct application of herbicides. Reed canary grass is also a widespread problem, particularly in Lake Ozette where the weed has overtaken the lake’s edge and encouraged sedimentation in spawning gravels.

10.7 Fish Habitat-Related Plans and Policies Summary

The Endangered Species Act (ESA) provides protection for species that are listed as threatened or endangered. Within WRIA 20 Lake Ozette sockeye and bull trout have been identified as threatened pursuant to ESA, which initiated a recovery process for these species.

The Clean Water Act directs that clean up plans be written for waters that do not meet water quality standards and are therefore included on the Federal 303(d) list. Several water bodies in WRIA 20 have been listed on the 303(d) list for a variety of pollutants, primarily temperature, however no cleanup plans have been developed to date.

10.7.1 Federal Plans and Programs Summary

The Bull Trout Recovery Plan discusses recovery activities for bull trout on the Olympic Peninsula. Two populations of bull trout have been identified in WRIA 20, both occurring in the Hoh sub-basin. These two populations are targeted as core populations for restoration. The goal of the restoration is to increase the abundance of bull trout to 1000 spawning adults over the next two to 25 years.

The Lake Ozette sockeye was listed as Threatened under the ESA in 1999. The Lake Ozette Sockeye Recovery Working Group, chaired by the Olympic National Park and the Makah Tribe, is developing a strategy for restoring the Lake Ozette sockeye. The group is currently in the process of completing a limiting factors analysis for the sockeye.

Federal forest lands in WRIA 20 (the Olympic National Forest) are managed according to the Northwest Forest Plan. This plan contains management strategies and goals, including the protection of fish habitat. This plan provides guidance for management of riparian and aquatic habitat and maintenance and creation of ecosystem traits relevant to the control of sedimentation problems associated with timber harvest and road building.

The Olympic Coast National Marine Sanctuary is managed by the NOAA. The current 1994 management plan protects the sanctuary through preventing activities which may threaten any part of the sanctuary, and acknowledges that activities outside the sanctuary boundaries may affect the sanctuary.

The Olympic National Park comprises about 35% of WRIA 20. This land is managed for conservation with a goal of maintaining habitat conditions similar to a pristine environment.

10.7.2 State Policies and Programs Summary

The co-managers (Treaty Tribes and WDFW) work to protect, restore, and enhance fish and wildlife and their habitats in Washington State and provide for sustainable fish and wildlife related recreational and commercial opportunities.

Washington State's Growth Management Act (GMA) (RCW 36.70A) requires local governments to balance competing societal goals with the intent of encouraging conservation, responsible use of lands and resources, and sustainable economic development. This plan includes provisions to protect fish habitat. Clallam and Jefferson counties and the City of Forks have Comprehensive Plans as well as provisions for Critical Areas.

State Forest Practice Rules direct the management of commercial forest lands, including many State and private forest lands in WRIA 20. These rules provide protection, but not restoration of fisheries habitat. A Habitat Conservation Plan is implemented on State lands to fulfill ESA requirements.

The Salmon Recovery Act was passed in order to address the decline of salmon statewide. In WRIA 20, the lead entity for the Salmon Recovery Act is the North Olympic Peninsula Lead Entity (NOPLE). NOPLE's mission is to "develop a regional project strategy that when implemented will help to achieve genetically diverse, self-sustaining, salmon populations that will support healthy ecosystems and ceremonial, subsistence, recreational, and commercial fisheries."

A 2001 Memorandum of Agreement (MOA) between the U.S. Forest Service (USFS), Region 6 and the Department of Ecology establishes responsibilities of these agencies under federal and state water quality laws and establishes the USFS and Ecology responsibility for implementation of the policies necessary for compliance with the Clean Water Act.

The Washington State Department of Transportation maintains a plan that guides development and maintenance of some highways in WRIA 20, including Highway 101. A current restoration project along Highway 101 on the Hoh River will install engineered log jams in an effort to prevent the River from washing out the road in a flood.

10.8 Water Quality Summary

Water quality information is limited in many areas of WRIA 20. There are 63 sites listed on the 1998 Department of Ecology's 303(d) list for temperature, dissolved oxygen and pH infractions. The majority of the sites are located within the Dickey, Sol Duc, Bogachiel and Hoh watersheds. Many of the temperature issues are related to barriers; low dissolved oxygen is often associated with excessive sedimentation. There are few reaches that are naturally dewatered in summer months due to underlying geology. Other reaches have naturally open canopies which contribute to poor water quality ratings.

The 2002/2004 303(d) and Water Quality Assessment List is currently undergoing a final comment period, to be completed December 4, 2004. This 303(d) list contains 41 stream segments listed for elevated temperature in WRIA 20, as well as 5 for low dissolved oxygen, 4 for pH, and one for fecal coliform.

<u>Data Gaps and Recommendations</u>

There are very few stations within WRIA 20 that have had long term continuous sampling. Though the Department of Ecology is in the process of updating the 303(d) list, most of their ratings are from data collected before 1998. There is a need for continuous and updated water quality sampling in streams of concern, especially for temperature.

11.0 REFERENCES

10,000 Years Institute, 2003. Hoh River Watershed Monitoring First Interim Project Report. Prepared for the Hoh Indian Tribe and the Northwest Indian Fisheries Commission.

Abbe, T, S. Fisher, M. McBride and A. Ritchie, 2002. The effects of Ozette River logjams on Lake Ozette: Assessing historic conditions and the potential for restoring logjams. Prepared by Philip Williams & Associates for the Makah Tribe.

ASCE, 2001. Standard Guidelines for Artificial Recharge of Ground Water. American Society of Civil Engineers and Environmental and Water Resources Institute, 106pp.

Benda, L., 1996. Stream Channel Assessment. In North Fork Calawah Watershed Analysis. Olympic National Forest, Olympia, WA.

Berris, S.N. and H.D. Harr. 1987. Comparative Snow Accumulation and Melt during Rainfall in Forested and Clear-cut Plots in the Western Cascades of Oregon. Water Resources Research 23: 135-142.

Beschta, R.L., R.E. Bilby, G.W. Brown, L.B. Holtby, and T.D. Hofstra, 1987. Stream temperatures and aquatic habitat: fisheries and forestry interactions. In E.O. Salo and T.W. Cundy (eds). Streamside management: forestry and fisheries interactions, p. 191-232. University of Washington. Contribution No. 57, Seattle.

Bidlake, William R., 2003. Watershed Analysis of the Salmon River Watershed, Washington: Hydrology. U.S. Geological Survey. Water Resource Investigations Report 03-4204 prepared in cooperation with the Quinault Indian Nation. Available online at: http://water.usgs.gov/pubs/wri/wri034204/pdf/wrir034204.pdf (Accessed 08/04).

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 the Pacific Northwest: past, present and future. In E.O. Salo and T.W. Cundy (eds). Streamside management: forestry and fisheries interactions, p. 143-190. University of Washington. Contribution No. 57, Seattle.

Blum, J.P., 1988. Assessment of factors affecting sockeye salmon (Oncorhynchus nerka) production in Lake Ozette, WA. MS Thesis, University of Washington.

Bortleson, G.C. and N.P. Dion, 1979. Preferred and observed conditions for sockeye salmon in Ozette Lake and its tributaries, Clallam County, Washington. United States Department of the Interior, U.S. Geological Survey. Water-Resources Investigations 78-64. Tacoma, WA.

Bretherton, K., D. Christensen, and T. Taylor, 1998. Riparian Function Assessment. In East/West Dickey Watershed Analysis Draft Report. Pentec Environmental, Inc. Edmonds, WA.

Chesney, C., 1996. Channel Morphology. In Sol Duc Pilot Watershed Analysis. Washington State Department of Natural Resources, Olympia, WA.

Christensen, D., 1996. Riparian. In Sol Duc Pilot Watershed Analysis. Washington State Department of Natural Resources, Olympia, WA.

City of Forks, 2004. Monthly Pumping Data 2002-2004.

Clallam County, 2002. Western Regional Comprehensive Plan.

Crewson, M., J. Freudenthal, P. Gearin, M. Haggerty, J. Haymes, J. Meyer, A. Ritchie, and W. Sammarco, 2002. Lake Ozette sockeye Limiting Factors Analysis. DRAFT. Prepared as part of the Lake Ozette Steering Committee.

Daly, Chris and G. Taylor. 1994. Washington Average Monthly or Annual Precipitation, 1961-1990. Oregon Climate Service at Oregon State University, Portland, OR.

Dawson, Todd E., unpublished, The Use Of Fog Precipitation By Plants In Coastal Redwood Forest. http://www.cnr.berkeley.edu/~jleblanc/WWW/Redwood/rdwd-The-4.html.

De Cillis, P., 1998. Fish Habitat. In Stikum and South Fork Calawah Watershed Analysis. Olympic National Forest, Olympia, WA.

Dieu, J. and B. Shelmerdine., 1996. Sedimentation Assessment. In North Fork Calawah Watershed Analysis. Olympic National Forest, Olympia, WA.

Dieu, J., K. Kreuger and P. Vanderhoof, 1998. Unpublished Water Quality Module. In East/West Dickey Watershed Analysis.

Dieu, J., (Rayonier Inc., Geomporphologist). Personal Communication. May 2004.

Dion, N.P., Walters, K.L., and Nelson, L.M., 1980. Water Resources of the Makah Indian Reservation, Washington. U.S. Geological Survey Water Resources Investigations 80-15; 54pp.

Dlugokenski, C., W. Bradshaw, and S. Hager, 1981. An investigation of the limiting factors to Lake Ozette sockeye salmon production and a plan for their restoration. U. S. Fish and Wildlife Service, Fisheries Assistance Office, p.52.

Driscoll, F.G., 1986. Groundwater and Wells. Johnson Screens; 1089pp.

Drost, B.W., 1986. Water Resources of Clallam County, Washington: Phase 1 Report. U.S.G.S. Water-Resources Investigations Report 83-4227. 263pp, 5 plates.

Dunne, T. and L.B. Leopold, 1978. Water in Environmental Planning. W.H Freeman, New York.

Erickson, A. 2001. Middle Hoh River Watershed Baseline Environmental Assessment. Prepared for U.S. Forest Service Olympic National Forest Pacific Ranger District. Forks, WA. March 28, 2001

Everest, F.H., R.L. Beschta, J.C. Scrivener, K.V. Koski, J.R. Sedell, C.J. Cedarholm. 1987. Fine sediment and salmonid production: a paradox. In E.O. Salo and T.W. Cundy (eds). Streamside management: forestry and fisheries interactions, p. 143-190. University of Washington. Contribution No. 57, Seattle.

Ferrell, Vern (USFS). Personal Communication. June 18, 2004.

Fretwell, M.O. 1984. Quality of Water, Quillayute River Basin, Washington. US Geological Survey. Water Resources Investigations. Report 83-4162.

Gerstel, W.J., 1999. Deep-Seated Landslide Inventory of the West-Central Olympic Peninsula. Washington State Department of Natural Resources; 36pp, 2 plates.

Haggerty, M., 2004. Data summary of Lake Ozette tributary habitat conditions. DRAFT. Prepared for the Makah Indian Tribe, Neah Bay, WA.

Harr, R.D., 1982, Fog drip in the Bull Run Municipal Watershed, Oregon: American Water Resources Association, Water Resources Bulletin, v. 18, p. 785-789.

Harr, R.D., 1983, Potential for augmenting water yield through forest practices in western Washington and western Oregon: American Water Resources Association, Water Resources Bulletin, v. 19, p. 383-393.

Hatten, J. 1991. The effects of debris torrents on spawning gravel quality in tributary basins and side channels of the Hoh River, Washington. Prepared for the Hoh Indian Tribe, Washington.

Hatten, J. 1992. The effects of logging activities on stream temperatures in tributaries of the Hoh River basin, Washington. Prepared for the Hoh Indian Tribe, Washington.

Hatten J. and R. Conrad. 1991. A comparison of summer stream temperatures in unmanaged and managed sub-basins of Washington's western Olympic Peninsula. Prepared for the Northwest Indian Fisheries Commission, Olympia, WA.

Heckman, J.L. 1964. Reconnaissance Report: Fisheries Management Program, Makah Indian Reservation. Prepared by the United States Department of the Interior Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife, Branch of Fishery Management Services, Olympia, WA.

Holtrop, Joe (Clallam County Conservation District). Personal Communication. June 1, 2004.

Hook, A. 2004. WRIA 20 Technical Assessment Level I Water Quality and Habitat, Presented to the WRIA 20 Planning Unit. 71pp, June 10, 2004.

Huntington, C.W., W. Nehlsen and J. Bowers., 1996. Healthy native stocks of anadromous salmonids in the Pacific Northwest and California. Fisheries (21)3: 6-13.

Ingwersen, J.B., 1985, Fog drip, water yield, and timber harvesting in the Bull Run municipal watershed, Oregon. Water Resources Bulletin 21:469-473.

Jackson, R., 1996a. Hydrologic Change Assessment. In North Fork Calawah Watershed Analysis. Olympic National Forest, Olympia, WA.

Jackson, R., 1996b. Hydrology. In Sol Duc Pilot Watershed Analysis. Washington State Department of Natural Resources, Olympia, WA.

Jackson, R., 1997. North Fork Calawah Watershed Assessment Module C Hydrologic Change Assessment; 34pp and forms.

Jackson, R., 1998. Hydrology. In East/West Dickey Watershed Analysis Draft Report. Prepared for the Washington Department of Natural Resources.

Jacobs, R., G. Larson, J. Meyer, N. Currence, J. Hinton, M. Adkison, R. Burgner, 1996. The sockeye salmon populations in Lake Ozette, Washington, USA. US Dept. of the Interior, National Park Service, p. 140.

Jensen, A. (US Fish and Wildlife Service, Fisheries Biologist). Personal Communication. May 2004.

Jorgenson, J. (Hoh Tribe, Fisheries Biologist). Personal Communication. July 12, 2004.

Kennard, P., 2001. Channel Module. In Middle Hoh Watershed Analysis. Draft Report to the Hoh Tribe.

Kidder, J.S., and M.G. LaRiviere, 1991. Lake Ozette Sockeye Salmon Enhancement Facility Feasibility Report. Prepared for the Makah Tribe by Chinook Engineering, Mukilteo, WA.

Kramer, R., 1953. Completion report by stream clearance unit on Ozette and Big Rivers April, 1953. Prepared for the Department of Fisheries, Olympia, WA.

LaManna, J., J. Dieu, and C. Cahill, 1998. Sedimentation Assessment. In East/West Dickey Watershed Analysis Draft Report. Prepared for the Washington Department of Natural Resources.

Lane, R.C., 2004. Estimated Domestic, Irrigation, and Industrial Water Use in Washington, 2000. USGS Scientific Investigations Report 2004-5015.

Lasorsa, D., 1998. Riparian. In Stikum and South Fork Calawah Watershed Analysis. Olympic National Forest, Olympia, WA.

Latham, Al (Jefferson County Conservation District). Personal Communication. June 1, 2004.

Lien, R., (Quileute Tribe, Fisheries Biologist). Personal Communication. May, 2004.

Lingley, L., 1998. Mass Wasting. In Stikum and South Fork Calawah Watershed Analysis. Olympic National Forest, Olympia, WA.

Logan, R.L., L. Kaler and P.K. Bigelow., 1991. Prediction of sediment yield from tributary basins along Huelsdonk Ridge, Hoh River, Washington. Open File Report 91-7. Washington Division of Geology and Earth Resources, Olympia, WA.

Long, W.A., 1975. Glacial studies on the Olympic Peninsula. U.S. Forest Service, 1 vol. 9 plates.

Long, W.A., 1976. Glacial geology of the Olympic Peninsula, Washington. U.S. Forest Service, 135pp.

Lum, W.E. and L.M. Nelson. 1986. Reconnaissance of the water resources of the Hoh Indian Reservation and the Hoh River Basin, Washington. US Geological Survey, Water Resources Investigations Report 85-4018.

Luxton, S.S., Bliemeister, L.P. and NTI (Northwest Territories, Inc.). 1989. Quileute Water Facilities Water Development Analysis. Prepared for United States Public Health Service Indian Health Science Division.

Luxton, S.S. and NTI (Northwest Territories, Inc.). 1995. Hydrogeologic Reconnaissance and Test Well Drilling of the Lower Hoh River Region, Report of Findings. Prepared for the Hoh Indian Tribe.

Maidment, David, 1993. Handbook of Hydrology, USDA Forest Service Rocky Mountain Forest and Experiment Range Station, GTR RM-118, 1985.

Manci, Karen M., 1989. Riparian Ecosystem Creation and Restoration: A Literature Summary. Biol. Rep. 89(20) Fish and Wildlife Serv., U.S. Dep. of the Interior. Washington D.C. Calawah Sitkum Watershed Assessment

Martin, D., T. Powell, D. Netnon, E. Tierney and E. Patino, 1998. Fish Habitat Assessment. In East/West Dickey Watershed Analysis Draft Report. Pentec Environmental, Inc. Edmonds, WA.

Martin, D., P. De Cillis, and J. Haymes, 1996. Fish Habitat Assessment. In North Fork Calawah Watershed Analysis. Olympic National Forest, Olympia, WA.

McHenry, M., D. Morrill, and E. Currence, 1994. Spawning gravel quality, watershed characteristics and early life history survival of coho salmon and steelhead in five north Olympic Peninsula watersheds. Wash. Dept. of Ecology, p. 60.

McHenry, M., J. Lichatowich, R. Kowalski-Hagaman, 1996. Status of pacific salmon and their habitats on the Olympic Peninsula, Washington. Report to the Lower Elwa S'Kallam Tribe, Port Angeles, Washington.

McHenry, M., 2000. Fisheries Habitat Module. In Middle Hoh Watershed Analysis. Draft Report to the Hoh Tribe.

Meyer, J. and S. Brenkman, 2001. Status report on the Water quality of Lake Ozette and Potential Human-related impacts to salmonids. Olympic National Park, Port Angeles, WA.

Murray, G.L., R.L. Edmonds, and J.L. Marra, 2000. Influence of partial harvesting on stream temperatures, chemistry and turbidity in forests on the western Olympic Peninsula, Washington. Northwest Science, Vol. 74, No. 2.

Naughton, B. and M. Parton, 1996. Fish Habitat. In Sol Duc Pilot Watershed Analysis. Washington State Department of Natural Resources, Olympia, WA.

Nehlsen W., J.E. Williams and J.A. Lichatowich, 1991. Pacific salmon at the crossroads: stocks at risk from California, Oregon, Idaho, and Washington. Fisheries 16:2.

NOAA, 1994. Olympic Coast National Marine Sanctuary Final Environmental Impact Statement and Management Plan. Available online at: http://olympiccoast.noaa.gov/protection/pubdocs/mgmtplan.pdf. (Accessed 10/04).

Olympic National Forest, 1992 USFS Region 6 Channel Surveys, Sol Duc Ranger District. Olympia, WA.

Olympic National Forest, 1994 USFS Region 6 Channel Surveys, Sol Duc Ranger District. Olympia, WA.

Olympic National Forest, 1994 USFS Region 6 Channel Surveys, Soleduck Ranger District. Olympia, WA.

Parks, D., 1999. Mass Wasting Module. In Middle Hoh Watershed Analysis. Draft Report to the Hoh Tribe.

Parks, D. and R. Figlar-Barnes, 1996. Water Quality. In Sol Duc Pilot Watershed Analysis. Washington State Department of Natural Resources, Olympia, WA.

Peach, Bill, Rayonier Timber Company. Personal Communication. July 8, 2004.

Phinney, L.A. and P. Bucknell, 1975. A catalog of Washington streams and salmon utilization, Volume 2 - Coastal Region. Washington Department of Fisheries.

Plotnikoff, R.W., 1998. Stream Biological Assessments (Benthic Macroinvertebrates) for Watershed Analysis: Mid-Sol Duc Watershed Case Study. Prepared for the Department of Ecology Publication No. 98-334. Olympia, WA.

Powell, J., 2000. Surface Erosion Module. In Middle Hoh Watershed Analysis. Draft Report to the Hoh Tribe.

QNR, 2000-2003. Quileute Natural Resources. Bogachiel stream surveys. Unpublished data.

QNR. 1992. Quileute Natural Resources, Water Quality Monitoring Program. Unpublished data.

QNR. 1992. Summary of habitat conditions in the Quillayute River system, 1990-91. Unpublished data.

QNR. 1993. Quileute Natural Resources, Water Quality Monitoring Program. Unpublished data.

QNR. 1994. Quileute Natural Resources, Water Quality Monitoring Program. Unpublished data.

QNR. 1995. Quileute Natural Resources, Water Quality Monitoring Program. Unpublished data.

Quileute Public Works, 2004. Three Rivers Water Plant Monthly Production Data (1995, 1997, 2000 & 2002).

Rashin, Ed, Clishe, Casey, Loch, Andy, and Bell, Johanna, 1999. Effectiveness of Forest Road and Timber Harvest Best Management Practices with Respect to Sediment-Related Water Quality Impacts. Washington Department of Ecology Publication Number 99-317. May 1999. Submitted to Timber/Fish/Wildlife Cooperative Management, Evaluation, and Research Committee.

Rau, W., 1973. Geology of the Washington coast between Point Grenville and the Hoh River. Washington Division of Geology and Earth Resources Bulletin 66, 58 p.

Rau, W., 1979. Geologic Map in the Vicinity of the Lower Bogachiel and Hoh River Valleys, and Washington Coast. Geologic Map GM 24. State of Washington Department of Natural Resources, Olympia, WA.

Ritchie, A., Biologist, Makah Tribe. Personal Communication. May 2004.

Rot, B., 1996. The importance of floodplain backchannels to overwintering salmonids: a literature review with specific references to the floodplain at RM 19 on the Hoh River, Washington. Report commissioned by the Hoh Tribe.

Rayonier, 1998. East/West Dickey Watershed Analysis: Resource Assessment Report and Prescriptions. Project initiated by Rayonier Timberlands Operating Company, in cooperation with the Quileute Tribe, Washington Department of Natural Resources, Washington Department of Fish and Wildlife, and Washington Environmental Council; Produced by Pentec Environmental Inc.

Sasich, J and J. Dieu, 1996. Mass Wasting. In Sol Duc Pilot Watershed Analysis. Washington State Department of Natural Resources, Olympia, WA.

Schuch, Harvey (Quileute Public Works Director), 2003. Memo to Katie Krueger summarizing Quileute Well Information.

Shellberg, J. Hydrologist, Makah Tribe. Personal Communication. Jan – June, 2004.

Simonds, F.W. and Sinclair, K.A., 2002. Surface Water-Ground Water Interactions Along the Lower Dungeness River and Vertical Hydraulic Conductivity of Streambed Sediments, Clallam County, Washington, September 1999-July 2001. U.S. Geological Survey Water-Resources Investigations Report 02-4161 and Washington State Department of Ecology Report 02-03-027.

Smith, C., 2000. Salmon and Steelhead Habitat Limiting Factors in the North Washington Coastal Streams of WRIA 20. Prepared for the Washington Conservation Commission, Olympia, WA.

Springer, J., 1996. Riparian Function Assessment. In North Fork Calawah Watershed Analysis. Olympic National Forest, Olympia, WA.

Stoddard, R., 1998. Hydrology. In Stikum and South Fork Calawah Watershed Analysis. Olympic National Forest, Olympia, WA.

Storck, Pascal, Lettenmaier, Dennis P., Connelley, Brian A., and Cundy, Terrance W., 1995. Implications of Forest Practices on Downstream Flooding, Phase II, Final Report. Report to: Washington Forest Protection Association, King County Surface Water Management Division, Weyerhauser Co., U.S. Forest Service, National Council of the Paper Industry for Air and Stream Improvement, University of Washington. July 1, 1995.

Tabacci, E., Lambs, L., Guilloy, H., Planty-Tabacci, A., Muller, E., and Decamps, H., 2000. Impacts of Riparian Vegetation on Hydrological Processes. Hydrological Processes vol. 14.

Tabor, R.W. and Cady, W.M., 1978. The Structure of the Olympic Mountains, Washington – Analysis of a Subduction Zone, USGS Professional Paper 1033.

Tabor, R.W. and Cady, W.M., 1978a. Geologic Map of the Olympic Peninsula, Washington: U.S. Geological Survey Miscellaneous Investigations Series Map I-994, 2 sheets, scale 1:125:000.

Tabor, R.W. and Cady, W.M., 1978b. The Structure of the Olympic Mountains, Washington – Analysis of a Subduction Zone. U.S. Geological Survey Professional Paper 1033; 25pp.

Thackray, G.D., 1997. Glaciation and neotectonic deformation on the western Olympic Peninsula, Washington: University of Washington Doctor of Philosophy thesis, 139pp, 2 plates.

Trettevik, Sue (WDNR). Personal Communication. June 18, 2004.

U.S. Bureau of Reclamation, 2004. Overview of Watershed Conditions and Seasonal Variability in Streamflow for Select Streams within WRIA 20, Olympic Peninsula, Washington, U.S. Bureau of Reclamation, Water Supply, Use and Conservation Technical Service Center, Denver, CO, April 23, 2004.

U.S. Census Bureau, 2000. Gateway to Census 2000 web page: http://www.census.gov/main/www/cen2000.html), U.S. Census Bureau, Public Information Office, created January 23, 2002.

U.S. Census Bureau, 1990. Census '90 web page: http://www.census.gov/main/www/cen1990.html , Information & Research Services, Internet Staff (Population Division), Created: March 2002.

U.S. Department of Agriculture (USDA) National Agricultural Statistics Services, 2002. 2002 Census of Agriculture, Volume 1, Chapter 2, Washington County Level Data. Available online at: http://www.nass.usda.gov/census/census02/volume1/wa/index2.htm. (Accessed 8/04).

USDA Forest Service (USFS), 1985. Rocky Mountain Forest and Experimental Range Station, GTR RM-118.

USDA Forest Service (USFS), 1994. Olympic National Forest Watershed Improvement Needs Inventory.

USDA Forest Service (USFS) and US Department of the Interior Bureau of Land Management (BLM), 1994. Final supplement environmental impact statement on management of habitat for late-successional old-growth forest related species within the range of the northern spotted owl. USFS, BLM, US Fish and Wildlife Service, National Park Service, US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, US Environmental Protection Agency. Portland, OR.

USDA Forest Service (USFS), 1996. North Fork Calawah Watershed Analysis: Resource Assessment Report and Prescriptions. Prepared as an interagency effort between U.S. Department of Agriculture Forest Service, Olympic National Forest, Rayonier Timberlands Operating Company; and the Quileute Tribe.

USDA Forest Service (USFS), 1998. Sitkum and South Fork Calawah Watershed Analysis. Prepared by U.S. Department of Agriculture Forest Service, Olympic National Forest; with collaboration from Olympic National Park, and the Quileute Tribe.

USDA Forest Service (USFS), 1995. Sol Duc Pilot Watershed Analysis. Prepared in association with U.S. Department of Agriculture Forest Service, Olympic National Forest; Washington Department of Natural Resources; and the Quileute Tribe as Team Leaders.

USGS, 1978. Low-Flow Characteristics of Streams on the Olympic Peninsula, Washington. U.S. Geological Survey Open-File Report 77-812. U.S. Geological Survey, Tacoma, Washington.

USFWS, 2004. Draft Olympic Peninsula Management Unit Bull Trout Recovery Plan. U.S. Fish and Wildlife Service. Available online at: http://ecos.fws.gov/docs/recovery_plans/2004/040701.pdf. (Accessed 10/04).

University of Washington Climate Impacts Group (UW CIG), 2004. Memo Regarding Climate Impacts Language for Watershed Planning Program Activities, to: Watershed Planning Units, from: Laura Whitely Binder. University of Washington Joint Institute for the Study of the Atmosphere and Ocean, Center for Science in the Earth System Climate Impacts Group, April 15, 2004,

Van Heeswijk, Marijke, Kimball, John S., and Marks, Danny, 1996. TFW Effectiveness Monitoring Report: Simulation of Water Available for Runoff in Clearcut Forest Openings During Rain-On-Snow Events in the Western Cascade Region of Oregon and Washington. 12/1/1996. Water-Resources Investigations Report 95-4219. U.S. Geological Survey.

Veldhuisen, Curt and Russell, Periann, 1999. TFW Effectiveness Monitoring Report. Forest Road Drainage and Erosion Initiation in Four West-Cascade Watersheds. Washington Department of Ecology. June 1999. Prepared for: Timber/Fish/Wildlife Monitoring Advisory Group and the Northwest Indian Fisheries Commission.

Waring, R.H. and W.H. Schlesinger, 1985. Forest Ecosystems Concepts and Management. 340 pp.

Washington Conservation Commission, 2000. Water Resource Inventory Area 20 Soleduck-Hoh Watersheds Salmon Habitat Limiting Factors.

Washington Department of Ecology, 1998. Water Quality in Washington State (Section 303(d) of the Federal Clean Water Act). Washington Department of Ecology, Olympia, WA.

Washington Department of Ecology, 2004. Draft Washington State Water Quality Assessment List [pursuant to Sections 303(d) and 305(b) of the Federal Clean Water Act as of November 16, 2004]. Washington Department of Ecology, Olympia, WA.

Washington Department of Ecology, 2003a. Water Rights Application Tracking System (WRATS) database, abbreviated version "**WRATS**-**O**n-a-**B**un,", web page: http://www.ecy.wa.gov /programs/wr/rights/tracking-apps.html. Washington Department of Ecology, Olympia, WA.

Washington Department of Ecology, 2003b. Investigation of Backgroud Inorganic and Organic Arsenic in Four Washington Lakes. Publication No. 03-03-024. Washington Department of Ecology, Olympia, WA.

Washington Department of Ecology, 2004. Water Quality in Washington State (Section 303(d) of the Federal Clean Water Act). Washington Department of Ecology, Olympia, WA. Accessed November 16, 2004.

Washington Department of Fisheries and Western Washington Treaty Indian Tribes, 1992. Washington State salmon and steelhead stock inventory (SASSI). Washington Department of Fisheries, Olympia, WA.

Washington Department of Health (WDOH), 2002. Washington Department of Health Compliance Monitoring Database.

Washington Department of Natural Resources (WDNR), 1997. Habitat Conservation Plan.

Washington Department of Natural Resources (WDNR). 2001. Digital geologic maps of the 1:100,000 quadrangles of Washington: Division of Geology and Earth Resources Digital Report 2, version 1, 1 CD-ROM disk.

Washington Department of Natural Resources (WDNR), 2002. Washington Timber Harvest summarized data, 1065-2002. Available online at: http://www.dnr.wa.gov/htdocs/obe/timhar6501.xls. (Accessed 8/04).

Washington Division of Geology and Earth Resources Staff, 2001. Digital geologic maps of the 1:100,000 quadrangles of Washington: Washington Division of Geology and Earth Resources Digital Report 2, version 1, 1 CD-ROM disk.

Washington Forest Practices Board (WFPB), 1997. Standard Methodology for Conducting Watershed Analysis Manual, Version 4.0, November 1997.

Washington Forest Protection Association (WFPA), 2003. Forest Management, Salmon Recovery, and Watershed Planning. Washington Forest Protection Association, 724 Columbia Street NW, Suite 250, Olympia, WA 98501.

Washington Office of Financial Management (OFM), 2002. Washington State County Growth Management Population Projections: 2000 to 2025. Available at: http://www.ofm.wa.gov/pop/gma/index.htm (Accessed 10/04).

Watershed Sciences, 2001. Aerial surveys in the Hoh River basin using thermal infrared and color videography. Report conducted for the Hoh Tribe by Watershed Sciences.

Washington Forest Practice Board (WFPB), 1994. Standard Methodology for Conducting Watershed Analysis, Version 2.1 under Chapter 222-22 WAC. Timber/Fish/Wildlife Group and Washington Forest Practices Board, Olympia, Washington.

Wilson, S, 1998. Channel. In Sitkum and South Fork Calawah Watershed Analysis. Olympic National Forest, Olympia, WA.

Zajac, D., 2002. An assessment of anadromous fish habitat use and fish passage above Makah National Fish Hatchery in the Sooes River. U.S. Fish and Wildlife Division of Fisheries and Watershed Assessment, Lacey, WA.

12.0 ADDITIONAL REFERENCES

(These are references that were summarized in the primary documents used for this report – watershed analyses etc.)

Abbe, T., 1996. Geomorphological Survey of Hoh River Floodplain, RM 19, at the confluence with Elk Creek. Consultants report to the Hoh Tribe.

Agee, J.K., 1994. Catastrophic forest disturbance on the Olympic Peninsula. Research paper prepared for Rayionier Inc. P.O. Box 200 Hoquiam, WA.

Beauchamp, D., M. LaRiviere, and G. Thomas, 1995. Evaluation of competition and predation as limits to juvenile kokanee and sockeye salmon production in Lake Ozette, Washington. N. Am. J. of Fish Mgt. 15:193-207.

Benda, L. C. Veldhuisen and J. Black, 2003. Debris flows as agents of morphological heterogeneity at low-order confluences, Olympic Mountains, Washington. Geological Society of America Bulletin: Vol. 115, No. 9, pp. 1110-1121.

Bjornn, T.C. and D.W. Reiser, 1991. Habitat requirements of salmonids in streams. American Fisheries Soceity Special Publication 19:83-138.

Blew, R.D., and R.L. Edmonds, 1995. Precipitation along an inland transect on the Olympic Peninsula, Washington. Journal of Environmental Quality, 24:239-245.

Boyce, J.S., 1929. Deterioration of wind-thrown timber on the Olympic Peninsula, Washington. USDA Tech. Bull. 104. Washington DC.

Brummer, C. J. and Montgomery, D. R., 2003 Downstream coarsening in headwater channels, Water Resources Research, 39(10), 1294, doi: 10.1029/2003WR001981.

Cederholm, C.J. and W.J. Scarlett, 1997. Hoh River tributaries: salmon habitat survey report and recommendations for rehabilitation. Washington Department of Natural Resources, Olympia, WA.

Chitwood, S., 1981. Quillayute River navigation project. US Army Corps of Engineers Technical Report.

Coho, C.S., 1993. Dam break floods in low order mountain channels of the Pacific Northwest. MS Thesis, University of Washington.

Cummans, J.E., M.R. Collins, and E.G. Nassar., 1975. Magnitude and frequency of floods in Washington. US Geological Survey Open-File Report 74-336.

Decillis, P., 1991. Summary of data collection and habitat conditions in the Quillayute River system, 1990-1991. Quileute Natural Resources Department, Quileute Indian Tribe, LaPush, WA.

Edmonds, R.L., T.B. Thomas, and J.J. Rhodes. 1991. Canopy and soil modification of precipitation chemistry in a temperate rain forest. Soil Science Society of America Journal, 55:1685-1693.

Edmonds, R.L., T.B. Thomas, and R.D. Blew. 1995. Biogeochemistry of an old-growth forested watershed, Olympic National Park, Washington. Water Resources Bulletin, Paper No. 94019.

Edmonds, R.L. and R.D. Blew. 1997. Trends in precipitation and stream chemistry in a pristine old-growth forest watershed, Olympic National Park, Washington. Journal of American Water Resources Association, 33:4, pp. 781-793.

Edmonds, R.L., R.D. Blew, J.L. Marra, J. Blew, A.K. Barg, G. Murray and T.B. Thomas. 1998. Vegetation patterns, hydrology, and water chemistry in small watersheds in the Hoh River valley, Olympic National Park. Scientific Monograph NPSD/NRUSGS/NRSM-98/02. US Department of the Interior, National Park Service.

Gearin, P.J., Lehmen, L.L., Hughes, K.M., Cooke, L., DeLong, R.L., and M.E. Gosho. 1998. Investigations of pinniped interactions with Lake Ozette sockeye salmon, Oncorhynchus nerka, 1998. National Marine Mammal Laboratory. Alaska Fisheries Science Center. National Marine Fisheries Service. Seattle, WA.

Gerstel, W. 1999. Deep-seated landslide inventory of the west-central Olympic Peninsula. Washington Division of Geology and Earth Resources Open File Report 99-2.

Hallock, D. 2001. River and Stream Ambient Monitoring Report for Water Year 2000. Washington State Department of Ecology, Publication No. 01-03-042, Olympia, WA.

Hanell, C. 2003. Mass Wasting and Surface Erosion Inventory for the Middle Coast Landscape, Olympic Peninsula, WA. Prepared for the Olympic Region Department of Natural Resources

Hatten, J. 1991. Salmonid Life Histories of the Hoh River Basin. Prepared for the Hoh Tribe.

Hauschild, W.L. and D.E. LaFrance. 1978. Low flow characteristics of streams on the Olympic Peninsula, Washington. US Geological Survey Open-File Report 77-812.

Haymes, J. and E. Tierney. 1996. Supplementation of wild coho smolt production in the Dickey River drainage, Washington. Final report to the Northwest Indian Fisheries Commission, Olympia, WA.

Henderson, J.A. , D.H. Peter, R.D. Lesher and D.C. Shaw. 1989. Plant associations of the Olympic National Forest. US Department of Agriculture Forest Service, Pacific Northwest Region, R6-ECOL-001-88, Portland, OR.

Heusser, C.J., 1974. Quaternary vegetation, climate, and glaciation of the Hoh River valley, Washington. Geologic Society of America Bulletin, v. 85, p.1547-1560.

Hughes, K.M., M.J. Crewson, and A.C. Ritchie, 2002. FY-2001 Hatchery Reform Phase II Telemetry Study of Lake Ozette Sockeye. Makah Fisheries Management, P.O. Box 115, Neah Bay, WA 98357. unpubl. rept. P. 6.

Lestelle, L.C., G.S. Morishima and T.D. Cooney, 1984. Determining spawning escapement goals for wild coho salmon on the Washington North Coast. Pages 243-254 in: J.M. Walton and D.B. Houston (eds), Proceddings of the Olympic Wild Fish Conference. March 23-25, 1983, Port Angeles, WA.

Long, William A., 1975. Salmon Springs and Vashon continental ice in the Olympic Mountains and relation of Vashon continental ice to Fraser Olympic ice. US Forest Service unpublished report.

Makah, 2000. Lake Ozette Sockeye Hatchery and Genetic Management Plan - Biological Assessment, Section 7 Consultation. October 23, 2000. Prepared by Makah Fisheries Management for Bureau of Indian Affairs. Makah Indian Tribe. Neah Bay, WA. p. 219.

McDonald, L.H., A.W. Smart and R.C. Wissmar, 1991. Logging and Water Quality in the Pacific Northwest and Alaska. Environmental Protection Agency Report EPA/910/9-91-001.

Murray, G.L., R.L. Edmonds, and J.L. Marra, 2000. Influence of partial harvesting on stream temperatures, chemistry and turbidity in forests on the western Olympic Peninsula, Washington. Northwest Science, Vol. 74, No. 2.

Nelson, L.M., 1982. Streamflow and sediment transport in the Quillayute River basin, Washington. US Geological Survey Open-File Report 82-627.

O'Connor M.D. and T.W. Cundy, 1993. North Fork Calawah watershed condition survey: landslide inventory and geomorphic analysis of mainstem alluvial system. Prepared for US Dept of Agriculture Forest Service, Olympic National Forest, Olympia, WA.

Perkins, S.J., 2003. Lower Hoh Channel Migration Study DRAFT. Prepared for the Hoh Tribe by Perkins Geoscience Consultants and TerraLogic GIS Consultants.

Rau, W., 1973. Geology of the Washington coast between Point Grenville and the Hoh River. Washington Division of Geology and Earth Resources Bulletin 66, 58 p.

Samuelson, C.E., E.G. Hoffman, and S. H. Olsen, 1982. Effects of current logging practices on fish habitat in five western Washington streams. Prepared for ITT Rayonier, Shelton, WA.

Schoonmaker, P., B. von Hagen and E. Wolf, 1997. The Rainforests of Home: Profile of a North American Bioregion. Island Press: Washington, D.C.

Sheldon and Klein, 1994. Inventory of Western Clallam County Wetlands. In: Clallam County Comprehensive Flood Hazard Management Plan. Sheldon and Associates. Seattle, WA.

Silver, J., 2000. Final report on aquatic habitat restoration in the Hoh Basin BIA watershed restoration grant, fiscal year 1999-2000. Hoh Tribe report.

Smillie, G.M., 2001. National Park Service trip report on Lake Ozette.

Somers, D.J., 1995. The influence of stream valley landform on riparian forest composition in Hoh River tributaries, Washington. MS Thesis, College of Forest Resources, University of Washington.

Wasserman, L.J., C.J. Cederholm and E.O. Salo, 1984. The impact of logging on benthic communities in selected watersheds of the Olympic Peninsula, Washington. Fisheries Research Institute, School of Fisheries, University of Washington.

Washington Department of Ecology (Ecology), 1992. Statewide Water Quality Assessment (305(b) Report). Pub. No. 92-04. Washington Department of Ecology. Olympia, WA.

Washington Department of Ecology (Ecology), 1992. Water quality standards for surface waters of the State of Washington. WAC 173-201A. Water Quality Program, Olympia.

Weitcamp, L.A., T.C. Wainwright, G.J. Bryant, G.B. Milner, D.J. Teel, R.G. Kope, and R.S. Waples, 1995. Status review of coho salmon from Washington, Oregon and California. National Oceanic and Atmospheric Administration, Technical Memorandum NMFS-NWFSC-24.

Wiggins, W.D., G.P. Ruppert, R.R. Smith, L.L. Reed, and M.L. Courts, 1998. Water Resources Data Washington. Water Year 1997. US Department of Interior, US Geologic Survey Water Data Reprt WA-95-1. Prepared in cooperation with the State of Washington and other agencies. Tacoma, WA.

Williams, J.R. and H.E. Pearson, 1985. Streamflow statistics and drainage basin characteristics for southwestern Washington: US Geological Survey Open-File Report 84-145-A.

TABLES

TABLE 2-1

Generalized Locations of Wells in Sub-Basins WRIA 20

Sub-Basin Name	Approximate Township and Range of Well Concentration	Description/Comments
Sub-Basin with wells		
Pacific 1	T33N, R15W	Wells located on the Makah Indian Reservation.
Sooes	T32N, R15W	Wells located on the Makah Indian Reservation, mostly near Sooes River.
Dickey	T28N (northern half), Ranges 14W and 15W	Some wells located in vicinity of Dickey Creek, some wells located south of Creek by 1-2 miles.
Sol Duc	2 Zones • T28N (southern half), Ranges 14W and 15W; and, • T29N, Range 13W and T30N, Ranges 10W, 11W, 12W and 13W	• Wells in the vicinity of Quillayute River; and, • Wells in the vicinity of Sol Duc River
Bogachiel	T28N, Range 14W and T28N, R13W	Most wells located in the vicinity of Bogachiel River.
Hoh	T26N, Ranges 10W, 11W, 12W, and 13W	Wells located on Hoh Indian Reservation and upstream along Hoh River.
Calawah	Townships 28N and 29N and R13W	Wells located near Calawah River in vicinity of Forks.
Sub-Basins with few or no wells		
Ozette	T31N, R15W	Few wells located in sub-basin, mostly near outlet of Lake Ozette.
Pacific 2	T29N, R15W	Few wells located in sub-basin.
Pacific 3		No wells located in sub-basin.
Pacific 4	T27N, R12W	Few wells located in sub-basin.
Pacific 5	T26N, R13W	Few wells located in sub-basin.

TABLE 2-2

Transmissivity Values for Aquifer Material in WRIA 20

Aquifer Unit	Average Transmissivity (ft^2/day)	Transmissivity Range (ft^2/day)	Number of Wells Examined
Coarse Unconsolidated (sand and gravel)	1,352	13 to 45,840	133
Sedimentary Rocks	75	5 to 1,433	5
Basalt	83	17 to 1,113	6

TABLE 2-3

Water Quality Inorganic MCL Exceedances in Public Water Systems in WRIA 20

PWS ID	Source Number	TRS	1/4 1/4	Measurement (mg/L)	Date
IRON - Secondary MCL = 0.3 mg/L					
09200	01	T33N R14W, Sec. 20	SE NE	0.4	3/31/2000
NP010	01	T29N R07W, Sec. 09	NE SW	0.5	10/24/1991
HD275	01	T29N R13W, Sec. 32	SW SE	0.66	4/20/1988
HD275	01	T29N R13W, Sec. 32	SW SE	0.68	9/25/1989
09200	01	T33N R14W, Sec. 20	SE NE	0.7	6/26/1979
NP510	01	T31N R15W, Sec. 29	SW SW	0.7	9/6/2000
26000	04	T28N R13W, Sec. 04	SW SE	0.77	1/7/1985
HD275	01	T29N R13W, Sec. 32	SW SE	0.83	2/1/1990
26000	03	T28N R13W, Sec. 04	SE SE	0.88	1/11/1984
NP750	01	T28N R15W, Sec. 21	NE NE	0.92	8/10/1978
NP010	01	T29N R07W, Sec. 09	NE SW	1.18	6/26/1978
HD275	01	T29N R13W, Sec. 32	SW SE	1.38	2/13/1990
09200	01	T33N R14W, Sec. 20	SE NE	1.45	6/2/1982
SP090	01	T28N R13W, Sec. 34	NW NE	2.4	8/28/1984
NP510	01	T31N R15W, Sec. 29	SW SW	2.5	6/10/1980
NP510	01	T31N R15W, Sec. 29	SW SW	2.8	2/26/1992
26000	05	T28N R13W, Sec. 04	SW SE	2.87	1/7/1985
NP010	01	T29N R07W, Sec. 09	NE SW	3.7	11/21/1988
13560	03	T26N R11W, Sec. 29	NE SE	3.7	12/8/1998
NP510	01	T31N R15W, Sec. 29	SW SW	5.6	2/17/1987
NP510	01	T31N R15W, Sec. 29	SW SW	18.7	2/17/1987
LEAD - Action Level = 0.015 mg/L					
NP510	01	T31N R15W, Sec. 29	SW SW	0.015	9/13/1994
NP010	01	T29N R07W, Sec. 09	NE SW	0.034	11/21/1988
NP010	01	T29N R07W, Sec. 09	NE SW	0.035	6/26/1978
13560	03	T26N R11W, Sec. 29	NE SE	0.039	12/8/1998
HD275	01	T29N R13W, Sec. 32	SW SE	0.05	4/20/1988
HD275	01	T29N R13W, Sec. 32	SW SE	0.051	6/10/1988
HD275	01	T29N R13W, Sec. 32	SW SE	0.095	9/25/1989
HD275	01	T29N R13W, Sec. 32	SW SE	0.191	2/1/1990
HD275	01	T29N R13W, Sec. 32	SW SE	0.196	11/7/1989

TABLE 2-3 (Con't)

Water Quality Inorganic MCL Exceedances in Public Water Systems in WRIA 20

PWS ID	Source Number	TRS	1/4 1/4	Measurement (mg/L)	Date
MANGANESE - Secondary MCL = 0.05 mg/L					
NP510	01	T31N R15W, Sec. 29	SW SW	0.011	6/14/1978
13560	03	T26N R11W, Sec. 29	NE SE	0.06	12/8/1998
NP510	01	T31N R15W, Sec. 29	SW SW	0.06	9/6/2000
SP090	01	T28N R13W, Sec. 34	NW NE	0.063	9/16/1985
HD275	01	T29N R13W, Sec. 32	SW SE	0.077	9/25/1989
09200	01	T33N R14W, Sec. 20	SE NE	0.096	6/26/1979
09200	01	T33N R14W, Sec. 20	SE NE	0.119	6/2/1982
NP510	01	T31N R15W, Sec. 29	SW SW	0.143	2/26/1992
SP090	01	T28N R13W, Sec. 34	NW NE	0.162	9/4/1985
NP510	01	T31N R15W, Sec. 29	SW SW	0.21	6/10/1980
NP510	01	T31N R15W, Sec. 29	SW SW	0.31	2/17/1987
26000	05	T28N R13W, Sec. 04	SW SE	0.366	1/7/1985
NP510	01	T31N R15W, Sec. 29	SW SW	0.52	2/17/1987

Source: (WDOH Database, 2002)

Note: The 0.0015 mg/L is not a maximum contaminant level (MCL), but rather an action level that requires a Treatment Technique if more than 10% of tap water samples exceed this concentration.

TABLE 2-4

Generalized Water Quality of Wells on the Hoh Reservation

Water Quality Parameter	Average Reading	Secondary Drinking Water Standard
Fe (mg/L)	0.3	0.3
pH	5.67	6.5 to 8.5
Hardness (mg/L as $CaCO_3$)	35*	None
Chloride (mg/L)	27#	250

Source: (Luxton, 1995), wells in in T26N, R13W Sections 20, 28, and 29

Note: Six wells tested unless indicated otherwise.

* = Three wells tested

\# = Five wells tested

TABLE 2-5

Generalized Water Quality of Wells on the Makah Reservation

Water Quality Parameter	Range of Values	Drinking Water Standard
Fe (mg/L)	< 0.05 to 0.12	0.3 [2]
Mn (mg/L)	0.014 to 0.022	0.05 [2]
Hardness (mg/L as $CaCO_3$)	26 to 244	N/A
Specific Conductivity (umho/cm)	377 to 516	N/A
Chloride (mg/L)	7 to 550	250 [2]
Sodium (mg/l)	14 to 56	N/A
Nitrate + Nitrite (mg/l)	0.9 to 3.9	10 mg/L [1]

Source: (Dion, Walters, and Nelson, 1980)

Note: The number of wells tested varied between one and six. Testing was undertaken between 1952 and 1977.

1 = Primary MCL

2 = Secondary MCL

N/A = No standard currently exists

TABLE 2-6

Generalized Water Quality of Wells Serving the Quileute Reservation

Water Quality Parameter	Range of Values	Drinking Water Standard
Fe (mg/L)	0.03 to 0.7	0.3 [2]
Mn (mg/L)	< 0.01 to 0.019	0.05 [2]
Chloride (mg/L)	7 to 21.3	250 [2]
Sulfate (as SO_4 mg/l)	< 10	250 [2]
Nitrate (as N mg/l)	0.3 to 0.5	10 mg/L [1]

Source: (Luxton and Bliemeister, 1989)

Note: The number of wells tested varied between one and six. Testing was undertaken October 1989.
1 = Primary MCL
2 = Secondary MCL
N/A = No standard currently exists

TABLE 3-1

Summary of WOB Database for WRIA 20 (Number of Documents)

Purpose of Use	Application[a]	Certificates: All Certificates[b]	Certificates: Supplemental Certificates[c]	Permit	Claim	Long Form Claim	Short Form Claim	Total	Percent
Municipal	0	3	2	1	0	0	0	4	1%
Domestic	16	118	4	4	5	153	120	416	74%
Irrigation	3	26	1	0	3	37	36	105	19%
Commercial-Industrial	0	13	2	0	1	0	0	14	3%
Other Uses[d]	0	2	0	0	0	2	0	4	1%
Non-Consumptive[e]	2	13	0	1	0	0	0	16	3%
Total	21	175	-	6	9	192	156	559	100%
Percent	4%	31%	-	1%	2%	34%	28%	100%	

Notes:
a. New (20) and changes (1).
b. All certificates, including primary, supplemental, and unknown.
c. Supplemental certificates only
d. Includes stock watering and recreation purposes of use.
e. Includes power, fish propagation, and fire protection.
Data source: "Washington State Department of Ecology Water Rights Application Tracking System (WRATS) database on a Bun", December 2003.
Includes 2 reservoir certificates and one "B" certificate.

TABLE 3-2

WOB Database Analysis

	Groundwater Certificates and Permits					Surface Water Certificates and Permits				
	Muncipal	Domestic	Irrigation	Commercial-Industrial	Other	Muncipal	Domestic	Irrigation	Commercial-Industrial	Other
Number of Documents	4	25	5	5	0	0	97	21	8	1
Percent without Qa	0	4%	0	0	-	-	34%	38%	38%	0
Mean Qa (AF/yr)	538	5.2	9.9	15.6	-	-	1.4	9.5	13.7	0.5
Median Qa (AF/yr)	484	1.3	9	21	-	-	1.0	3.0	5.0	0.5
Mean Qi/Qa (cfs/AF/yr)	0.00197	0.01829	0.05659	0.01134	-	-	0.0371	0.0502	0.0106	0.0200
Median Qi/Qa (cfs/AF/yr)	0.00181	0.01337	0.06684	0.00258	-	-	0.0200	0.0150	0.0100	0.0200
Mean Irrigated Acres	-	-	3.8	-	-	-	-	5.7	-	-
Median Irrigated Acres	-	-	2.0	-	-	-	-	2.9	-	-
Mean Duty (ft)	-	-	5.3	-	-	-	-	2.1	-	-
Median Duty (ft)	-	-	1.8	-	-	-	-	2.0	-	-

Data source: "Washington State Department of Ecology Water Rights Application Tracking System (WRATS) database on a Bun", December 2003.
Does not include reservoir certificates.

Summary of Allocation Assessment

Groundwater (AF/yr)							
Purpose of Use	Certificate	Claim	Claim Long Form	Claim Short Form	Permit	Total	Percent
Commercial-Industrial	78	0	0	0	0	78	4%
Domestic	118	4	47	34	0	202	10%
Irrigation	50	0	522	9	0	580	28%
Municipal	950	0	0	0	232	1,182	58%
Other	0	0	0	0	0	0	0%
Subtotal	1,196	4	569	42	232	2,042	100%
Surface Water (AF/yr)							
Purpose of Use	Certificate	Claim	Claim Long Form	Claim Short Form	Permit	Total	Percent
Commercial-Industrial	281	1	0	0	0	282	20%
Domestic	176	11	30	26	2	243	18%
Irrigation	314	38	486	10	0	847	62%
Municipal	0	0	0	0	0	0	0%
Other	1	0	4	0	0	5	0%
Subtotal	771	50	520	36	2	1,377	100%
TOTAL	**1,967**	**54**	**1,089**	**78**	**234**	**3,419**	

Note:
Does not include supplemental water rights.

Summary of Allocation by Sub-Basin and Document Type

	Subbasin (AF/yr)												
Groundwater	Bogachiel	Calawah	Dickey	Hoh	Ozette	Pacific 1	Pacific 2	Pacific 3	Pacific 4	Pacific 5	Sol Duc	Sooes	Total
Application	0	0	0	0	0	0	0	0	0	0	0	0	0
Certificate	968	15	0	32	0	0	0	0	0	0	181	0	1,196
Claim	0	0	0	0	0	0	0	0	0	0	4	0	4
Claim Long Form	44	3	32	6	2	0	0	0	0	0	482	0	568
Claim Short Form	7	3	2	3	0	0	0	0	0	0	27	0	41
Permit	0	0	0	0	0	0	0	0	0	0	232	0	232
Subtotal (AF/yr)	1,019	21	34	40	2	0	0	0	0	0	926	0	2,040
Surface Water													
Application	0	0	0	0	0	0	0	0	0	0	0	0	0
Certificate	179	116	0	26	17	5	0	0	0	0	422	5	769
Claim	3	6	1	11	0	0	0	0	0	0	29	0	50
Claim Long Form	242	2	62	110	5	1	0	0	0	0	98	1	518
Claim Short Form	5	4	0	3	4	0	0	0	0	0	21	0	35
Permit	1	0	0	0	0	0	0	0	0	0	1	0	2
Subtotal (AF/yr)	429	127	63	149	25	6	0	0	0	0	570	5	1,373
Total (AF/yr)	**1,447**	**147**	**96**	**189**	**27**	**6**	**0**	**0**	**0**	**0**	**1,496**	**5**	**3,413**

Note:
WOB database includes 17 records (totaling 7.77 AF/yr) that are included in WRIA 20 that could not be assigned a matching subbasin centroid.
Does not include supplemental water rights.

TABLE 3-5

Summary of Allocation by Sub-Basin and Purpose of Use

	Subbasin (AF/yr)												
Groundwater	Bogachiel	Calawah	Dickey	Hoh	Ozette	Pacific 1	Pacific 2	Pacific 3	Pacific 4	Pacific 5	Sol Duc	Sooes	Total
Municipal	950	0	0	0	0	0	0	0	0	0	232	0	1,182
Domestic	20	21	2	7	2	0	0	0	0	0	150	0	200
Irrigation	49	0	32	3	0	0	0	0	0	0	497	0	580
Commercial-Industrial	0	0	0	31	0	0	0	0	0	0	47	0	78
Other	0	0	0	0	0	0	0	0	0	0	0	0	0
Subtotal (AF/yr)	**1,019**	**21**	**34**	**40**	**2**	**0**	**0**	**0**	**0**	**0**	**926**	**0**	**2,040**
Surface Water													
Municipal	0	0	0	0	0	0	0	0	0	0	0	0	0
Domestic	20	12	3	32	15	6	0	0	0	0	153	1	240
Irrigation	372	114	60	114	11	0	0	0	0	0	176	0	847
Commercial-Industrial	35	0	0	1	0	0	0	0	0	0	241	5	282
Other	2	1	0	2	0	0	0	0	0	0	0	0	5
Subtotal (AF/yr)	429	127	63	149	25	6	0	0	0	0	570	5	1,373
Total (AF/yr)	**1,447**	**147**	**96**	**189**	**27**	**6**	**0**	**0**	**0**	**0**	**1,496**	**5**	**3,413**

Note:
WOB database includes 17 records (totaling 7.77 AF/yr) that are included in WRIA 20 that could not be assigned a matching subbasin centroid.
Does not include supplemental water rights.

TABLE 4-1

Public Water Supply Systems in WRIA 20

PWS/ Source ID	PWS Group Code	PWS Type [1]	Subbasin Name	PWS Name	Number PWS Nonresidential Connections	Number PWS Residential Connections	Number Residents on PWS	Source Category [2]	Source Use Code [3]	Source Well Depth
26000-01	A	COMM	Calawah	FORKS MUNICIPAL WATER DEPT	0	1450	5000	WW	P	135
26000-02	A	COMM	Calawah	FORKS MUNICIPAL WATER DEPT	same as above	same as above	same as above	WW	P	135
26000-03	A	COMM	Calawah	FORKS MUNICIPAL WATER DEPT	same as above	same as above	same as above	WW	P	116
26000-04	A	COMM	Calawah	FORKS MUNICIPAL WATER DEPT	same as above	same as above	same as above	WW	P	127
26000-05	A	COMM	Calawah	FORKS MUNICIPAL WATER DEPT	same as above	same as above	same as above	WW	P	130
26000-06	A	COMM	Calawah	FORKS MUNICIPAL WATER DEPT	same as above	same as above	same as above	WF	P	102
26000-07	A	COMM	Calawah	FORKS MUNICIPAL WATER DEPT	same as above	same as above	same as above	WF	P	117
51150-01	A	COMM	Sol Duc	MAPLE HAVEN	0	18	73	W	P	56
63240-01	A	COMM	Sol Duc	OLD CHIEFS MOBILE HOME PARK	27	40	160	W	P	120
SP090-01	A	TNC	Bogachiel	BOGACHIEL STATE PARK	6	2	5	W	E	30
SP090-02	A	TNC	Bogachiel	BOGACHIEL STATE PARK	same as above	same as above	same as above	SP	P	0
NP350-01	A	TNC	Hoh	HOH	30	7	18	W	P	30
NP510-01	A	TNC	Ozette	OZETTE LAKE	3	3	8	W	P	40
03928-01	A	TNC	Sol Duc	BEAVER	3	4	14	W	P	128
04105-01	A	TNC	Sol Duc	SODERLIND, RON	1	4	10	W	P	130
08345-01	A	TNC	Sol Duc	RAYONIER SOL DUC	1	0	0	W	P	40
34870-01	A	TNC	Sol Duc	HUNGRY BEAR CAFE/BEAR CREEK	2	2	5	SP	P	0
34870-02	A	TNC	Sol Duc	HUNGRY BEAR CAFE/BEAR CREEK	same as above	same as above	same as above	W	P	24
76200-01	A	TNC	Sol Duc	SAPPHO JUNCTION	1	0	0	W	P	80
NP620-01	A	TNC	Sol Duc	MORA RANGER STATION	4	3	8	W	P	40
NP800-01	A	TNC	Sol Duc	SOL DUC RESORT 16	98	2	8	S	P	0
NP800-04	A	TNC	Sol Duc	SOL DUC RESORT 16	same as above	same as above	same as above	S	E	0
25552-01	B		Bogachiel	FISHERMANS HOLLOW	6	6	12	W	P	22
25561-01	B		Calawah	DAVIS WATER SYSTEM	0	4	10	SP	P	0
HD275-01	B		Calawah	D O T MAINTENANCE FORKS NORTH	1	0	0	W	P	120
04789-01	B		Dickey	DELTA WINGS WEST	0	5	15	W	P	110
04646-01	B		Hoh	HOH HUMM RANCH	1	1	5	W	P	2
04749-01	B		Ozette	LOST RESORT	1	0	0	W	P	23
01424-01	B		Sol Duc	FRED ORR MEMORIAL BALL PARK	1	0	0	W	S	116
02289-01	B		Sol Duc	QUILLAYUT AIRPORT	0	3	8	W	P	130
02463-01	B		Sol Duc	BRIGHTWATER HOUSE	1	1	3	W	P	0
03197-01	B		Sol Duc	PRIOR WATER SYSTEM	0	3	8	W	P	70
04219-01	B		Sol Duc	JOHNSTEN, LLOYD	0	2	8	W	P	123
04305-01	B		Sol Duc	FORD, HUGH	0	2	6	W	P	47

TABLE 4-1

Public Water Supply Systems in WRIA 20

PWS/ Source ID	PWS Group Code	PWS Type [1]	Subbasin Name	PWS Name	Number PWS Nonresidential Connections	Number PWS Residential Connections	Number Residents on PWS	Source Category [2]	Source Use Code [3]	Source Well Depth
04500-01	B		Sol Duc	CHRISTENSEN, DAN	1	1	3	SP	P	0
04501-01	B		Sol Duc	SUSLICK, LARRY	0	2	4	W	P	51
04986-01	B		Sol Duc	LONG, VERENCE	0	2	6	W	P	47
04996-01	B		Sol Duc	PRICE, SUE	0	3	10	W	P	65
05070-01	B		Sol Duc	BEAR CREEK LODGE	0	9	23	W	P	210
05294-01	B		Sol Duc	SKI DRIVE WATERWORKS	0	6	20	W	P	61
05341-01	B		Sol Duc	FRENCHY'S TAVERN	1	0	0	W	P	1
07644-01	B		Sol Duc	FARMLAND TRUST	0	2	4	W	P	70
07828-01	B		Sol Duc	JEFFS WELL	1	0	0	W	P	78
08234-01	B		Sol Duc	MISTY VALLEY INN B&B	1	2	4	W	P	13
08996-01	B		Sol Duc	SOLDUC HATCHERY	1	4	10	W	P	0
35352-01	B		Sol Duc	ITT RAYONIER/SAPPHO WELL	0	5	13	W	P	0
61029-01	B		Sol Duc	MANITOU LODGE	1	1	2	W	P	37
FS855-01	B		Sol Duc	SNIDER WORK CTR	7	1	4	W	P	100
FW006-01	B		Sooes	MAKAH NATIONAL FISH HATCHERY	1	3	5	W	P	80

[1] PWS Type (COMM-community; TNC-Transient/Non-Community)

[2] Source Catagory Type: (W - Well, WF- Wellfield, WW- Well in Wellfield, SP- Spring, S- Surface Water)

[3] Source Use Code: (P- Permanent, S- Seasonal, E- Emergency)

Current 2000 Public Water System (PWS) and Exempt Well Use

Sub-Basin	2000 Population[1]	Residential Public Water Systems				Exempt Wells				Totals	
		Number of PWS Connections [2]	Residential Population on PWS[3]	Annual PWS Water Use (AF/yr)[4]	Annual PWS Water Use (cfs)	Exempt Well Population[6]	Exempt Well Residences Served	Annual Exempt Well Water Use (AF/yr)	Annual Exempt Well Water Use (cfs)	Total Annual Domestic Population Based Water Use (AF/yr)[7]	Total Annual Domestic Population Based Water Use (cfs)
Bogachiel[5]	1,376	383	1,053	142.8	0.197	323	117	43.7	0.060	186.5	0.258
Calawah[5]	3,754	1,019	2,802	379.8	0.525	952	346	129.0	0.178	508.8	0.703
Dickey	106	5	14	1.9	0.003	92	34	12.5	0.017	14.4	0.020
Hoh	234	1	3	0.4	0.001	232	84	31.4	0.043	31.8	0.044
Ozette	79	0	0	0.0	0.000	79	29	10.7	0.015	10.7	0.015
Sol Duc[5]	1,566	165	454	61.5	0.085	1,112	404	150.8	0.208	212.3	0.293
Sooes	65	3	8	1.1	0.002	57	21	7.7	0.011	8.8	0.012
Totals	**7,181**	**1,576**	**4,334**	**587.4**	**0.811**	**2,847**	**1,035**	**385.9**	**0.533**	**973.3**	**1.344**

[1] From U.S. Census 2000.

[2] From WDOH; Includes Group A & B Community Systems.

[3] Assumes 2.75 people/connection (Clallam County, 2002) .

[4] Per capita water use assumed at 121 gpdpc for subbasins. Assumes no conservation. Calculated from Forks 2002-2004 pumping data.

[5] Forks population divided among 3 subbasins, calculated using percentage of land area within each subbasin and WDOH reported population served by Forks PWS.

[6] Exempt well population taken from 2000 population minus residential population on PWS.

[7] Total annual domestic water use equals PWS plus exempt well water use.

Current 2000 Non-Community Public Water System (PWS) Water Use

Sub-Basin	2000 Population[1]	Number of Connections[2]	Water Use/ Connection (gal/yr)[3]	Average Annual Water Use (AF/year)	Average Annual Water Use (cfs)
Bogachiel	1,376	6	499	0.0015	2.12E-06
Calawah	3,754	0	0	0.0000	0.00E+00
Dickey	106	0	0	0.0000	0.00E+00
Hoh	234	30	2496	0.0077	1.06E-05
Ozette	79	3	250	0.0008	1.06E-06
Sol Duc	1,566	110	9151	0.0281	3.88E-05
Sooes	65	0	0	0.0000	0.00E+00
Totals	**7,181**	**149**	**12,395**	**0.038**	**5.25E-05**

[1] From U.S. Census, 2000.

[2] From WDOH; Includes Group A Non-Community Systems.

[3] Calculated as (number of connections x 2.75 x 121) / 4. Assuming use similar to residential connections (2.75 people per connection) and per capita use (121 gpdpc), and that use occurs half of the year at half of the rate of residential connections.

City of Forks Monthly Water Use and Wastewater Discharge Summary

Month		Monthly Demand (Gallons)					Monthly Wastewater Discharge (Gallons)		
	Days/Month	2002	2003	2004	Average	Average Water Use Per Capita (gpdpc)[1]	Monthly Wastewater Treatment Plant Discharge 2004 (Gallons)	Discharge Per Capita (gpdpc)[3]	Percent Discharge of Average Water Use
January	31		18,091,876	15,510,528	16,801,202	108	4,563,700	117	108%
February	28		16,300,416	18,239,232	17,269,824	123	4,046,100	115	93%
March	31		16,453,756	19,743,460	18,098,608	117	4,169,600	107	91%
April	30		16,584,656	15,791,776	16,188,216	108	3,468,100	92	85%
May	31	19,351,508	12,398,100	16,050,584	15,933,397	103	3,725,200	95	93%
June	30	15,963,816	21,424,964	16,314,628	17,901,136	119	3,439,300	91	76%
July	31	16,751,460	23,663,728		20,207,594	130	3,976,500	102	78%
August	31	19,679,880	17,370,056		18,524,968	120	3,749,700	96	80%
September	30	22,060,016	25,363,932		23,711,974	158	3,715,000	98	62%
October[2]	31	21,735,384	22,965,096		22,350,240	144	3,872,578	99	69%
November[2]	30	16,221,128	17,341,632		16,781,380	112	3,872,578	102	92%
December[2]	31	16,031,884	18,998,452		17,515,168	113	3,872,578	99	88%
ANNUAL	**365**		**226,956,664**		**221,283,707**	**121**	**46,470,933**	**101**	**85%**

[1] Calculated from City of Forks 2002-2004 pumping data, assumes Forks population of 5000.

[2] Discharge data not available to date. Monthly value calculated from average of January through September data.

[3] Per capita discharge calculated from number of residences on sewer service (458) and 2.75 people per residence.
Number of residences served by City of Forks sewer service from: Personal communication, Vivian, City of Forks, November 10, 2004.
Number of residences served by City of Forks sewer service does not account for quantity of businesses served, assumes all residential serivce.

TABLE 4-4

Total Annual Agricultural Water Use by Sub-Basin

Sub-Basin	Agricultural Acreage	Irrigated Acreage[1]	Duty (ft/yr)	Agricultural Water Use (AF/yr)	Agricultural Water Use (cfs)
Bogachiel	478.6	64.1	1.5	96.20	0.13
Calawah	636.5	85.3	1.5	127.94	0.18
Dickey	365.8	49.0	1.5	73.54	0.10
Hoh	264.9	35.5	1.5	53.24	0.07
Ozette	102.7	13.8	1.5	20.65	0.03
Sol Duc	500.4	67.1	1.5	100.58	0.14
Sooes	6.2	0.8	1.5	1.25	0.002
Total	2,355.2	315.6	--	473.40	0.65

1) Assumes 13.4% of total agricultural acreage is irrigated.

TABLE 4-5

Quileute Tribe Monthly Water Use Summary

Month	Monthly Demand (Gallons)					Monthly Average (AF)	Monthly Average (cfs)
	1995	1997a	2000	2002	Average		
January	4,573,600		4,302,700	4,084,000	4,320,100	13.26	0.018
February	3,821,100	3,890,300	3,890,500	4,667,300	4,067,300	12.48	0.017
March	3,982,500	4,001,800	4,943,650	4,401,200	4,332,288	13.30	0.018
April	3,825,400	3,611,200	3,679,300	4,090,500	3,801,600	11.67	0.016
May	4,297,000	3,661,800	4,019,000	4,088,200	4,016,500	12.33	0.017
June	3,754,800	3,555,100	4,254,100	4,016,998	3,895,250	11.95	0.017
July	4,008,067	4,133,800	4,826,800	4,934,700	4,475,842	13.74	0.019
August	4,090,200	3,611,800	3,952,500	3,998,400	3,913,225	12.01	0.017
September	3,659,350	4,038,202	3,655,760	3,634,600	3,746,978	11.50	0.016
October	3,083,783	4,059,375	3,411,555	3,270,800	3,456,378	10.61	0.015
November	3,236,800	3,404,050	3,713,400	3,017,300	3,342,888	10.26	0.014
December	3,944,420	4,030,500	3,927,390	3,441,200	3,835,878	11.77	0.016
ANNUAL	**46,277,020**	**41,997,927**	**48,576,655**	**47,645,198**	**47,204,225**	**144.9**	**0.200**

a Incomplete data.

TABLE 4-6

Total Annual Water Use by Sub-Basin

Sub-Basin	Municipal/ Residential (AF/yr)	Exempt Wells (AF/yr)	Municipal/ Non-Community (AF/yr)	Agricultural (Irrigation) (AF/yr)	Forestry (AF/yr)	Tribal (AF/yr) [a]	Total Water Use (AF/yr)	Total Water Use (cfs)
Bogachiel	143	44	0.0015	96	0	NA	283	0.39
Calawah	380	129	0.0000	128	0	NA	637	0.88
Dickey	2	12	0.0000	74	0	NA	88	0.12
Hoh	0	31	0.0077	53	0	NA [b]	85	0.12
Ozette	0	11	0.0008	21	0	NA [b]	31	0.04
Sol Duc	62	151	0.0281	101	0	145	458	0.63
Sooes	1	8	0.0000	1	0	NA	10	0.014
Total	**587**	**386**	**0**	**473**	**0**[c]	**145**	**1,592**	**2.20**

[a] Quileute data based on Three Rivers Water Plant usage.

[b] Water use by the Makah and Hoh Tribes is not quantified as part of this assessment upon request from tribal representatives.

[c] Personal communication, Bill Peach (July 8, 2004).

TABLE 4-7

Projected 2025 Residential and Water Use (Group Aand B and Exempt Wells)

Sub-Basin	1990	2000	Increase/ Decrease	10-year Percent Increase/ Decrease	Projected 2025 Population[1,2]	Total Water Use (AF/Yr)[3]	Total Water Use (cfs)
Bogachiel	2092	1,376	-716	-34%	1376	186.5	0.258
Calawah	3021	3,754	734	24%	5588	757.4	1.046
Dickey	216	106	-110	-51%	106	14.4	0.020
Hoh	211	234	24	11%	294	39.8	0.055
Ozette	76	79	3	4%	87	11.8	0.016
Sol Duc	1628	1,566	-62	-4%	1566	212.3	0.293
Sooes	61	65	4	7%	76	10.3	0.014
Total	**7,304**	**7,181**	**-123**	**-2%**	**9,093**	**1,232**	**1.70**

[1] Based on same percent increase in subbasin populations as 10-year period from 1990 - 2000.

[2] In subbasins where population decreased, population is conservatively estimated to remain at levels observed in 2000.

[3] Projected water use calculated from average annual per capita water use (121 gpdpc), converted to AF/yr.

TABLE 5-1

Potential ENSO and PDO Impacts on the Pacific Northwest Environment

El Niño and warm PDO conditions in the Pacific Northwest *increase* chances for:	
ENSO	**PDO**
o Lower than average mountain snowpack o Lower than average streamflow o Fewer floods o Lower quality coastal and near-shore marine habitat o Drought o Conflict over water resources o Coastal erosion	o Lower than average salmon returns o Forest fires o Increased tree growth, seedling establishment, and forest productivity at higher elevations o Decreased tree growth, seedling establishment, and forest productivity at lower elevations

La Niña and cool PDO conditions in the Pacific Northwest *increase* chances for:	
ENSO	**PDO**
o Higher than average mountain snowpack o Higher than average streamflow o Flooding o Higher quality coastal and near-shore marine habitat o Fewer droughts o Landslides o Coastal flooding	o Higher salmon returns o Fewer forest fires o Decreased tree growth, seedling establishment, and forest productivity at higher elevations o Increased tree growth, seedling establishment, and forest productivity at lower elevations

ENSO – El Niño Southern Oscillation
PDO – Pacific Decadal Oscillation

TABLE 5-2

ENSO/PDO Phases Since 1900

ENSO/PDO State	**Cool phase PDO** *1900-1924, 1947-1976, 1999-??***	**Warm phase PDO** *1925-1946, 1977-1998*
La Niña *(cool phase ENSO)*	1904, 1907, 1909, 1910, 1911, 1917, 1918, 1921, 1923, 1950, 1951, 1955, 1956, 1963, 1965, 1968, 1971, 1972, 1974, 1975, 1976, 1999, 2000, 2001	1925, 1932, 1934, 1938, 1939, 1943, 1944, 1945, 1984, 1985, 1986, 1989, 1996
ENSO Neutral	1901, 1902, 1908, 1913, 1916, 1922, 1947, 1948, 1949, 1953, 1954, 1957, 1960, 1961, 1962, 1967, 2002, 2004	1927, 1928, 1929, 1933, 1935, 1936, 1937, 1946, 1979, 1981, 1982, 1990, 1991, 1993, 1994, 1997
El Niño *(warm phase ENSO)*	1900, 1903, 1905, 1906, 1912, 1914, 1915, 1919, 1920, 1924, 1952, 1958, 1959, 1964, 1966, 1969, 1970, 1973	1926, 1930, 1931, 1940, 1941, 1942, 1977, 1978, 1980, 1983, 1987, 1988, 1992, 1995, 1998, 2003

NOTE: Years are categorized as El Niño or La Niña when December-February temperatures in the Niño-3.4 region of the tropical Pacific are ½ standard deviation above (El Niño) or below (La Niña) mean temperature. Years that do not exceed the ½ standard deviation threshold are considered ENSO Neutral. The ENSO and PDO states assigned to any given year span the winter of the listed year and the fall prior (e.g., 2004 means (Oct-Dec) 2003 and winter (Jan-March) 2004 were, in this case, ENSO Neutral). The potential for precipitation and temperature extremes is higher when ENSO and PDO are in the same phase (shaded cells). ** *It is believed that the PDO shifted to cool phase in mid-1998, but a recent shift back to warm phase PDO (in mid-2002) makes it difficult to determine at this time if the 1998 shift was a true phase shift*.

ENSO – El Niño Southern Oscillation
PDO – Pacific Decadal Oscillation

TABLE 5-3

Projected Changes in Average Annual Pacific Northwest Temperature and Precipitation for the Decades of the 2020s and 2040s.

	Temperature change	**Precipitation change**	
Decades	Avg. Annual (°F)	Oct-Mar	Apr-Sept.
2020s			
Low	0.8 °F	+ 2%	- 4%
Average	2.5 °F	+ 8%	+ 4%
High	3.3 °F	+ 18%	+ 14%
2040s			
Low	2.7 °F	- 2%	- 7%
Average	3.8 °F	+9 %	+ 2%
High	4.9 °F	+ 22%	+ 9%

NOTE: The projections are based on analysis of seven climate models driven by an increase in equivalent carbon dioxide of approximately 1% per year. Changes are benchmarked to the decade of the 1990s.

TABLE 5-4

Potential Effects of Deforestation

Component Affected	Principal Hydrologic Processes Involved	Geographic Scale and Likely Magnitude of Effect
Interception	Decreased interception decreased soil moisture deficits and increased dry season flow as well as wet season flow.	Basin scale; magnitude proportional to forest cover
Transpiration	Decreased transpiration in dry periods increase dry season flow	Basin scale;
Fog-Drip	Decreased fog or mist deposition may result in decreased flows during fog season (generally during dry season).	Fog impacted basins: Can have significant effect on dry season flow
Floods	Decreased interception increases flood flows	Basin scale: Most relevant for small storm events.
	Road construction and drainage increase flood flows	Basin Scale: increased floods for all size storm events
Snow Accumulation and Melt	Snow pack is deeper and holds more water.	Dependent on predominance of rain-on-snow events: increased floods for snow melt events.
	Increased rate of snow melt	Basin Scale: increased floods for all size storm events.
Infiltration	Road construction and drainage can decrease infiltration and intercept shallow baseflow resulting in increased flood flows.	Basin Scale: Magnitude varies with forest type and subsequent land use.
Water Quality	Increased Nutrient Leaching	Basin scale: Magnitude varies with forest type and subsequent land use.
Erosion – Event	Decreased infiltration rates increase surface runoff and erosion	Basin Scale
	Decreased slope stability	Basin scale: increased erosion
	Reduced tree weight and windthrow of trees increases slope stability	Basin scale: decrease erosion
	Management activities: cultivation, drainage, road construction and felling all increase erosion	Basin scale: Management activities are often more important than the direct effect of the forest
Climate	Decreased evapotranspiration and increase sensible heat fluxes from forest affect climate	Forests generally cool and humidify the atmosphere
Snow - Seasonal	Accumulation is generally greater in cleared areas due to decreased interception	Basin scale
	Melt rate is generally increased due to increased radiation	Basin scale

Sources: Handbook of Hydrology, Maidment, 1993.
WFPB, 1997, Standard Methodology for Conducting Watershed Analysis Manual, Version 4.0.

TABLE 5-5

WRIA 20 Sub-Basin Elevations and Areas

Subbasin Name	Mean Elevation (NAVD 27 ft)[1]	Basin Area (Acres)
Bogachiel	1331.46	97,847
Calawah	1418.89	87,034
Dickey	397.38	68,072
Hoh	2126.61	190,944
Ozette	286.39	64,766
Sol Duc	1737.61	149,511
Sooes	486.00	31,693

1. Elevation for each sub-basin was derived by averaging (using areally weighted averages) USGS 10m data (NAVD 27)for the state of Washington.

2. Areas obtained from Golder delineation of sub-basins.

PRISM Annual and Monthly Precipitation

SUB-BASIN NAME	Precipitation Zone	MEAN MONTHLY PRECIPITATION (INCHES)												Mean Annual Precipitation (inches)
		O	N	D	J	F	M	A	M	J	J	A	S	
Bogachiel	rain	12.02	17.21	19.56	17.63	15.09	13.59	8.70	5.81	3.47	2.73	2.74	5.31	123.87
	ros	14.94	20.98	26.84	23.16	18.86	16.80	10.69	6.69	4.50	3.12	3.54	6.80	156.93
	snow	15.53	21.85	28.16	24.23	19.62	17.53	11.11	6.95	4.77	3.20	3.71	7.02	163.68
	SUB-BASIN AVERAGE	**13.02**	**18.52**	**22.04**	**19.52**	**16.38**	**14.70**	**9.38**	**6.12**	**3.83**	**2.86**	**3.02**	**5.82**	**135.22**
Calawah	rain	11.62	17.10	18.90	16.80	14.72	13.01	8.34	5.55	3.28	2.61	2.60	5.07	119.58
	ros	12.28	17.99	20.48	18.18	15.42	13.44	8.65	5.65	3.61	2.65	2.89	5.58	126.81
	snow	12.48	17.95	21.48	18.90	15.67	13.78	8.84	5.69	3.82	2.66	2.95	5.73	129.94
	SUB-BASIN AVERAGE	**11.84**	**17.39**	**19.44**	**17.26**	**14.95**	**13.16**	**8.44**	**5.58**	**3.39**	**2.62**	**2.69**	**5.24**	**122.02**
Dickey	rain	11.10	16.01	17.46	15.92	13.86	12.42	7.97	5.58	3.20	2.61	2.60	4.94	113.66
	ros	11.34	16.54	19.02	16.77	14.49	12.32	8.07	5.24	3.19	2.64	2.52	4.88	117.01
	snow[2]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	SUB-BASIN AVERAGE	**11.10**	**16.01**	**17.47**	**15.93**	**13.86**	**12.42**	**7.97**	**5.58**	**3.20**	**2.61**	**2.60**	**4.94**	**113.66**
Hoh	rain	12.27	17.47	21.48	18.72	15.70	13.74	8.91	5.67	3.75	2.58	2.96	5.62	128.87
	ros	14.06	21.00	25.94	22.00	19.05	16.22	10.60	6.59	4.26	2.79	3.35	6.27	152.12
	snow	17.53	25.48	31.55	26.76	22.66	19.88	12.60	7.86	5.28	3.49	4.08	7.94	185.09
	SUB-BASIN AVERAGE	**14.17**	**20.54**	**25.33**	**21.74**	**18.42**	**16.04**	**10.33**	**6.50**	**4.30**	**2.89**	**3.37**	**6.43**	**150.05**
Ozette	rain	10.65	15.04	16.33	15.44	12.65	11.51	7.47	5.14	3.16	2.59	2.57	4.76	107.32
	ros	11.54	15.55	17.95	17.80	13.03	13.70	8.11	5.16	3.11	2.68	2.56	4.88	116.06
	snow[2]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	SUB-BASIN AVERAGE	**10.65**	**15.04**	**16.33**	**15.45**	**12.65**	**11.51**	**7.47**	**5.14**	**3.16**	**2.59**	**2.57**	**4.76**	**107.33**
Sol Duc	rain	10.02	14.88	15.82	14.33	12.51	10.94	7.02	4.75	2.79	2.23	2.32	4.43	102.04
	ros	11.13	16.71	18.08	16.30	13.85	12.07	7.48	4.91	3.10	2.24	2.56	4.86	113.28
	snow	12.53	18.78	21.90	19.35	15.87	14.07	8.44	5.33	3.53	2.36	2.82	5.41	130.38
	SUB-BASIN AVERAGE	**10.77**	**16.06**	**17.53**	**15.77**	**13.48**	**11.81**	**7.40**	**4.90**	**3.00**	**2.26**	**2.47**	**4.72**	**110.18**
Sooes	rain	10.86	15.42	17.02	17.13	12.92	11.43	7.52	4.78	3.17	2.49	2.58	4.63	109.97
	ros	10.67	15.55	17.76	18.50	12.95	11.46	7.87	4.92	2.95	2.48	2.52	4.53	112.16
	snow[2]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	SUB-BASIN AVERAGE	**10.86**	**15.42**	**17.02**	**17.14**	**12.92**	**11.43**	**7.53**	**4.78**	**3.17**	**2.49**	**2.58**	**4.63**	**109.98**

Notes

1. Monthly precipitation for each sub-basin was derived by averaging (using areally weighted averages) mean monthly PRISM data for the state of Washington. Source: Daly, Chris, "Washington Average Monthly or Annual Precipitation, 1961-90", Oregon Climate Service at Oregon State University.

2. Snow zones do not exist in this sub-basin

PRISM - Parameter-elevation Regressions on Independent Slopes Model

TABLE 5-7

Climate Station Summary and Comparison with PRISM Output (1961-1999)

Station Name [1]	Station Number	Elevation (feet)	Period of Record	PRISM Annual Precipitation (inches)	Measured Annual Precipitation (inches)	Percent Error
Forks 1E	452914	350	1/1/1931 – present	122.05	118.27	3.2%
Forks[2]	452913	302	4/1/1959 – present	N/A	N/A	N/A
Neah Bay Lightboat Station[2,5]	455799	20	9/1/1963 – present	N/A	N/A	N/A
Neah Bay 1E/2E[3,5]	455801	10	6/1/1948 – 8/25/1987	104.69	90.30	15.9%
Quillayute AP[4]	456858	185	8/1/1966 – present	104.65	**101.24	3.4%
Sappho 8E	457319	760	6/1/1948 – 4/1/1998	91.22	79.23	15.1%
Sol Duc Hot Springs[2]	457808	1,650	7/1/1963 – 6/9/1965	N/A	N/A	N/A
Spruce	457987	371	1/1/1931 – 12/31/1980	139.25	132.86	4.8%

Notes:

[1] Source: NOAA/NWS COOP data

[2] Data not available

[3] Period of record for NWS COOP climate station: 1961-1987.

[4] Period of record for NWS COOP climate station: 1966-1990.

[5] Located in WRIA 19, immediately outside the WRIA 20 boundary.

NOAA - National Oceanic and Atospheric Administration
NWS COOP - National Weather Service Cooperative Stations
PRISM - Parameter-elevation Regressions on Independent Slopes Model

TABLE 5-8a

BOR Mean Monthly Flows at Sub-basin Outlet (cfs)

River Sub-basin	October	November	December	January	February	March	April	May	June	July	August	September	Mean Annual Flow
Bogachiel River at Outlet	2157.4	4358.3	5153.4	4850.9	3987.0	3423.4	2194.1	1338.9	790.3	519.2	360.2	587.6	**2476.7**
Calawah River at Outlet	965.0	1968.8	2336.5	2190.6	1803.6	1559.9	989.4	583.5	336.1	215.8	148.6	249.5	**1112.3**
Dickey River at Outlet	596.4	1309.8	1492.3	1405.6	1133.3	950.9	624.2	328.0	180.1	112.7	71.4	151.0	**696.3**
Hoh River at Outlet	2545.9	4652.8	5053.8	4630.3	3798.1	3257.6	2414.7	2391.2	2364.0	1972.4	1424.1	1290.0	**2982.9**
Ozette River at Outlet	72 1	207.3	557.4	882.0	959.5	842.6	748.5	469.8	270.6	148.6	94.0	49.5	**441.8**
Sol Duc/Quillayute at Outlet	3864.3	8102.4	9580.9	8951.2	7281.6	6223.2	4132.1	2757.7	1801.2	1146.8	726.9	1082.6	**4637.6**
Sooes River at Outlet	71 1	239.3	477.9	538.6	513.1	422.5	358.4	237.9	142.0	73.6	60.3	37.3	**264.3**

Table 5-8b

BOR Altered Monthly Runoff (inches) [1]

River Represented	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Bogachiel River at sub-basin outlet, excluding Calawah River inflows	9.0	17.4	21.2	20.1	14 9	14.1	8.8	5.7	3.3	2.3	1.6	2.5	**120.8**
Calawah River at Outlet	8.2	16.2	19.8	18.6	13.8	13.2	8.1	4.9	2.8	1.8	1.3	2.0	**110.7**
Dickey River at Outlet	6.5	13.7	16.2	15.2	11 1	10.3	6.5	3.6	1.9	1.2	0.8	1.6	**88.6**
Hoh River at Outlet	9.8	17.4	19.5	17.9	13 3	12.6	9.0	9.2	8.8	7.6	5.5	4.8	**135.6**
Ozette River at Outlet	0.8	2.3	6.4	10.1	9.9	9.6	8.3	5.4	3.0	1.7	1.1	0.5	**59.1**
Sol Duc River at sub-basin outlet, excluding Calawah, Bogachiel and Dickey	5.5	11.7	14.6	13.4	9.7	9.2	6.3	5.4	4.0	2.6	1.5	1.7	**85.4**
Sooes River at Outlet	1.7	5.4	11.1	12.5	10.8	9.8	8.1	5.5	3.2	1.7	1.4	0.8	**72.0**

1. Altered indicates that a influents rivers flow is removed from the receiving rivers flow in order to facilitate a water balance for each sub-basin.
2. Calawah flows removed from Bogachiel River flow for sub-basin water balance.
3. Calawah, Bogachiel and Dickey flows removed from Sol Duc flow for Sol Duc sub-basin water balance.

BoR - Bureau of Reclamation

PRISM Annual and Monthly Temperature

SUB-BASIN NAME	Precipitation Zone	MEAN MONTHLY TEMPERATURE (°C) O	N	D	J	F	M	A	M	J	J	A	S	Mean Annual Temp (°C)
Bogachiel	rain	10.4	6.1	3.8	3.6	5.1	6.1	8.2	11.1	13.8	16.0	16.5	14.5	9.6
	ros	9.5	4.5	2.8	2.4	3.7	5.1	7.1	10.6	12.8	15.9	16.6	14.6	8.8
	snow	9.1	4.0	2.4	2.0	3.2	4.6	6.5	10.1	12.3	15.5	16.3	14.4	8.4
	SUB-BASIN AVERAGE	**10.1**	**5.5**	**3.5**	**3.2**	**4.6**	**5.8**	**7.8**	**10.9**	**13.4**	**15.9**	**16.5**	**14.5**	**9.3**
Calawah	rain	10.3	5.8	3.6	3.3	4.8	5.9	8.1	11.2	13.9	16.1	16.6	14.5	9.5
	ros	10.0	5.1	3.1	2.8	4.1	5.5	7.5	10.6	13.3	15.8	16.4	14.5	9.1
	snow	10.4	5.5	3.6	3.2	4.6	6.0	8.1	11.2	13.8	16.3	17.0	15.0	9.5
	SUB-BASIN AVERAGE	**10.2**	**5.6**	**3.4**	**3.2**	**4.6**	**5.8**	**7.9**	**11.0**	**13.7**	**16.0**	**16.5**	**14.5**	**9.4**
Dickey	rain	11.0	6.7	4.3	4.2	5.8	6.7	8.7	11.2	13.8	15.8	16.3	14.6	9.9
	ros	11.3	6.4	3.8	3.9	5.6	7.0	8.9	11.3	13.9	16.1	16.7	14.8	10.0
	snow[2]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	SUB-BASIN AVERAGE	**11.0**	**6.7**	**4.3**	**4.2**	**5.8**	**6.7**	**8.7**	**11.2**	**13.8**	**15.8**	**16.3**	**14.6**	**9.9**
Hoh	rain	10.1	5.5	3.4	3.1	4.6	5.8	7.8	10.9	13.4	15.9	16.5	14.5	9.3
	ros	8.7	3.7	2.1	1.7	2.9	4.2	6.1	9.8	12.0	15.2	15.9	14.0	8.0
	snow	7.1	1.8	0.3	0.1	1.2	2.2	4.0	8.0	10.1	13.7	14.3	12.7	6.3
	SUB-BASIN AVERAGE	**8.9**	**4.0**	**2.3**	**1.9**	**3.2**	**4.4**	**6.3**	**9.8**	**12.2**	**15.1**	**15.7**	**13.8**	**8.2**
Ozette	rain	10.7	6.7	4.5	4.2	5.7	6.5	8.3	10.8	13.3	15.2	15.6	14.1	9.6
	ros	10.7	6.3	3.7	3.9	5.5	6.7	8.3	11.0	13.6	15.7	16.2	14.5	9.7
	snow[2]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	SUB-BASIN AVERAGE	**10.7**	**6.7**	**4.5**	**4.2**	**5.7**	**6.5**	**8.3**	**10.8**	**13.3**	**15.2**	**15.6**	**14.1**	**9.6**
Sol Duc	rain	10.2	5.8	3.6	3.4	4.8	6.0	7.9	10.8	13.5	15.7	16.2	14.3	9.3
	ros	8.8	3.5	1.9	1.7	2.5	4.1	6.0	9.2	11.8	14.7	15.4	13.6	7.8
	snow	7.6	2.1	0.5	0.5	1.3	2.6	4.5	8.2	10.8	14.1	14.6	12.9	6.6
	SUB-BASIN AVERAGE	**9.4**	**4.6**	**2.6**	**2.4**	**3.6**	**4.9**	**6.8**	**10.0**	**12.6**	**15.2**	**15.7**	**13.8**	**8.5**
Sooes	rain	10.8	6.5	4.9	4.0	5.6	6.6	8.5	10.7	13.3	15.2	15.7	14.1	9.7
	ros	10.8	6.1	3.4	3.8	5.4	6.9	8.1	10.9	13.5	15.8	16.4	14.5	9.6
	snow[2]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	SUB-BASIN AVERAGE	**10.8**	**6.5**	**4.9**	**4.0**	**5.6**	**6.6**	**8.5**	**10.7**	**13.3**	**15.2**	**15.7**	**14.1**	**9.7**

Notes

1. Monthly precipitation for each sub-basin was derived by averaging (using areally weighted averages) mean monthly PRISM data for the state of Washington. Source: Daly, Chris, "Washington Average Monthly or Annual Precipitation, 1961-90", Oregon Climate Service at Oregon State University.

2. Snow zones do not exist in this sub-basin

PRISM - Parameter-elevation Regressions on Independent Slopes Model

TABLE 5-10a

Monthly Domestic Water Use (AF/Month)

Sub-Basin	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Bogachiel	18.9	14.2	14.8	14.2	14.6	15.3	13.7	13.5	15.1	17.1	15.6	20.0	**186.9**
Calawah	51.5	38.7	40.4	38.7	39.8	41.7	37.3	36.7	41.2	46.6	42.7	54.6	**509.9**
Dickey	1.5	1.1	1.1	1.1	1.1	1.2	1.1	1.0	1.2	1.3	1.2	1.5	**14.4**
Hoh	3.2	2.4	2.5	2.4	2.5	2.6	2.3	2.3	2.6	2.9	2.7	3.4	**31.8**
Ozette	1.1	0.8	0.9	0.8	0.8	0.9	0.8	0.8	0.9	1.0	0.9	1.2	**10.7**
Sol Duc[1]	32.1	26.4	28.6	29.4	29.1	30.7	27.2	27.6	29.2	33.2	29.8	34.3	**357.6**
Sooes	0.9	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.7	0.8	0.7	0.9	**8.9**
Total	**109.1**	**84.2**	**89.0**	**87.3**	**88.6**	**93.1**	**83.0**	**82.6**	**90.9**	**102.8**	**93.7**	**116.0**	**1120.2**

[1]Includes Quileute Monthly Water Use

TABLE 5-10b

Monthly Agricultural Water Use (AF/Month)

Sub-Basin	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Bogachiel	8.02	0.00	0.00	0.00	0.00	0.00	8.02	16.03	16.03	16.03	16.03	16.03	**96.2**
Calawah	10.66	0.00	0.00	0.00	0.00	0.00	10.66	21.32	21.32	21.32	21.32	21.32	**127.9**
Dickey	6.13	0.00	0.00	0.00	0.00	0.00	6.13	12.26	12.26	12.26	12.26	12.26	**73.5**
Hoh	4.44	0.00	0.00	0.00	0.00	0.00	4.44	8.87	8.87	8.87	8.87	8.87	**53.2**
Ozette	1.72	0.00	0.00	0.00	0.00	0.00	1.72	3.44	3.44	3.44	3.44	3.44	**20.7**
Sol Duc	8.38	0.00	0.00	0.00	0.00	0.00	8.38	16.76	16.76	16.76	16.76	16.76	**100.6**
Sooes	0.10	0.00	0.00	0.00	0.00	0.00	0.10	0.21	0.21	0.21	0.21	0.21	**1.3**
TOTAL	39.4	0.0	0.0	0.0	0.0	0.0	39.4	78.9	78.9	78.9	78.9	78.9	**473.4**

TABLE 5-10c

Total Monthly Water Use (AF/Month)

Sub-Basin	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Bogachiel	26.9	14.2	14.8	14.2	14.6	15.3	21.7	29.5	31.2	33.1	31.7	36.1	**283.1**
Calawah	62.2	38.7	40.4	38.7	39.8	41.7	48.0	58.0	62.6	67.9	64.0	76.0	**637.8**
Dickey	7.6	1.1	1.1	1.1	1.1	1.2	7.2	13.3	13.4	13.6	13.5	13.8	**87.9**
Hoh	7.7	2.4	2.5	2.4	2.5	2.6	6.8	11.2	11.4	11.8	11.5	12.3	**85.1**
Ozette	2.8	0.8	0.9	0.8	0.8	0.9	2.5	4.2	4.3	4.4	4.3	4.6	**31.4**
Sol Duc[1]	40.5	26.4	28.6	29.4	29.1	30.7	35.6	44.4	45.9	49.9	46.6	51.1	**458.1**
Sooes	1.0	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.9	1.0	1.0	1.2	**10.1**
TOTAL	**148.6**	**84.2**	**89.0**	**87.3**	**88.6**	**93.1**	**122.5**	**161.5**	**169.8**	**181.7**	**172.6**	**194.9**	**1593.6**

[1]Includes Quileute Monthly Water Use

TABLE 5-11

Summary of Annual and Monthly Actual Evapotranspiration (AET)

Sub-Basin Name	Monthly AET (inches)												Annual AET (inches)
	October	November	December	January	February	March	April	May	June	July	August	September	
Bogachiel	0.97	0.43	0.25	0.23	0.33	0.63	1.01	1.66	2.13	2.60	2.47	1.73	**14.44**
Calawah	0.77	0.34	0.20	0.18	0.26	0.50	0.80	1.31	1.70	2.05	1.95	1.35	**11.40**
Dickey	1.77	0.81	0.47	0.44	0.64	1.18	1.87	2.85	3.69	4.34	4.10	2.94	**25.09**
Hoh	0.95	0.39	0.23	0.21	0.31	0.59	0.95	1.66	2.11	2.69	2.58	1.81	**14.49**
Ozette	3.42	1.63	0.96	0.88	1.27	2.30	3.60	5.53	7.12	8.30	7.83	5.64	**48.48**
Sol Duc	1.70	0.71	0.42	0.38	0.54	1.06	1.72	2.87	3.76	4.63	4.40	3.10	**25.30**
Sooes	2.70	1.24	0.80	0.66	0.98	1.81	2.84	4.29	5.54	6.48	6.14	4.40	**37.88**

Table 5-12

Comparison of Monthly Actual Evapotranspiration Using Three Methods

Method	Monthly PET (inches)												Total Annual
	October	November	December	January	February	March	April	May	June	July	August	September	
Estimated using Blaney-Criddle Method [1]	1.66	0.74	0.44	0.40	0.58	1.08	1.72	2.76	3.56	4.29	4.08	2.88	24.18
Estimated using measured Evapotranspiration data of Doug Fir and Spruce [2]	1.74	2.24	0.34	0.34	0.34	0.34	2.02	2.64	2.89	2.52	3.14	2.31	20.87
Monthly Pan Evaporation [3]	1.80	1.60	1.20	1.60	1.60	2.10	2.50	3.20	3.40	3.00	2.50	2.30	26.80

Notes
1 Method Used for WRIA 20 Water Balance.
2 Evapotranspiration data reported for Douglas Fir in Waring and Schlesinger, 1985 and for Spruce in USDA Forest Service, 1985
3 Pan Evaporation data reported at the Tatoosh Island WB (458322) gaging station.
Reported numbers are estimated totals computed from meteorological measurements using a form of the Penman equation.

Table 5-13

Annual Water Balance for WRIA 20

Sub-Basin Name	Area	Total Precipitation		Observed Run-off [1]		Irrigated Net Use		Domestic Net Use		Non-Irrigated ET	
	(acres)	acre-ft	cfs	acre-ft	cfs	acre-ft	cfs	acre-ft	cfs	acre-ft	cfs
Bogachiel	97,847	1,102,546	1,523	984,803	1,360	96	0.13	187	0.26	117,743	163
Calawah	87,034	884,958	1,222	802,283	1,108	128	0.18	510	0.70	82,675	114
Dickey	68,072	644,776	891	502,438	694	74	0.10	14	0.02	142,338	197
Hoh	190,944	2,387,535	3,298	2,156,993	2,979	53	0.07	32	0.04	230,542	318
Ozette	64,766	579,284	800	317,592	439	21	0.03	11	0.01	261,691	361
Sol Duc	149,511	1,372,768	1,896	1,057,533	1,461	101	0.14	358	0.49	315,235	435
Sooes	31,693	290,474	401	190,424	263	1	0.00	9	0.01	100,050	138
Total	689,867	7,262,342	10,031	6,012,067	8,304	473	1	1,120	2	1,250,275	1,589
Annual Percent of total precipitation input				82.78%		0.01%		0.02%		17.22%	

Notes

[1] Bureau of Reclamation, 2004

Naturalized streamflows with estimated water use volumes subtracted

Table 5-14 [5]

Bogachiel Sub-Basin Monthly Water Balance

Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Precip.	13.02	18.52	22.04	19.52	16.38	14.70	9.38	6.12	3.83	2.86	3.02	5.82	135.22
Cum. Precip.	13.02	31.54	53.58	73.10	89.49	104.18	113.57	119.69	123.52	126.38	129.40	135.22	
Snow Accum. SWE [4]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rainfall + Melt	13.02	18.52	22.04	19.52	16.38	14.70	9.38	6.12	3.83	2.86	3.02	5.82	135.22
Irrigated Net Use	0.0010	0.0000	0.0000	0.0000	0.0000	0.0000	0.0010	0.0020	0.0020	0.0020	0.0020	0.0020	0.0118
Domestic Net Use	0.0023	0.0017	0.0018	0.0017	0.0018	0.0019	0.0017	0.0017	0.0019	0.0021	0.0019	0.0025	0.0229
Observed Run-off [1]	8.99	17.44	21.24	20.06	14.87	14.05	8.79	5.69	3.31	2.28	1.59	2.46	120.78
Actual ET	0.97	0.43	0.25	0.23	0.33	0.63	1.01	1.66	2.13	2.60	2.47	1.73	14.44
Predicted Runoff [2]	12.05	18.09	21.79	19.29	16.05	14.07	8.37	4.46	1.70	0.26	0.54	4.08	120.74
Net Residual [3]	-3.06	-0.65	-0.54	0.77	-1.18	-0.02	0.42	1.23	1.61	2.02	1.05	-1.62	0.03

Notes

1 Observed run-off is based on naturalized streamflow records developed by the BOR and adjusted for current monthly water use.
2 Predicted Runoff represents water available for run-off from precipitation after accounting for water released from snow pack, evapotranspiration and consumptive water use.
3 Uncorrected residual is calculated as the difference between Observed and Predicted run-off. Negative number indicates surface water recharge to groundwater; positive number indicates groundwater discharge to surface water.
4 The value reported as total Snow Accumulated as SWE is the maximum inches of snow that acccumulated over the year.
5 All units are inches.

Table 5-15 [5]

Calawah Sub-Basin Monthly Water Balance

Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Precip.	11.84	17.39	19.44	17.26	14.95	13.16	8.44	5.58	3.39	2.62	2.69	5.24	122.02
Cum. Precip.	11.84	29.23	48.67	65.94	80.89	94.05	102.49	108.07	111.46	114.08	116.77	122.02	
Snow Accum. SWE [4]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rainfall + Melt	11.84	17.39	19.44	17.26	14.95	13.16	8.44	5.58	3.39	2.62	2.69	5.24	122.02
Irrigated Net Use	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0029	0.0029	0.0029	0.0029	0.0029	0.0176
Domestic Net Use	0.0071	0.0053	0.0056	0.0053	0.0055	0.0058	0.0051	0.0051	0.0057	0.0064	0.0059	0.0075	0.0703
Observed Run-off [1]	8.17	16.15	19.80	18.57	13.81	13.22	8.11	4.94	2.75	1.82	1.25	2.04	110.62
Actual ET	0.77	0.34	0.20	0.18	0.26	0.50	0.80	1.31	1.70	2.05	1.95	1.35	11.40
Predicted Runoff [2]	11.06	17.05	19.24	17.08	14.69	12.66	7.63	4.26	1.68	0.57	0.74	3.88	110.53
Net Residual [3]	-2.89	-0.90	0.56	1.49	-0.88	0.56	0.48	0.68	1.07	1.25	0.51	-1.84	0.09

Notes

1 Observed run-off is based on naturalized streamflow records developed by the BOR and adjusted for current monthly water use.

2 Predicted Runoff represents water available for run-off from precipitation after accounting for water released from snow pack, evapotranspiration and consumptive water use.

3 Uncorrected residual is calculated as the difference between Observed and Predicted run-off. Negative number indicates surface water recharge to groundwater; positive number indicates groundwater discharge to surface water.

4 The value reported as total Snow Accumulated as SWE is the maximum inches of snow that acccumulated over the year.

5 All units are inches.

Table 5-16 [5]

Dickey Sub-Basin Monthly Water Balance

Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Precip.	11.10	16.01	17.47	15.93	13.86	12.42	7.97	5.58	3.20	2.61	2.60	4.94	113.66
Cum. Precip.	11.10	27.11	44.57	60.50	74.36	86.78	94.75	100.32	103.52	106.13	108.73	113.66	
Snow Accum. SWE [4]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rainfall + Melt	11.10	16.01	17.47	15.93	13.86	12.42	7.97	5.58	3.20	2.61	2.60	4.94	113.66
Irrigated Net Use	0.0011	0.0000	0.0000	0.0000	0.0000	0.0000	0.0011	0.0022	0.0022	0.0022	0.0022	0.0022	0.0130
Domestic Net Use	0.0003	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0003	0.0025
Observed Run-off [1]	6.46	13.74	16.17	15.24	11.10	10.31	6.55	3.55	1.89	1.22	0.77	1.58	88.57
Actual ET	1.77	0.81	0.47	0.44	0.64	1.18	1.86	2.85	3.69	4.34	4.10	2.94	25.09
Predicted Runoff [2]	9.33	15.20	16.99	15.49	13.22	11.24	6.10	2.72	-0.50	-1.73	-1.50	2.00	88.56
Net Residual [3]	-2.87	-1.46	-0.82	-0.25	-2.13	-0.93	0.45	0.83	2.39	2.95	2.27	-0.42	0.02

Notes

1 Observed run-off is based on naturalized streamflow records developed by the BOR and adjusted for current monthly water use.

2 Predicted Runoff represents water available for run-off from precipitation after accounting for water released from snow pack, evapotranspiration and consumptive water use.

3 Uncorrected residual is calculated as the difference between Observed and Predicted run-off. Negative number indicates surface water recharge to groundwater; positive number indicates groundwater discharge to surface water.

4 The value reported as total Snow Accumulated as SWE is the maximum inches of snow that acccumulated over the year.

5 All units are inches.

Table 5-17 [5]

Hoh Sub-Basin Monthly Water Balance

Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Precip.	14.17	20.54	25.33	21.74	18.42	16.04	10.33	6.50	4.30	2.89	3.37	6.43	150.05
Cum. Precip.	14.17	34.70	60.04	81.78	100.20	116.24	126.57	133.06	137.36	140.25	143.62	150.05	
Snow Accum. SWE [4]	0.00	0.00	7.72	14.26	19.80	19.65	18.99	17.20	14.83	11.45	7.92	4.83	19.80
Rainfall + Melt	19.00	20.54	17.62	15.19	12.88	16.19	10.99	8.28	6.67	6.27	6.90	9.51	150.05
Irrigated Net Use	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0006	0.0006	0.0006	0.0006	0.0006	0.0033
Domestic Net Use	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0002	0.0002	0.0002	0.0002	0.0020
Observed Run-off [1]	9.84	17.40	19.53	17.89	13.26	12.59	9.03	9.24	8.84	7.62	5.50	4.82	135.56
Actual ET	0.95	0.39	0.23	0.21	0.31	0.59	0.96	1.66	2.11	2.69	2.58	1.81	14.49
Predicted Runoff [2]	18.05	20.15	17.38	14.98	12.57	15.61	10.04	6.62	4.55	3.58	4.32	7.70	135.55
Net Residual [3]	-8.21	-2.75	2.15	2.91	0.68	-3.02	-1.01	2.62	4.29	4.04	1.18	-2.88	0.01

Notes

1 Observed run-off is based on naturalized streamflow records developed by the BOR and adjusted for current monthly water use.

2 Predicted Runoff represents water available for run-off from precipitation after accounting for water released from snow pack, evapotranspiration and consumptive water use.

3 Uncorrected residual is calculated as the difference between Observed and Predicted run-off. Negative number indicates surface water recharge to groundwater; positive number indicates groundwater discharge to surface water.

4 The value reported as total Snow Accumulated as SWE is the maximum inches of snow that acccumulated over the year.

5 All units are inches.

Table 5-18 [5]

Ozette Sub-Basin Monthly Water Balance

Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Precip.	10.65	15.04	16.33	15.45	12.65	11.51	7.47	5.14	3.16	2.59	2.57	4.76	107.33
Cum. Precip.	10.65	25.69	42.02	57.47	70.12	81.63	89.10	94.25	97.41	100.00	102.57	107.33	
Snow Accum. SWE [4]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rainfall + Melt	10.65	15.04	16.33	15.45	12.65	11.51	7.47	5.14	3.16	2.59	2.57	4.76	107.33
Irrigated Net Use	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0006	0.0006	0.0006	0.0006	0.0006	0.0038
Domestic Net Use	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0002	0.0002	0.0002	0.0002	0.0020
Observed Run-off [1]	0.79	2.29	6.35	10.05	9.87	9.60	8.25	5.35	2.98	1.69	1.07	0.54	58.84
Actual ET	3.42	1.63	0.96	0.88	1.27	2.30	3.60	5.53	7.12	8.30	7.83	5.64	48.49
Predicted Runoff [2]	7.23	13.41	15.37	14.57	11.38	9.21	3.87	-0.38	-3.96	-5.71	-5.26	-0.88	58.84
Net Residual [3]	-6.43	-11.12	-9.02	-4.52	-1.51	0.39	4.38	5.74	6.94	7.41	6.33	1.42	0.01

Notes

1 Observed run-off is based on naturalized streamflow records developed by the BOR and adjusted for current monthly water use.
2 Predicted Runoff represents water available for run-off from precipitation after accounting for water released from snow pack, evapotranspiration and consumptive water use.
3 Uncorrected residual is calculated as the difference between Observed and Predicted run-off. Negative number indicates surface water recharge to groundwater; positive number indicates groundwater discharge to surface water.
4 The value reported as total Snow Accumulated as SWE is the maximum inches of snow that acccumulated over the year.
5 All units are inches.

Table 5-19 [5]

Sol Duc Sub-Basin Monthly Water Balance

Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Precip.	10.77	16.06	17.53	15.77	13.48	11.81	7.40	4.90	3.00	2.26	2.47	4.72	110.18
Cum. Precip.	10.77	26.83	44.36	60.13	73.61	85.43	92.83	97.73	100.73	102.99	105.46	110.18	
Snow Accum. SWE [4]	0.00	0.00	3.65	6.87	9.51	9.32	8.77	7.51	5.77	3.39	0.93	0.00	9.51
Rainfall + Melt	10.77	16.06	13.89	12.55	10.84	12.01	7.95	6.16	4.75	4.63	4.94	5.65	110.18
BOR Naturalized Run-Off [1]	5.48	11.63	14.49	13.30	9.63	9.12	6.27	5.38	3.97	2.54	1.46	1.64	84.92
Maybe add a USGS flow row if data is close to outlet???													
Irrigated Net Use	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0013	0.0013	0.0013	0.0013	0.0013	0.0081
Domestic Net Use	0.0026	0.0021	0.0023	0.0024	0.0023	0.0025	0.0022	0.0022	0.0023	0.0027	0.0024	0.0028	0.0287
Observed Run-off [1]	5.48	11.62	14.48	13.30	9.63	9.12	6.27	5.38	3.96	2.54	1.45	1.64	84.88
Actual ET	1.70	0.71	0.42	0.38	0.54	1.06	1.72	2.87	3.76	4.63	4.40	3.10	25.30
Predicted Runoff [2]	9.06	15.35	13.47	12.16	10.29	10.94	6.23	3.28	0.99	0.00	0.53	2.55	84.84
Net Residual [3]	-3.58	-3.73	1.02	1.14	-0.66	-1.82	0.05	2.09	2.98	2.54	0.92	-0.91	0.04

Notes

1 Observed run-off is based on naturalized streamflow records developed by the BOR and adjusted for current monthly water use.

2 Predicted Runoff represents water available for run-off from precipitation after accounting for water released from snow pack, evapotranspiration and consumptive water use.

3 Uncorrected residual is calculated as the difference between Observed and Predicted run-off. Negative number indicates surface water recharge to groundwater; positive number indicates groundwater discharge to surface water.

4 The value reported as total Snow Accumulated as SWE is the maximum inches of snow that acccumulated over the year.

5 All units are inches.

Table 5-20 [5]

Sooes Sub-Basin Monthly Water Balance

Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Precip.	10.86	15.42	17.02	17.14	12.92	11.43	7.53	4.78	3.17	2.49	2.58	4.63	109.98
Cum. Precip.	10.86	26.28	43.30	60.45	73.37	84.80	92.33	97.11	100.28	102.78	105.35	109.98	
Snow Accum. SWE [4]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rainfall + Melt	10.86	15.42	17.02	17.14	12.92	11.43	7.53	4.78	3.17	2.49	2.58	4.63	109.98
Irrigated Net Use	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0005
Domestic Net Use	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002	0.0002	0.0003	0.0003	0.0003	0.0004	0.0034
Observed Run-off [1]	1.65	5.39	11.13	12.54	10.79	9.84	8.07	5.54	3.20	1.71	1.40	0.84	72.10
Actual ET	2.70	1.24	0.80	0.66	0.98	1.81	2.84	4.29	5.54	6.48	6.14	4.40	37.88
Predicted Runoff [2]	8.16	14.18	16.23	16.48	11.94	9.62	4.68	0.49	-2.37	-3.98	-3.57	0.23	72.10
Net Residual [3]	-6.51	-8.79	-5.10	-3.94	-1.16	0.22	3.39	5.05	5.57	5.70	4.97	0.61	0.00

Notes

1 Observed run-off is based on naturalized streamflow records developed by the BOR and adjusted for current monthly water use.
2 Predicted Runoff represents water available for run-off from precipitation after accounting for water released from snow pack, evapotranspiration and consumptive water use.
3 Uncorrected residual is calculated as the difference between Observed and Predicted run-off. Negative number indicates surface water recharge to groundwater; positive number indicates groundwater discharge to surface water.
4 The value reported as total Snow Accumulated as SWE is the maximum inches of snow that acccumulated over the year.
5 All units are inches.

Precip = PRISM Precip
Snow Accum = Water in snow in any one month
Rainfall + melt = expected run-off from snowmelt module
BOR naturalized run-off

TABLE 6-1

NLCD Land Cover in Acres by Sub-Basin [a]

Type/Acres	Bogachiel	Calawah	Dickey	Hoh	Ozette	Pacific Sum	Sol Duc	Sooes	Total WRIA 20
Water	687	104	633	6,968	7,627	150	1,400	89	17,658
Residential/Commercial	304	334	89	32	1	28	573	11	1,370
Barren (No Transitional)	556	350	89	8,664	12	67	1,420	46	11,205
Transitional	4,140	3,946	8,544	9,740	2,885	6,341	7,247	1,172	44,015
Forested Upland	90,668	81,533	56,553	157,582	52,867	66,916	135,666	29,795	671,579
Shrubland	595	370	324	3,293	220	182	1,603	217	6,803
Grasslands/Herbaceous	288	65	264	2,660	131	180	540	153	4,282
Agriculture/Orchards	478	637	366	265	103	8	500	6	2,362
Wetlands	428	36	830	878	707	681	299	245	4,104
Total Sub-Basin	**98,144**	**87,375**	**67,692**	**190,082**	**64,553**	**74,553**	**149,248**	**31,734**	**763,378**

[a] Area calculations made from 30 meter resolution National Land Cover Data (NLCD) raster files. Total sub-basin areas vary in comparison to Table 5-5 sub-basin areas due to differing resolutions of data sources.

TABLE 6-2

NLCD Land Cover by Percent of Sub-Basin

Type	Bogachiel	Calawah	Dickey	Hoh	Ozette	Pacific Sum	Sol Duc	Sooes	Total WRIA 20
Water	0.7%	0.1%	0.9%	3.7%	11.8%	0.2%	0.9%	0.3%	2.3%
Residential/Commercial	0.3%	0.4%	0.1%	0.0%	0.0%	0.0%	0.4%	0.0%	0.2%
Barren (No Transitional)	0.6%	0.4%	0.1%	4.6%	0.0%	0.1%	1.0%	0.1%	1.5%
Transitional	4.2%	4.5%	12.6%	5.1%	4.5%	8.5%	4.9%	3.7%	5.8%
Forested Upland	92.4%	93.3%	83.5%	82.9%	81.9%	89.8%	90.9%	93.9%	88.0%
Shrubland	0.6%	0.4%	0.5%	1.7%	0.3%	0.2%	1.1%	0.7%	0.9%
Grasslands/Herbaceous	0.3%	0.1%	0.4%	1.4%	0.2%	0.2%	0.4%	0.5%	0.6%
Agriculture/Orchards	0.5%	0.7%	0.5%	0.1%	0.2%	0.0%	0.3%	0.0%	0.3%
Fallow	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Wetlands	0.4%	0.0%	1.2%	0.5%	1.1%	0.9%	0.2%	0.8%	0.5%
Total Percent	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

TABLE 6-3

Jefferson County Zoning in WRIA 20

Zone	Acres	Percent of WRIA 20
Commercial Forest-80	106,724.0	14.98%
National Park	79,627.7	11.17%
Rural Residential 1-20	2,0013.1	2.81%
Rural Residential 1-10	1,921.5	0.27%
Rural Forest-40	1,825.8	0.26%
Inholding Forest	1,395.6	0.20%
National Forest	803.0	0.11%
Hoh Tribal Reservation	400.5	0.06%
Forest Resource-Based Industrial	122.3	0.02%
Unknown	21.4	0.00%

TABLE 6-4

Clallam County Zoning in WRIA 20

Comprehensive Plan Code	Zoning Code	Zoning Description	Acres	Percent of WRIA 20
CF	CF	Commercial Forest	323,060.1	45.34%
ONP	ONP	Olympic National Park	127,613.9	17.91%
TRIBE	MAKAH	Makah Tribe	19,209.8	2.70%
LAKE	LAKE	Lake	7,916.4	1.11%
RL	RW5	Rural Low - Western Regional	7,246.2	1.02%
RM	RW2	Rural Moderate - Western Regional	2,879.2	0.40%
URL	URL	Urban Residential Low	2,056.7	0.29%
RC	WRC	Western Region Rural Center	1,697.2	0.24%
QR	QR	Quillayute Residential	1,153.0	0.16%
TRIBE	QUILEUTE	Quileute Tribe	949.2	0.13%
R	RW1	Rural - Western Regional	934.3	0.13%
RL	R5	Rural Low	789.5	0.11%
TRIBE	OZETTE	Ozette Tribe	744.6	0.10%
	F_R3	Moderate Density Residential	583.5	0.08%
	F_R1	Very Low Density Residential	410.5	0.06%
RVL	R20	Rural Very Low	348.0	0.05%
LD	LD	Urban Low Density	320.9	0.05%
	F_OL5		305.3	0.04%
TC	TC	Tourist Commercial	229.6	0.03%
M	M	Industrial	158.0	0.02%
UC	UC	Urban Center	148.8	0.02%
	F_R2	Low Density Residential	148.2	0.02%
	F_C2	Moderate Density Commercial	144.6	0.02%
	F_PL	Public Land (Public Buildings, Open Space)	131.6	0.02%
	F_C3	High Density Commercial	126.2	0.02%
	F_I	Industrial	108.7	0.02%
	F_IP	Industrial Park	107.2	0.02%
	F_OL6		60.3	0.01%
	F_OL4		35.9	0.01%
UNC	UNC	Urban Neighborhood Commercial	30.2	0.00%
	F_R4	High Density Residential	27.6	0.00%
	F_OL2		20.7	0.00%
P	P	Public Land	19.4	0.00%
	F_OL1		3.2	0.00%

Source: Clallam County, 2002

TABLE 7-1

Bogachiel Salmon and Steelhead Stocks and Status

Stock	SASSI (1992)	McHenry et al. (1996)
Summer Chinook	Unknown	Threatened
Fall Chinook	Healthy	Healthy
Fall coho	Healthy	Threatened
Summer steelhead	Unknown	Unknown
Winter steelhead	Healthy	Healthy

TABLE 7-2

Run and Spawn Times for Quillayute/Bogachiel Salmonids

Species	A	S	O	N	D	J	F	M	A	M	J	J
Summer Chinook	■	■	■									
Fall Chinook			■	■	■							
Summer Coho			■	■	■							
Fall Coho				■	■	■						
Fall Chum			■	■	■							
Summer Steelhead							■	■	■			
Winter Steelhead								■	■	■	■	

Source: SASSI, 1992, R. Lien personal communication, 2004.

TABLE 7-3

Run Times for Calawah Salmonids

Species	A	S	O	N	D	J	F	M	A	M	J	J
Summer Chinook	■	■	■									
Fall Chinook			■	■	■							
Fall Coho				■	■	■						
Fall Chum			■	■	■							
Summer Steelhead								■	■	■	■	
Winter Steelhead								■	■	■	■	

Source: SASSI, 1992, R. Lien, personal communication, 2004.

TABLE 7-4

Dickey Salmon and Steelhead Stocks and Status

Stock	Huntington et al. (1996)	SASSI (1992)	McHenry et al. (1996)
Dickey fall Chinook	Healthy	Healthy	Threatened
Dickey fall coho	Healthy	Healthy	Stable
Dickey winter steelhead	Healthy	Healthy	Threatened

TABLE 7-5

Run and Spawn Times for Dickey Salmonids

Species	A	S	O	N	D	J	F	M	A	M	J	J
Fall Chinook												
Fall Coho												
Fall Chum												
Winter Steelhead												

Source: SASSI, 1992, R. Lien personal communication, 2004.

TABLE 7-6

Hoh Salmon and Steelhead Stocks and Status

Stock	SASSI (1992)	McHenry et al. (1996)
Spring/summer chinook	Healthy	Stable
Fall Chinook	Healthy	Healthy
Fall chum	Long term decline	
Fall coho	Healthy	Healthy
Summer steelhead	Unknown	
Winter steelhead	Healthy	Stable

TABLE 7-7

Run and Spawn Times for Hoh Salmonids

Species	A	S	O	N	D	J	F	M	A	M	J	J
Spring/Summer Chinook												
Fall Chinook												
Coho												
Winter Steelhead												

Source: SASSI, 1992, J. Jorgenson, personal communication, 2004.
Run times are solid. Spawn times are cross-hatched.

TABLE 7-8

Ozette Salmon and Steelhead Stocks and Status

Stock	Nehlsen et al. (1991)	SASSI (1992)	McHenry et al. (1996)
Ozette fall Chinook	High risk of extinction	Extinct	Critical
Ozette fall chum	High risk of extinction	Unknown	Threatened
Ozette coho	Of special concern	Unknown	Threatened
Ozette sockeye	Moderate risk of extinction	Depressed	Critical
Ozette winter steelhead		Healthy	

TABLE 7-9

Run Times for Ozette Salmonids

Species	A	S	O	N	D	J	F	M	A	M	J	J
Fall Chum			■	■	■							
Coho			■	■	■	■						
Sockeye	░		▒	▒	▒	▒			░	░	░	░
Winter Steelhead							■	■	■	■	■	

Source: SASSI, 1992
Ozette sockeye hold in the lake before spawning. Run times are depicted by dotted cells. Spawning is depicted with cross-hatch.

TABLE 7-10

Contribution of Selected Sol Duc Watershed Salmonid Stocks to Total Natural Spawning Escapements in the Quillayute River Basin

Stock	Range of Contribution to Quillayute Escapement
Fall Chinook	50.0% - 68.5%
Summer Chinook	42.8% - 66.3%
Fall (winter) coho	37.5% - 68.3%
Sockeye	100%
Summer coho	100%
Winter steelhead	40.6% - 57.5%

Source: Quileute Natural Resources data as reviewed by Naughton and Parton , 1996

TABLE 7-11

Status of Select Anadromous Fish Stocks in the Sol Duc Watershed

		McHenry et al. (1996)	SASSI (WDF et al. 1992)	Huntington et al. 1994
Stock	**Production**	**Stock Status**	**Stock Status**	**Stock Health**
Chinook:				
Fall	Natural/hatchery*	Healthy	Healthy	Present
Spring	Native/hatchery		Healthy	Healthy
Summer	Natural	Threatened	Healthy	Healthy
Coho:				
Fall	Natural/hatchery	Stable	Healthy	Present
Summer	Natural/hatchery	Threatened	Healthy	(not recognized)
Steelhead:				
Winter	Natural	Stable	Healthy	(not recognized)
Summer	Natural		Unknown	Not present
Sockeye:				
Fall	Natural		Unknown	Not present
Chum:				
Fall	Natural		Unknown	Not present
Cutthroat:				
Sea-run	Natural			

*Hatchery production of fall chinook are currently considered insignificant at < 10,000 smolts/yr (Naughton and Parton, 1996).

TABLE 7-12

Run Times for Sol Duc Salmonids

Species	A	S	O	N	D	J	F	M	A	M	J	J
Spring Chinook	■	■										
Summer Chinook	■	■	■									
Fall Chinook			■	■	■							
Summer Coho			■	■	■							
Fall Coho				■	■	■						
Fall Chum			■	■	■							
Lake Pleasant Sockeye				■	■	■						
Summer Steelhead							■	■	■			
Winter Steelhead							■	■	■	■	■	

Source: SASSI, 1992, R. Lien, personal communication, 2004.

TABLE 7-13

Sooes/Waatch Salmon and Steelhead Stocks and Status

Stock	Nehlsen et al. (1991)	SASSI (1992)	McHenry et al. (1996)
Sooes fall Chinook		Unknown (hatchery produced)	
Sooes fall chum		Unknown	Critical
Sooes/Waatch coho		Unknown	Unknown
Sooes/Waatch winter steelhead		Unknown	

TABLE 7-14

Run and Spawn Times for Sooes Salmonids

Species	A	S	O	N	D	J	F	M	A	M	J	J
Fall Chinook	■	■	■	■								
Fall Chum				■								
Coho			■	■	■	■						
Hatchery Steelhead				■	■	■	■					
Wild Steelhead								■	■	■		

Source: SASSI 1992, A. Jensen, personal communication, 2004.

TABLE 9-1

Water Quality Excursions on the 1998 303(d) list in the Class AA Bogachiel Watershed

River	Listing Agency	Type of Exceedance	Number of Exceedances	Date
Bogachiel RM 15.7	Quileute Tribe	Temperature	5	1992 – 1995
Bogachiel RM 20	Quileute Tribe	Dissolved Oxygen	2	1992 – 1995
Bogachiel RM 8.7	Quileute Tribe	Temperature	2	1992 – 1995
Bogachiel RM 9	Quileute Tribe	Temperature	6	1992 – 1995
Bogachiel RM 12.6	Quileute Tribe	Temperature	2	1994 – 1995
Bogachiel RM 0	Quileute Tribe	Temperature	6	1994 – 1995
Bogachiel RM 9.8	Quileute Tribe	Temperature	4	1992 – 1995
Maxfield Creek	Quileute Tribe	Temperature	Numerous	1992

Source: Ecology, 1998

TABLE 9-2

Water Quality Excursions on the 1998 303(d) list in the Class AA North Fork Calawah Watershed

River	Listing Agency	Type of Exceedance	Number of Exceedances	Date
NF Calawah RM 2	Quileute Tribe	Temperature (natural conditions)	12	1995
Devils Creek	Quileute Tribe	Temperature (natural conditions)	5	1995
Fahnestock Creek	Quileute Tribe	Temperature (natural conditions)	3	1995

Source: Ecology, 1998

TABLE 9-3

Summary of Water Temperature Data in the South Fork Calawah and Sitkum Watersheds

Stream Name	Site (RM) Seg #	Date	Max Temp/ Date (C)	Total # Days Exceeding 16 C	# Days 16 – 18 C	# Days 18 – 21 C
Rainbow Creek	1.0, F2	7/96 – 9/96 7/97 – 9/97	17.5 7/5 7/27 15.6 8/14	11 0	11 0	0 0
Hyas Creek	0.2, B1	7/96 – 9/96 7/97 – 9/97	18 7/27 16.8 8/14	12 11	12 11	0 0
Sitkum River	0.2, D1	7/96 – 9/96 7/97 – 9/97	21.6 7/14 21.4 7/28	45 52	N/A 27	N/A 25
S.F. Calawah	16.3, 12	7/96 – 9/96 7/97 – 9/97	21.2 7/14 7/27 19.3 8/13	43 24	N/A 11	N/A 13
N.F. Sitkum	1.2, E2	7/96 – 9/96	18 7/28	14	14	0
Trib. 0221	0.3, D77	7/96 – 9/96	18.1 7/27	14	13	1
Lost Creek	0.1, C1	7/96 – 9/96 7/97 – 9/97	16.2 7/27 16.3 15 8/13	1 0	1 0	0 0

Source: DeCillis, 1998

TABLE 9-4

Summary of Dissolved Oxygen Data for South Fork Calawah and Sitkum Watersheds

Stream Name	Site Location (RM)	Date	D/O Average mg/L	# Days Below 9.5 mg/L	Range D/O (low/high)
Rainbow Creek	1.0	7/5 – 9/9/96	10.5	0	10.2-11.0
N.F. Sitkum	1.2	7/12 – 9/9/96	9.9	2	9.0-10.6
Trib. 0221	0.3	7/12 – 9/9/96	10.4	0	9.8-10.8
Lost Creek	0.1	7/9 – 9/6/96	10.6	0	10.3-10.9
Hyas Creek	0.2	7/6 – 9/9/96	10.5	0	9.9-10.8
Sitkum River	0.2	7/9 – 9/6/96	10.0	1	9.1-10.8
S.F. Calawah	16.3	7/9 – 9/6/96	10.3	0	9.7-10.7

Source: DeCillis, 1998

TABLE 9-5

Water Quality Excursions on the 1998 303(d) list in the Class A Dickey Watershed

River	Listing Agency	Type of Exceedance	Number of Exceedances	Date
Coal Creek T29N-R15W-S35	Quileute Tribe	Temperature	Numerous	6/23/92 – 9/28/92
Coal Creek T28N-R15W-S12	Quileute Tribe	Temperature	Numerous	6/23/92 – 9/28/92
E. Dickey T29N-R14W-S29	Quileute Tribe	Temperature	Numerous	7/19/90 – 9/20/90
E. Dickey T30N-R13W-S30	Quileute Tribe	Temperature	Numerous	7/19/90 – 9/20/90
Middle Dickey T30N-R14W-S23	Quileute Tribe	Temperature	2	7/24/91 – 7/30/91
Middle Dickey T29N-R15W-S35	Quileute Tribe	Temperature	2	7/24/91 – 7/30/91
W. Dickey T30N-R14W-S21	Quileute Tribe	Temperature	Numerous	7/19/90 – 10/14/91
W. Dickey T29N-R14W-S33	Quileute Tribe	Temperature	Numerous	7/19/90 – 10/14/91

Source: Ecology, 1998

TABLE 9-6

Water Quality Excursions on the 1998 303(d) list in the Class AA Hoh Watershed

River	Listing Agency	Type of Exceedance	Number of Exceedances	Date
Alder Creek	Hoh Tribe	Temperature	31	7/1/92 – 8/31/92
Anderson Creek	Hoh Tribe	Temperature	11	7/1/92 – 8/31/92
Canyon Creek	Hoh Tribe	Temperature	2	7/1/92 – 8/31/92
Fisher Creek	Hoh Tribe	Temperature	47	7/1/92 – 8/31/92
Line Creek	Hoh Tribe	Temperature	20	7/1/92 – 8/31/92
Maple Creek	Hoh Tribe	Temperature	9	7/1/92 – 8/31/92
Nolan Creek	Hoh Tribe	Temperature	49	7/1/92 – 8/31/92
Owl Creek	Hoh Tribe	Temperature	34	7/1/92 – 8/31/92
Rock Creek	Hoh Tribe	Temperature	30	7/1/92 – 8/31/92
Split Creek	Hoh Tribe	Temperature	54	7/1/92 – 8/31/92
Tower Creek	Hoh Tribe	Temperature	2	7/1/92 – 8/31/92
Willoughby Creek	Hoh Tribe	Temperature	16	7/1/92 – 8/31/92
Winfield Creek	Hoh Tribe	Temperature	44	7/1/92 – 8/31/92

Source: Ecology, 1998

TABLE 9-7

Water Quality Excursions on the 1998 303(d) list in the Class AA Sol Duc Watershed

River	Listing Agency	Type of Exceedance	Number of Exceedances	Date
Beaver Creek	Quileute Tribe	Temperature	44	1994
Elk Creek RM 1.8	Horrock and Lombard	Temperature	10	1994
Lake Creek RM 2.75	Quileute Tribe	Temperature	16	1992 – 1995
Lake Creek RM 2.75	Quileute Tribe	Dissolved Oxygen	8	1992 – 1995
Lake Creek RM 2	Quileute Tribe	Temperature	5	1994 – 1995
Lake Creek RM 2	Quileute Tribe	Dissolved Oxygen	7	1994 – 1995
Sol Duc RM 44.9	Quileute Tribe	Temperature	3	1992 – 1995
Sol Duc RM 23.75	Quileute Tribe	Temperature	2	1992 – 1995
Sol Duc RM 22.1	Quileute Tribe	Temperature	3	1992 – 1995
Sol Duc RM 13	Quileute Tribe	Temperature	3	1992 – 1995
Sol Duc RM 19	Quileute Tribe	Temperature	2	1992 – 1995
Sol Duc RM 6.5	Quileute Tribe	Temperature	4	1992 – 1995
Sol Duc – WDFW hatchery	WDFW	Temperature	Numerous	NA
Sol Duc RM 44.9	Quileute Tribe	Dissolved Oxygen	2	1992 – 1995
Sol Duc RM 22.1	Quileute Tribe	Dissolved Oxygen	2	1992 – 1995
Sol Duc RM 19	Quileute Tribe	Dissolved Oxygen	2	1992 – 1995

Source: Ecology, 1998

TABLE 9-8

Water Quality Excursions on the 1998 303(d) list in the Class AA Sooes/Waatch Watershed

River	Listing Agency	Type of Exceedance	Number of Exceedances	Date
Sooes River	Makah Tribe	Dissolved Oxygen	3	6/27/91, 7/24/91, 9/4/91
Sooes River	Makah Tribe	Temperature	1	7/24/91
Sooes River	Makah Tribe	Fecal Coliform	2	5/8/91, 6/14/91
Waatch River	Makah Tribe	Temperature	1	6/5/91
Waatch River	Makah Tribe	Dissolved Oxygen	1	7/5/91
Waatch River	Makah Tribe	pH	1	9/11/91
Educket River	Makah Tribe	pH	1	9/4/91
Educket River	Makah Tribe	Dissolved Oxygen	1	6/27/91

Source: Ecology, 1998

TABLE 9-9

Draft 2002/2004 Water Quality Assessment

Watershed Assessment Category	Category Definition	Parameter	# Segments Listed in WRIA 20
5	303(d) list	Dissolved oxygen	5
5	303(d) list	Fecal Coliform	1
5	303(d) list	pH	4
5	303(d) list	Temperature	41
4C	Impaired by nonpollutant	Bioassessment	3
4C	Impaired by nonpollutant	Fish Habitat	1
2	Waters of concern	Bioassessment	2
2	Waters of concern	Dissolved oxygen	29
2	Waters of concern	Fecal Coliform	2
2	Waters of concern	pH	15
2	Waters of concern	Temperature	18
2	Waters of concern	Total Phosphorus	1
1	Meets standards	Ammonia-N	3
1	Meets standards	Arsenic	2
1	Meets standards	Bioassessment	3
1	Meets standards	Dissolved oxygen	13
1	Meets standards	Fecal Coliform	4
1	Meets standards	pH	25
1	Meets standards	Temperature	29
1	Meets standards	Total Phosphorus	8

Source: Ecology, November 16, 2004

TABLE 9-10

Draft 2002/2004 Water Quality Assessment Listings in Bogachiel Sub-Basin

Bogachiel Sub-Basin			
Listing ID	**Category**	**Water Body**	**Parameter**
7695	2	Bogachiel River	Dissolved oxygen
7694	2	Bogachiel River	Dissolved oxygen
6901	2	Kahkwa Creek	Temperature
7696	5	Bogachiel River	Temperature
7693	5	Bogachiel River	Temperature
7697	5	Bogachiel River	Temperature
7701	5	Bogachiel River	Temperature
7698	5	Bogachiel River	Temperature
7699	5	Bogachiel River	Temperature
7700	5	Bogachiel River	Temperature
7718	5	Maxfield Creek	Temperature

Source: Ecology, November 16, 2004

TABLE 9-11

Draft 2002/2004 Water Quality Assessment Listings in Calawah Sub-Basin

Calawah Sub-Basin			
Listing ID	**Category**	**Water Body**	**Parameter**
7702	2	Calawah River, N.F.	Temperature
7706	2	Devils Creek	Temperature
42892	2	Elk Creek	Dissolved oxygen
35027	2	Sitkum River	Dissolved oxygen
7729	2	Upper Cool Creek	Temperature
35021	5	Calawah River, S.F.	Temperature
7713	5	Elk Creek	Temperature
35023	5	Sitkum River	Temperature
35026	5	Sitkum River	Temperature

Source: Ecology, November 16, 2004

TABLE 9-12

Draft 2002/2004 Water Quality Assessment Listings in Dickey Sub-Basin

Dickey Sub-Basin			
Listing ID	**Category**	**Water Body**	**Parameter**
10964	2	Dickey River	Dissolved oxygen
10962	2	Dickey River	pH
10963	2	Dickey River	Temperature
11536	2	Unnamed Creek	Dissolved oxygen
11537	2	Unnamed Creek	pH
16743	5	Dickey River	Fecal Coliform
7708	5	Dickey River, E.F.	Temperature
7707	5	Dickey River, E.F.	Temperature
7710	5	Dickey River, M.F.	Temperature
7709	5	Dickey River, M.F.	Temperature
7712	5	Dickey River, W.F.	Temperature
7711	5	Dickey River, W.F.	Temperature

Source: Ecology, November 16, 2004

TABLE 9-13

Draft 2002/2004 Water Quality Assessment Listings in Hoh Sub-Basin

Hoh Sub-Basin			
Listing ID	**Category**	**Water Body**	**Parameter**
42680	2	Hoh River	Fecal Coliform
6580	2	Hoh River	Temperature
6900	2	Unnamed Creek	Temperature
6759	2	West Twin Creek	pH
6895	5	Alder Creek	Temperature
6893	5	Anderson Creek	Temperature
6898	5	Fisher Creek	Temperature
6894	5	Line Creek	Temperature
6892	5	Maple Creek	Temperature
6897	5	Nolan Creek	Temperature
6890	5	Owl Creek	Temperature
6891	5	Split Creek	Temperature
6896	5	Winfield Creek	Temperature

Source: Ecology, November 16, 2004

TABLE 9-14

Draft 2002/2004 Water Quality Assessment Listings in Ozette Sub-Basin

Ozette Sub-Basin			
Listing ID	**Category**	**Water Body**	**Parameter**
11539	2	Big River	Dissolved oxygen
6742	2	Big River	Dissolved oxygen
42960	2	Big River	Dissolved oxygen
6762	2	Big River	Temperature
6743	2	Coal Creek	Dissolved oxygen
42873	2	Coal Creek	Dissolved oxygen
6744	2	Crooked Creek	Dissolved oxygen
6764	2	Crooked Creek	Temperature
6745	2	Ozette River	Dissolved oxygen
42945	2	Ozette River	Dissolved oxygen
5818	2	Ozette River	pH
6765	2	Ozette River	Temperature
11532	2	Quinn Creek	Temperature
22754	2	Seafield Lake	Total Phosphorus
14131	2	Siwash Creek	Dissolved oxygen
6746	2	Siwash Creek	Dissolved oxygen
42875	2	Siwash Creek	Dissolved oxygen
14130	2	Siwash Creek	pH
5821	2	Siwash Creek	pH
6752	2	South Creek	Dissolved oxygen
42929	2	South Creek	Dissolved oxygen
5828	2	South Creek	pH
6753	2	Umbrella Creek	Dissolved oxygen
42877	2	Umbrella Creek	Dissolved oxygen
6757	2	Umbrella Creek	pH
6761	2	Willoughby Creek	pH
6754	5	Big River	pH
5813	5	Coal Creek	pH
7703	5	Coal Creek	Temperature
7704	5	Coal Creek	Temperature
5815	5	Crooked Creek	pH
7705	5	Crooked Creek, N.F.	Temperature
6889	5	Willoughby Creek	Temperature
14113	4C	Ozette Lake	Fish Habitat

Source: Ecology, November 16, 2004

TABLE 9-15

Draft 2002/2004 Water Quality Assessment Listings in the Pacific 5 Sub-Basins

Pacific 5 Sub-Basins			
Listing ID	**Category**	**Water Body**	**Parameter**
42893	2	Cedar Creek	Dissolved oxygen
6756	2	Cedar Creek	pH
5816	2	Ellen Creek	pH
6899	2	Mosquito Creek	Temperature
5827	2	South Branch Ellen Creek	pH

Source: Ecology, November 16, 2004

TABLE 9-16

Draft 2002/2004 Water Quality Assessment Listings in Sol Duc Sub-Basin

Sol Duc Sub-Basin			
Listing ID	**Category**	**Water Body**	**Parameter**
40701	2	Bear Creek	Bioassessment
40702	2	Bear Creek	Bioassessment
42888	2	Bear Creek	Dissolved oxygen
42910	2	Camp Creek	Dissolved oxygen
42911	2	Camp Creek	Temperature
6755	2	Canyon Creek	pH
42846	2	Lake Creek	Dissolved oxygen
42847	2	Lake Creek	Fecal Coliform
21512	2	Lake Creek	Temperature
42848	2	Lake Creek	Temperature
6748	2	Soleduck River	Dissolved oxygen
7720	2	Soleduck River	Dissolved oxygen
7721	2	Soleduck River	Dissolved oxygen
7722	2	Soleduck River	Dissolved oxygen
6768	2	Soleduck River	Temperature
7719	2	Soleduck River	Temperature
35031	2	Soleduck River, S.F.	Temperature
6758	2	Unnamed Creek	pH
42889	5	Bear Creek	Dissolved oxygen
7692	5	Beaver Creek	Temperature
7715	5	Lake Creek	Dissolved oxygen
7716	5	Lake Creek	Dissolved oxygen
42844	5	Lake Creek	Dissolved oxygen
42845	5	Lake Creek	Dissolved oxygen
7714	5	Lake Creek	Temperature
7717	5	Lake Creek	Temperature
42849	5	Lake Creek	Temperature
5824	5	Soleduck River	pH
7728	5	Soleduck River	Temperature
7724	5	Soleduck River	Temperature
7725	5	Soleduck River	Temperature
7727	5	Soleduck River	Temperature
7723	5	Soleduck River	Temperature
7726	5	Soleduck River	Temperature
42887	4C	Bear Creek	Bioassessment
40704	4C	Lake Creek	Bioassessment
42843	4C	Lake Creek	Bioassessment

Source: Ecology, November 16, 2004

TABLE 9-17

Draft 2002/2004 Water Quality Assessment Listings in Sooes Sub-Basin

Sooes Sub-Basin			
Listing ID	**Category**	**Water Body**	**Parameter**
5819	2	Petroleum Creek	pH

Source: Ecology, November 16, 2004

Comparison of Water Rights versus Water Use Quantities

Purpose of Use	Water Rights (AF/yr)	Water Rights (cfs)	Water Use (AF/yr) [a]	Water Use (cfs) [a]
Commercial-Industrial	360	0.5	Not quantified	Not quantified
Domestic [b]	440	0.61	Not available	Not available
Irrigation [b]	1,427	2	473	0.65
Municipal [c]	1,182	1.6	735	1.01
Exempt Wells [d]	5,797	8	386	0.53
Other [b]	5	0.007	0.038	0.00005
TOTAL	**9,211**	**12.7**	**1,594** [a]	**2.2** [a]

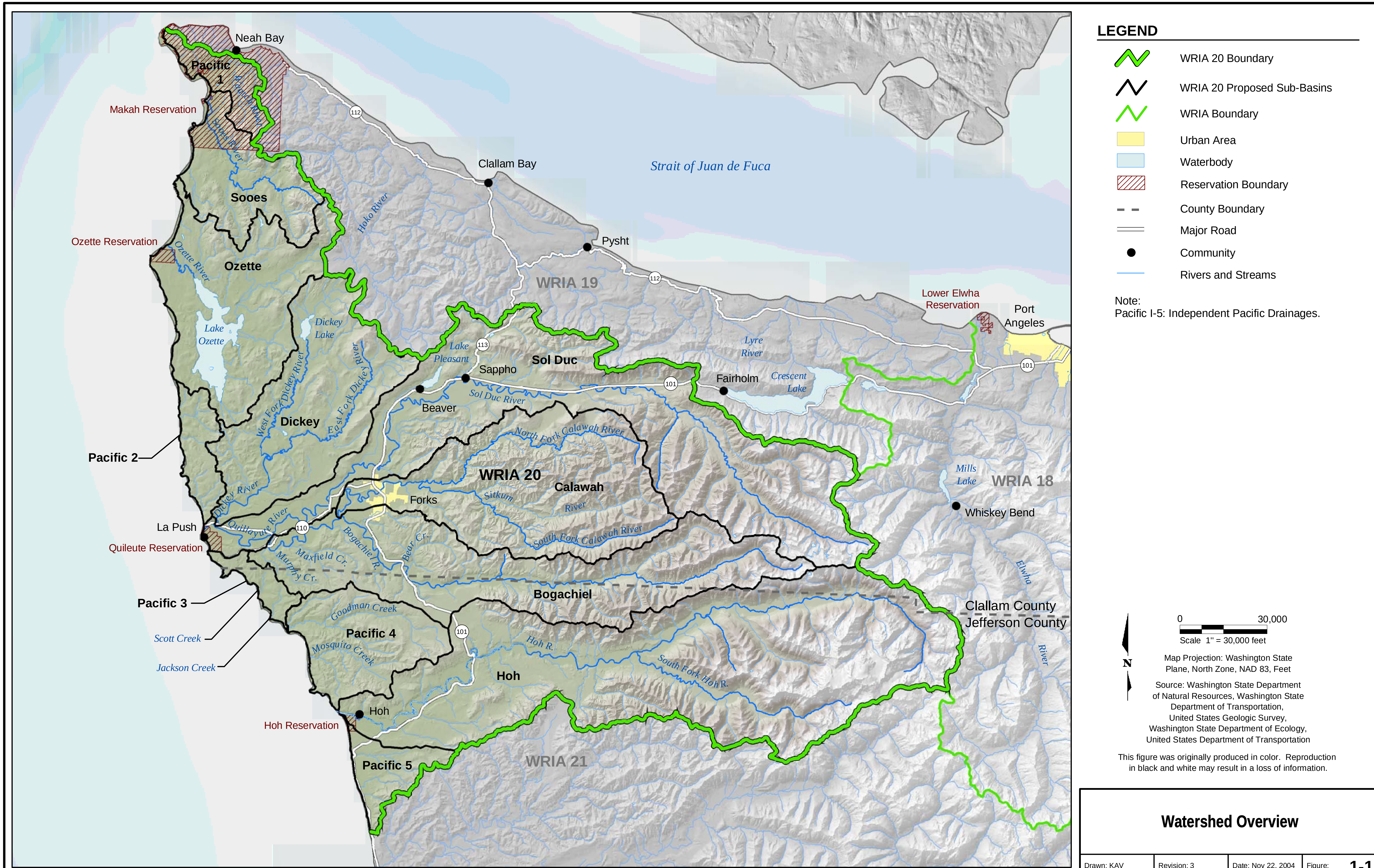
[a] Assumes no stock watering uses.

[b] Water rights include several purposes of use, including stock watering.

[c] Includes the Quileute Tribal supply with an Ecology Water Right, other Quileute water use and water use by Makah and Hoh tribes not quantified.

[d] Water rights value based on 5,000 gpd allocated for each exempt well assumed to exist within WRIA.. Water use value based on population and City of Forks per capita water use.

FIGURES



Watershed Overview

Drawn: KAV	Revision: 3	Date: Nov 22, 2004	Figure: 1-1

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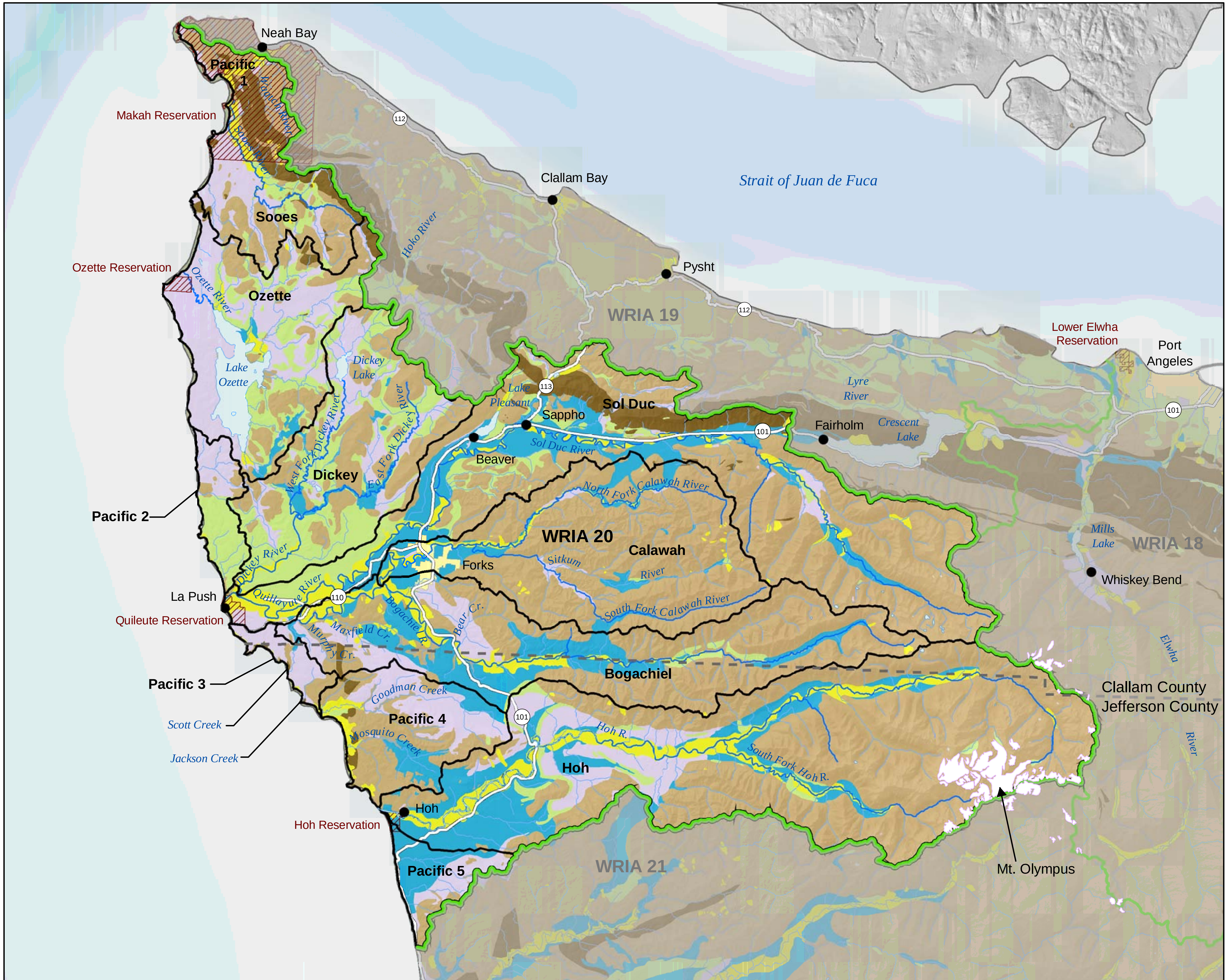

LEGEND

Geology Type and Description

Unlithified

- Alluvium
- Drift (undifferentiated)
- Outwash
- Till

Lithified

- Marine Sedimentary Rocks
- Bedrock (mainly basalt)
- Ice

- WRIA 20 Boundary
- WRIA 20 Proposed Sub-Basins
- WRIA Boundary
- Waterbody
- County Boundary
- Rivers and Streams
- Indian Reservation
- TRS Grid

Note: Geology was consolidated from 1:100,000 digital coverage (WDNR, 2001). Tectonic zones, intrusive igneous and metamorphic rocks comprise a small portion of the WRIA and were included in the area labeled "Bedrock".

Pacific 1-5: Independent Pacific Drainages

N

0 30,000

Scale 1" = 30,000 feet

Map Projection: Washington State Plane, North Zone, NAD 83, Feet

Source: Washington State Department of Natural Resources, United States Geologic Survey, Washington State Department of Ecology, Washington State Department of Transportation, United States Department of Transportation,

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Generalized Geology

Drawn: KAV	Revision: 3	Date: Nov 22, 2004	Figure: 2 - 1

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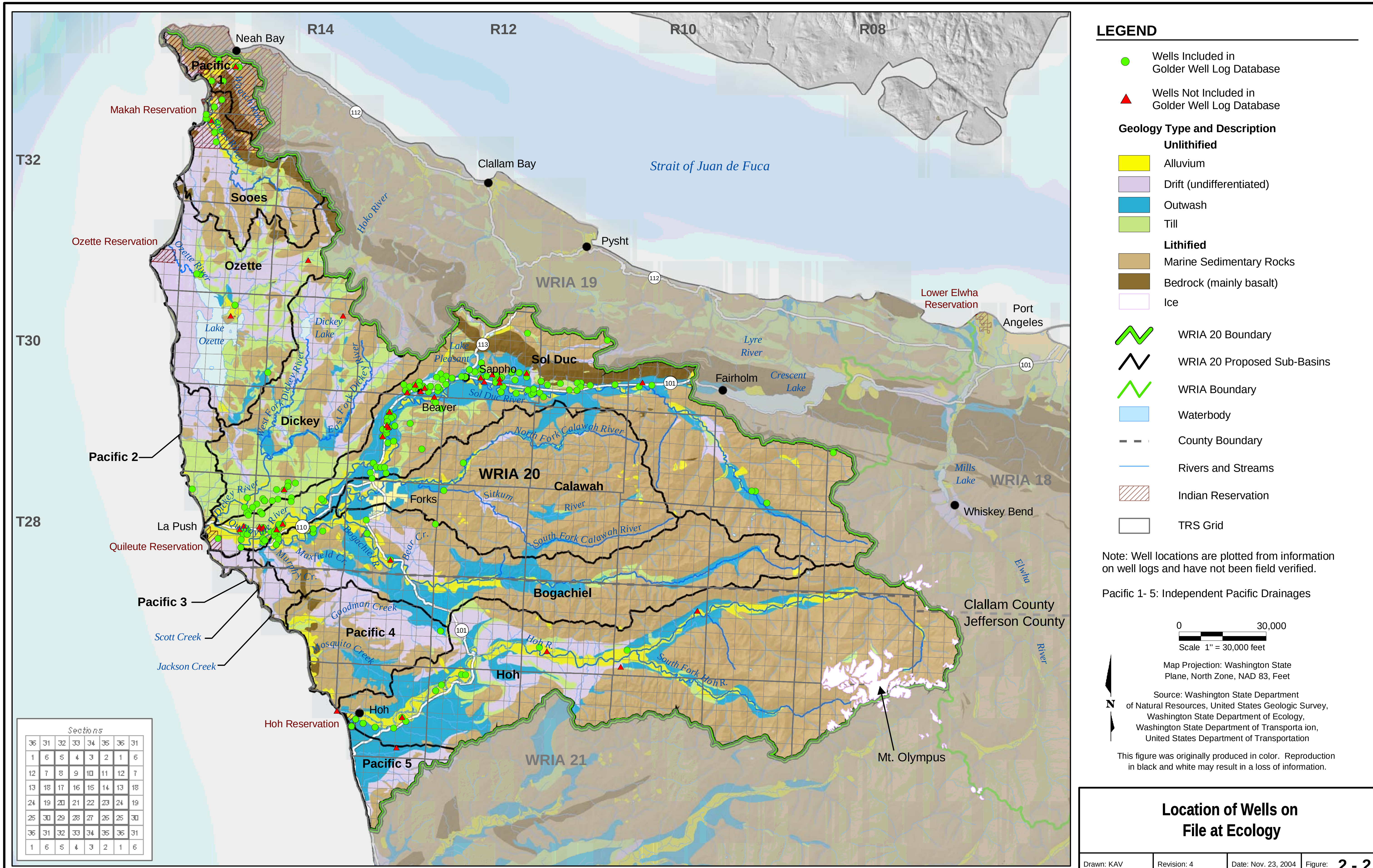

Location of Wells on File at Ecology

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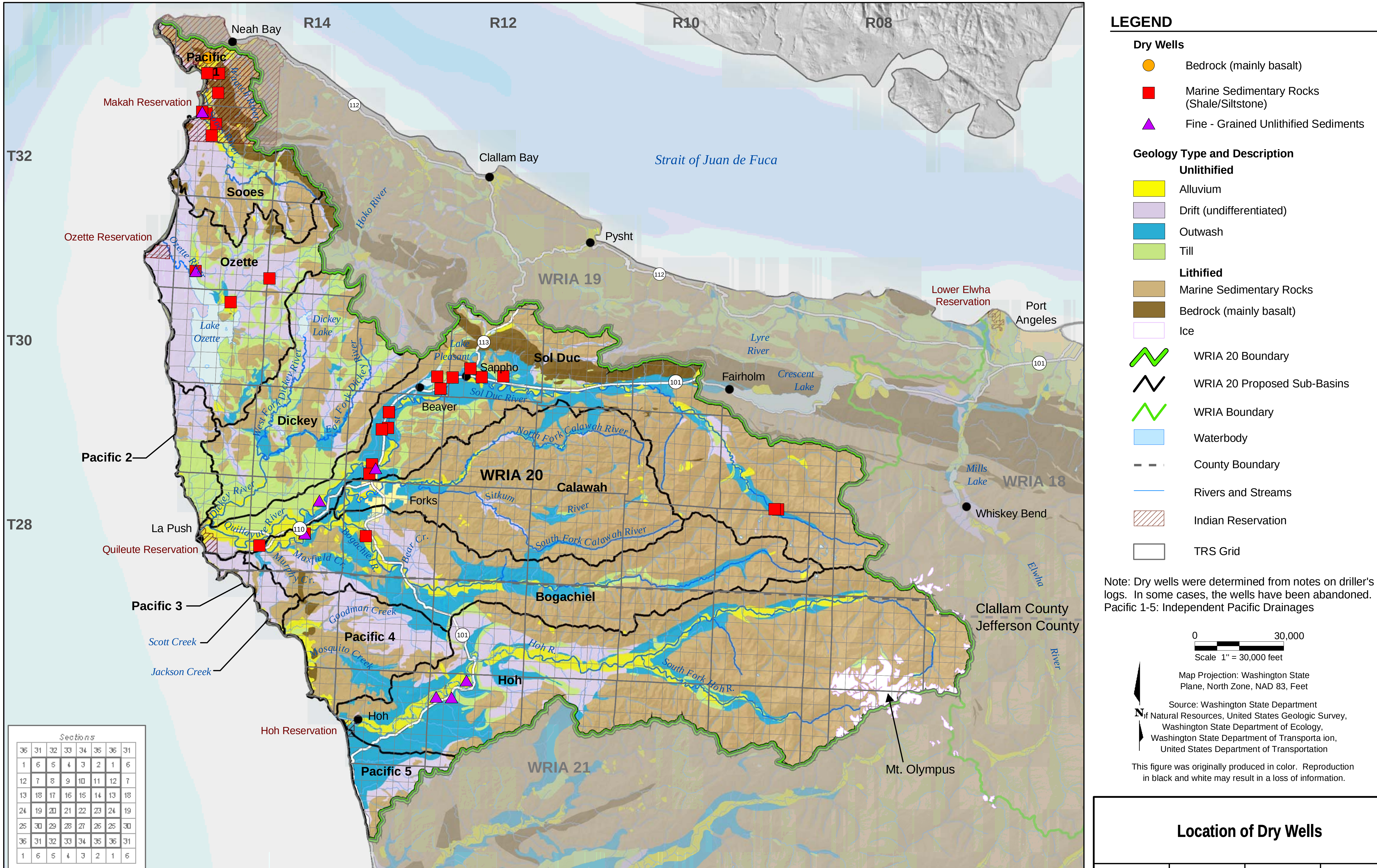
Golder Associates



Location of Dry Wells

Drawn: RMT	Revision: 3	Date: Nov 23, 2004	Figure: 2 - 3

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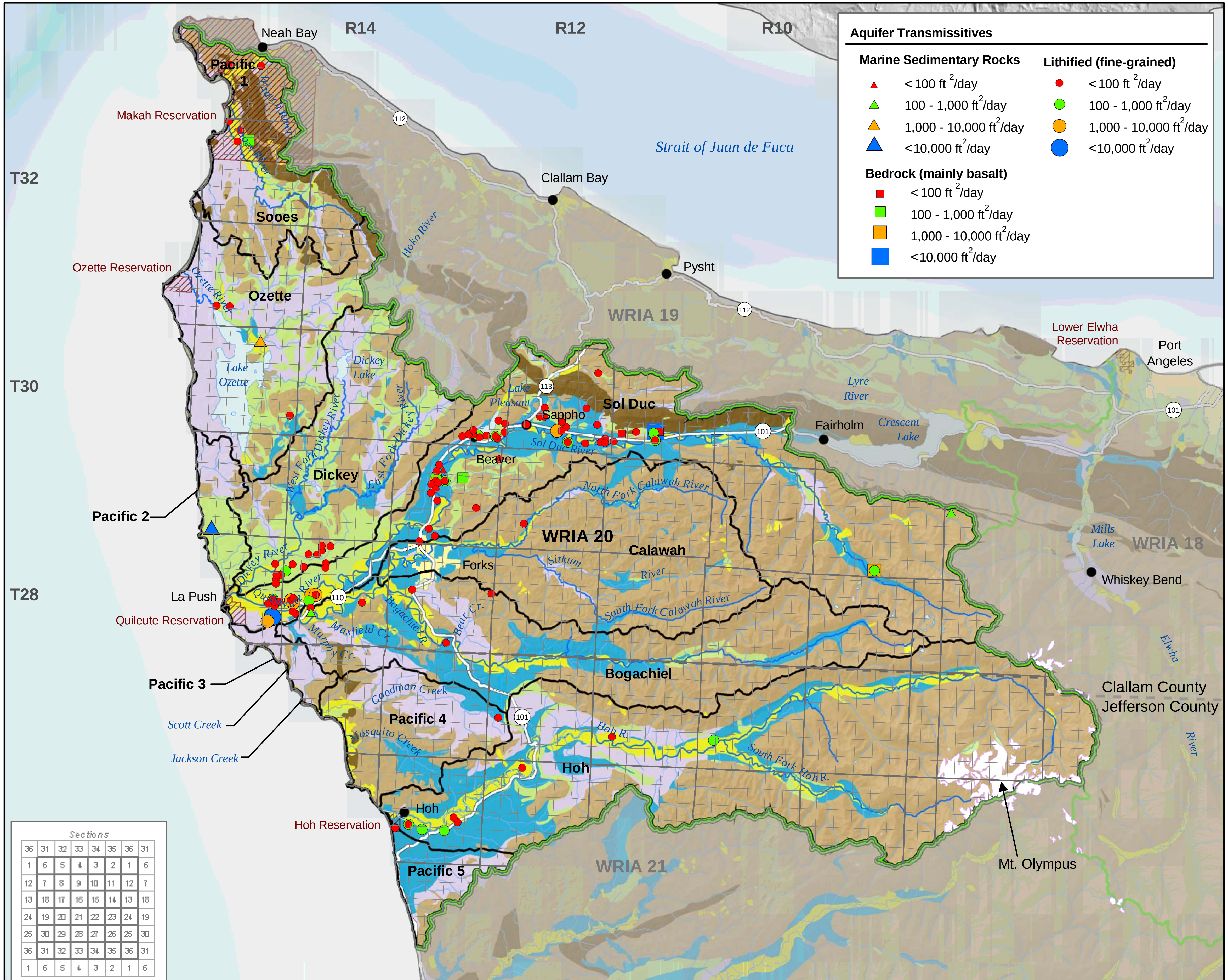

LEGEND

Geology Type and Description

Unlithified
- Alluvium
- Drift (undifferentiated)
- Outwash
- Till

Lithified
- Marine Sedimentary Rocks
- Bedrock (mainly basalt)
- Ice

- WRIA 20 Boundary
- WRIA 20 Proposed Sub-Basins
- WRIA Boundary
- Waterbody
- County Boundary
- Rivers and Streams
- Indian Reservation
- TRS Grid

Note: Transmissity values were estimated from pumping data provided on well logs.
Pacific 1-5: Independent Pacific Drainages

0 30,000
Scale 1" = 30,000 feet

N

Map Projection: Washington State Plane, North Zone, NAD 83, Feet

Source: Washington State Department of Natural Resources, United States Geologic Survey, Washington State Department of Ecology, Washington State Department of Transporta ion, United States Department of Transportation

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Aquifer Transmissivities Estimates

Drawn: KAV	Revision: 3	Date: Nov. 23, 2004	Figure: 2 - 4

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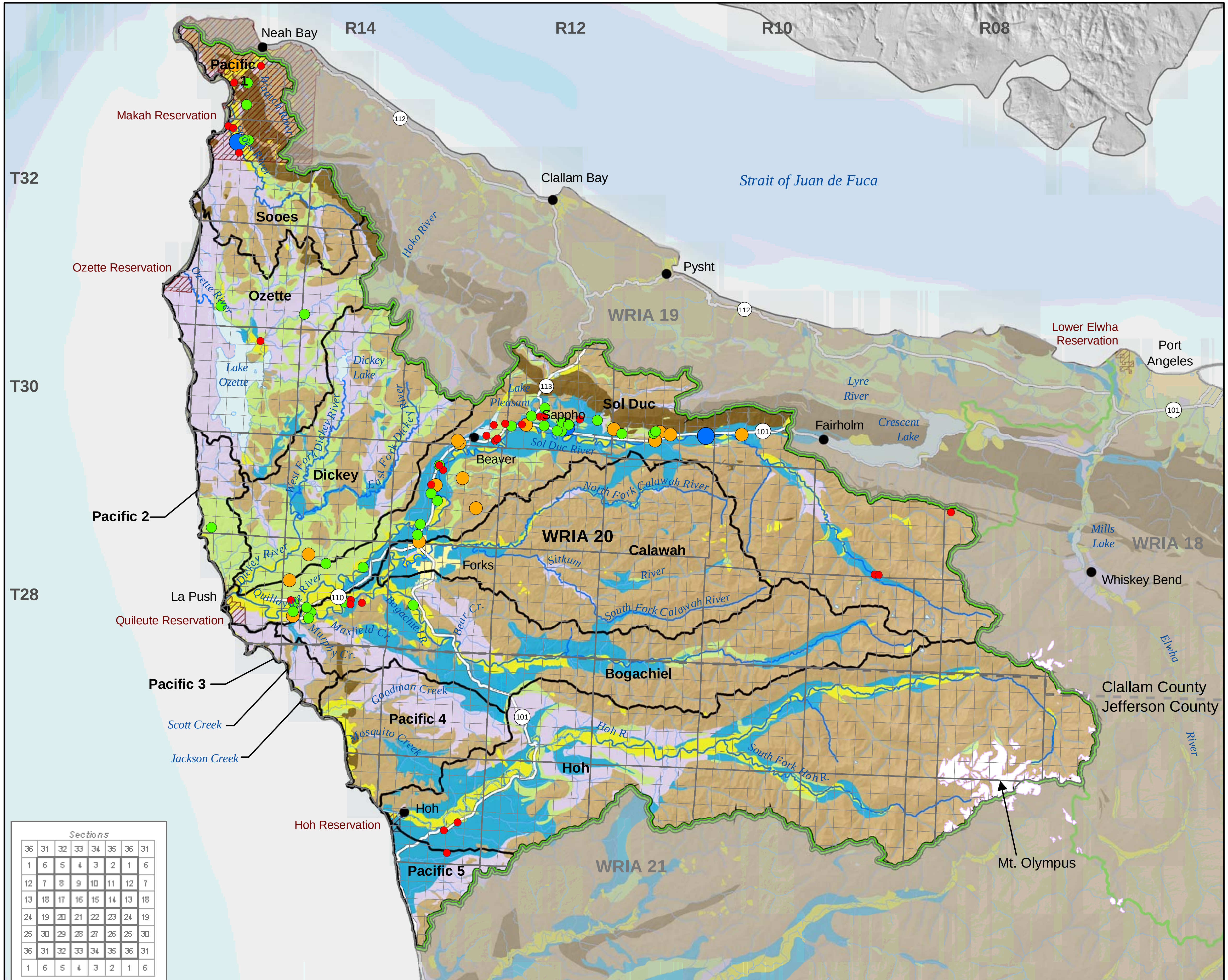

LEGEND

Depth to Consolidated Rock

- 0 - 50 ft.
- 51 - 100 ft.
- 101 - 150 ft.
- > 150 ft.

Geology Type and Description

Unlithified

- Alluvium
- Drift (undifferentiated)
- Outwash
- Till

Lithified

- Marine Sedimentary Rocks
- Bedrock (mainly basalt)
- Ice

- WRIA 20 Boundary
- WRIA 20 Proposed Sub-Basins
- WRIA Boundary
- Waterbody
- County Boundary
- Rivers and Streams
- Indian Reservation
- TRS Grid

Note: Consolidated rock types are shale, siltstone/sandstone, and basalt.
Pacific 1- 5: Independent Pacific Drainages

0 30,000
Scale 1" = 30,000 feet

N

Map Projection: Washington State Plane, North Zone, NAD 83, Feet

Source: Washington State Department of Natural Resources, United States Geologic Survey, Washington State Department of Ecology, Washington State Department of Transporta ion, United States Department of Transportation

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Depth to Consolidated Rock

Drawn: RMT	Revision: 3	Date: Nov 23, 2004	Figure: 2 - 5

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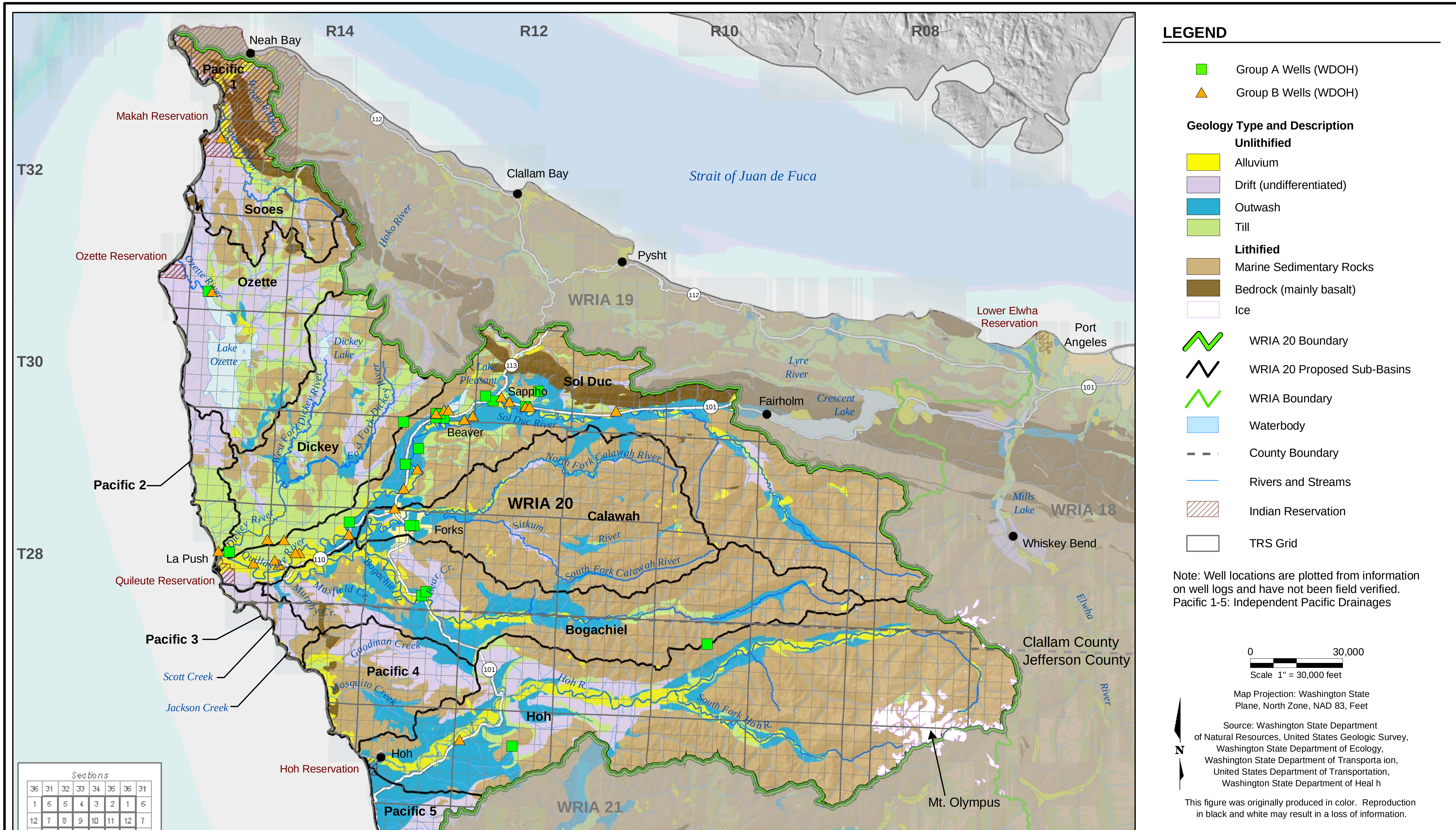

Location of Public Water System Wells

Drawn: KAV | Revision: 3 | Date: Nov 23, 2004 | Figure: 2 - 6

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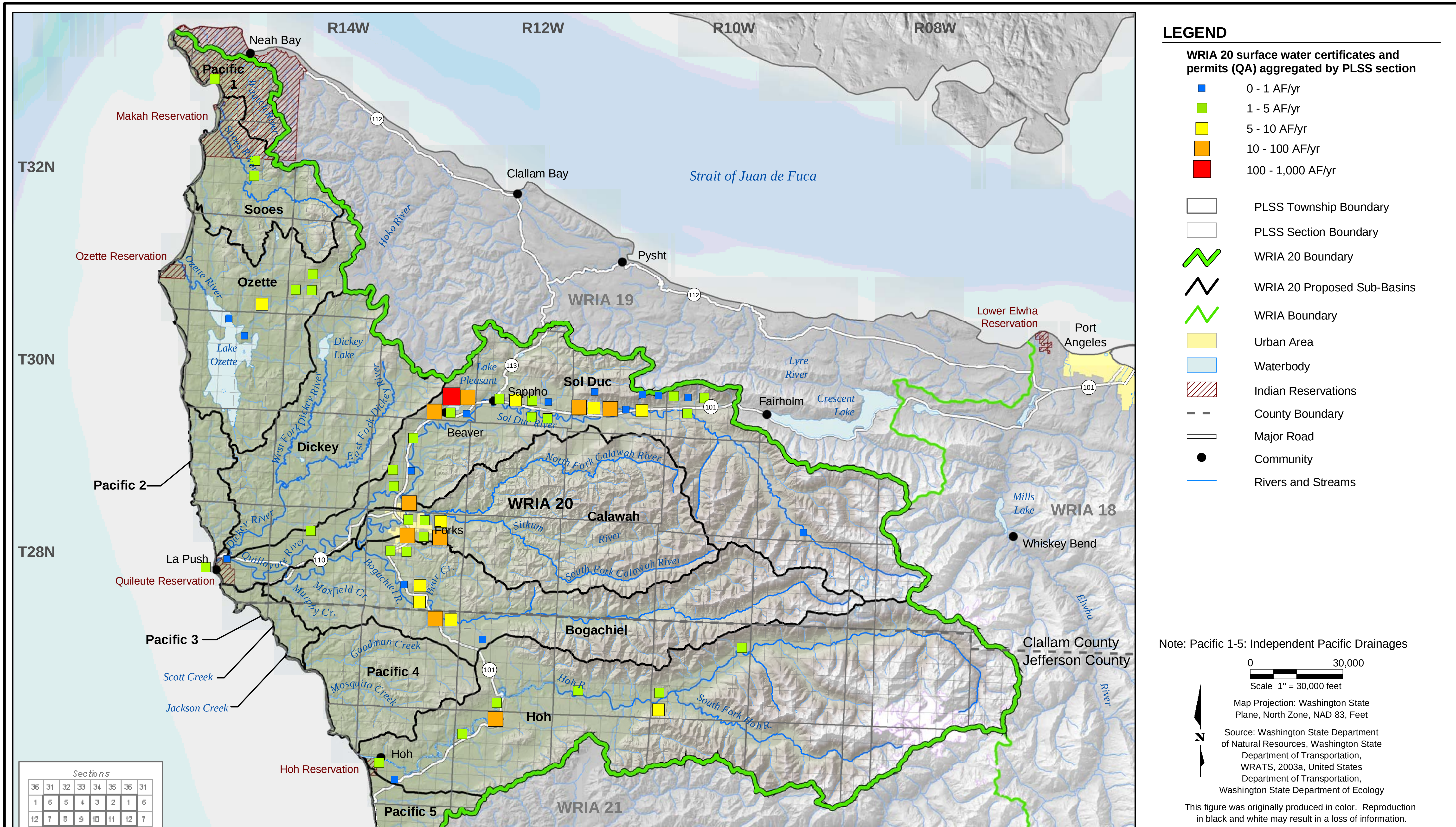

Surface Water Certificates and Permits

Drawn: KAV	Revision: 4	Date: Nov. 23, 2004	Figure: 3-1

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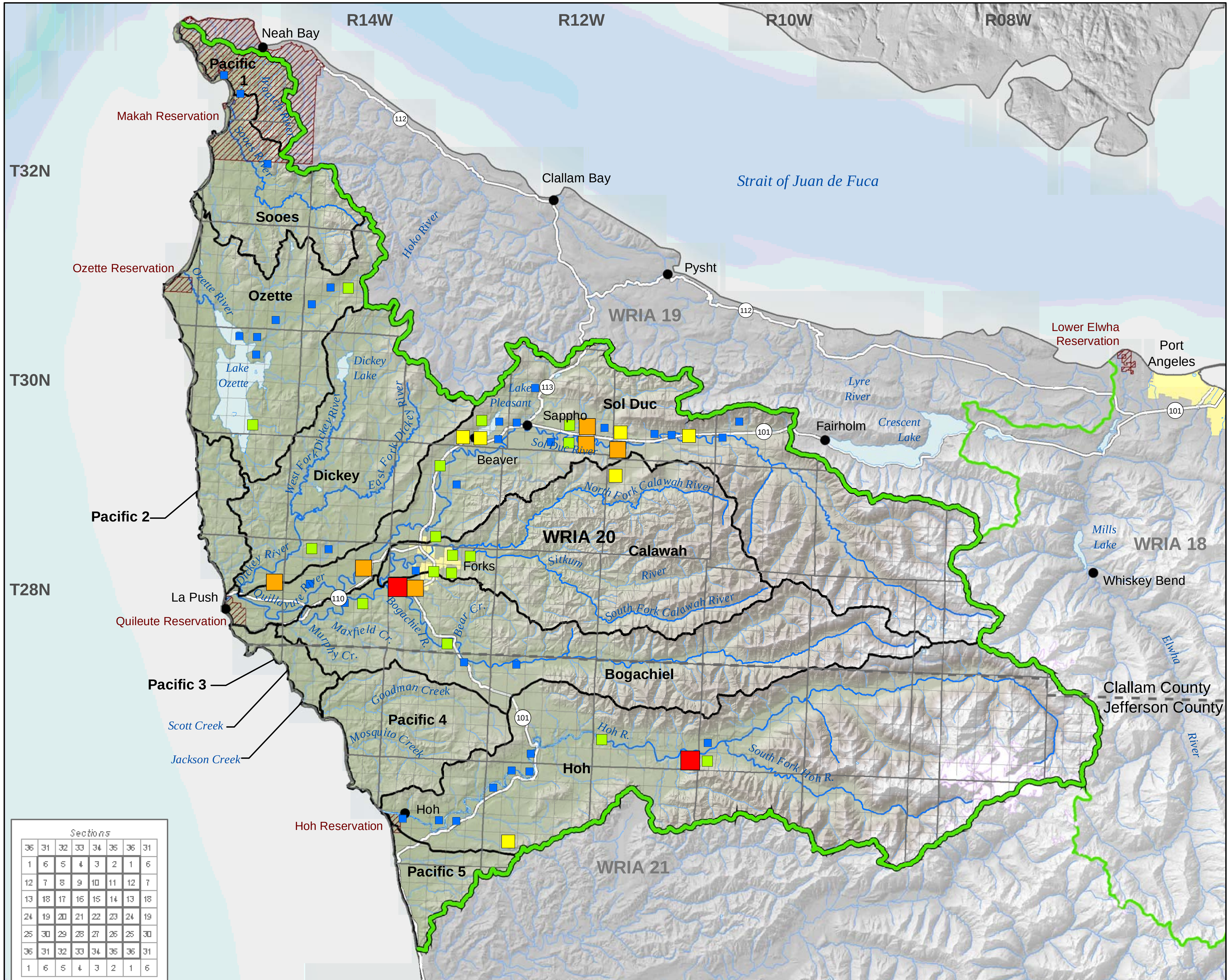

LEGEND

WRIA 20 surface water claims (QA) aggregated by PLSS section

- 0 - 1 AF/yr
- 1 - 5 AF/yr
- 5 - 10 AF/yr
- 10 - 100 AF/yr
- 100 - 1,000 AF/yr

- PLSS Township Boundary
- PLSS Section Boundary
- WRIA 20 Boundary
- WRIA 20 Proposed Sub-Basins
- WRIA Boundary
- Urban Area
- Waterbody
- Indian Reservations
- County Boundary
- Major Road
- Community
- Rivers and Streams

Note: Pacific 1-5: Independent Pacific Drainages

0 30,000
Scale 1" = 30,000 feet

N

Map Projection: Washington State Plane, Nor h Zone, NAD 83, Feet

Source: Washington State Department of Natural Resources, Washington State Department of Transportation, WRATS, 2003a, United States Department of Transportation, Washington State Department of Ecology

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Surface Water Claims

Drawn: KAV	Revision: 4	Date: Nov 23, 2004	Figure: 3-2

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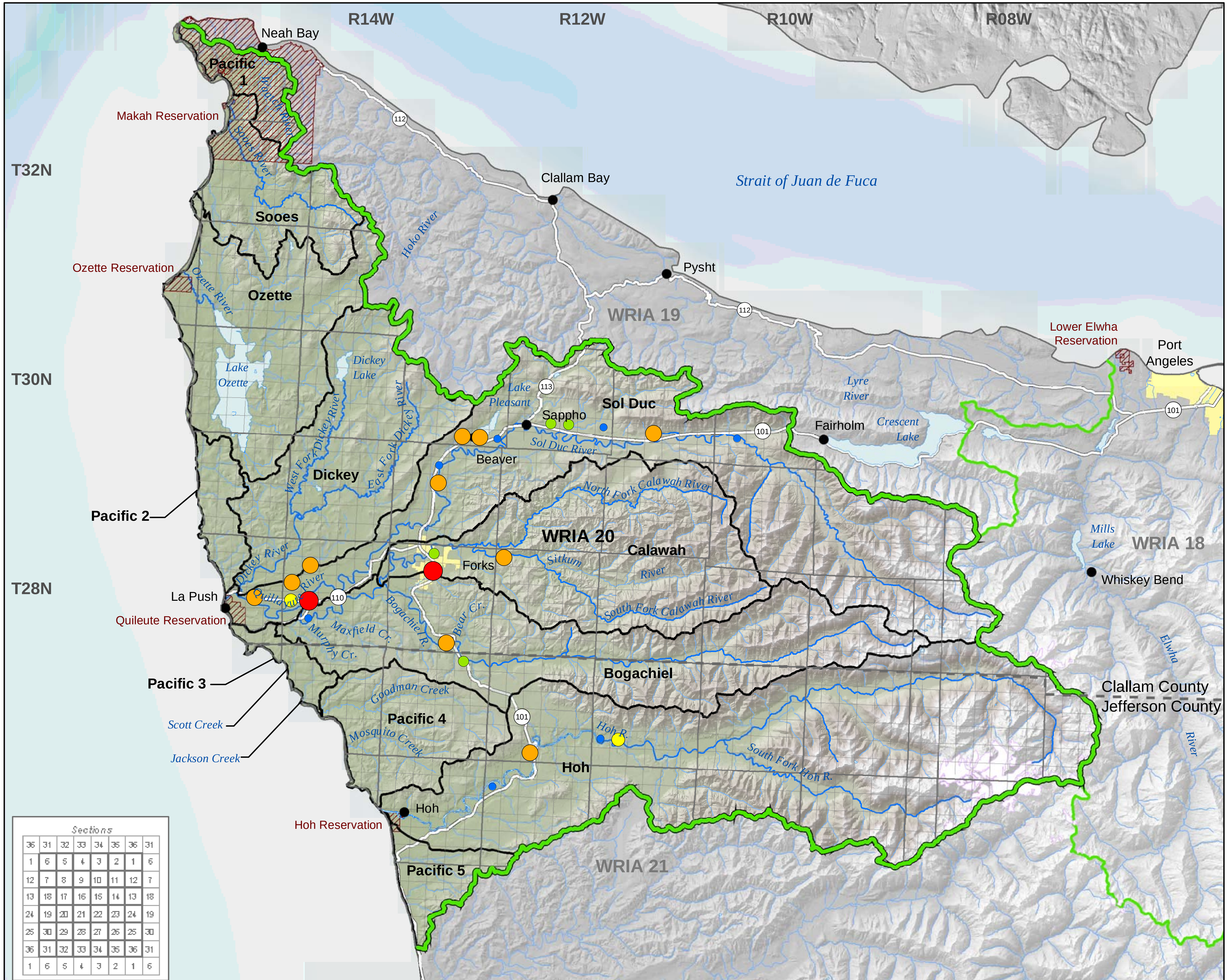

LEGEND

WRIA 20 groundwater certificates and permits (QA) aggregated by PLSS section

- 0 - 1 AF/yr
- 1 - 5 AF/yr
- 5 - 10 AF/yr
- 10 - 100 AF/yr
- 100 - 1,000 AF/yr
- PLSS Township Boundary
- PLSS Section Boundary
- WRIA 20 Boundary
- WRIA 20 Proposed Sub-Basins
- WRIA Boundary
- Urban Area
- Waterbody
- Indian Reservations
- County Boundary
- Major Road
- Community
- Rivers and Streams

Note: Pacific 1-5: Independent Pacific Drainages

0 30,000
Scale 1" = 30,000 feet

N

Map Projection: Washington State Plane, North Zone, NAD 83, Feet

Source: Washington State Department of Natural Resources, Washington State Department of Transportation, WRATS, 2003a, United States Department of Transportation, Washington State Department of Ecology

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Groundwater Certificates and Permits

Drawn: KAV	Revision: 5	Date: Nov 23, 2004	Figure: 3-3

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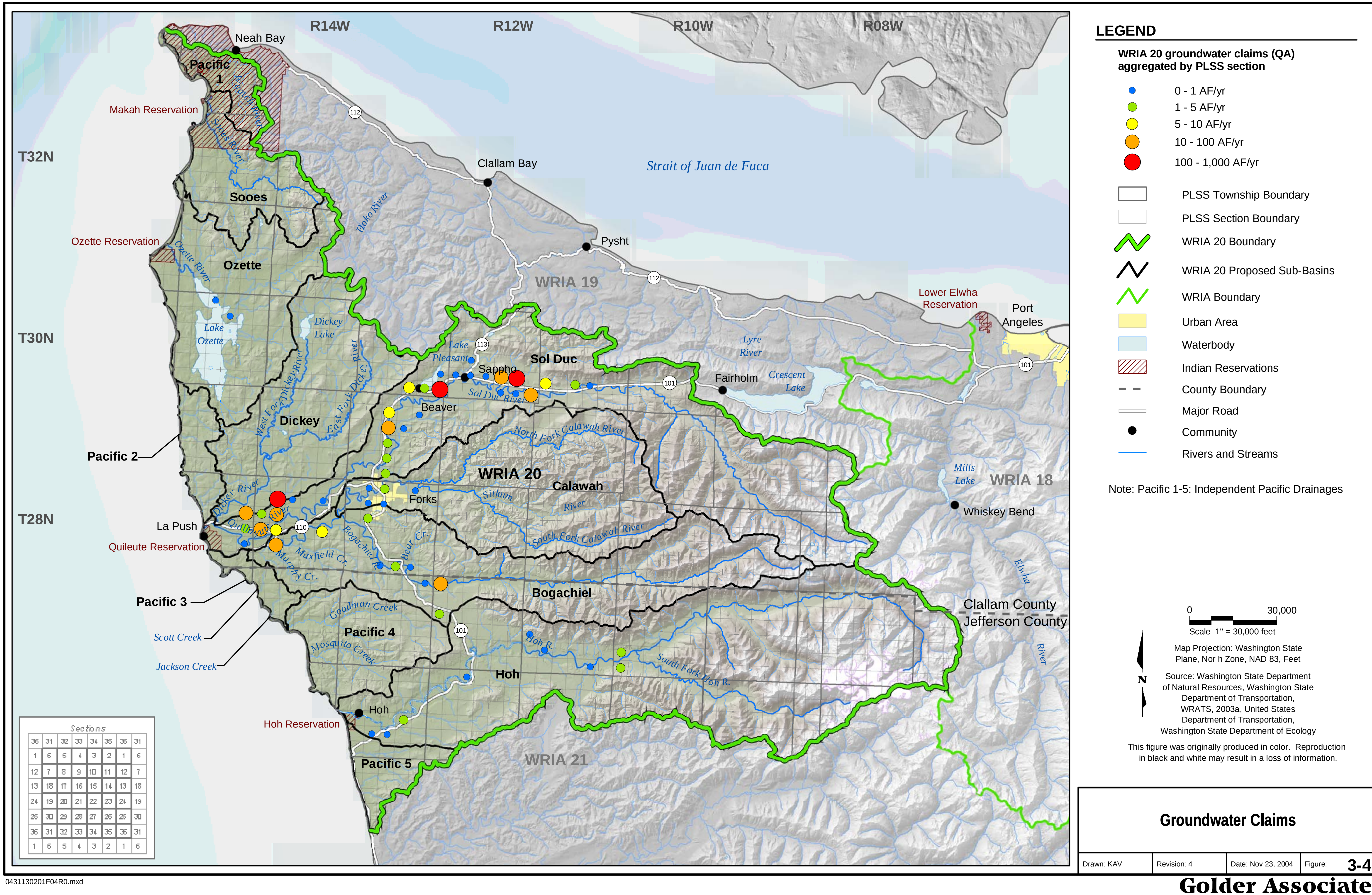

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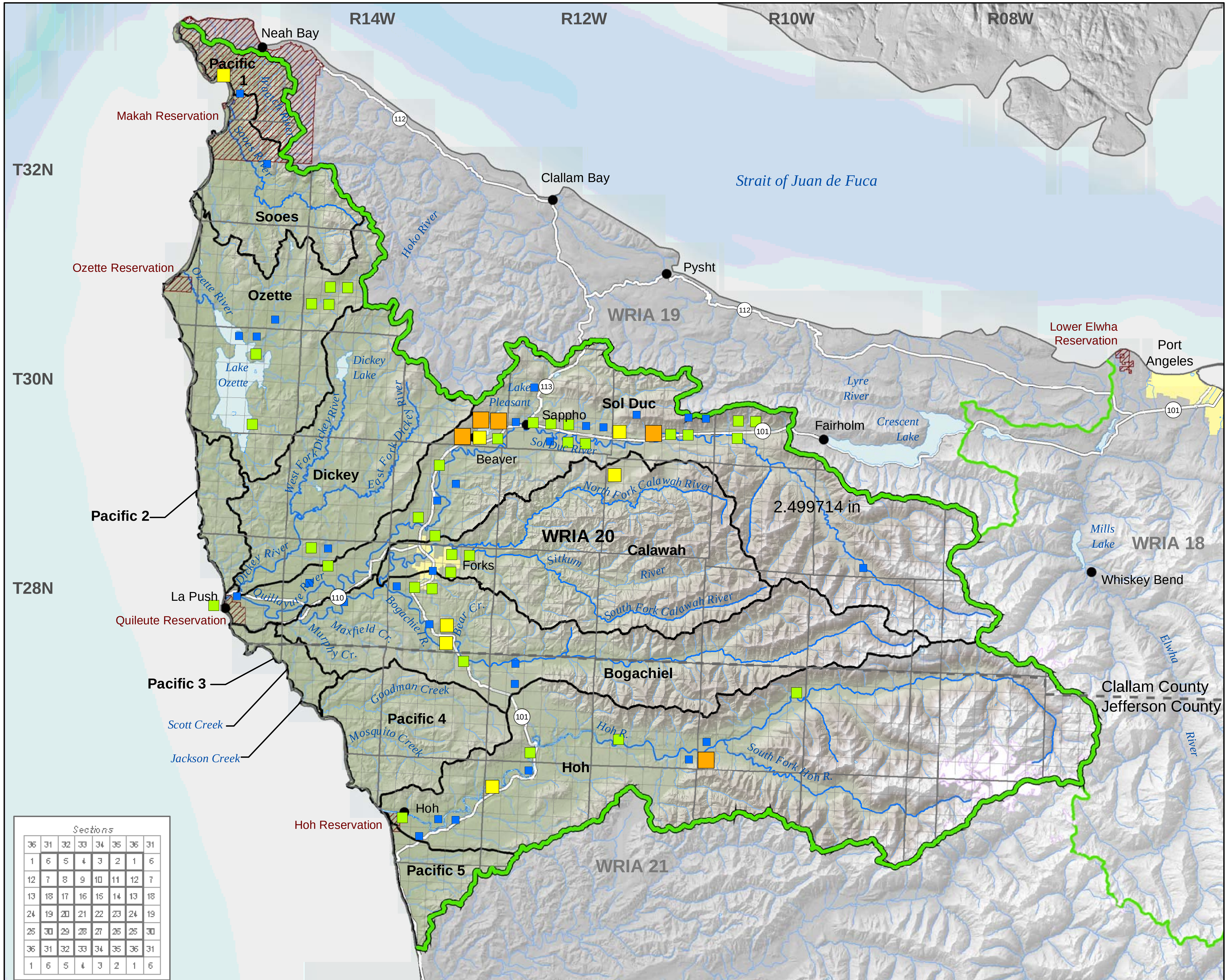

LEGEND

WRIA 20 (QA) municipal and domestic surface water rights and claims (QA) aggregated by PLSS section

- 0 - 1 AF/yr
- 1 - 5 AF/yr
- 5 - 10 AF/yr
- 10 - 100 AF/yr
- 100 - 1,000 AF/yr

- PLSS Township Boundary
- PLSS Section Boundary
- WRIA 20 Boundary
- WRIA 20 Proposed Sub-Basins
- WRIA Boundary
- Urban Area
- Waterbody
- Indian Reservations
- County Boundary
- Major Road
- Community
- Rivers and Streams

Note: Pacific 1-5: Independent Pacific Drainages

0 30,000

Scale 1" = 30,000 feet

Map Projec ion: Washington State Plane, Nor h Zone, NAD 83, Feet

N

Source: Washington State Department of Natural Resources, Washington State Department of Transportation, WRATS, 2003a, United States Department of Transportation, Washington State Department of Ecology

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Municipal and Domestic Surface Water Rights and Claims

Drawn: KAV	Revision: 4	Date: Nov. 23, 2004	Figure: 3-5

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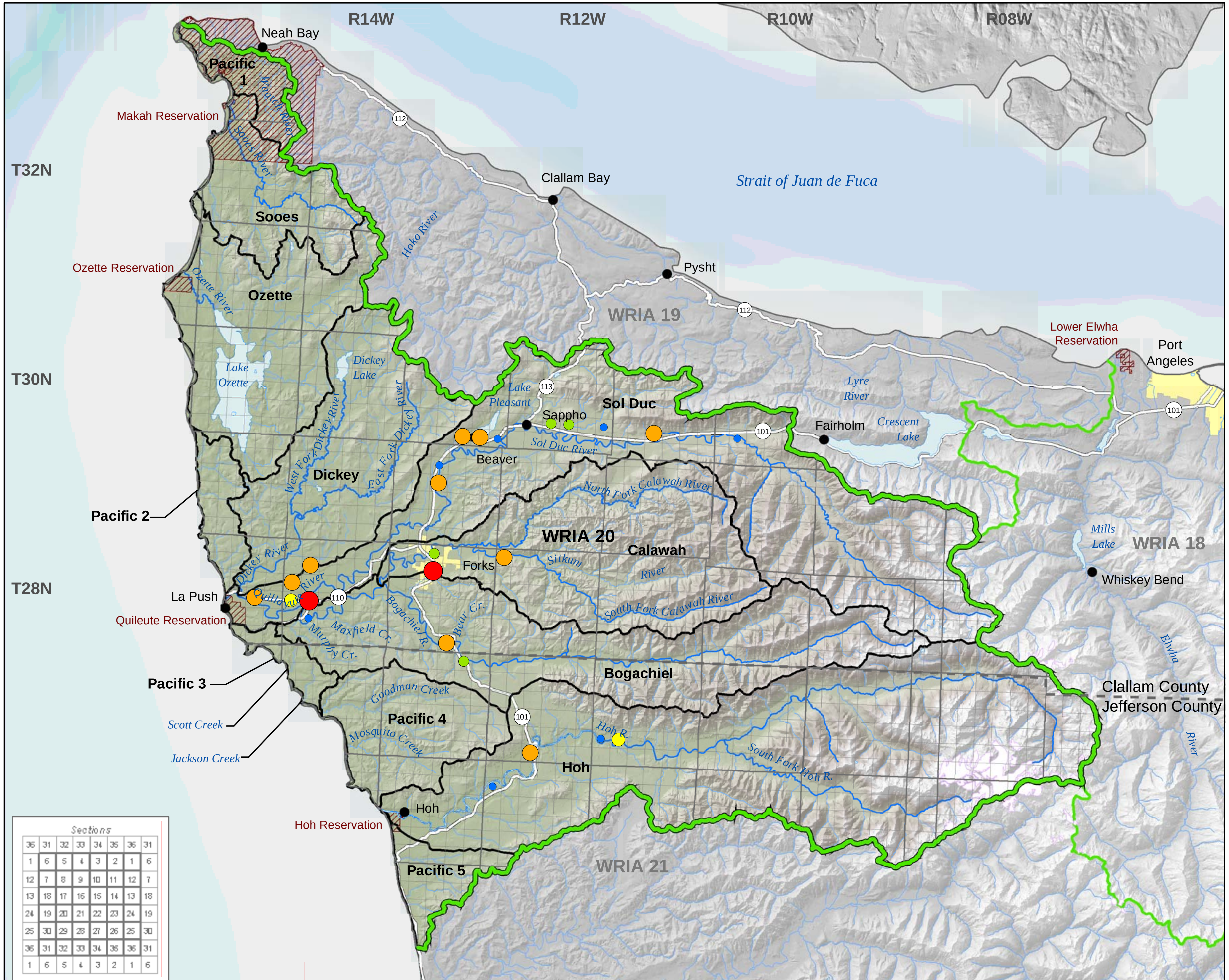

LEGEND

WRIA 20 (QA) municipal and domestic groundwater rights and claims (QA) aggregated by PLSS section

- 0 - 1 AF/yr
- 1 - 5 AF/yr
- 5 - 10 AF/yr
- 10 - 100 AF/yr
- 100 - 1,000 AF/yr
- PLSS Township Boundary
- PLSS Section Boundary
- WRIA 20 Boundary
- WRIA 20 Proposed Sub-Basins
- WRIA Boundary
- Urban Area
- Waterbody
- Indian Reservations
- County Boundary
- Major Road
- Community
- Rivers and Streams

Note: Pacific 1-5: Independent Pacific Drainages

0 30,000
Scale 1" = 30,000 feet

N

Map Projection: Washington State Plane, North Zone, NAD 83, Feet

Source: Washington State Department of Natural Resources, Washington State Department of Transportation, WRATS, 2003a, United States Department of Transportation, Washington State Department of Ecology

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Municipal and Domestic Groundwater Rights and Claims

Drawn: KAV	Revision: 4	Date: Nov. 23, 2004	Figure: 3-6

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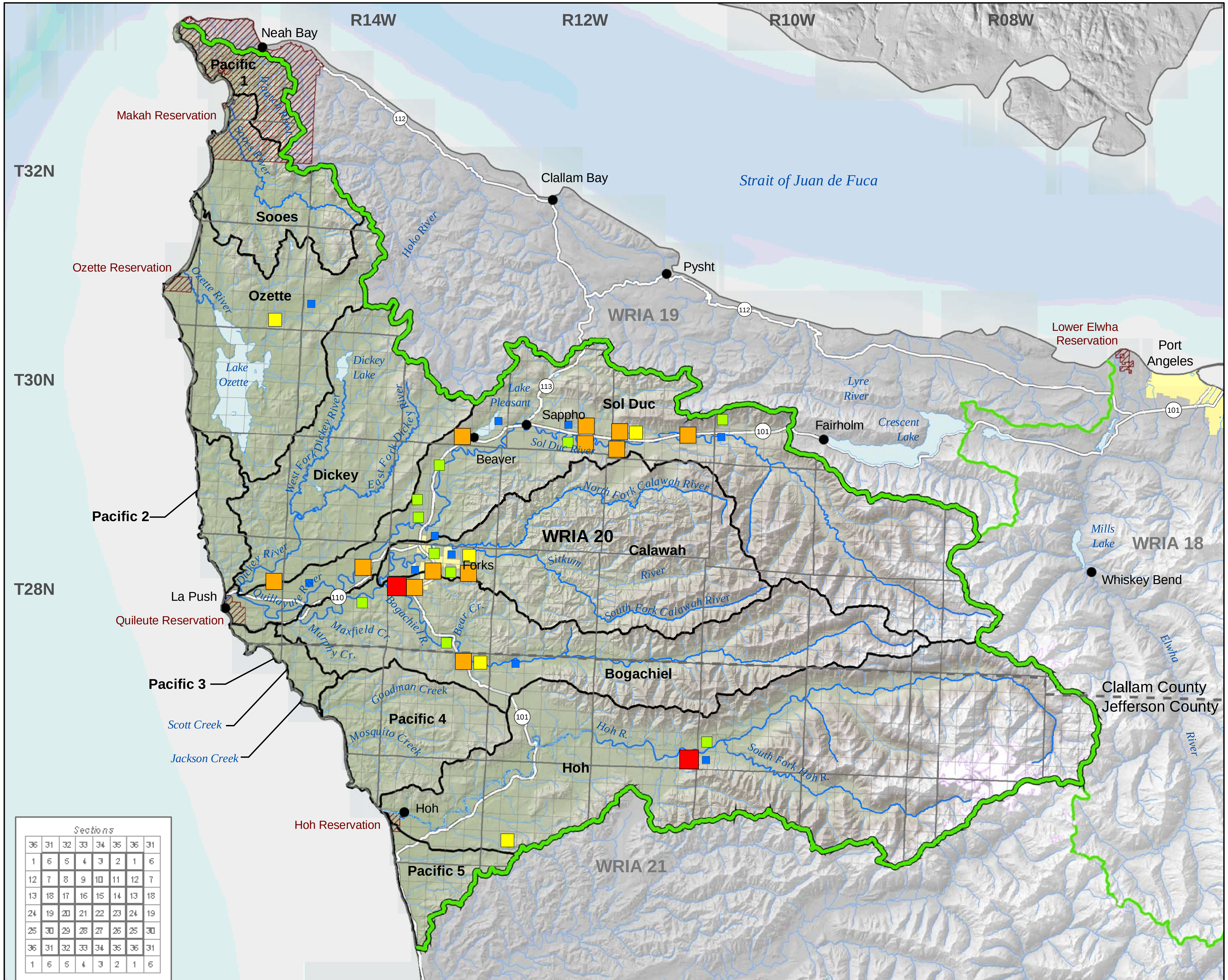

LEGEND

WRIA 20 irrigation surface water rights and claims (QA) aggregated by PLSS section

- 0 - 1 AF/yr
- 1 - 5 AF/yr
- 5 - 10 AF/yr
- 10 - 100 AF/yr
- 100 - 1,000 AF/yr

- PLSS Township Boundary
- PLSS Section Boundary
- WRIA 20 Boundary
- WRIA 20 Proposed Sub-Basins
- WRIA Boundary
- Urban Area
- Waterbody
- Indian Reservations
- County Boundary
- Major Road
- Community
- Rivers and Streams

Note: Pacific 1-5: Independent Pacific Drainages

0 30,000

Scale 1" = 30,000 feet

N

Map Projection: Washington State Plane, North Zone, NAD 83, Feet

Source: Washington State Department of Natural Resources, Washington State Department of Transportation, WRATS, 2003a, United States Department of Transportation, Washington State Department of Ecology

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Irrigation Surface Water Rights and Claims

Drawn: KAV	Revision: 4	Date: Nov. 23, 2004	Figure: 3-7

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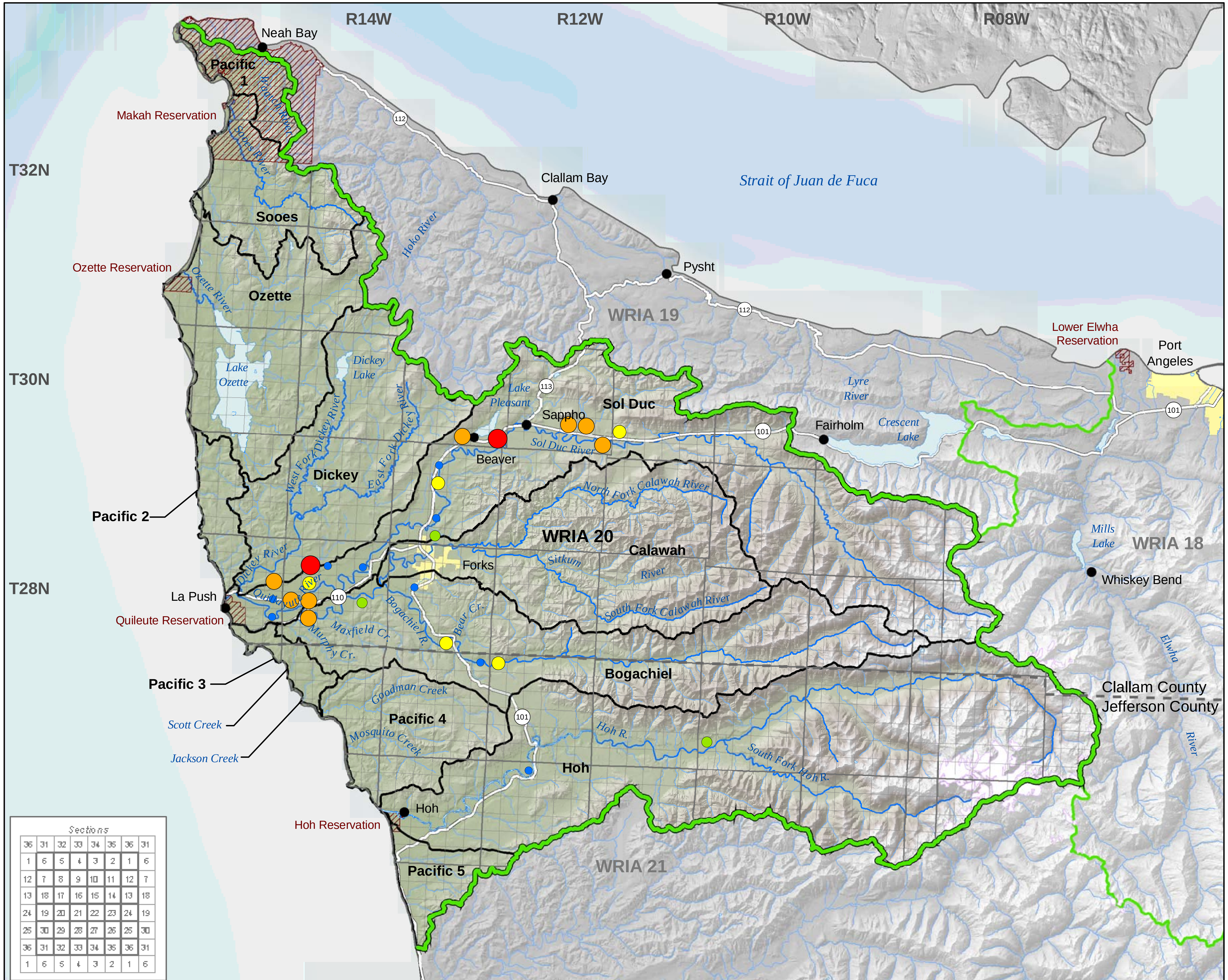

LEGEND

WRIA 20 irrigation groundwater rights and claims (QA) aggregated by PLSS section

- 0 - 1 AF/yr
- 1 - 5 AF/yr
- 5 - 10 AF/yr
- 10 - 100 AF/yr
- 100 - 1,000 AF/yr

- PLSS Township Boundary
- PLSS Section Boundary
- WRIA 20 Boundary
- WRIA 20 Proposed Sub-Basins
- WRIA Boundary
- Urban Area
- Waterbody
- Indian Reservations
- County Boundary
- Major Road
- Community
- Rivers and Streams

Note: Pacific 1-5: Independent Pacific Drainages

0 30,000
Scale 1" = 30,000 feet

N

Map Projection: Washington State Plane, North Zone, NAD 83, Feet

Source: Washington State Department of Natural Resources, Washington State Department of Transportation, WRATS, 2003a, United States Department of Transportation, Washington State Department of Ecology

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Irrigation Groundwater Rights and Claims

Drawn: KAV	Revision: 4	Date: Nov. 23, 2004	Figure: 3-8

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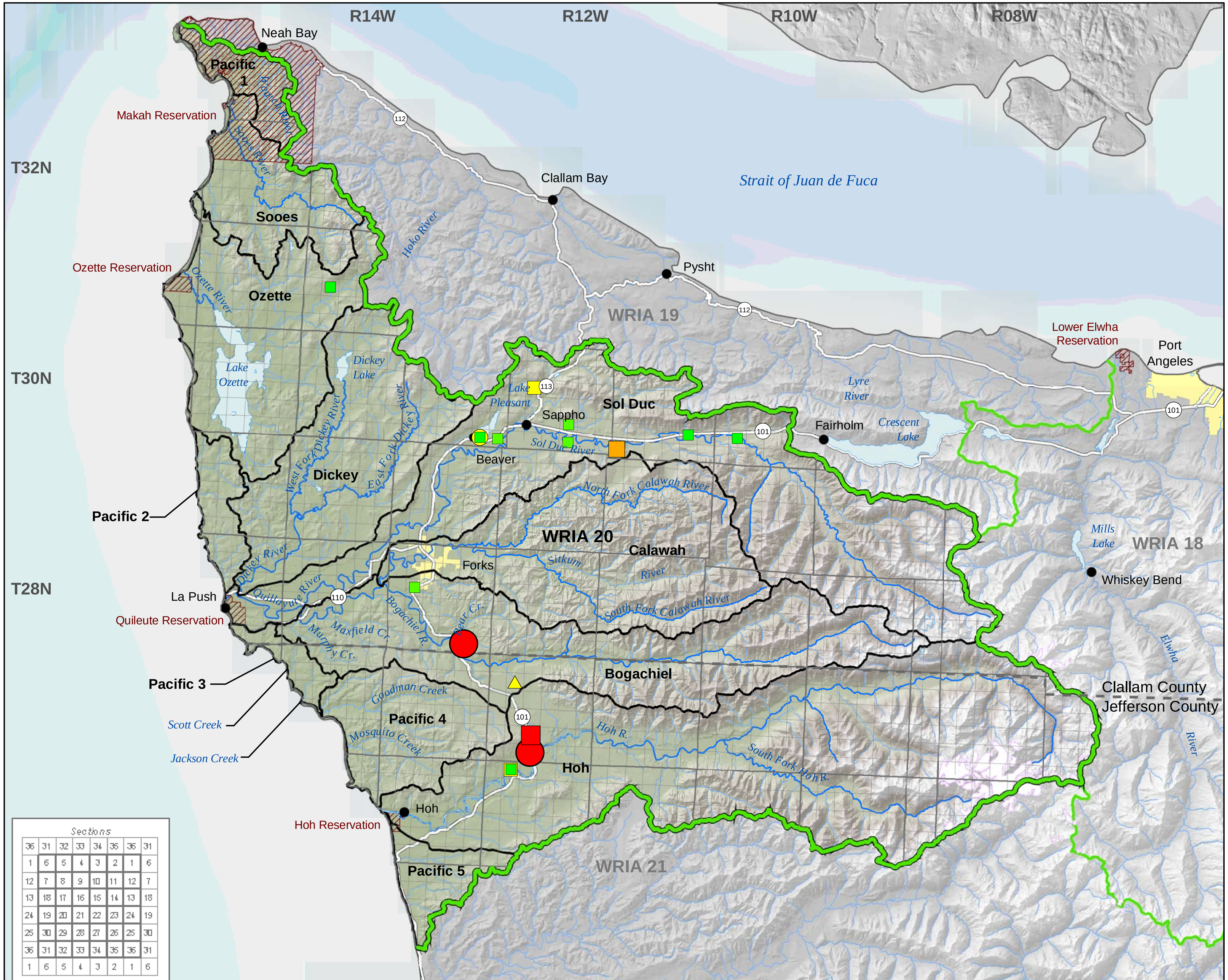
Golder Associates



LEGEND

Applications for New Surface Water Rights *

- 0 - 0.05 cfs
- 0.05 - 1.0 cfs
- 1 - 10 cfs
- 10 - 1,000 cfs

Applications for New Groundwater Rights *

- 0 - 100 gpm
- 100 - 150 gpm

** Aggregated by PLSS Section*

- Change Applications
- PLSS Township Boundary
- PLSS Section Boundary
- WRIA 20 Boundary
- WRIA 20 Proposed Sub-Basins
- WRIA Boundary
- Urban Area
- Waterbody
- Indian Reservations
- County Boundary
- Major Road
- Community
- Rivers and Streams

Note: Pacific 1-5: Independent Pacific Drainages

0 30,000

Scale 1" = 30,000 feet

N

Map Projection: Washington State Plane, North Zone, NAD 83, Feet

Source: Washington State Department of Natural Resources, Washington State Department of Transportation, WRATS, 2003a, United States Department of Transportation, Washington State Department of Ecology

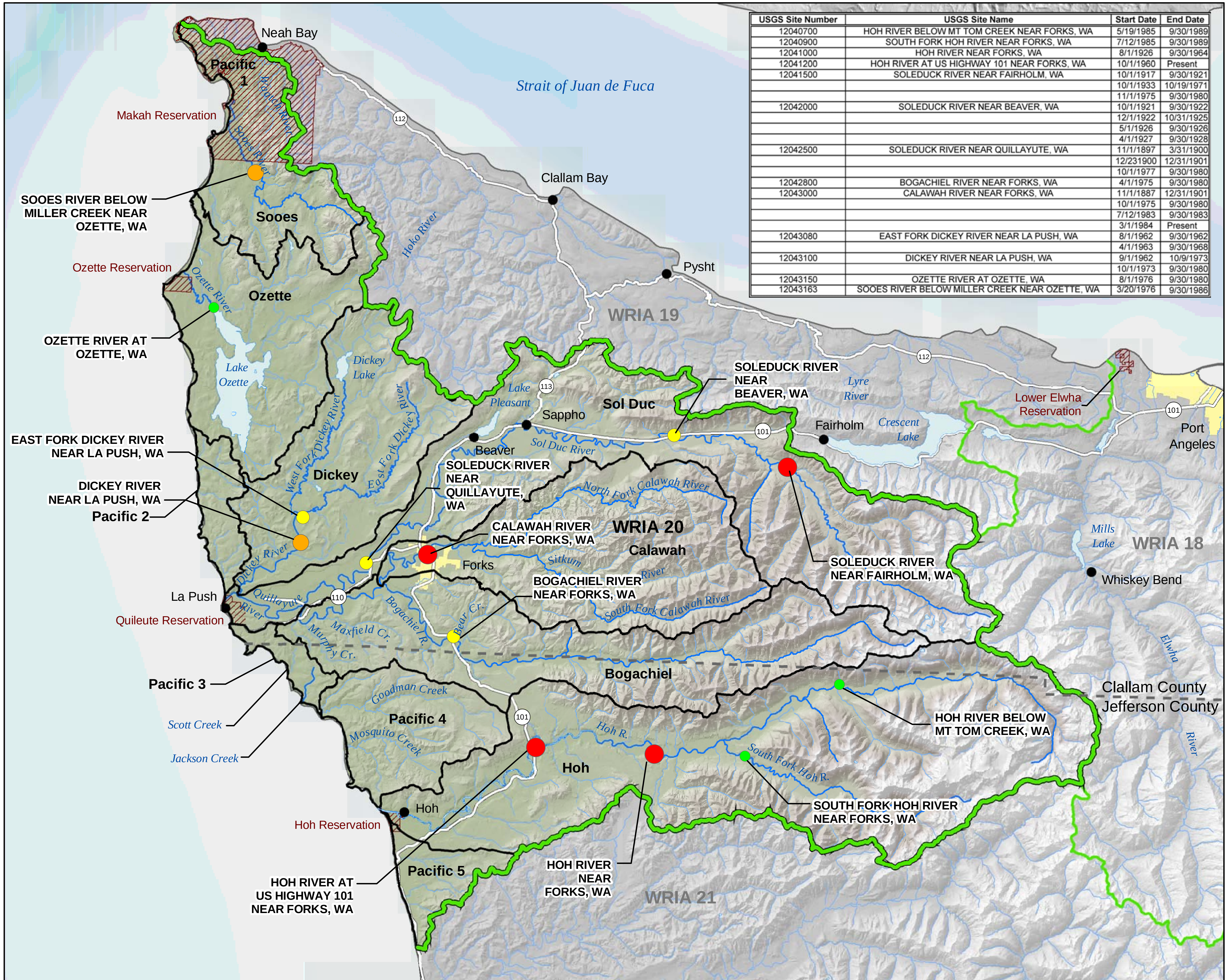
This figure was originally produced in color. Reproduction in black and white may result in a loss of information.

Applications for New Water Rights and Change Applications

Drawn: KAV	Revision: 4	Date: Nov. 23, 2004	Figure: 3-9

0431130201F09R01.mxd

Golder Associates



USGS Site Number	USGS Site Name	Start Date	End Date
12040700	HOH RIVER BELOW MT TOM CREEK NEAR FORKS, WA	5/19/1985	9/30/1989
12040900	SOUTH FORK HOH RIVER NEAR FORKS, WA	7/12/1985	9/30/1989
12041000	HOH RIVER NEAR FORKS, WA	8/1/1926	9/30/1964
12041200	HOH RIVER AT US HIGHWAY 101 NEAR FORKS, WA	10/1/1960	Present
12041500	SOLEDUCK RIVER NEAR FAIRHOLM, WA	10/1/1917	9/30/1921
		10/1/1933	10/19/1971
		11/1/1975	9/30/1980
12042000	SOLEDUCK RIVER NEAR BEAVER, WA	10/1/1921	9/30/1922
		12/1/1922	10/31/1925
		5/1/1926	9/30/1926
		4/1/1927	9/30/1928
12042500	SOLEDUCK RIVER NEAR QUILLAYUTE, WA	11/1/1897	3/31/1900
		12/231900	12/31/1901
		10/1/1977	9/30/1980
12042800	BOGACHIEL RIVER NEAR FORKS, WA	4/1/1975	9/30/1980
12043000	CALAWAH RIVER NEAR FORKS, WA	11/1/1887	12/31/1901
		10/1/1975	9/30/1980
		7/12/1983	9/30/1983
		3/1/1984	Present
12043080	EAST FORK DICKEY RIVER NEAR LA PUSH, WA	8/1/1962	9/30/1962
		4/1/1963	9/30/1968
12043100	DICKEY RIVER NEAR LA PUSH, WA	9/1/1962	10/9/1973
		10/1/1973	9/30/1980
12043150	OZETTE RIVER AT OZETTE, WA	8/1/1976	9/30/1980
12043163	SOOES RIVER BELOW MILLER CREEK NEAR OZETTE, WA	3/20/1976	9/30/1986

LEGEND

PERIOD OF RECORD

- < 1 Year
- 1 - 5 Years
- 5 - 10 Years
- 10 - 20 Years
- 20 - 50 Years

- WRIA 20 Boundary
- WRIA 20 Proposed Sub-Basins
- WRIA Boundary
- Urban Area
- Waterbody
- Reservation Boundary
- County Boundary
- Major Road
- Community
- Rivers and Streams

Note:
Pacific I-5: Independent Pacific Drainages. Water Balance calculations not performed in these areas.

0 30,000
Scale 1'' = 30,000 feet

N

Map Projection: Washington State Plane, North Zone, NAD 83, Feet

Source: Washington State Department of Natural Resources, Washington State Department of Transportation, United States Geologic Survey, United States Department of Transportation, Washington State, Department of Ecology

This figure was originally produced in color. Reproduction in black and white may result in a loss of information.

Sub-Basins and Surface Water Monitoring Stations

Drawn: KAV	Revision: 11	Date: May. 26, 2005	Figure: 5-1

0431130401F03R04.mxd

Golder Associates

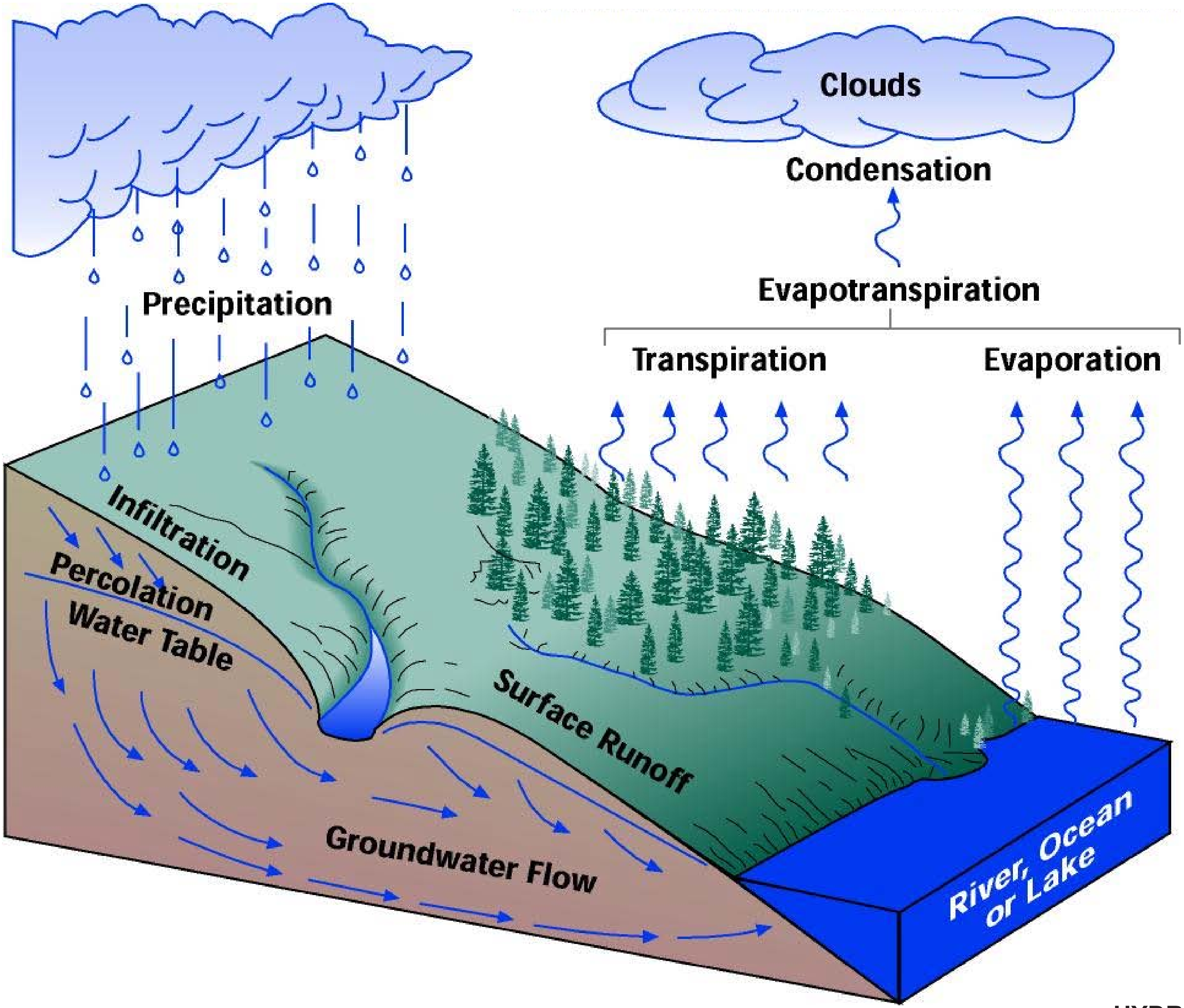
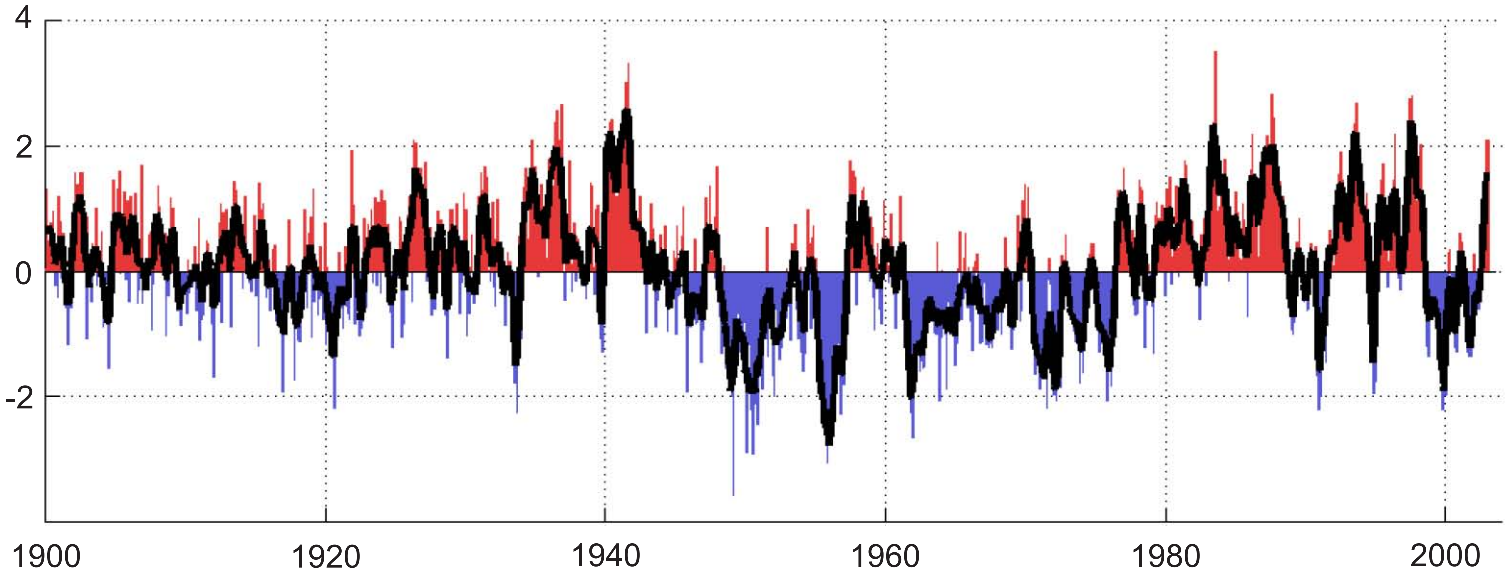


FIGURE **5-2**
HYDROLOGIC CYCLE
CLALLAM/WRIA 20 WATERSHED PLAN/WA

DRAWING NO. 0431130401fg07.fh11 DATE 09/28/04 DRAWN BY EFS

Golder Associates

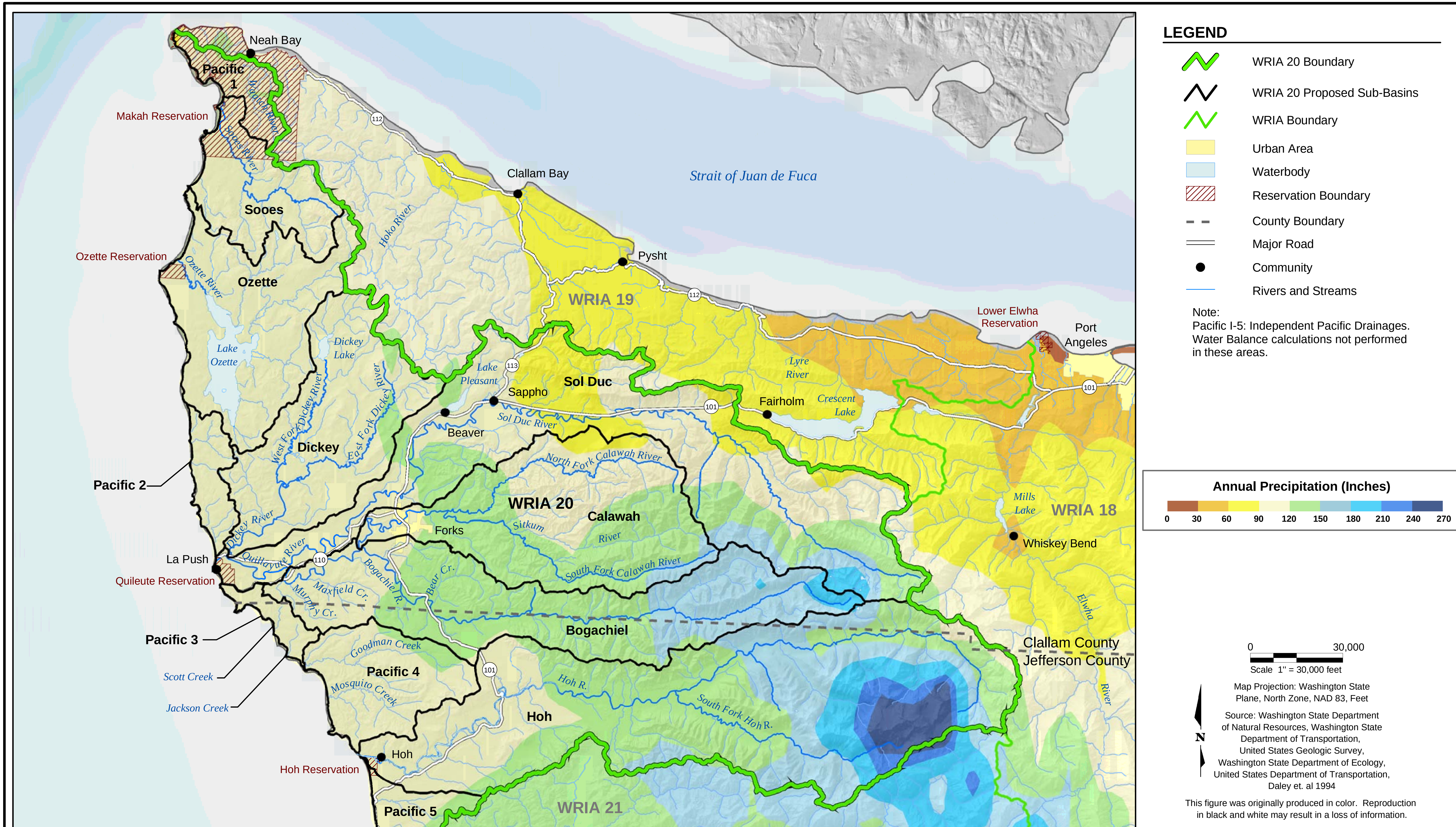


Positive (red) index values indicate a warm phase PDO; negative (blue) index values indicate a cool phase PDO. While short-term flips in PDO phases do occur, PDO phases generally persist for 20-30 years, as indicated in this figure. (Figure source: NOAA, Bering Climate)
PDO - Pacific Decadal Oscillation.

FIGURE **5-3**

MONTHLY VALUES FOR THE PDO INDEX
JANUARY 1900 TO FEBRUARY 2003

CLALLAM/WRIA 20 WATERSHED PLAN/WA

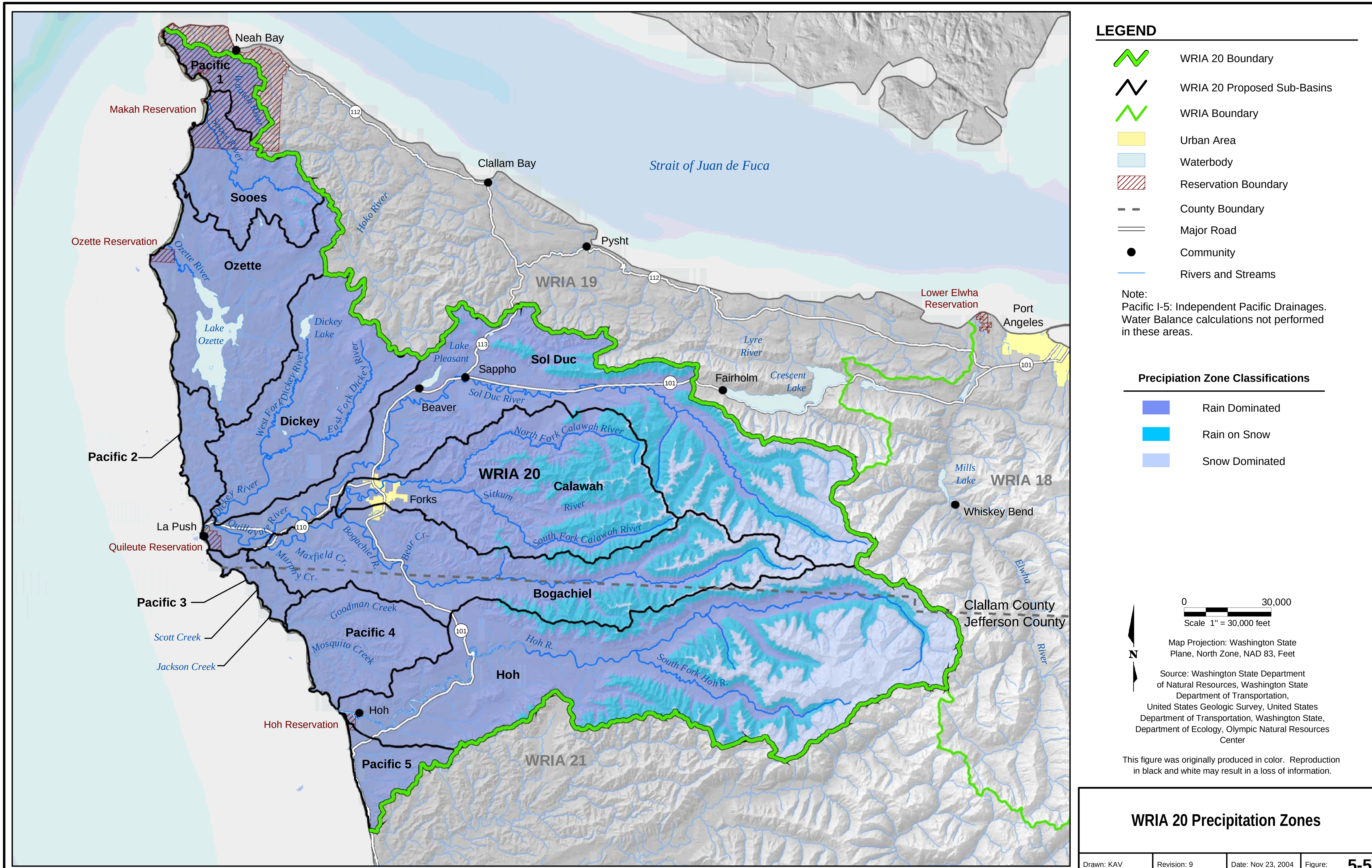


WRIA 20
Average Annual PRISM Precipitation

Drawn: KAV	Revision: 9	Date: Nov 23, 2004	Figure: 5-4

0431130401F04R01.mxd

Golder Associates

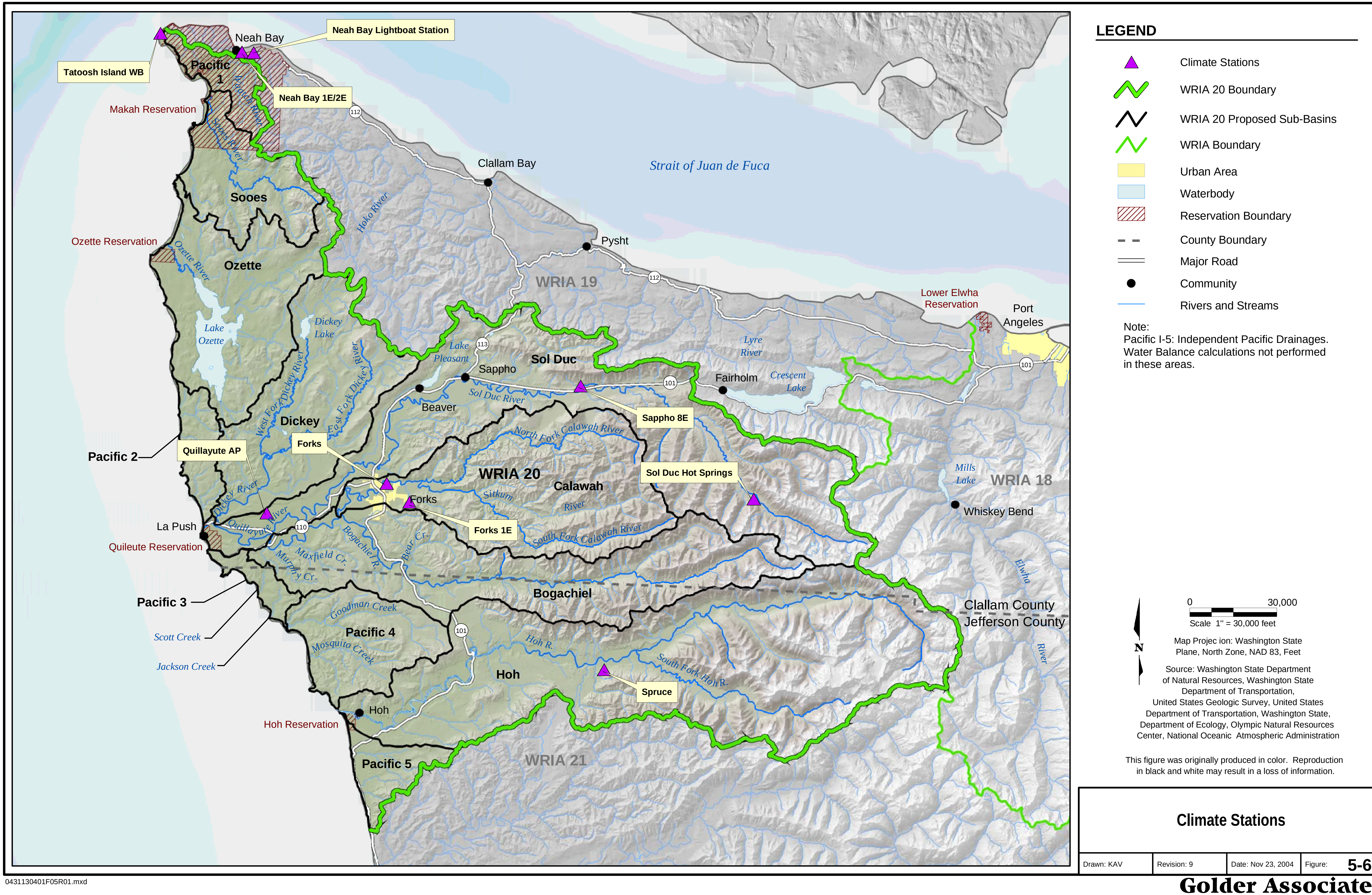


WRIA 20 Precipitation Zones

Drawn: KAV | Revision: 9 | Date: Nov 23, 2004 | Figure: 5-5

0431130401F02R01.mxd

Golder Associates



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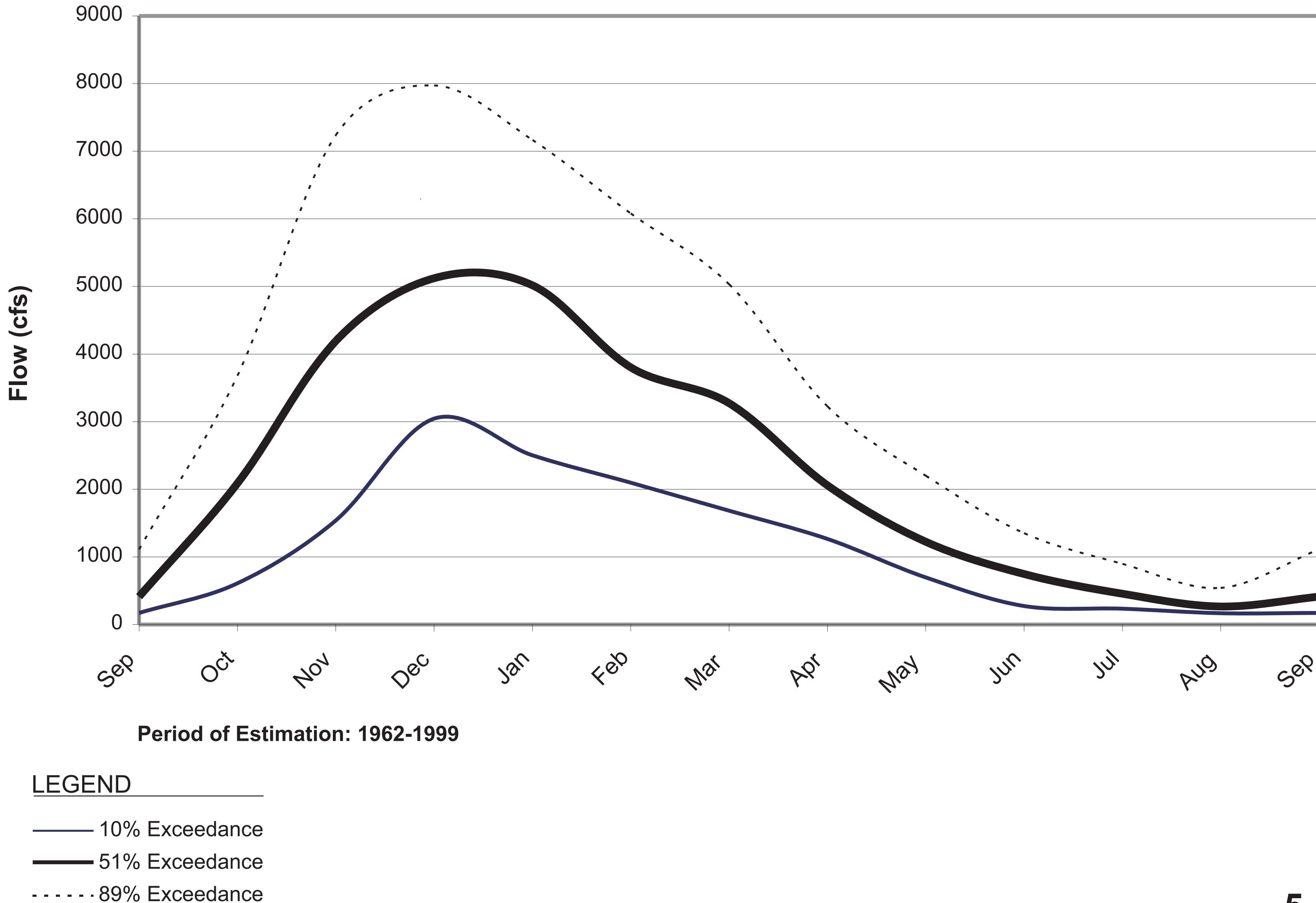


[a]Provided by Bureau of Reclamation (2004).

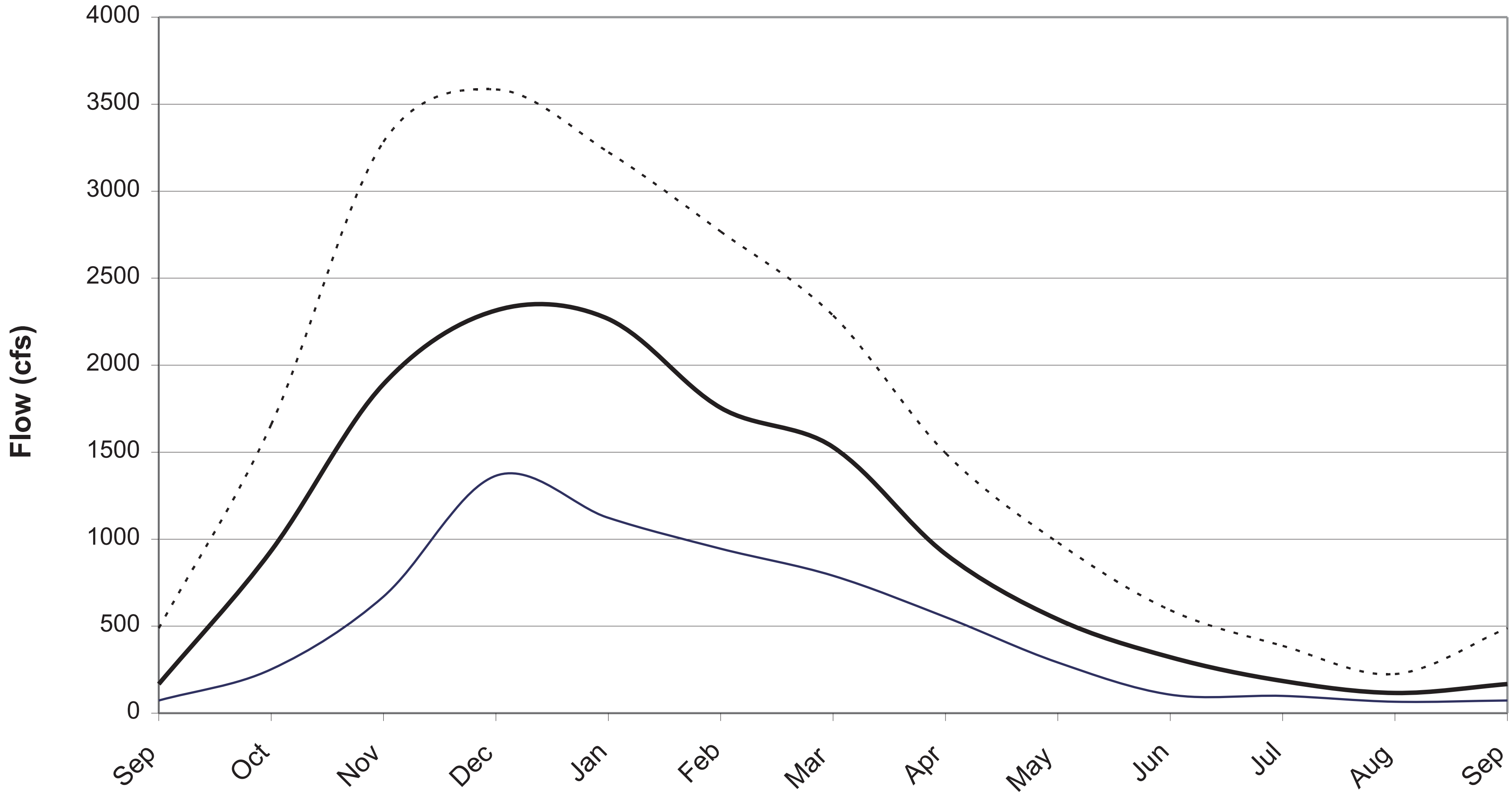
FIGURE **5-7a**

BOGACHIEL RIVER AT OUTLET EXCEEDANCE FLOWS[a]

CLALLAM/WRIA 20 WATERSHED PLAN/WA

DRAWING NO. 0431130401fg01.fh11 DATE 09/28/04 DRAWN BY EFS

Golder Associates



Period of Estimation: 1962-1999

LEGEND

- 10% Exceedance
- 51% Exceedance
- 89% Exceedance

[a]Provided by Bureau of Reclamation (2004).

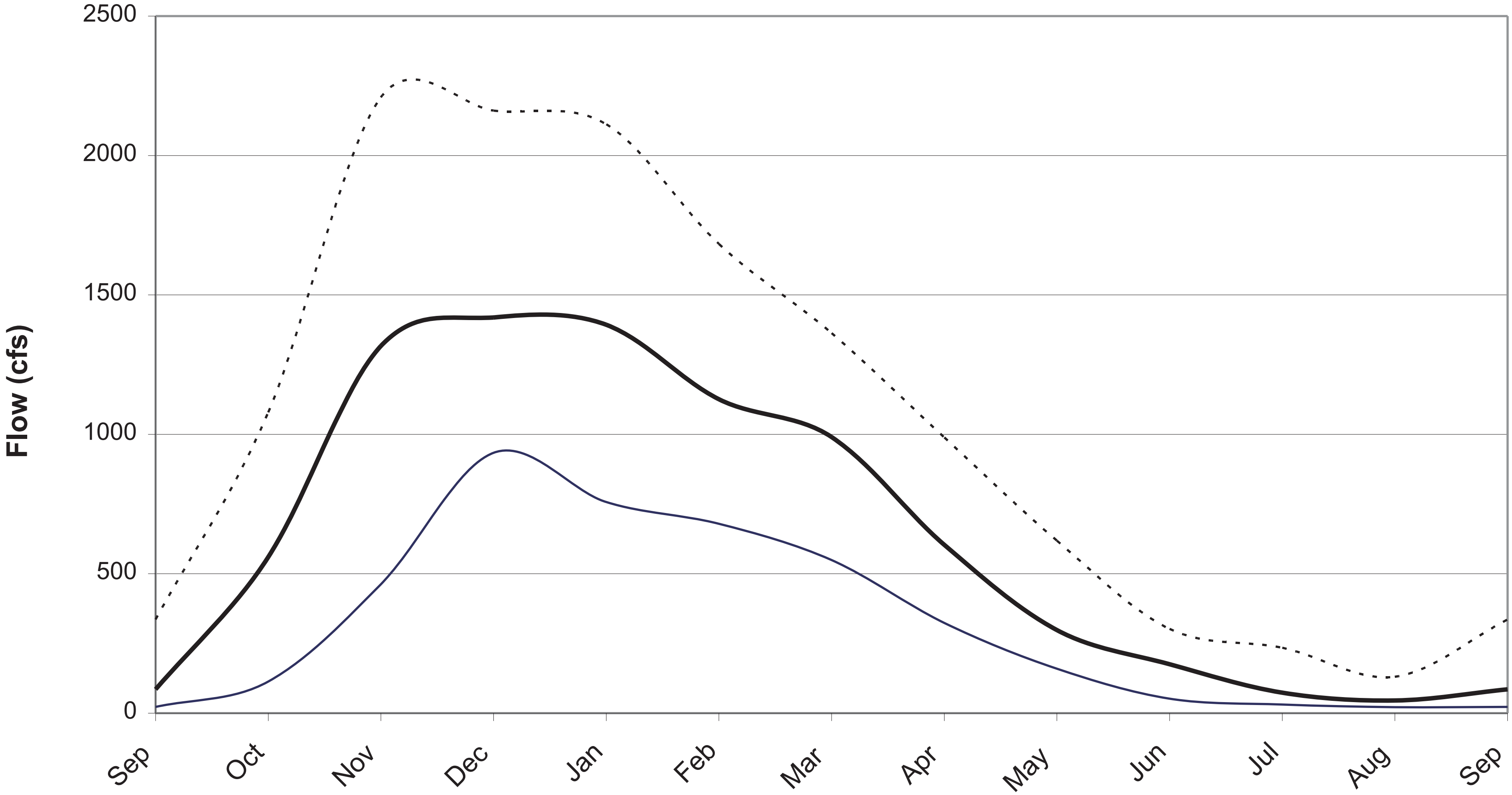
FIGURE **5-7b**

CALAWAH RIVER AT OUTLET EXCEEDANCE FLOWS[a]

CLALLAM/WRIA 20 WATERSHED PLAN/WA

DRAWING NO. 0431130401fg02.fh11 DATE 09/30/04 DRAWN BY EFS

Golder Associates



Period of Estimation: 1962-1999

LEGEND

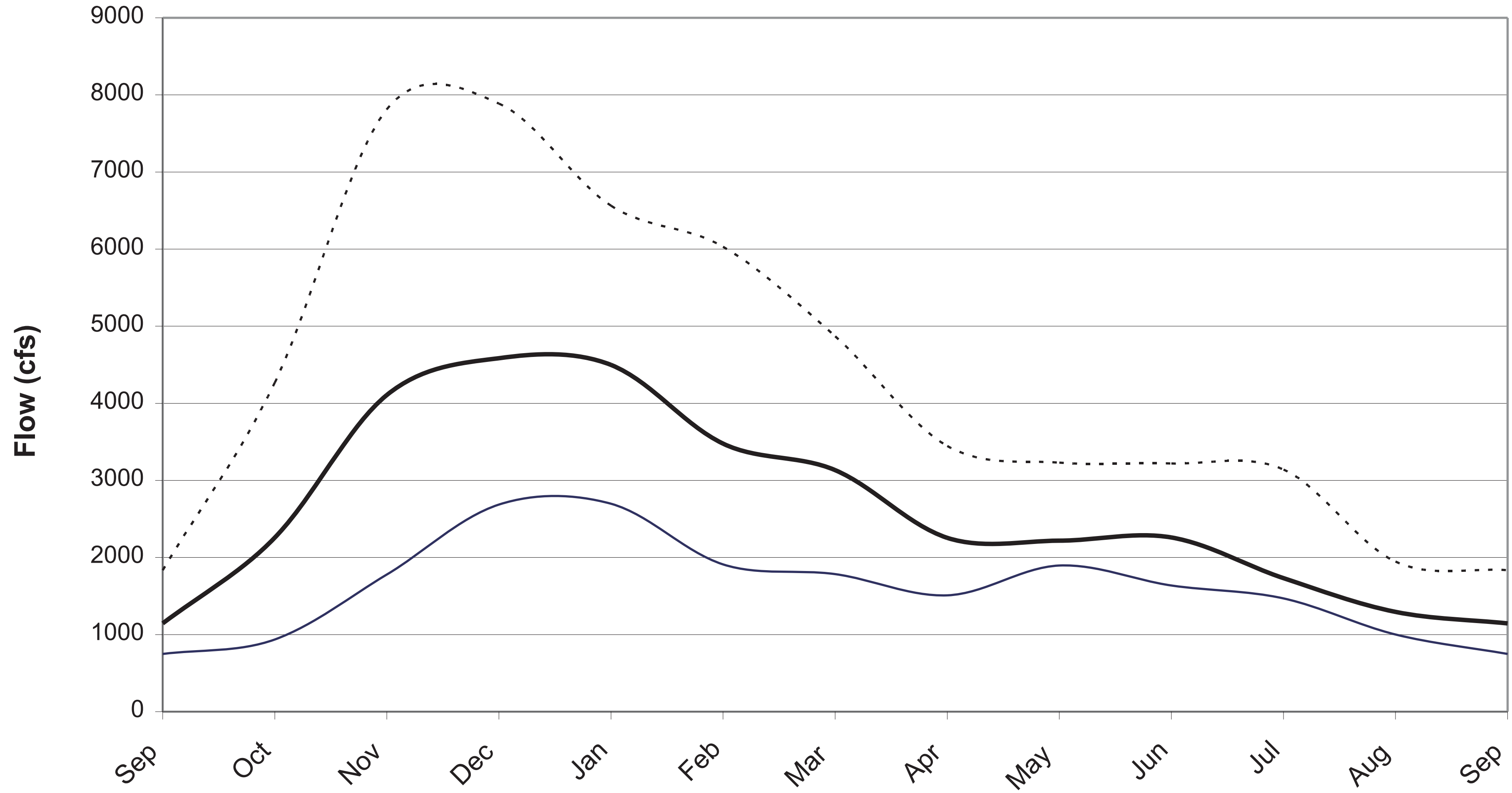
10% Exceedance
51% Exceedance
89% Exceedance

[a]Provided by Bureau of Reclamation (2004).

FIGURE **5-7c**
DICKEY RIVER AT OUTLET EXCEEDANCE FLOWS[a]
CLALLAM/WRIA 20 WATERSHED PLAN/WA

DRAWING NO. 0431130401fg03.fh11 DATE 09/28/04 DRAWN BY EFS

Golder Associates



Period of Estimation: 1961-1999

LEGEND

- 10% Exceedance
- 50% Exceedance
- 89% Exceedance

[a]Provided by Bureau of Reclamation naturalized streamflow estimates (2004).

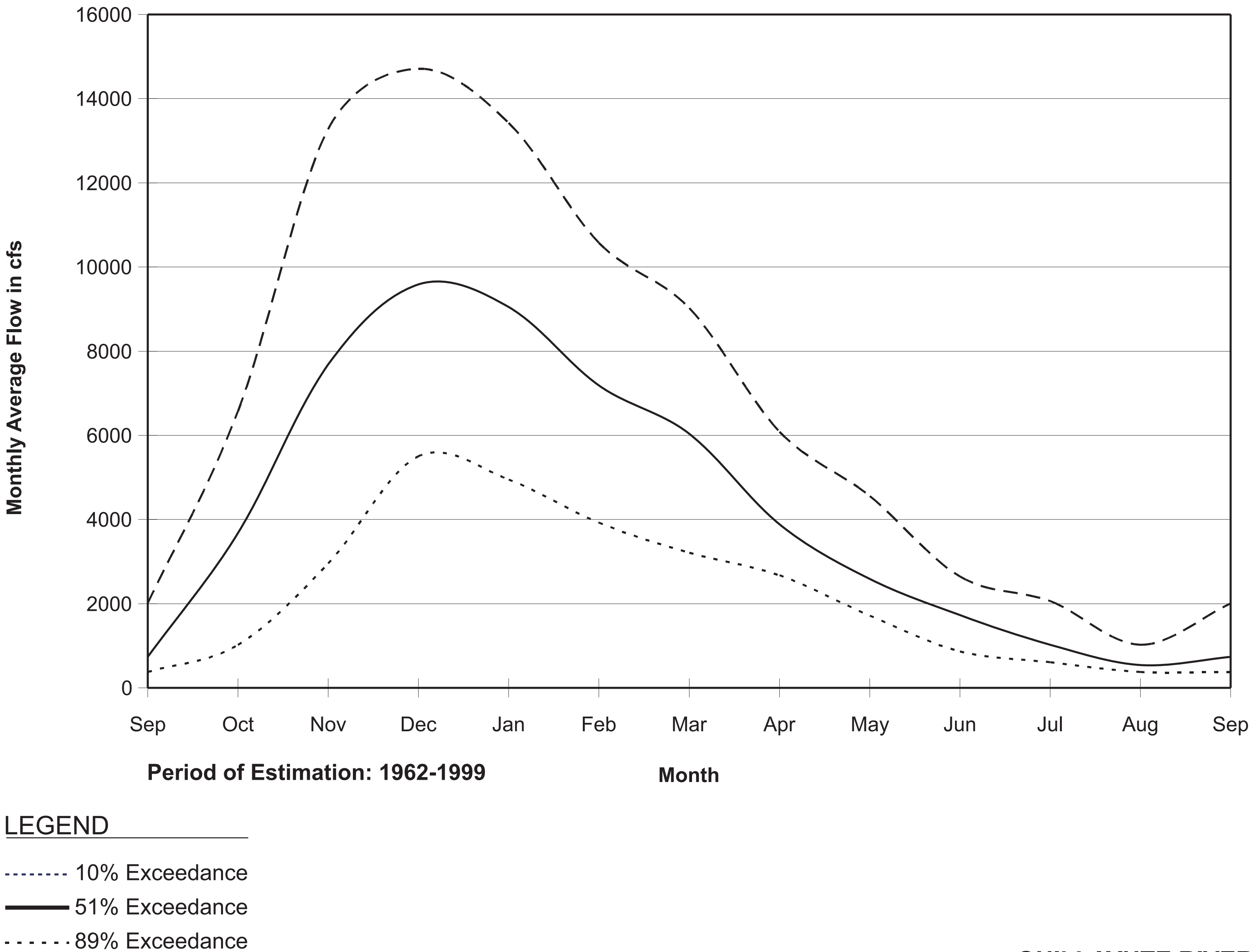
FIGURE **5-7d**

HOH RIVER AT OUTLET EXCEEDANCE FLOWS[a]

CLALLAM/WRIA 20 WATERSHED PLAN/WA

DRAWING NO. 0431130401fg04.fh11 DATE 09/28/04 DRAWN BY EFS

Golder Associates



[a]Provided by Bureau of Reclamation (2004).

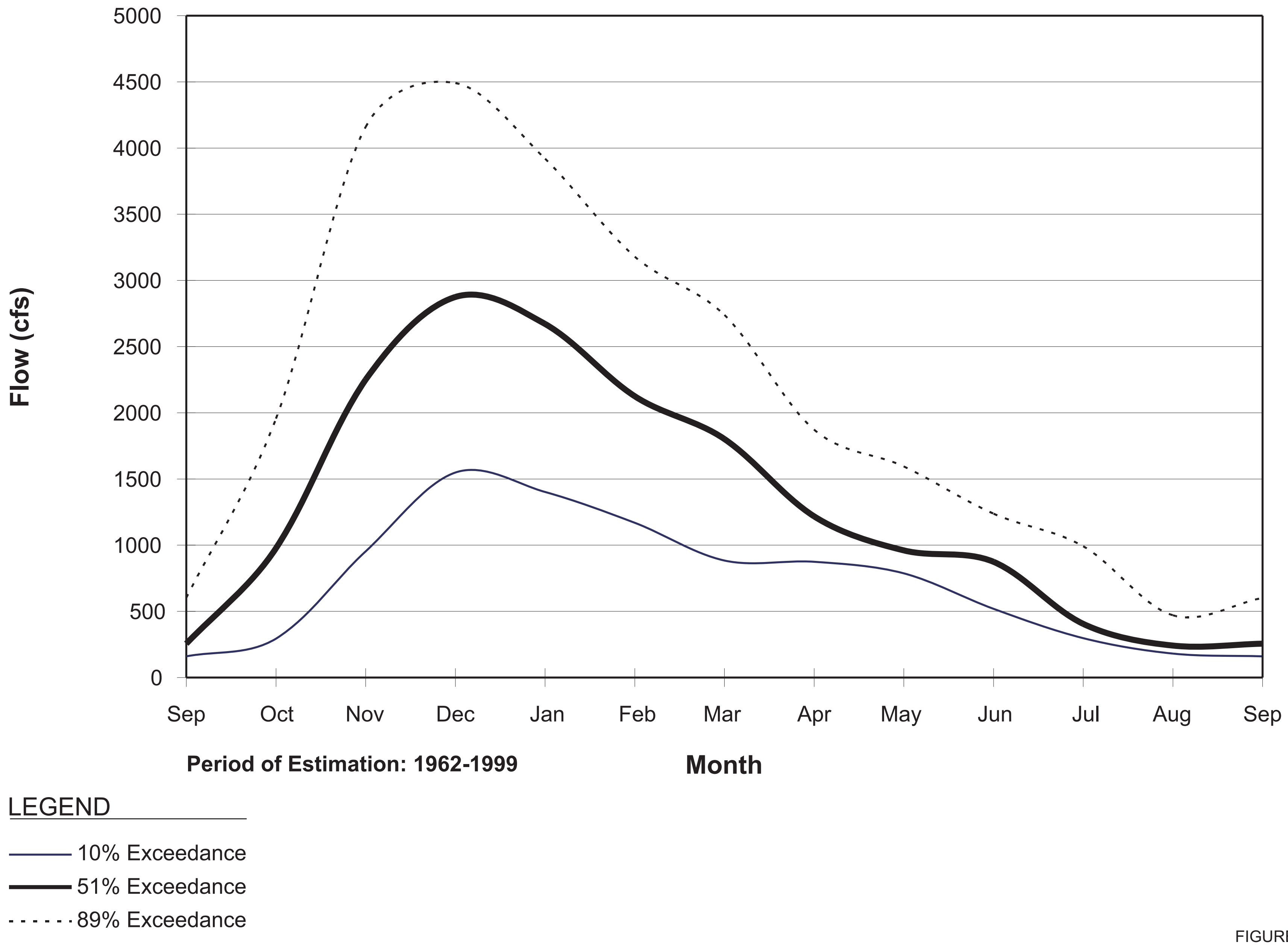
FIGURE **5-7e**

QUILLAYUTE RIVER AT OUTLET EXCEEDANCE FLOWS[a]

CLALLAM/WRIA 20 WATERSHED PLAN/WA

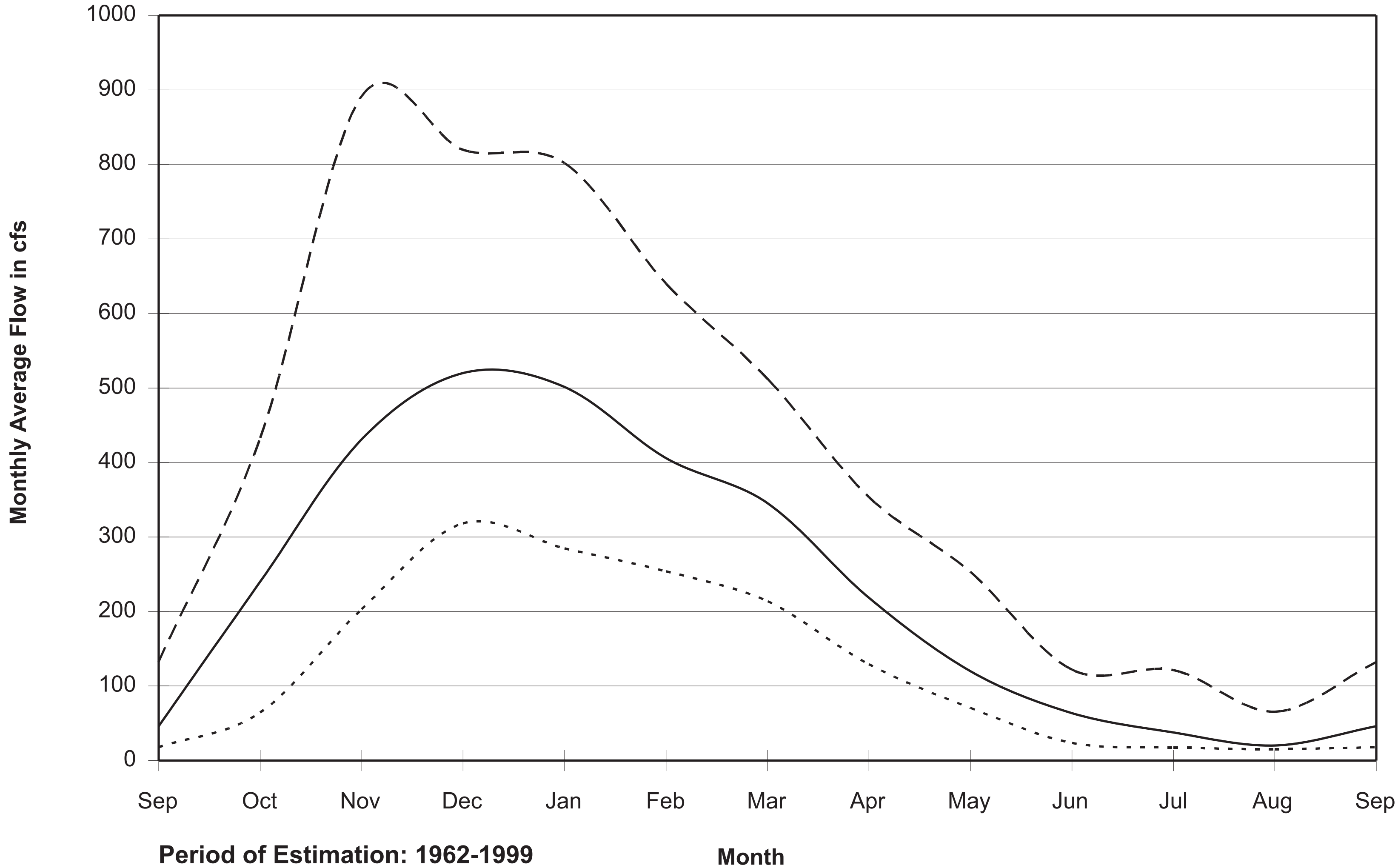
DRAWING NO. 0431130210fg04.fh11 DATE 04/13/05 DRAWN BY AMP

Golder Associates



[a]Provided by Bureau of Reclamation (2004).

FIGURE **5-7f**
SOL DUC RIVER AT OUTLET EXCEEDANCE FLOWS[a]
CLALLAM/WRIA 20 WATERSHED PLAN/WA



LEGEND

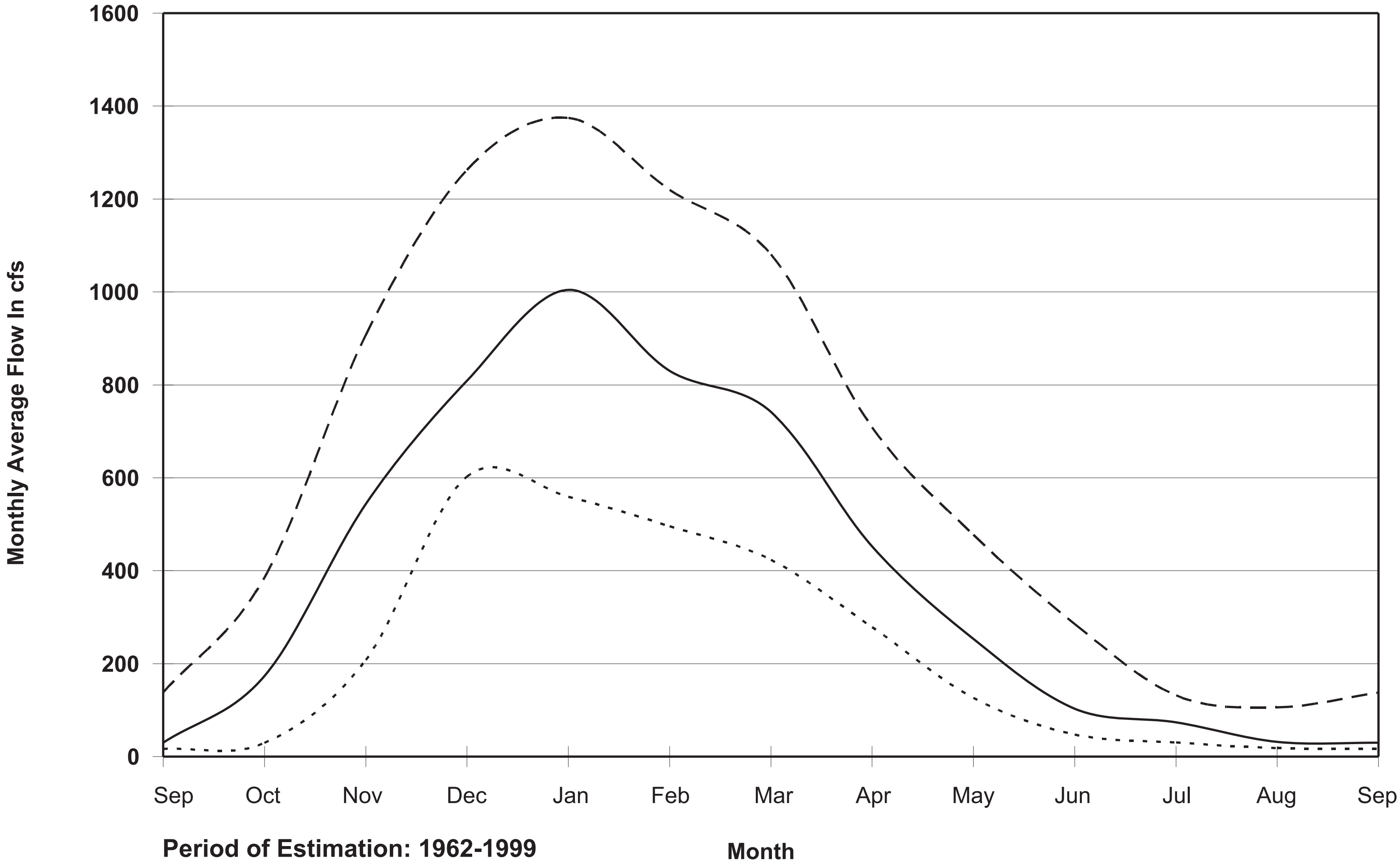
- 10% Exceedance
- 51% Exceedance
- 89% Exceedance

[a]Provided by Bureau of Reclamation (2004).

FIGURE **5-7g**

SOOES RIVER AT OUTLET EXCEEDANCE FLOWS

CLALLAM/WRIA 20 WATERSHED PLAN/WA



Period of Estimation: 1962-1999

LEGEND

- 10% Exceedance
- 51% Exceedance
- 89% Exceedance

[a]Provided by Bureau of Reclamation (2004).

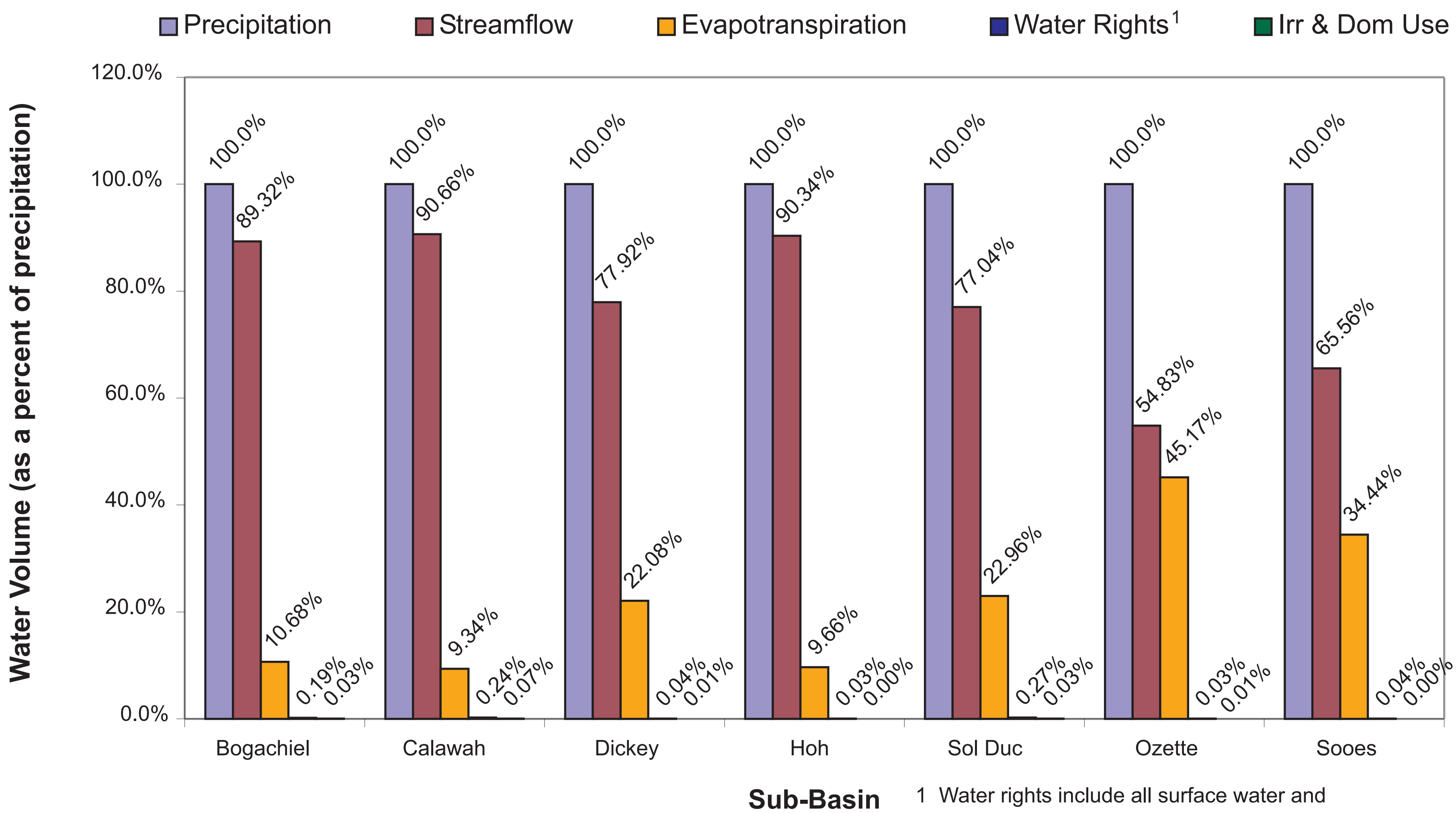
FIGURE **5-7h**

OZETTE RIVER AT OUTLET EXCEEDANCE FLOWS

CLALLAM/WRIA 20 WATERSHED PLAN/WA

DRAWING NO. 0431130210fg06.fh11 DATE 04/13/05 DRAWN BY AMP

Golder Associates



1 Water rights include all surface water and groundwater rights and exempt well allocation

FIGURE **5-8**

ANNUAL WATER BALANCE BY SUB-BASIN[1]

CLALLAM/WRIA 20 WATERSHED PLAN/WA

DRAWING NO. 0431130210fg03.fh11 DATE 04/13/05 DRAWN BY AMP

Golder Associates

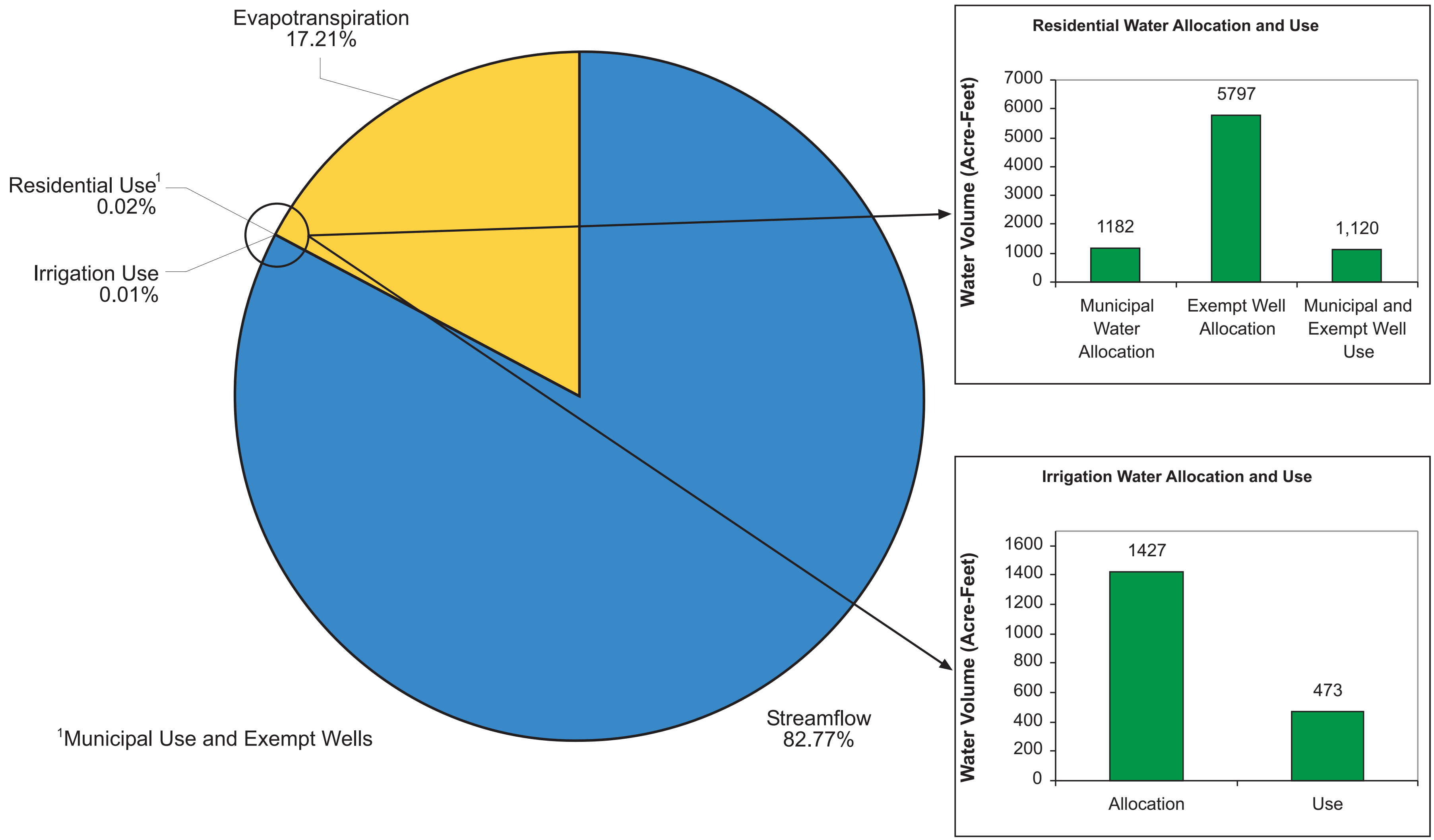


FIGURE **5-9**

ANNUAL DISTRIBUTION OF WATER IN WRIA 20

CLALLAM/WRIA 20 WATERSHED PLAN/WA

DRAWING NO. 0431130210fg01.fh11 DATE 04/13/05 DRAWN BY AMP

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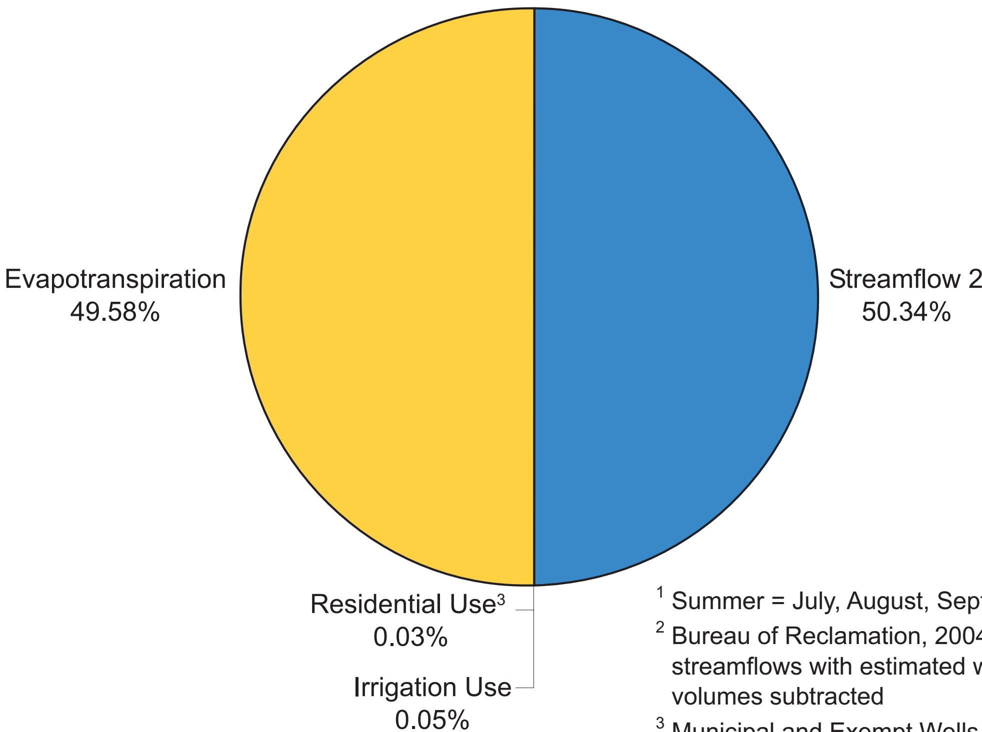
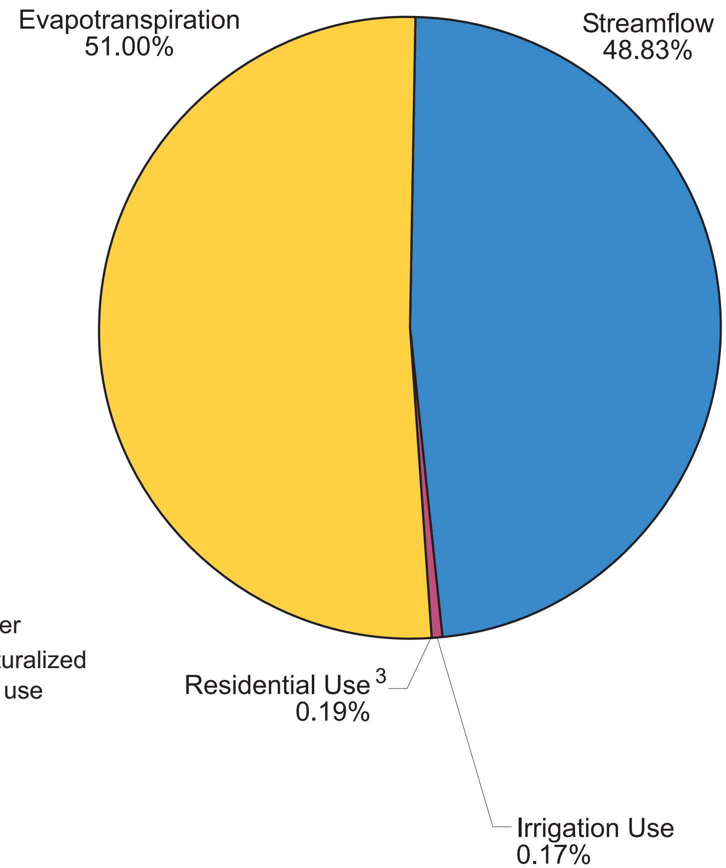
Total Summer[1] Distribution of Water in WRIA 20 [2]



Summer[1] Distribution of Water in Calawah[2]



[1] Summer = July, August, September

[2] Bureau of Reclamation, 2004; naturalized streamflows with estimated water use volumes subtracted

[3] Municipal and Exempt Wells

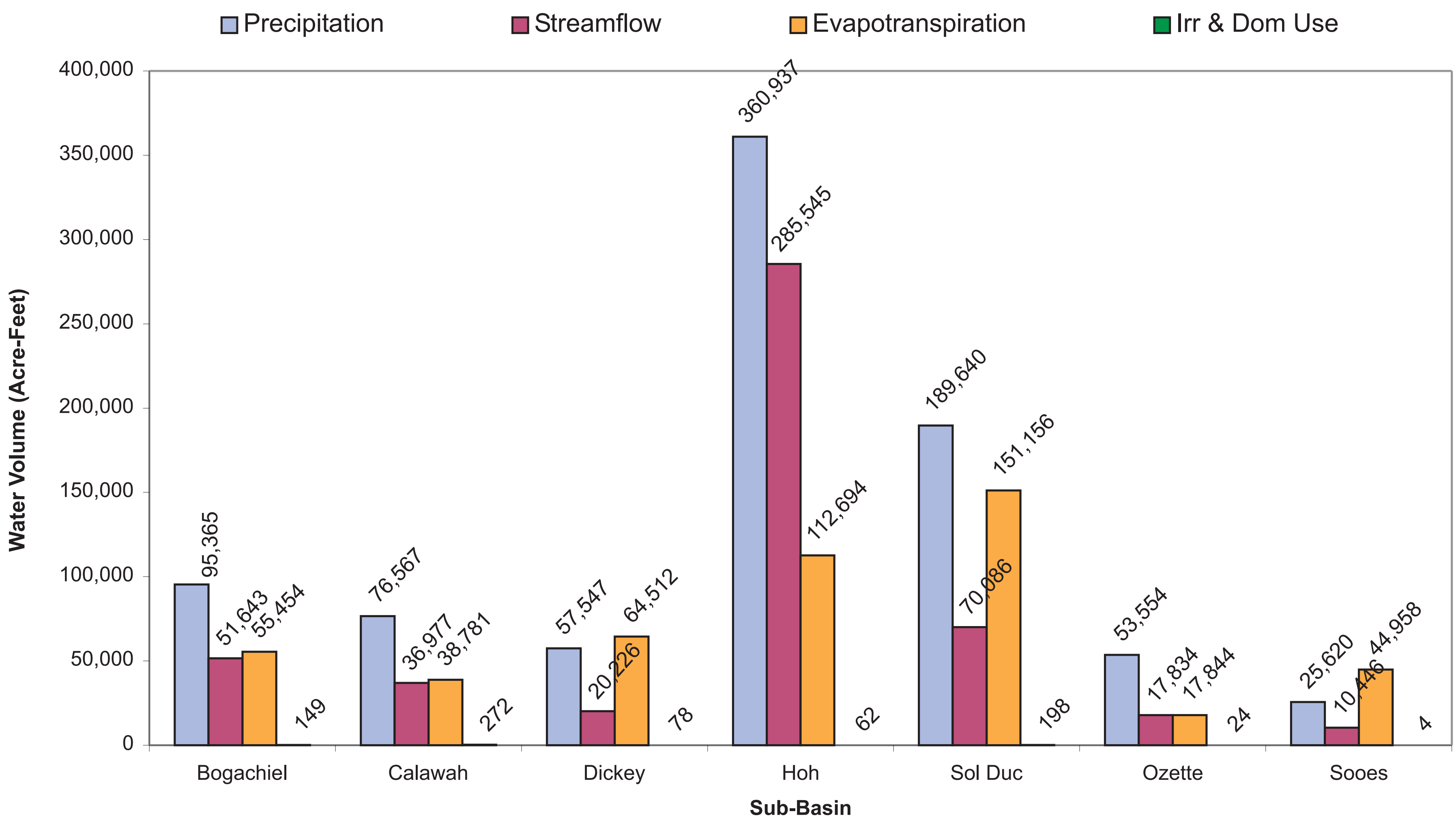
FIGURE **5-10**

SUMMER[1] WATER BALANCE BY SUB-BASIN[2]

CLALLAM/WRIA 20 WATERSHED PLAN/WA

DRAWING NO. 0431130210fg02.fh11 DATE 04/13/05 DRAWN BY AMP

Golder Associates



[1] Summer = July, August, September

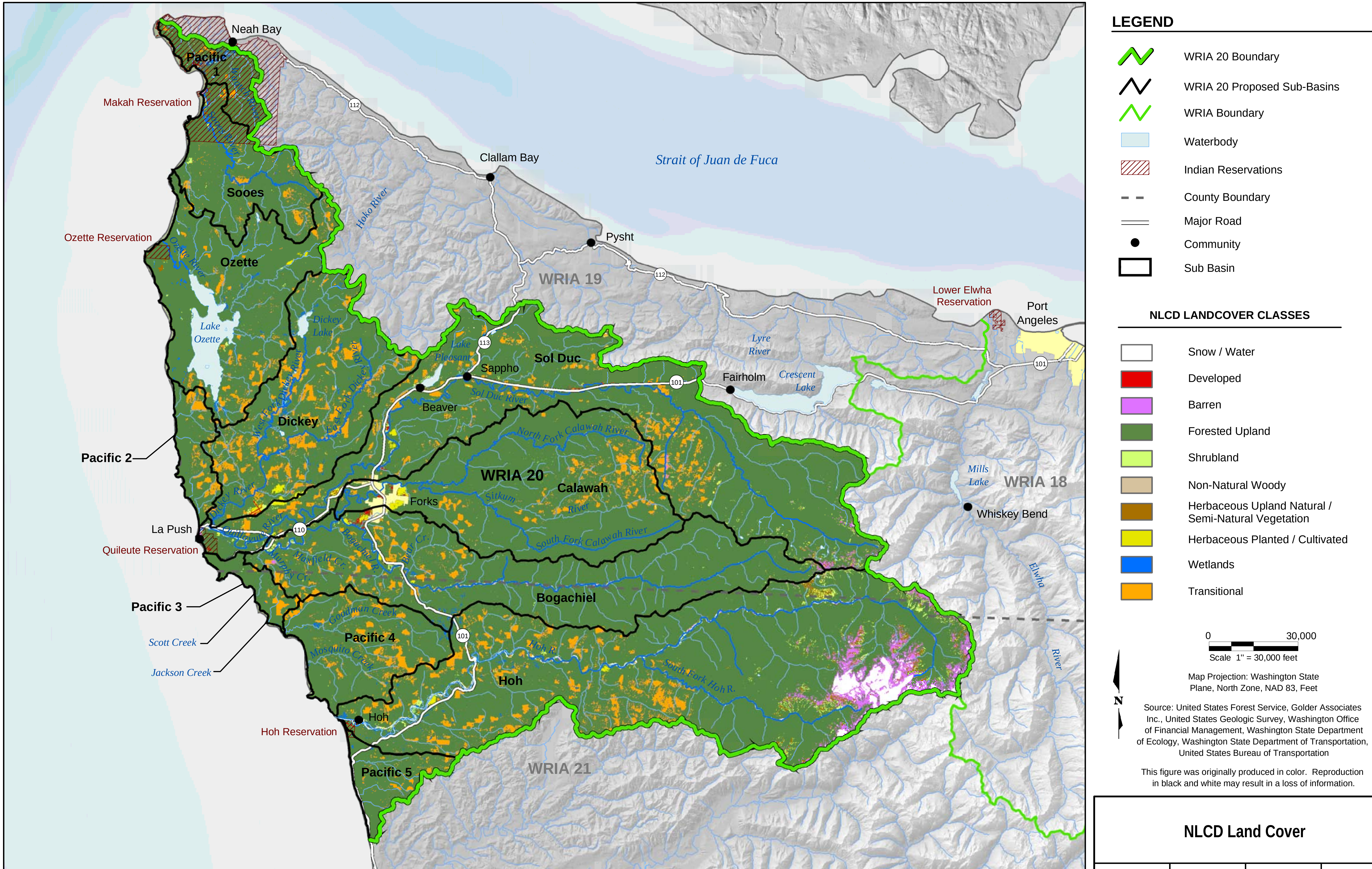
FIGURE **5-11**

SUMMER[1] WATER BALANCE BY SUB-BASIN[2]

CLALLAM/WRIA 20 WATERSHED PLAN/WA

DRAWING NO. 0431130210fg05.fh11 DATE 04/13/05 DRAWN BY AMP

Golder Associates



Map Projection: Washington State Plane, North Zone, NAD 83, Feet

Source: United States Forest Service, Golder Associates Inc., United States Geologic Survey, Washington Office of Financial Management, Washington State Department of Ecology, Washington State Department of Transportation, United States Bureau of Transportation

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NLCD Land Cover

Drawn: KAV	Revision: 3	Date: Nov. 23, 2004	Figure: 6 - 1

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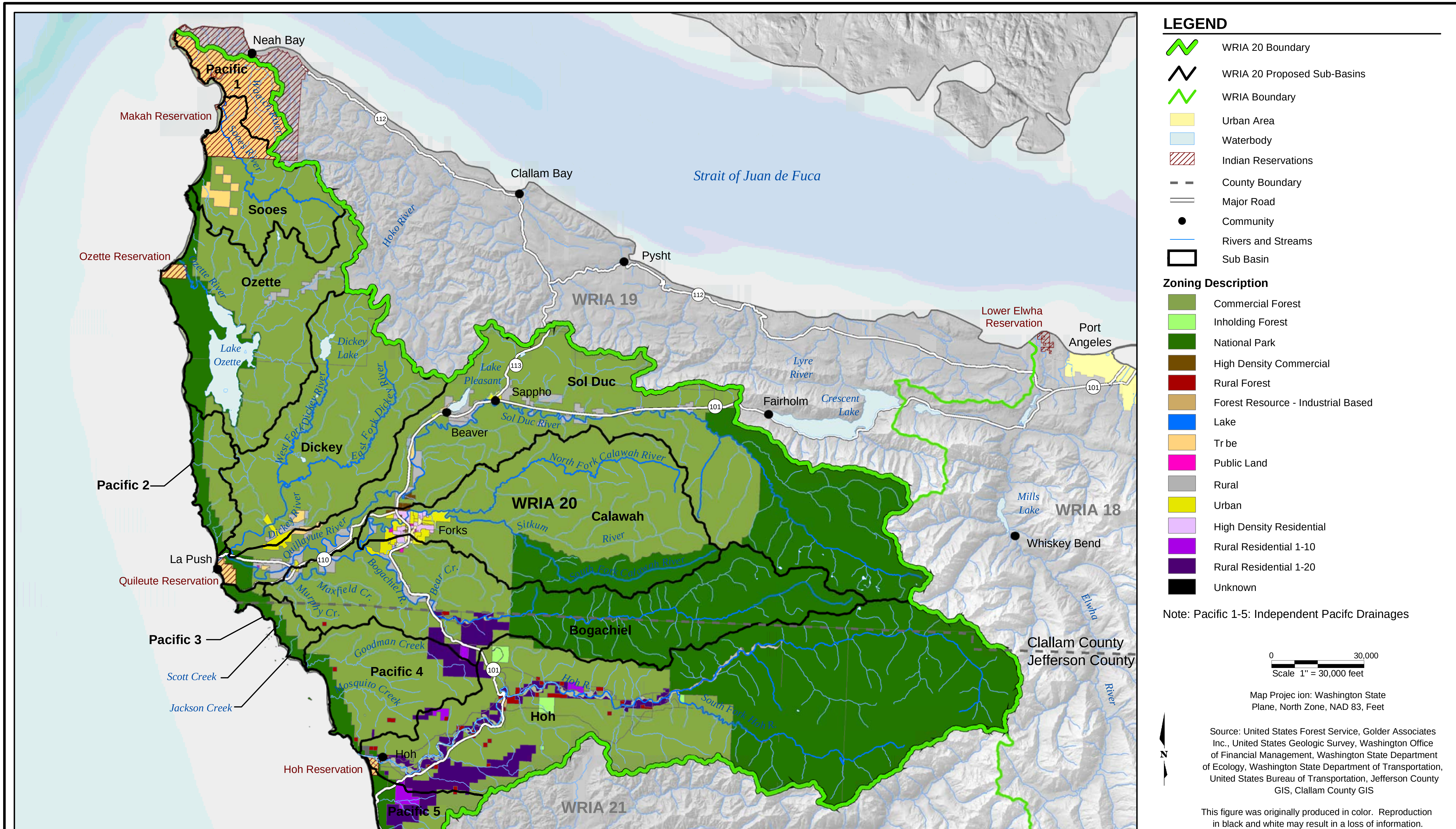
Golder Associates



WRIA 20 Clallam and Jefferson County Zoning

Drawn: KAV	Revision: 3	Date: Nov 23, 2004	Figure: 6 - 2

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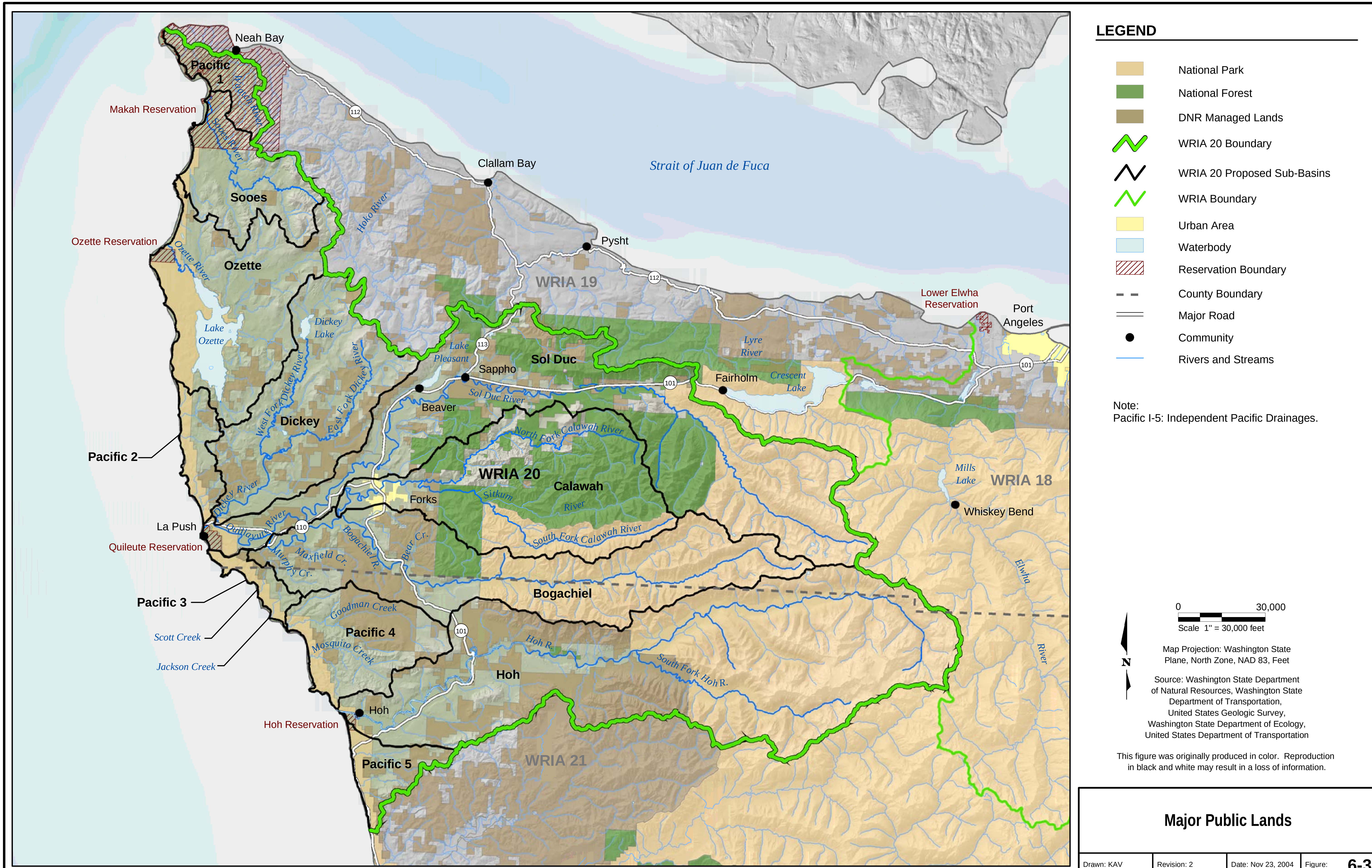
Golder Associates



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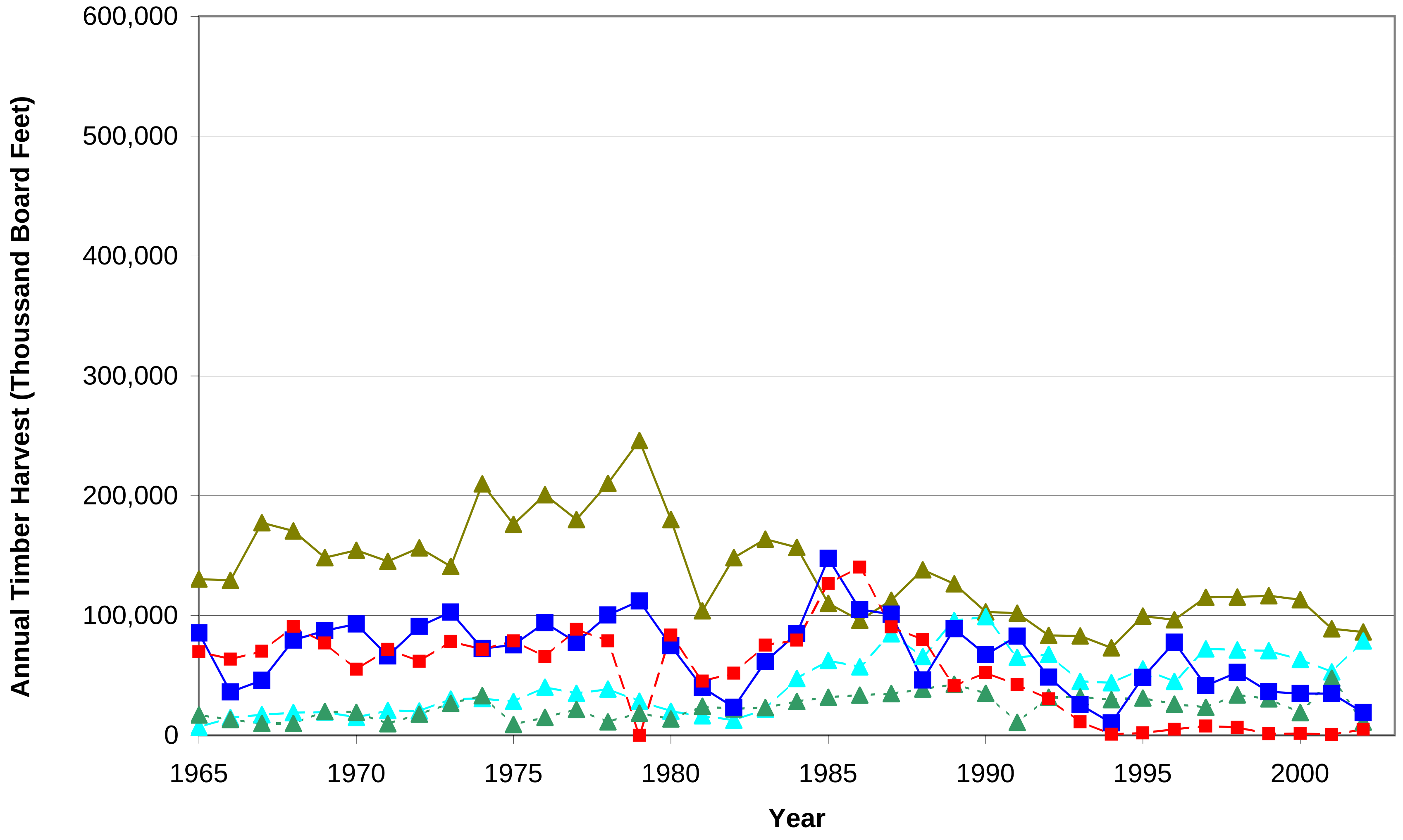

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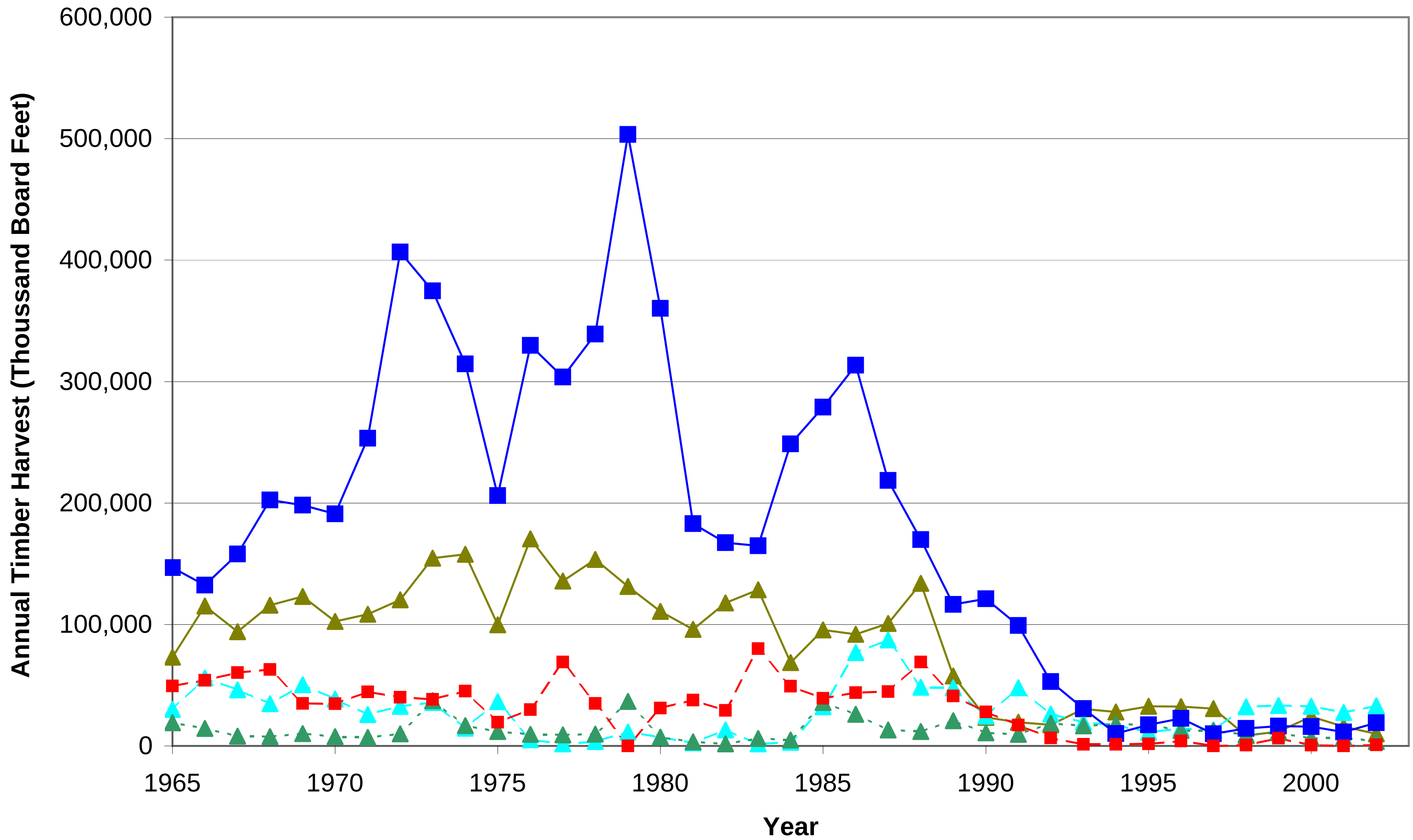
WRIA 20/Phase II Technical Assessment

Timber Harvest Summary Clallam County

JOB NUMBER:	043-1130	DATE:	11-Nov-04
DRAWN BY:	DGC	FIGURE NO.:	**6-4**

File Name: Land Use Figures.xls



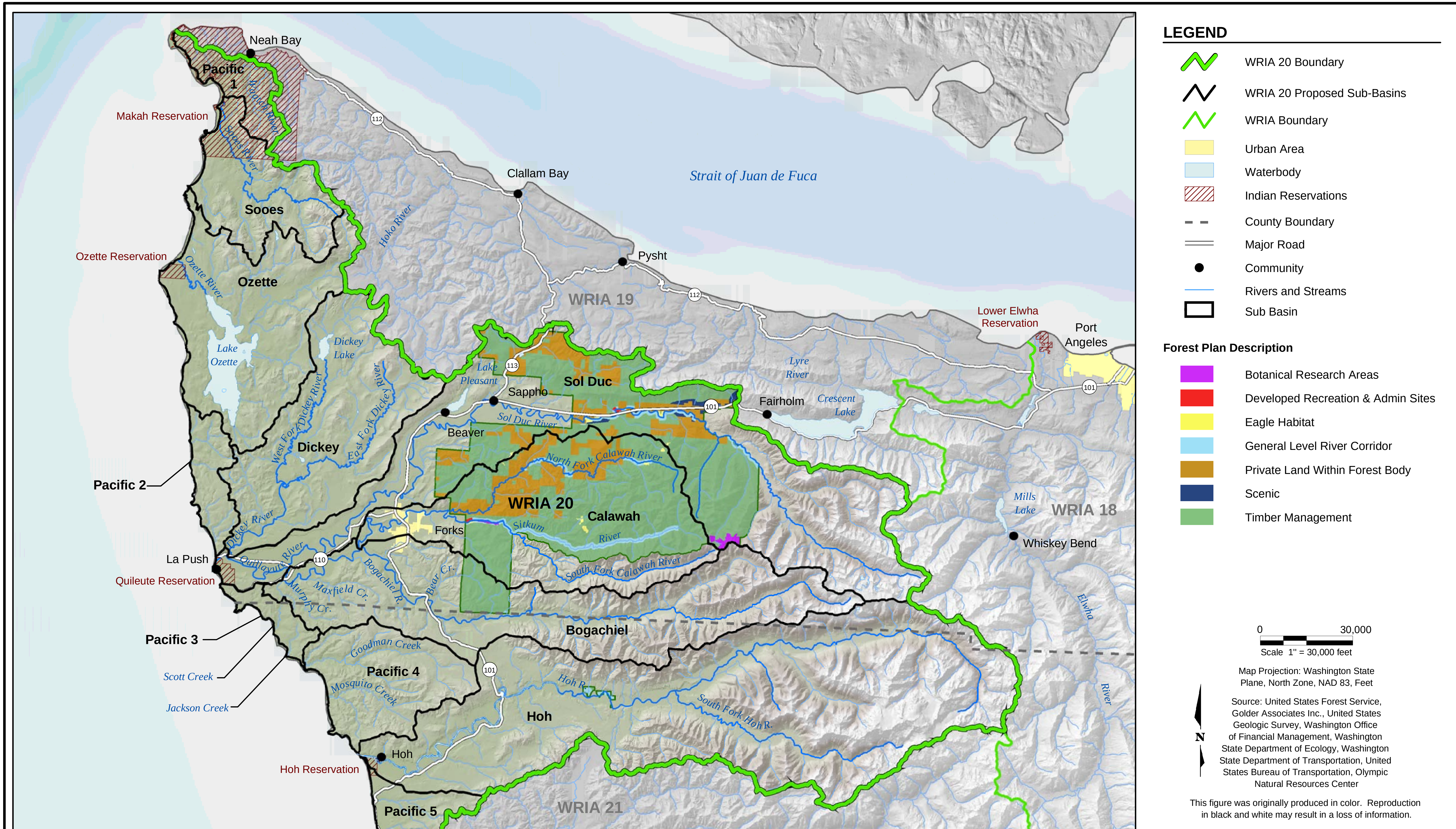
Golder Associates

WRIA 20/Phase II Technical Assessment

Timber Harvest Summary Jefferson County

JOB NUMBER:	043-1130	DATE:	11-Nov-04
DRAWN BY:	DGC	FIGURE NO.:	**6-5**

File Name: Land Use Figures.xls



Northwest Forest Plan Zoning in Olympic National Forest

Drawn: KAV | Revision: 3 | Date: Nov. 23, 2004 | Figure: 6 - 6

Golder Associates

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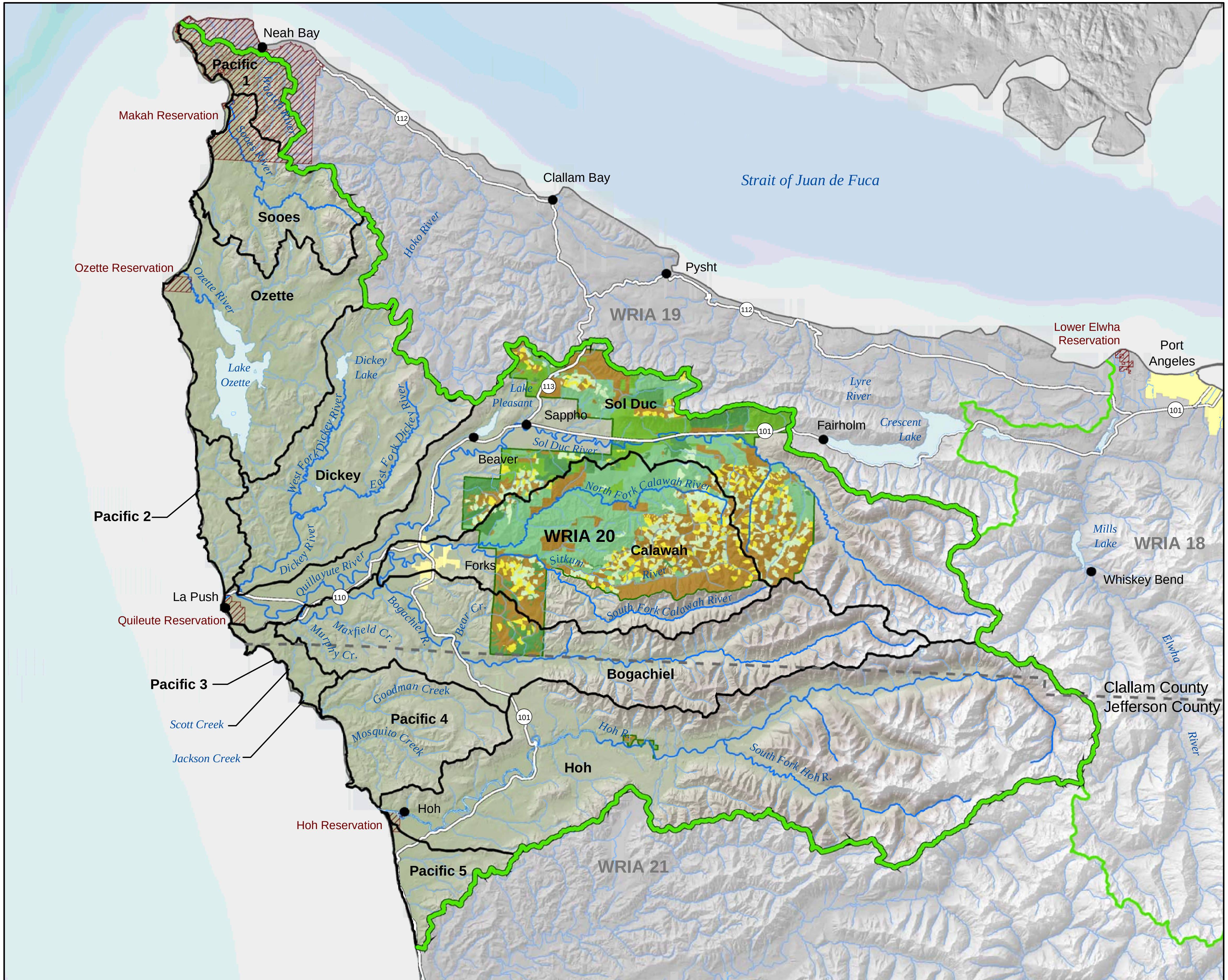

LEGEND

- WRIA 20 Boundary
- WRIA 20 Proposed Sub-Basins
- WRIA Boundary
- Urban Area
- Waterbody
- Indian Reservations
- County Boundary
- Major Road
- Community
- Rivers and Streams
- Sub Basin

Olympic National Forest Tree Age Class

- 0-20yrs
- 21-40yrs
- 41-60yrs
- 61-80yrs
- 81-160yrs
- Over 160yrs

Note: Pacific 1-5: Independent Pacifc Drainages

0 30,000
Scale 1" = 30,000 feet

N

Map Projec ion: Washington State Plane, North Zone, NAD 83, Feet

Source: United States Forest Service, Golder Associates Inc., United States Geologic Survey, Washington Office of Financial Management, Washington State Department of Ecology, Washington State Department of Transportation, United States Bureau of Transportation, Olympic Natural Resources Center

This figure was originally produced in color. Reproduction in black and white may result in a loss of information.

WRIA 20 Olympic National Forest Tree Age Class

Drawn: KAV	Revision: 3	Date: Nov 23, 2004	Figure: 6 - 7

0431130204F02R0.mxd

Golder Associates

APPENDIX A

ANNOTATED BIBLIOGRAPHY BY ABIGAIL HOOK

Annotated References
WRIA 20 Level I Technical Assessment
Abigail Hook
6/10/04

WRIA 20

Agee, J.K. 1994. Catastrophic forest disturbance on the Olympic Peninsula. Research paper prepared for Rayonier Inc. P.O. Box 200 Hoquiam, WA.
This paper outlines the historical fire and windthrow events on the western Olympic Peninsula.

Benda, L. C. Veldhuisen and J. Black. 2003. Debris flows as agents of morphological heterogeneity at low-order confluences, Olympic Mountains, Washington. Geological Society of America Bulletin: Vol. 115, No. 9, pp. 1110-1121.
Field data and information from study sites indicates how variation in debris flow volume and composition, stream energy, and valley width at the point of deposition influence the relationship between low-order confluences and channel morphology.

Boyce, J.S. 1929. Deterioration of wind-thrown timber on the Olympic Peninsula, Washington. USDA Tech. Bull. 104. Washington DC.
Reviews the effects of the 1921 windstorm and subsequent longevity of the wood on the ground. Examines the response of different species to rot and fungus typical of blowdown

Cummans, J.E., M.R. Collins, and E.G. Nassar. 1975. Magnitude and frequency of floods in Washington. US Geological Survey Open-File Report 74-336.

DOE. 1992. Statewide Water Quality Assessment (305(b) Report). Pub. No. 92-04. Washington Department of Ecology. Olympia, WA.
The purpose of the Section 305(b) report is to present to the U.S. Congress and the public the current conditions of the state's waters. Section 305(b) of the federal Clean Water Act requires each state to prepare a water quality assessment report every two years. The EPA compiles the information from the state reports and prepares a summary for Congress on the status of the nation's waters. The 2000 Washington State 305(b) report has been prepared in accordance with EPA guidelines for preparation of 305(b) reports. The difference between the 305(b) report and the 303(d) list is that the 305(b) report is a state-wide assessment where the 303(d) list reports just on the impaired waters of the state.

DOE. 1992. Water quality standards for surface waters of the State of Washington. WAC 173-201A. Water Quality Program, Olympia.
This code outlines standards put into place consistent with public health and public enjoyment of the waters and the propagation and protection of fish, shellfish, and wildlife, pursuant to the provisions of chapter 90.48 RCW (water pollution control).

DOE. 1998. Water Quality in Washington State (Section 303(d) of the Federal Clean Water Act). Washington Department of Ecology, Olympia, WA.
Section 303(d) of the federal Clean Water Act requires Washington State periodically to prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality limited estuaries, lakes, and streams that fall short of state surface water quality standards, and are not expected to improve within the next two years.

Gerstel, W. 1999. Deep-seated landslide inventory of the west-central Olympic Peninsula. Washington Division of Geology and Earth Resources Open File Report 99-2.
Gertsel inventories landslides from La Push to the Queets River, bounded to the west by Olympic National Park. The deep-seated landslide inventory and subsequent geologic information is intended to be used as a landslide hazard map for land-use planners and land managers trying to identify hazardous areas. The landslides were identified through aerial-photo interpretation and ground verified. They were then digitized into a GIS system.

Hauschild, W.L. and D.E. LaFrance. 1978. Low flow characteristics of streams on the Olympic Peninsula, Washington. US Geological Survey Open-File Report 77-812.
The purpose of this study was to determine (for the benefit of water users and managers) the magnitude, frequency and normal time of occurrence of low flows of streams on the Olympic Peninsula. The magnitude and frequency of 7-day low flows were estimated for 116 stations either from frequency analyses of data at long-term stations or from correlation of data at a short-term station with data at an appropriate long-term station.

Huntington, C.W., W. Nehlsen and J. Bowers. 1996. Healthy native stocks of anadromous salmonids in the Pacific Northwest and California. Fisheries (21)3: 6-13.
This report summarizes a survey of healthy native stocks of anadromous salmonids in the Pacific Northwest and California. The information was gathered using a questionnaire approach combined with spatial analysis to describe the status and distribution of stocks considered to be in relatively good condition.

Lestelle, L.C., G.S. Morishima and T.D. Cooney. 1984. Determining spawning escapement goals for wild coho salmon on the Washington North Coast. Pages 243-254 in: J.M. Walton and D.B. Houston (eds), Proceedings of the Olympic Wild Fish Conference. March 23-25, 1983, Port Angeles, WA.
This paper asserts that the accuracy of habitat quantity estimates and the classification of habitat by potential productivity have not been historically accurate and discusses the effects on maximum sustainable harvest policies.

Long, William A. 1975. Salmon Springs and Vashon continental ice in the Olympic Mountains and relation of Vashon continental ice to Fraser Olympic ice. US Forest Service unpublished report.

Nehlsen W., J.E. Williams and J.A. Lichatowich. 1991. Pacific salmon at the crossroads: stocks at risk from California, Oregon, Idaho, and Washington. Fisheries 16:2.
The American Fisheries Society (AFS) provides a list of Pacific salmon, steelhead and sea-run cutthroat stocks from CA, OR, ID, and WA to accompany the list of rare inland fishes reported by AFS in 1989.

Phinney, L.A. and P. Bucknell. 1975. A catalog of Washington streams and salmon utilization, Volume 2 - Coastal Region. Washington Department of Fisheries.
Outlines status of anadromous salmonids in WA and possible links to land use between land use and habitat degradation.

Schoonmaker, P., B. von Hagen and E. Wolf. 1997. The Rainforests of Home: Profile of a North American Bioregion. Island Press: Washington, D.C.
Describes the physical characteristics, history, economy and culture of the coastal temperate rain forest from Northern CA to AK. Presents a series of chapters from conservationists, ecologists, anthropologists and community developers.

Sheldon and Klein. 1994. Inventory of Western Clallam County Wetlands. In: Clallam County Comprehensive Flood Hazard Management Plan. Sheldon and Associates. Seattle, WA.

Smith, C. 2000. Salmon and Steelhead Habitat Limiting Factors in the North Washington Coastal Streams of WRIA 20. Prepared for the Washington Conservation Commission, Olympia, WA.
As part of ESHB 2496, the habitat conditions of salmonid-producing watersheds within WRIA 20 are reviewed and rated in this document. Maps of updated salmon and steelhead trout distribution, culverts and other blockages, large woody debris (LWD) and riparian conditions, and floodplain complexes were prepared and are located in a separate electronic file on this disc. This first round report examines salmon and steelhead trout habitat conditions. The streams addressed in this report include all salmon- and steelhead-producing streams in the following basins: Waatch, Sooes, Ozette, Quillayute, Goodman, Mosquito, Hoh, Cedar, and Steamboat.

Tabor, R.W. and Cady, W.M. 1978. The Structure of the Olympic Mountains, Washington – Analysis of a Subduction Zone, USGS Professional Paper 1033.
Geologic map of the Olympic Peninsula, Washington.

USDA Forest Service, 1994. Olympic National Forest Watershed Improvement Needs Inventory.

An inventory of over 200,000 acres was conducted on the Forest. This Watershed Improvement Needs Inventory (WIN) is used to identify existing and potential problem areas, evaluate them and recommend restoration action. Inventory data is used as part of the watershed assessment process which evaluates the current condition and health of watersheds. The Inventory helps to prioritize areas within a watershed to concentrate restoration efforts for greatest efficiency.

Washington Department of Fisheries and Western Washington Treaty Indian Tribes. 1992 Washington state salmon and steelhead stock inventory (SASSI). Washington Department of Fisheries, Olympia, WA.
This report documents the results of an initial stock status inventory that is the first step in a statewide effort to maintain and restore wild salmon and steelhead stocks and fisheries. Overall objectives and future steps of the restoration initiative are briefly described. The report primarily focuses on current condition of Washington's naturally reproducing anadromous salmonid populations and not on the adequacy of current resource management objectives.

Watershed Analysis
Watershed Analysis is a structured approach developed by the Washington Department of Natural Resources as a result of the 1987 Timber/Fish/Wildlife Agreement. In 1991, the Forest Practices Board proposed adopted the Watershed Analysis process as which develops forest practices plans tailored to each watershed based on scientific understanding. As part of the state process, Washington has been divided into roughly 800 watersheds which range between 10,000 and 50,000 acres, termed Watershed Administrative Units (WAUs).

In watershed analysis, the scientists first develop information and interpretation of resource conditions at a watershed scale. These reports identify sensitive areas and describe the nature of the sensitivity. In theory, standard forest practices will be applied to less sensitive areas and managers will address sensitive areas so that cumulative effects do not occur. Once the sensitive areas are identified, the field manager team will develop prescriptions for the area.

The products in a watershed analysis include:
- *Resource condition reports describing the condition of the watershed*
- *Maps of sensitive areas requiring prescriptions*
- *Casual Mechanism reports describing the sensitive area and nature of the potential problems*
- *Rule calls based on resource vulnerability that determine standards of performance for the rule call*

Field managers will produce:
- *Prescriptions with justification for each mapped sensitive units*

The following modules and components are compiled to create a watershed analysis:

Mass Wasting - sediment sources, mass wasting potential, mass wasting processes, mass wasting features, sediment delivery potential, effects of forest management activities on mass wasting, and slope instability

Surface Erosion – Hillslope and Road Erosion – erosion potential, contributing activities, sediment delivery, sensitivity to forest practices, baseline sediment levels

Hydrologic Change - hydrologic conditions, historic patterns of peak flows, disturbance effects on peak flows, effect of vegetative cover on runoff, changes in flood peaks associated with runoff

Riparian Function – historical and current riparian conditions and ability to supply LWD, dominant processes by which LWD is added to system, ability for riparian zone to supply LWD in the near term and long term
Stream Channel –channel response types, historic conditions, active channel geomorphic processes, responses of reaches to inputs, dominant channel processes

Fish Habitat – distribution and abundance of salmonid fish species, areas of degraded habitat by species and life history stage, areas of high existing and potential use by species and life history stage, areas of limited habitat availability

Water Quality – vulnerability of waterbody parameters to changes in inputs, current and historic water quality, changes between current and historic water quality that indicated vulnerability, sources of vulnerability (sediment, nutrients, heat , etc) that may establish sensitivity

Wasserman, L.J., C.J. Cederholm and E.O. Salo. The impact of logging on benthic communities in selected watersheds of the Olympic Peninsula, Washington. Fisheries Research Institute, School of Fisheries, University of Washington, 1984.
This study compares benthic populations, habitat parameters and management activity in 25 streams (including sites in the Dickey, Calawah, Bogachiel and Hoh basins). Positive correlation was found between certain species of benthic invertebrates and habitat parameters although no differences in populations could be related casually to logging.

Weitcamp, L.A., T.C. Wainwright, G.J. Bryant, G.B. Milner, D.J. Teel, R.G. Kope, and R.S. Waples. 1995. Status review of coho salmon from Washington, Oregon and California. National Oceanic and Atmospheric Administration, Technical Memorandum NMFS-NWFSC-24.
This report summarizes biological and environmental information gathered in the 1993 status review, brought about by petitions seeking protection for coho salmon under the Endangered Species Act.

Wiggins, W.D., G.P. Ruppert, R.R. Smith, L.L. Reed, and M.L. Courts. 1998. Water Resources Data Washington. Water Year 1997. US Department of Interior, US Geologic Survey Water Data Report WA-95-1. Prepared in cooperation with the State of Washington and other agencies. Tacoma, WA.

Ozette

Abbe, T, S. Fisher, M. McBride and A. Ritchie. 2002. The effects of Ozette River logjams on Lake Ozette: Assessing historic conditions and the potential for restoring logjams. Prepared by Philip Williams & Associates for the Makah Tribe.
This report is contains the first two phases of a continuing study of the Ozette River logjam study. The first two phases include a compilation of existing data records, an outline of general methods used to predict the hydraulic effects of logjams, a steady-state backwater model of the Ozette River for the reach immediately downstream of the lake, and an evaluation of probable effects of different types of logjams on Ozette River surface elevations.

Beauchamp, D., M. LaRiviere, and G. Thomas. 1995. Evaluation of competition and predation as limits to juvenile kokanee and sockeye salmon production in Lake Ozette, Washington. N. Am. J. of Fish Mgt. 15:193-207.
Examines the spatial and temporal patterns of feeding, distribution and the relative abundance of potential predators and competitors of juvenile kokanee/sockeye salmon.

Blum, J.P. 1988. Assessment of factors affecting sockeye salmon (*Oncorhynchus nerka*) production in Lake Ozette, WA. MS Thesis, University of Washington.
Author examines the relationship between destabilized tributary incubation and rearing habitats and forestry activities in the basin. Presents evidence that road building and clearcutting has affected the frequency and magnitude of peak flows, stream bed scouring, and the input of excessive amounts of inorganic and organic materials, thereby degrading water quality. Author also uses the Plankton Acre Index model to estimate the productive potential of the lake.

Bortleson, G.C. and N.P. Dion. 1979. Preferred and observed conditions for sockeye salmon in Ozette Lake and its tributaries, Clallam County, Washington. United States Department of the Interior, U.S. Geological Survey. Water-Resources Investigations 78-64. Tacoma, WA.
This report examines conditions in the Lake Ozette system for the 1976-77 seasons which would affect sockeye salmon. This includes discharge for the Ozette River, Big River and Umbrella Creek, gravels from Big River and Umbrella Creek, temperatures for the lake and all tributaries and chlorophyll levels in the lake.

Crewson, M., J. Freudenthal, P. Gearin, M. Haggerty, J. Haymes, J. Meyer, A. Ritchie, and W. Sammarco. 2002. Lake Ozette sockeye Limiting Factors Analysis. DRAFT. Prepared as part of the Lake Ozette Steering Committee.
From 1999 through 2000, stakeholders from the Lake Ozette Steering Committee formed a habitat workgroup to study and discuss limiting factors to sockeye production in Lake Ozette. Among the limiting factors discussed are predation, habitat, water quality, tidal prisms, disease and flows.

Dlugokenski, C., W. Bradshaw, and S. Hager. 1981. An investigation of the limiting factors to Lake Ozette sockeye salmon production and a plan for their restoration. U. S. Fish and Wildlife Service, Fisheries Assistance Office, p.52.
This report summarizes the status of Lake Ozette sockeye from 1977 to 1979 following attempts in 1976 to improve sockeye passage to Lake Ozette by removing jams in Ozette River. Biological characteristics are summarized and specific habitat degradation is noted.

Haggerty, M. 2004. Data summary of Lake Ozette tributary habitat conditions. DRAFT. Prepared for the Makah Indian Tribe, Neah Bay, WA.
In effort to help understand the spatial distribution of anadromous fish and the limiting factors in the tributaries to Lake Ozette the Makah Tribe implemented a detailed field investigation of baseline habitat conditions. The primary objective of this report is to summarize and analyze the field data collected by the Tribe in 1999 and 2000. Where possible data from previous studies and habitat inventories is integrated with data collected as part of this project to assess habitat conditions. The specific products included in this report and accompanying datasets include: edited and formatted data for each stream surveyed, channel dataset including 51.6 miles (83.1 km) of summarized channel data, LWD dataset including 30,326 pieces of LWD, integrated LWD-habitat dataset summarizing LWD and pool conditions for 38.3 miles (61.6 km) of stream, and maps.

Hughes, K.M., M.J. Crewson, and A.C. Ritchie. 2002. FY-2001 Hatchery Reform Phase II Telemetry Study of Lake Ozette Sockeye. Makah Fisheries Management, P.O. Box 115, Neah Bay, WA 98357. Unpublished report, p. 6.

Jacobs, R., G. Larson, J. Meyer, N. Currence, J. Hinton, M. Adkison, R. Burgner, 1996. Information Summary: The sockeye salmon *Oncorhynchus nerka* population in Lake Ozette, Washington, USA. US Dept. of the Interior, National Biological Service, Forest and Rangeland Ecosystem Science Center.
Authors present an information summary as a precursor to a meeting to discuss research and management options for the species in Lake Ozette Basin. Includes a historical summary of known information about the species, biological characteristics of the fish, recent population numbers at various life stages, and some habitat information.

Kidder, J.S., and M.G. LaRiviere. 1991. Lake Ozette Sockeye Salmon Enhancement Facility Feasibility Report. Prepared for the Makah Tribe by Chinook Engineering, Mukilteo, WA.
Inspects proposed sites and biological criteria for a sockeye enhancement facility proposed within the Ozette Basin. The report includes costs, engineering design, environmental considerations within the area.

Kramer, R. 1953. Completion report by stream clearance unit on Ozette and Big Rivers April, 1953. Prepared for the Department of Fisheries, Olympia, WA.

This report documents the stream clearing activities of 1953 on Ozette River and Big River. The report includes observations of logging along the banks and descriptions and locations of the jams that were removed.

Makah. 2000. Lake Ozette Sockeye Hatchery and Genetic Management Plan - Biological Assessment, Section 7 Consultation. October 23, 2000. Prepared by Makah Fisheries Management for Bureau of Indian Affairs. Makah Indian Tribe. Neah Bay, WA. p. 219.

McHenry, M., D. Morrill, and E. Currence. 1994. Spawning gravel quality, watershed characteristics and early life history survival of coho salmon and steelhead in five north Olympic Peninsula watersheds. Lower Elwha S'Klallam Tribe and Makah Tribe, Port Angeles and Neah Bay, WA. 59 pp.
This paper evaluates the effects of managed and natural watershed characteristics on salmonid spawning gravel quality and early life history in five north Olympic Peninsula watersheds including the Ozette watershed. The authors positively correlate land use with stream geometry. The study also found that there is a significant threshold for fine sediment above which the chances of salmonids surviving are low.

McHenry, M., J. Lichatowich, R. Kowalski-Hagaman. 1996. Status of pacific salmon and their habitats on the Olympic Peninsula, Washington. Report to the Lower Elwha S'Kallam Tribe, Port Angeles, Washington.
Status report based on a full literature review. Watersheds in WRIA 20 covered include the Hoh and Ozette sub-basins.

Meyer, J. and S. Brenkman. 2001. Status report on the Water quality of Lake Ozette and Potential Human-related impacts to salmonids. Olympic National Park, Port Angeles, WA.
Physical, biological and chemical characteristics of Lake Ozette and water quality in six tributaries to the lake were described from 1993-1994. The annual range of water quality conditions were measured for waster temperature, specific conductance, turbidity, and pH at four locations on the lake, six tributary streams and at the lake outlet. Water quality conditions in the lake were generally favorable to salmonids while conditions in tributaries were less favorable. The authors surmise that degraded water quality in these streams appeared to result from timber harvesting which began at the turn of the century and persisted through the 1970s.

Smillie, G.M. 2001. National Park Service trip report on Lake Ozette. Draft Unpublished.
This report documents a trip to Lake Ozette in which author reports observations of lake condition (sediment, lake level) and hypothesizes role of historic and current LWD on flow regime and shoreline processes.

Sooes/Wa'atch

Zajac, D. 2002. An assessment of anadromous fish habitat use and fish passage above Makah National Fish Hatchery in the Sooes River. U.S. Fish and Wildlife Division of Fisheries and Watershed Assessment, Lacey, WA.
This paper presents options and recommendations regarding anadromous fish use of the upstream habitat currently blocked by the Makah National Fish Hatchery in the Sooes River. The current condition of the upstream habitat (estimated to be about 25 miles of potential habitat) is also summarized.

Heckman, J.L. 1964. Reconnaissance Report: Fisheries Management Program, Makah Indian Reservation. Prepared by the United States Department of the Interior Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife, Branch of Fishery Management Services, Olympia, WA.
This report is a result of meeting and field investigations during 1964 with the Makah Tribe over the issue of establishing an effective fisheries management program on reservation streams on streams outside the reservation on which Indians have historically fished. The report briefly comments on conditions of habitat parameters derived primarily from aerial photos.

<u>Quillayute (general)</u>

Chitwood, S. 1981. Quillayute River navigation project. US Army Corps of Engineers Technical Report.
Draft environmental impact statement including operations and maintenance information on inland navigation on the Quillayute River.

Decillis, P. 1991. Summary of data collection and habitat conditions in the Quillayute River system, 1990-1991. Quileute Natural Resources Department, Quileute Indian Tribe, LaPush, WA.

Fretwell, M.O. 1984. Quality of Water, Quillayute River Basin, Washington. US Geological Survey. Water Resources Investigations. Report 83-4162.
Documents 3 years of streamflow, sediment discharge and water quality data for the main rivers (Soleduck, Bogachiel and Dickey) in the Quillayute River Basin.

Nelson, L.M. 1982. Streamflow and sediment transport in the Quillayute River basin, Washington. US Geological Survey Open-File Report 82-627.

QNR. 1992. Summary of habitat conditions in the Quillayute River system, 1990-91. Unpublished

<u>Dickey</u>

Bretherton, K., D. Christensen, and T. Taylor. 1998. Riparian Function Assessment. In E/W Dickey Watershed Analysis Draft Report. Pentec Environmental, Inc. Edmonds, WA.
See Watershed Analysis Description

Dieu, J., K. Kreuger and P. Vanderhoof. 1998. Unpublished Water Quality Module. In E/W Dickey Watershed Analysis.
See Watershed Analysis Description

Haymes, J. and E. Tierney. 1996. Supplementation of wild coho smolt production in the Dickey River drainage, Washington. Final report to the Northwest Indian Fisheries Commission, Olympia, WA.

Jackson, R. 1998. Hydrology. In E/W Dickey Watershed Analysis Draft Report. Prepared for the Washington Department of Natural Resources.
See Watershed Analysis Description

LaManna, J., J. Dieu, and C. Cahill. 1998. Sedimentation Assessment. In E/W Dickey Watershed Analysis Draft Report. Prepared for the Washington Department of Natural Resources.
See Watershed Analysis Description

Martin, D., T. Powell, D. Netnon, E. Tierney and E. Patino. 1998. Fish Habitat Assessment. In E/W Dickey Watershed Analysis Draft Report. Pentec Environmental, Inc. Edmonds, WA.
See Watershed Analysis Description

Samuelson, C.E., E.G. Hoffman, and S. H. Olsen. 1982. Effects of current logging practices on fish habitat in five western Washington streams. Prepared for ITT Rayonier, Shelton, WA.
Examines the effects of logging on biological (fish and benthic populations), physical (stream temperatures and spawning area sediments), and chemical (dissolved oxygen) components in two sub-basins in the Dickey Watershed, Coal Creek and Skunk Creek.

QNR. 1993. Quileute Natural Resources, Water Quality Monitoring Program. Unpublished Data.

QNR. 1994. Quileute Natural Resources, Water Quality Monitoring Program. Unpublished Data.

QNR. 1995. Quileute Natural Resources, Water Quality Monitoring Program. Unpublished Data.

QNR. 1992. Quileute Natural Resources, Water Quality Monitoring Program. Unpublished Data.

QNR. 1992. Summary of habitat conditions in the Quillayute River system, 1990-91. Unpublished.

Sol Duc

Chesney, C. 1996. Channel Morphology. In Sol Duc Pilot Watershed Analysis. Washington State Department of Natural Resources, Olympia, WA.
See Watershed Analysis Description

Christensen, D. 1996. Riparian. In Sol Duc Pilot Watershed Analysis. Washington State Department of Natural Resources, Olympia, WA.
See Watershed Analysis Description

Jackson, R. 1996. Hydrology. In Sol Duc Pilot Watershed Analysis. Washington State Department of Natural Resources, Olympia, WA.
See Watershed Analysis Description

Naughton, B. and M. Parton. 1996. Fish Habitat. In Sol Duc Pilot Watershed Analysis. Washington State Department of Natural Resources, Olympia, WA.
See Watershed Analysis Description

Olympic National Forest. 1992 USFS Region 6 Channel Surveys, Soleduck Ranger District. Olympia, WA.
See below

Olympic National Forest. 1994 USFS Region 6 Channel Surveys, Soleduck Ranger District. Olympia, WA.
The class I, II, and most III streams were determined from streams surveys which were done in the late 1970's and 80's. It has been updated when there has been new information gathered during field review of proposed activities on the Ranger Districts. Many of the class IV and some class III streams have not been verified on the ground and were delineated from aerial photographs. Data was Manuscripted onto PBS (old) Quadrangles at 1:24000 by District Personnel. Data was then Digitized under contract by Vestra resources INC, Redding CA in 1998.

Parks, D. and R. Figlar-Barnes. 1996. Water Quality. In Sol Duc Pilot Watershed Analysis. Washington State Department of Natural Resources, Olympia, WA.
See Watershed Analysis Description

Plotnikoff, R.W. 1998. Stream Biological Assessments (Benthic Macroinvertebrates) for Watershed Analysis: Mid-Sol Duc Watershed Case Study. Prepared for the Department of Ecology Publication No. 98-334. Olympia, WA.
Benthic macroinvertebrate communities were evaluated on Upper Bockman, Lower Bockman, Upper Kugel, Lower Kugel and Littleton Creeks within the Sol Duc watershed.

The vulnerability of these communities was assessed in regard to sedimentation, stream temperature and physical stream change.

Sasich, J and J. Dieu. 1996. Mass Wasting. In Sol Duc Pilot Watershed Analysis. Washington State Department of Natural Resources, Olympia, WA.
See Watershed Analysis Description

North Fork Calawah

Benda, L. 1996. Stream Channel Assessment. In North Fork Calawah Watershed Analysis. Olympic National Forest, Olympia, WA.
See Watershed Analysis Description

Dieu, J. and B. Shelmerdine. 1996. Sedimentation Assessment. In North Fork Calawah Watershed Analysis. Olympic National Forest, Olympia, WA.
See Watershed Analysis Description

Jackson, R. 1996. Hydrologic Change Assessment. In North Fork Calawah Watershed Analysis. Olympic National Forest, Olympia, WA.
See Watershed Analysis Description

Martin, D., P. De Cillis, and J. Haymes. 1996. Fish Habitat Assessment. In North Fork Calawah Watershed Analysis. Olympic National Forest, Olympia, WA.
See Watershed Analysis Description

O'Connor M.D. and T.W. Cundy. 1993. North Fork Calawah watershed condition survey: landslide inventory and geomorphic analysis of mainstem alluvial system. Prepared for US Dept of Agriculture Forest Service, Olympic National Forest, Olympia, WA.

Springer, J. 1996. Riparian Function Assessment. In North Fork Calawah Watershed Analysis. Olympic National Forest, Olympia, WA.
See Watershed Analysis Description

South Fork Calawah and Sitkum

DeCillis, P. 1998. Fish Habitat. In Stikum and South Fork Calawah Watershed Analysis. Olympic National Forest, Olympia, WA.
See Watershed Analysis Description

Lasorsa, D. 1998. Riparian. In Stikum and South Fork Calawah Watershed Analysis. Olympic National Forest, Olympia, WA.
See Watershed Analysis Description

Lingley, L. 1998. Mass Wasting. In Stikum and South Fork Calawah Watershed Analysis. Olympic National Forest, Olympia, WA.
See Watershed Analysis Description

Stoddard, R. 1998. Hydrology. In Stikum and South Fork Calawah Watershed Analysis. Olympic National Forest, Olympia, WA.
See Watershed Analysis Description

Wilson, S. 1998. Channel. In Stikum and South Fork Calawah Watershed Analysis. Olympic National Forest, Olympia, WA.
See Watershed Analysis Description

<u>Bogachiel</u>

Hanell, C. 2003. Mass Wasting and Surface Erosion Inventory for the Middle Coast Landscape, Olympic Peninsula, WA. Prepared for the Olympic Region Department of Natural Resources.
This is a landscape level assessment of sediment sources on DNR-owned land within the boundaries of the Middle Coast Landscape (north of the Quillayute River to the Kalaloch). Initial sediment sources were identified through aerial photos and then field observed. Information was then digitized into GIS. This study is meant to complement earlier studies by Dave Parks (Middle Hoh watershed analysis mass wasting module), Jack Powell (Middle Hoh watershed analysis surface erosion module) and Wendy Gertsel (Deep-seated landslide inventory of west-central Olympic Peninsula).

Quileute Natural Resources. 2000-2003. Bogachiel stream surveys. Unpublished data.
In FY 2000 the Quileute Tribe surveyed the Bogachiel mainstem for blocked culverts and cross drains. The process was continued in detail with the tributaries in FY 2001-03: Weeden, Murphy and Maxfield Creeks. These were stream typed using the newly approved (4/01) Washington Administrative Code issuances for the Forest Practices rules—WAC 222-16-031. In FY 02 the tribe surveyed Mill, Grader, May, Dry and Bear Creeks.

<u>Hoh</u>

10,000 Years Institute. 2003. Hoh River Watershed Monitoring First Interim Project Report. Prepared for the Hoh Indian Tribe and the Northwest Indian Fisheries Commission.

Abbe, T. 1996. Geomorphological Survey of Hoh River Floodplain, RM 19, at the confluence with Elk Creek. Consultant report to the Hoh Tribe.

Blew, R.D., and R.L. Edmonds. 1995. Precipitation along an inland transect on the Olympic Peninsula, Washington. Journal of Environmental Quality, 24:239-245.
This study intended to examine the influences of ocean effect, seasonality and distance on the chemistry of precipitation falling on several sites in the Hoh River valley.

Brummer, C. J. and Montgomery, D. R., Downstream coarsening in headwater channels, Water Resources Research, 39(10), 1294, doi: 10.1029/2003WR001981, 2003.
Field data from four mountain drainage basins in western Washington (including a site on the South Fork Hoh River) document systematic downstream coarsening of median bed surface grain size (D_{50}) and a subsequent shift to downstream fining at a drainage area of about 10 km^2.

Cederholm, C.J. and W.J. Scarlett. 1997. Hoh River tributaries: salmon habitat survey report and recommendations for rehabilitation. Washington Department of Natural Resources, Olympia, WA.
This report is a detailed description of mainstem and subwatershed habitat conditions with substantial data appendices and recommendations.

Edmonds, R.L., T.B. Thomas, and R.D. Blew. 1995. Biogeochemistry of an old-growth forested watershed, Olympic National Park, Washington. Water Resources Bulletin, Paper No. 94019.
The West Twin Creek watershed was examined to determine (1) concentrations of major cations and anions and dissolved organic carbon in precipitation, throughfall, stemflow, soil solution, and the stream; (2) nutrient input/output budgets; and (3) nutrient retention mechanisms in the watershed.

Edmonds, R.L. and R.D. Blew. 1997. Trends in precipitation and stream chemistry in a pristine old-growth forest watershed, Olympic National Park, Washington. Journal of American Water Resources Association, 33:4, pp. 781-793.
The West Twin Creek watershed was examined to determine time trends in precipitation and stream chemistry and seasonal patterns in precipitation and stream chemistry.

Edmonds, R.L., R.D. Blew, J.L. Marra, J. Blew, A.K. Barg, G. Murray and T.B. Thomas. 1998. Vegetation patterns, hydrology, and water chemistry in small watersheds in the Hoh River valley, Olympic National Park. Scientific Monograph NPSD/NRUSGS/NRSM-98/02. US Department of the Interior, National Park Service.

Hallock, D. 2001. River and Stream Ambient Monitoring Report for Water Year 2000. Washington State Department of Ecology, Publication No. 01-03-042, Olympia, WA.
The DOE collected monthly water quality information at 88 river and stream monitoring stations as part of a long-term monitoring program. The only site within WRIA 20 was the Hoh River at the DNR campground and the data includes monthly temperature, flow,

conductivity, oxygen, pH, suspended solids, total nitrogen, ammonia nitrogen, nitrate nitrate, phosphorus, turbidity, and fecal coliform.

Hatten, J. 1991. Salmonid Life Histories of the Hoh River Basin. Prepared for the Hoh Tribe.
This paper compiles run timing, rearing, ocean phases and identification characteristics for each salmonid species in the Hoh Basin. Dolly Vardens are included as well.

Hatten, J. 1991. The effects of debris torrents on spawning gravel quality in tributary basins and side channels of the Hoh River, Washington. Prepared for the Hoh Indian Tribe, Washington.
This compares the composition of landslide affected and unaffected spawning grounds of tributaries and side-channels of the main Hoh and South Fork Hoh River in the summer of 1990. Based on the one hundred and fifteen samples, authors concluded that salmonid spawning gravels were significantly affected by landslide siltation in the Hoh River Basin.

Hatten, J. 1992. The effects of logging activities on stream temperatures in tributaries of the Hoh River basin, Washington. Prepared for the Hoh Indian Tribe, Washington.
This pilot study examined the relationship between logging activities and stream temperatures on eight tributaries to the Hoh River. Three of the eight sites were located within ONP which has no logging activity. Results showed that the affected (greater than 10% of hydrologic basin has been logged) diurnal temperature range and standard deviation and the maximum high and mean daily high temperatures were higher than the unaffected (less than 10% of hydrologic basin logged) group.

Hatten J. and R. Conrad. 1991. A comparison of summer stream temperatures in unmanaged and managed sub-basins of Washington's western Olympic Peninsula. Prepared for the Northwest Indian Fisheries Commission, Olympia, WA.
Hatten and Conrad evaluated summer temperatures on 11 streams in unmanaged (unlogged) basins and 15 streams in managed (logged) basins in the Hoh and Bogachiel basins. For overall water temperature variables, the managed group had significantly higher mean temperatures than the unmanaged group. The paper concludes that managing for a stream temperature at the reach level will not be successful unless logging activity throughout a sub-basin is considered.

Heusser, C.J. 1974. Quaternary vegetation, climate, and glaciation of the Hoh River valley, Washington. Geologic Society of America Bulletin, v. 85, p.1547-1560.
This paper traces the history of glaciation from Lake Ozette to the Queets River and estimates the climatic trends and associated plant communities of each age.

Kennard, P. 2001. Channel Module. In Middle Hoh Watershed Analysis. Draft Report to the Hoh Tribe.
See Watershed Analysis Description

Logan, R.L., L. Kaler and P.K. Bigelow. 1991. Prediction of sediment yield from tributary basins along Huelsdonk Ridge, Hoh River, Washington. Open File Report 91-7. Washington Division of Geology and Earth Resources, Olympia, WA.
Field investigations and aerial photos were used to determine that slope failure resulting from clearcuts occurred in 10 Hoh River tributary basins during the winter of 1989-1990. The authors conclude that sediment yield increases as a function of clearcut area.

Lum, W.E. and L.M. Nelson. 1986. Reconnaissance of the water resources of the Hoh Indian Reservation and the Hoh River Basin, Washington. US Geological Survey, Water Resources Investigations Report 85-4018.
USGS conducted a groundwater and surface water study from 1977-1980.The chemical and bacteriological quality of the Hoh River and its major tributaries downstream of ONP was tested. Fluvial transport on the Hoh River was also examined.

McHenry, M. 2000. Fisheries Habitat Module. In Middle Hoh Watershed Analysis. Draft Report to the Hoh Tribe.
See Watershed Analysis Description

Murray, G.L., R.L. Edmonds, and J.L. Marra. 2000. Influence of partial harvesting on stream temperatures, chemistry and turbidity in forests on the western Olympic Peninsula, Washington. Northwest Science, Vol. 74, No. 2.
Stream temperatures, chemistry and turbidity were monitored in two partially harvested sub-basins and one old-growth basin in the Hoh River Valley.

Parks, D. 1999. Mass Wasting Module. In Middle Hoh Watershed Analysis. Draft Report to the Hoh Tribe.
See Watershed Analysis Description

Powell, J. 2000. Surface Erosion Module. In Middle Hoh Watershed Analysis. Draft Report to the Hoh Tribe.
See Watershed Analysis Description

Rau, W. 1973. Geology of the Washington coast between Point Grenville and the Hoh River. Washington Division of Geology and Earth Resources Bulletin 66, 58 p.
Describes rock formations, geological events and formations on the Western Coast.

Rot, B. 1996. The importance of floodplain backchannels to overwintering salmonids: a literature review with specific references to the floodplain at RM 19 on the Hoh River, Washington. Report commissioned by the Hoh Tribe.
This report was commissioned by the Hoh Tribe to review the literature on the relationship between vegetation, landform, LWD and fish. The paper focuses on the importance of floodplain channels as overwintering habitat for juvenile salmonids but also looks at the interaction of vegetation and landform, the creation of LWD by vegetation successional processes, and how fish use the habitat created by LWD. Specific references are made to the floodplain at RM 19.

Somers, D.J. 1995. The influence of stream valley landform on riparian forest composition in Hoh River tributaries, Washington. MS Thesis, College of Forest Resources, University of Washington.
This study assessed the influence of valley landform on species composition and distribution of riparian forests along first through third order tributaries of the Hoh River. Data showed strong correlation between valley widening and riparian canopy openness.

Watershed Sciences. 2001. Aerial surveys in the Hoh River basin using thermal infared and color videography. Report conducted for the Hoh Tribe by Watershed Sciences.
This report presents longitudinal temperature profiles for each stream reach surveyed as well as a discussion of the thermal features observed in each basin. The report has an associated GIS database and includes images collected during the survey.

TECHNICAL REFERENCES

Beschta, R.L., R.E. Bilby, G.W. Brown, L.B. Holtby, and T.D. Hofstra. 1987. Stream temperatures and aquatic habitat: fisheries and forestry interactions. In E.O. Salo and T.W. Cundy (eds). Streamside management: forestry and fisheries interactions, p. 191-232. University of Washington. Contribution No. 57, Seattle.
Authors examine the temperature patterns in forested stream systems and try to account for pattern differences due to logging activities. Comments on the effectiveness of stream buffers and notes effects of temperature change on rates of salmonid development.

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 the Pacific Northwest: past, present and future. In E.O. Salo and T.W. Cundy (eds). Streamside management: forestry and fisheries interactions, p. 143-190. University of Washington. Contribution No. 57, Seattle.
Reviews the form, function, and management of woody debris in streams and concludes that LWD enhances fish habitat, the removal of LWD from streams has altered sources, and delivery mechanisms leading to degraded fish abundance and there is need for further studies that focus on the protection and recruitment of LWD.

Bjornn, T.C. and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. American Fisheries Society Special Publication 19:83-138.
Information from literature reviews and original research on the range of habitat conditions for each life stage that allow various species of salmon, trout and char to exist. Includes information on optimum and limiting conditions in relation to temperature, water velocity, depths, cover and substrate. Primary focus is on Pacific salmonids.

Brett, J.R. 1952. Temperature tolerances in young Pacific salmon, Oncorhynchus. J. Fish. Res. Board Can. 9:268-323
This paper outlines a laboratory experiment that tested the effects of temperature on juvenile salmonids. The fish were exposed to temperatures that acclimated from 5°C - 24°C and behavioral and physical reactions were recorded. The temperatures were then divided into categories by species: resistance to high temperatures, criterion of death at low temperatures, resistance to low temperatures, mixed lethal effect of low temperature, size effect, zones of thermal tolerance, and preferred temperatures.

Everest, F.H., R.L. Beschta, J.C. Scrivener, K.V. Koski, J.R. Sedell, C.J. Cedarholm. 1987. Fine sediment and salmonid production: a paradox. In E.O. Salo and T.W. Cundy (eds). Streamside management: forestry and fisheries interactions, p. 143-190. University of Washington. Contribution No. 57, Seattle.
This paper points out the difference between salmon and fine sediment studies and forest practices and fine sediment studies. The authors encourage a more holistic view of sediment in stream ecosystems which includes roughness elements and storage capacity. They also encourage the reevaluation of forest practice rules as the then current rules did not account for streamside vegetation or physical instream structures, both which directly affect instream sediment quality.

Ferguson, R. G. 1958. The preferred temperature of fish and their midsummer distribution in temperate lakes and streams. J. Fish. Res. Board Can.

McDonald, L.H., A.W. Smart and R.C. Wissmar. 1991. Logging and Water Quality in the Pacific Northwest and Alaska. Environmental Protection Agency Report EPA/910/9-91-001.
This document provides guidance for designing water quality monitoring programs and selecting monitoring parameters. The section on parameters includes a review of six categories: physical and chemical constituents, flow, sediment, channel characteristics, riparian, and aquatic organisms.

Sullivan, K., D. Martin, R. Cardwell, J. Toll, and S. Duke. 2001. The analysis of the effects of temperature on salmonids of the Pacific Northwest with implications for selecting temperature criteria. Sustainable Ecosystems Institute. Portland, OR.
This paper develops a risk-based approach to analyze summertime temperature effects on juvenile salmonid species. The study challenges the previously accepted temperature standards on the basis that these are laboratory studies and that on site streams rarely sustain high enough to cause mortality. The results of this study suggest that quantitative analysis of growth effects can be determined with reasonably simple methods that can be applied at specific sites of at a region scale to identify appropriate temperature thresholds.

APPENDIX B

BUREAU OF RECLAMATION WATERSHED CHARACTERISTICS METHODOLOGY

(TO BE PROVIDED BY BUREAU OF RECLAMATION)