1 INTRODUCTION

The purpose of this report is to describe and evaluate limiting factors currently and cumulatively affecting the survival and productivity of Lake Ozette sockeye salmon (*Oncorhynchus nerka*). A thorough analysis of Lake Ozette sockeye limiting factors has been a goal of those involved with the management and restoration of Lake Ozette sockeye for decades (see background below). In addition, the National Marine Fisheries Service (NMFS) is required under the Endangered Species Act (ESA) to develop recovery plans for each species under NMFS jurisdiction listed as threatened or endangered. This report provides critical information regarding factors limiting the survival and productivity of Lake Ozette sockeye for future incorporation into the Lake Ozette sockeye salmon recovery plan.

Within the context of this report, limiting factors are defined as physical, biological, or chemical conditions (e.g., inadequate spawning habitat, insufficient prey resources, or suspended sediment concentration) experienced by sockeye at the spawning aggregation scale that result in a reduction in viable salmonid population (VSP) parameters (abundance, productivity, spatial structure, and diversity). Limiting factors that affect sockeye at the spawning aggregation scale may threaten the viability of the evolutionarily significant unit (ESU). Key limiting factors are those with the greatest impacts on a population's ability to reach its desired status.

It is important to distinguish between factors responsible for the decline of the population (factors for decline), and factors that currently limit sockeye abundance, productivity, spatial structure, and diversity (limiting factors). Certain activities that may have contributed to the decline of Ozette sockeye may no longer operate to limit abundance or productivity (e.g. commercial sockeye harvest).

Both the factors for decline and the limiting factors affecting the productivity and survival of Lake Ozette sockeye have been previously investigated and documented in detail in several reports and studies (Bortleson and Dion 1979; Dlugokenski et al. 1981; Blum 1988; Jacobs et al. 1996; Gustafson et al. 1997; Makah Fisheries Management [MFM] 2000). Several hypotheses were developed regarding factors for decline of the Ozette sockeye population. MFM (2000) summarized the commonly presented factors for decline as follows: (1) loss of adequate quality and quantity of beach spawning habitat, (2) loss of tributary spawning sockeye populations, (3) past over-exploitation, (4) predation and disruption of natural predator-prey relationships, (5) introduction of non-native fish and plant species, (6) temporarily poor ocean conditions, and (7) interactions of these factors. The collective effects of these factors may have further influenced spawning habitat quality by reducing the population size to a threshold where lower densities of fish could not adequately maintain clean, vegetation-free spawning gravels.

This report is not intended to be a review of factors for decline, however, but instead a thorough investigation of factors currently limiting VSP parameters.

1.1 BACKGROUND

Historically Lake Ozette, the Ozette River, and tributaries draining into the lake were important components of the Makah Tribe's fisheries (Swindell 1941; Gustafson et al. 1997). The Ozette watershed also provided an important subsistence fishery for early settlers within the watershed.

Olympic National Park (ONP) is the only national park in the lower 48 states that contains significant numbers of all species of Eastern Pacific salmon. Lake Ozette sockeye salmon represent a critical component of biological integrity of ONP from both ecosystem and public interest perspectives. Lake Ozette sockeye are critical to ecosystem function in ONP; they link freshwater, marine, and terrestrial ecosystems. Three fish species in ONP are listed as threatened under the Endangered Species Act: Ozette sockeye salmon, Puget Sound Chinook (*Oncorhynchus tshawytscha*), and Puget Sound/Coastal bull trout (*Salvelinus confluentus*). In the Lake Ozette watershed only sockeye salmon are listed under the ESA. Ozette Chinook are not listed but are nearly extinct, if not functionally extinct. Bull trout are historically absent from the Lake Ozette watershed. Ozette sockeye are one of only two populations of sockeye that inhabit the approximately 1 million acres of land managed by ONP.

The decline in harvest of Lake Ozette sockeye salmon from a high of more than 17,500 fish in 1949 (Washington Department of Fisheries [WDF] 1955) to a low of 0 in 1974 and 1975 (Jacobs et al. 1996) acted as the catalyst to prompt research into the limiting factors affecting Lake Ozette sockeye. In 1976, the Makah Tribe requested assistance from the U.S. Geological Survey (USGS) and U.S. Fish and Wildlife Service (USFWS) to determine the limiting factors and status of Lake Ozette sockeye. The result of the Makah Tribe's request was two joint studies. One addressed the abundance and limiting factors of Lake Ozette sockeye (Dlugokenski et al. 1981), and the other focused on the preferred and observed conditions of sockeye habitat within the Ozette watershed (Bortleson and Dion 1979). These studies provided a tremendous amount of baseline data on abundance, distribution, and habitat conditions but did little to determine the primary limiting factors affecting Lake Ozette sockeye or the factors causing the population decline.

On April 1, 1981 the first meeting of the Lake Ozette Steering Committee was convened (MFM 1981). Initially the steering committee focused on hatchery supplementation plans. It included the following participants: the Makah Tribe, ONP, USFWS, Washington State Department of Fisheries (WDF), University of Washington, and Crown-Zellerbach Corporation (MFM 1981). The committee met over the next two years and helped to establish the Umbrella Creek hatchery. However, multi-agency recovery efforts waned from 1983 to 1987. Population monitoring efforts also diminished over this period. Another multi-agency planning meeting was held in July 1987, made up of representatives from the Makah Tribe and state and federal entities (Jacobs et al. 1996). As a result of the 1987 meeting, the team recommended compiling all existing information on Lake Ozette sockeye, increasing spawning ground surveys to determine the status of tributary spawners, and re-forming the Lake Ozette Steering

Committee. However, the Makah Tribe was unable to rally the multi-agency support needed to reestablish the steering committee (Jacobs et al. 1996), and little or no coordinated multi-agency efforts occurred after the 1987 meeting.

Two important independent studies were conducted between 1983 and 1993. The first was John Blum's Master's thesis, *Assessment of Factors Affecting Sockeye Salmon (Oncorhynchus nerka) Production in Ozette Lake, USA* (Blum 1988). The second was an evaluation of predation and competition limits on juvenile sockeye salmon (Beauchamp and LaRiviere 1993). In 1994, the National Park Service (NPS) funded the National Biological Service's Forest and Rangeland Ecosystem Science Center to compile existing data on Lake Ozette sockeye and assemble a panel of experts to make recommendations on future monitoring and management efforts (Jacobs et al. 1996). This effort focused on the same priorities recommended by the 1987 watershed planning team. The result was *The Sockeye Salmon (Oncorhynchus nerka) Population in Lake Ozette, Washington, USA* (Jacobs et al. 1996), known as the "Jacobs Report," which, at the time, was the most comprehensive document related to Lake Ozette sockeye.

The Jacobs Report was unable to specifically define the population limiting factors and concluded that the population decline was likely the result of a series of cumulative impacts, including the effects of the following: 1) introduced species, 2) predation, 3) loss of tributary spawning populations, 4) decline in the quality of beach spawning habitat, 5) short-term unfavorable ocean conditions, 6) historical over-fishing, 7) introduced disease, and 8) a combination of factors (Jacobs et al. 1996). The panel of experts concluded that the highest priority monitoring effort was to continue and improve weir counts on the Ozette River. Three of the four panel members recommended monitoring the fate of hatchery fish as the second highest priority.

On March 25, 1999, NMFS listed Lake Ozette sockeye salmon as threatened under the Endangered Species Act (64 FR 14528). The threatened status under the ESA was reaffirmed in 2005 (70 FR 37160). Largely as a result of the ESA 1999 listing, multi-agency efforts to coordinate research and recovery planning resumed, and the Lake Ozette Steering Committee was reorganized and expanded to include NMFS as well as local landowners and other interests. In 1999 and 2000, the Steering Committee formed a hatchery working group to coordinate issues relating to development of a Hatchery and Genetic Management Plan (HGMP)/Joint Resource Management Plan (JRMP) for Lake Ozette sockeye salmon. A habitat working group was also formed to develop a ranked list of potential limiting factors, as well as a ranked list of research and monitoring priorities.

The ESA requires the federal government to designate "critical habitat" for any species it lists under the ESA. Critical habitat is defined as: 1) specific areas within the geographical area occupied by the species at the time of listing, if they contain physical or biological features essential to conservation, and those features may require special management considerations or protection; and 2) specific areas outside the geographical area occupied by the species if the agency determines that the area itself is essential for conservation. NMFS formally designated the following areas within the Hoh/Quillayute subbasin as critical habitat that is necessary for the survival and recovery of the Ozette Lake sockeye salmon ESU (70 FR 52756, September 2, 2005): Ozette Lake and the Ozette Lake Watershed, including the Ozette River (Lat 48.1818, Long -124.7076) upstream to endpoints in: Big River (48.1844, -124.4987); Coal Creek (48.1631,-124.6612); the East Branch of Umbrella Creek (48.1835, -124.5659); North Fork Crooked Creek (48.1020, -124.5507); Ozette River (48.0370, -124.6218); South Fork Crooked Creek (48.0897, -124.5597); Umbrella Creek (48.2127, -124.5787); and three unnamed Ozette Lake tributaries (48.1771, -124.5967); (48.1740, -124.6005); and, (48.1649, -124.5208). See Figure 1.1 for watershed overview map and Figure 1.2 for detailed map depicting designated Critical Habitat within the Lake Ozette Sockeye ESU.

The Lake Ozette Sockeye HGMP (MFM 2000) and the ranked research and limiting factors lists were completed in 2000 and have guided recent and ongoing research and monitoring in the Ozette watershed. The Makah Tribe, ONP, and co-managers have recently implemented a series of detailed field investigations designed to increase understanding of the spatial distribution of anadromous fish and the habitat limiting factors in Lake Ozette and its tributaries. These include:

- A baseline inventory of tributary habitat conditions (Haggerty and Ritchie 2004)
- Increased quantity and quality of adult abundance monitoring from 1998 to present (Haggerty 2004A, 2005A, 2005B, 2005C, 2005D)
- Increased spawning ground survey effort along the spawning beaches and tributaries (data presented in this report)
- Adult weir, trapping, and tagging in lower Umbrella Creek (Hinton et al. 2002; Crewson 2003; Peterschmidt and Hinton 2005)
- Increased hatchery monitoring
- Smolt and fry migration studies
- Ozette River streamflow monitoring (Shellberg 2003)
- Egg-to-emergence survival studies on the lake beaches
- Fine sediment in spawning gravel study on lake beaches
- Combined radio-acoustic tagging study (Hughes et al. 2002)
- Genetic monitoring studies (Crewson et al. 2001; Hawkins 2004)
- pinniped predation studies (Gearin et al. 1999; Gearin et al. 2002)
- Hydrologic and hydraulic investigations in Lake Ozette (Herrera 2005)
- Reconnaissance survey of Lake Ozette geomorphic conditions (Herrera 2006)

The current report was conceived during the habitat and hatchery workgroup meetings that took place in 1999 and 2000. A lack of dedicated funding hindered progress until late 2004, when renewed interest by the Steering Committee and dedicated funding from the Makah Tribe and NMFS pulled the necessary resources together to complete the assessment. This report summarizes past information relating to factors limiting the productivity of Lake Ozette sockeye salmon (e.g. information found in the Jacobs Report), presents new information and data (bulleted list above), and analyzes factors limiting sockeye productivity and recovery.

1.2 ORGANIZATION OF REPORT

The report is divided into seven main chapters:

- Introduction (Chapter 1)
- Fish Populations of the Lake Ozette Watershed (Chapter 2)
- The Sockeye Salmon Population (Chapter 3)
- Habitat Conditions Affecting Lake Ozette Sockeye (Chapter 4)
- Limiting Factors Affecting Lake Ozette Sockeye (Chapter 5)
- Analysis of Limiting Factors (Chapter 6)
- Research, Monitoring, and Evaluation Needs (Chapter 7)

Chapters 1 through 4 include a review of the most up-to-date information related to the physical setting (Section 1.3), ecological setting (Section 1.4), watershed disturbance history (Section 1.5), non-sockeye fish species present and their interaction and relationship with sockeye salmon (Chapter 2), the sockeye salmon population (Chapter 3), and habitat conditions affecting sockeye salmon (Chapter 4). In addition, the report summarizes population trends, dynamics, and interactions for all non-sockeye fish species in the watershed (Chapter 2), and provides a thorough review of the Lake Ozette sockeye life history and spawning distribution (Section 3.1), sockeye hatchery practices (Section 3.2), population structure and diversity (Section 3.3), population trends (recent and historic; Section 3.4), and stock productivity (Section 3.5). These data are then integrated with habitat conditions (Section 4) and factors affecting the species productivity across the watershed (Section 5), to build an understanding of the current limiting factors affecting Lake Ozette Sockeye.

Limiting factors affecting sockeye salmon are discussed by geographical area and life history stage in Chapter 5. Limiting factors are then rated for degree of impact and synthesized in Chapter 6. Chapter 6 includes an analysis of limiting factors by life stage and presents a series of limiting factors hypotheses and sub-hypotheses. These hypotheses are intended to serve as the scientific foundation for identifying recovery actions in the Lake Ozette sockeye recovery plan. Chapter 7 includes a summary of recommended research, monitoring, and evaluation needs across the watershed.

1.3 PHYSICAL SETTING

Lake Ozette watershed is located along the northwest tip of the Olympic Peninsula in Washington State (Figure 1.1). Lake Ozette is situated on the coastal plain between the Pacific Ocean and the Olympic Mountains. The terrain of the Ozette watershed is slightly rolling to steep with a gradual increase in elevation from zero at sea level at the Ozette River mouth, to 40 feet at the Ozette Ranger Station, to just under 2000 feet at the watersheds highest point in the upper Big River watershed. Most of the watershed ranges from 200 to 800 feet elevation.

Lake Ozette is approximately 8 miles (12.9 km) from north to south and 2 miles (3.2 km) wide. The lake is irregularly shaped and contains 36.5 miles of shoreline (Ritchie 2005). It includes several bays (North End, Deer, Umbrella, Swan, Ericson's, Boat, Allen's, and South End), distinct points (Deer, Eagle, Shafer's, Rocky, Cemetery, and Birkestol) and three islands (Garden, Tivoli, and Baby). With a surface area of 11.8 mi^2 (30.6 km^2; 7,550 acres; 3,056 ha), Lake Ozette is the third largest natural lake in Washington State. The lake has a drainage basin area of 77 mi^2 (199.4 km^2), an average depth of approximately 130 feet (40 m), and a maximum depth of 320 feet (98 meters) (Dlugokenski et al. 1981). The average water surface elevation of the lake is 34 feet above mean sea level (10.4 meters; National Geodetic Vertical Datum of 1929 [NGVD 1929]). Extreme low and high water surface elevations of the lake range from 30.8 feet (9.4 m) to 41.5 feet (12.6 m) above mean sea level.

The Ozette River drains the lake from its north end, and there are no other outlet streams. The river travels approximately 5.3 miles (8.5 km) along a sinuous course to the Pacific Ocean. The total drainage area of the Ozette watershed at the confluence with the Pacific Ocean is 88.4 mi^2 (229 km^2). Coal Creek, which enters just downstream from the lake's outlet, is the largest tributary to the Ozette River. Several significant tributaries drain into Lake Ozette. The largest are Umbrella Creek, Big River, Crooked Creek, Siwash Creek, and South Creek (Table 1.1). Several smaller streams also feed the lake and include: Palmquist, Quinn, Elk, and Lost Net Creek, as well as several other unnamed streams.

Table 1.1. Lake Ozette and tributary drainage basin areas.

Watershed/Subbasin	Watershed/Subbasin Description	Basin Area (sq. mi.)	Basin Area (sq. km.)
Palmquist Creek	Entire Palmquist Creek Watershed	1.1	2.8
Umbrella Creek	Entire Umbrella Creek Watershed	10.6	27.6
Big River	Entire Big River Watershed	22.8	59.0
Lake Ozette Tributary	Unnamed Trib. between Crooked and Dunham Creeks	0.9	2.3
Crooked Creek	Entire Crooked Creek Watershed	12.2	31.6
Lake Ozette Tributary	Unnamed Tributary between Crooked and Quinn	0.7	1.7
Quinn Creek	Entire Quinn Creek Watershed	0.9	2.3
Unnamed Tributary 20.0073	Entire 20.0073 Watershed	0.4	0.9
Elk Creek	Entire Elk Creek Watershed	0.3	0.8
Siwash Creek	Entire Siwash Creek Watershed	2.9	7.4
Lake Ozette Tributary	Unnamed Tributary between Siwash and South Creeks	0.5	1.2
South Creek	Entire South Creek Watershed	3.3	8.4
Lake Ozette Watershed	**Entire Lake Ozette Watershed**	**77**	**199**
Coal Creek	Entire Coal Creek Watershed	4.6	11.8
Ozette River at Pacific Ocean	**Entire Lake Ozette and Ozette River Watershed**	**88.4**	**229**

1.3.1 Watershed Geology

The geology of the Ozette watershed (Figure 1.3) is an interesting mix of flat and gently sloping glacial and glacio-fluvial deposits situated between resistant knobs and small hills composed of Tertiary marine sedimentary rock units (mechanically weak silt- and sand-stones). Some glacial landforms extend for several square miles while others only occupy small valleys. Much of the land within the watershed is low-relief and contains numerous swamps, bogs, and wetlands. Other portions of the watershed (e.g. upper Big River) are steep and rugged and are underlain by Eocene age volcanic flows and breccias.

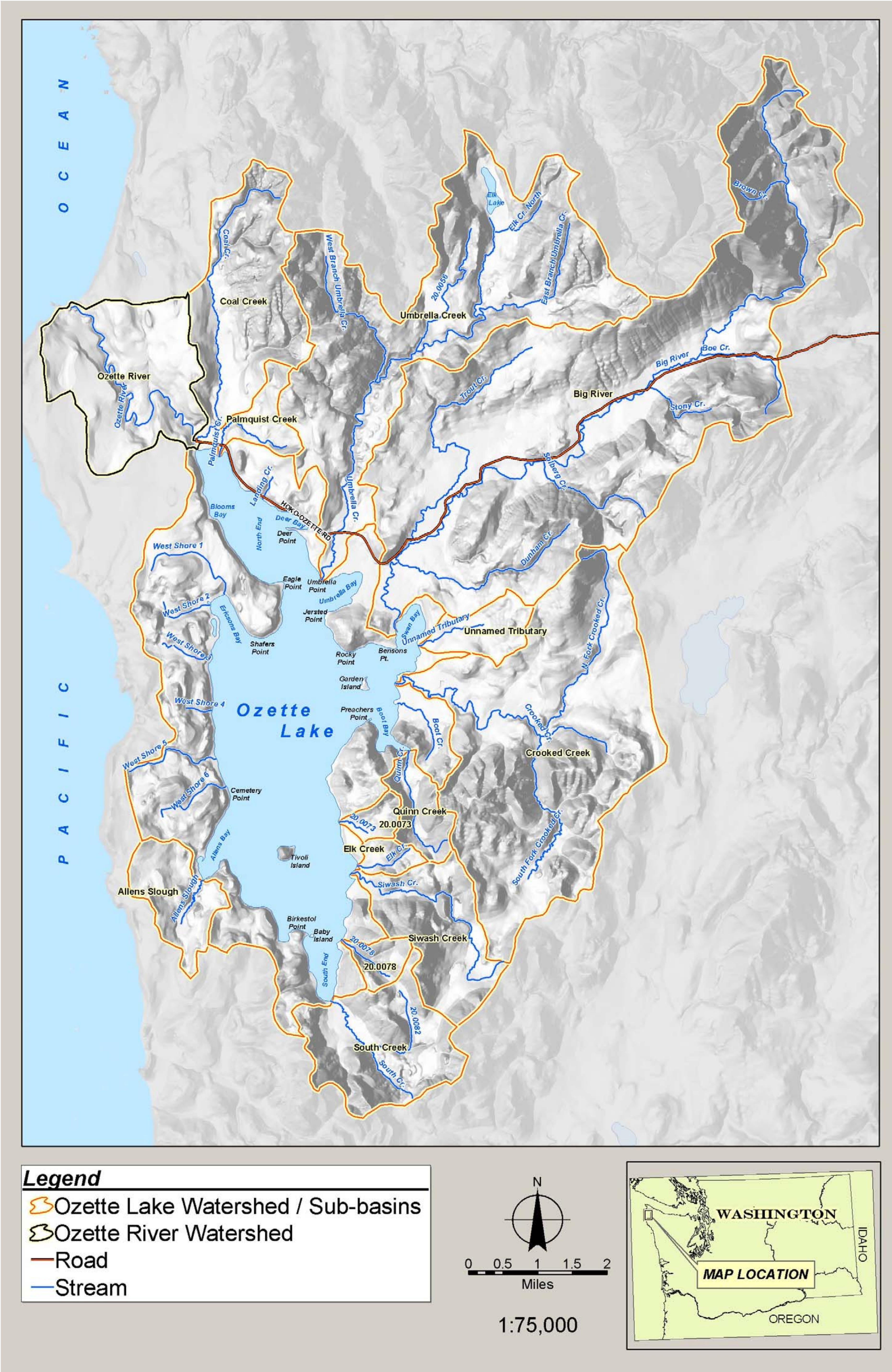

Figure 1.1. Lake Ozette watershed overview map.

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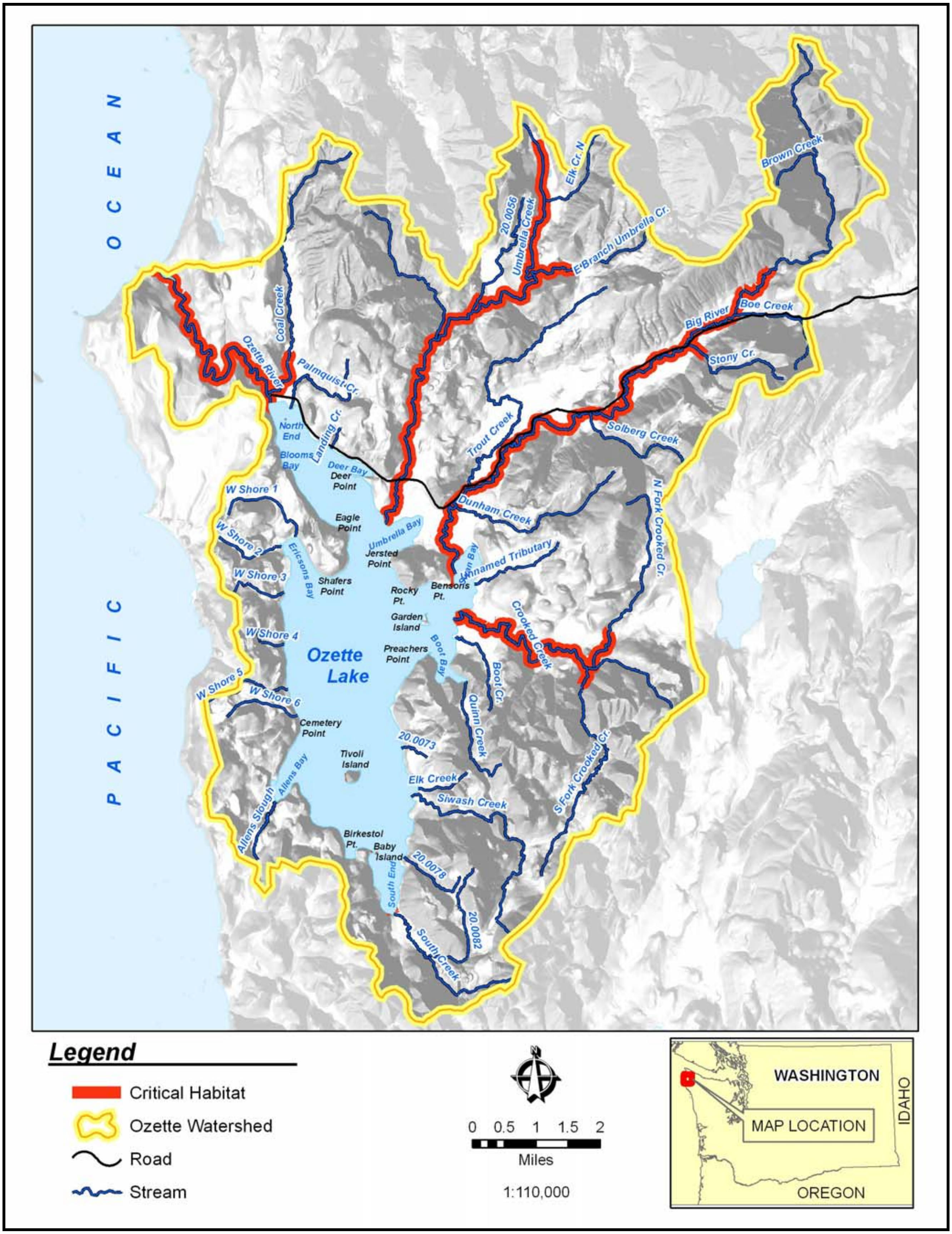

Figure 1.2. Designated critical habitat for Lake Ozette sockeye salmon (source: 70 FR 52756)

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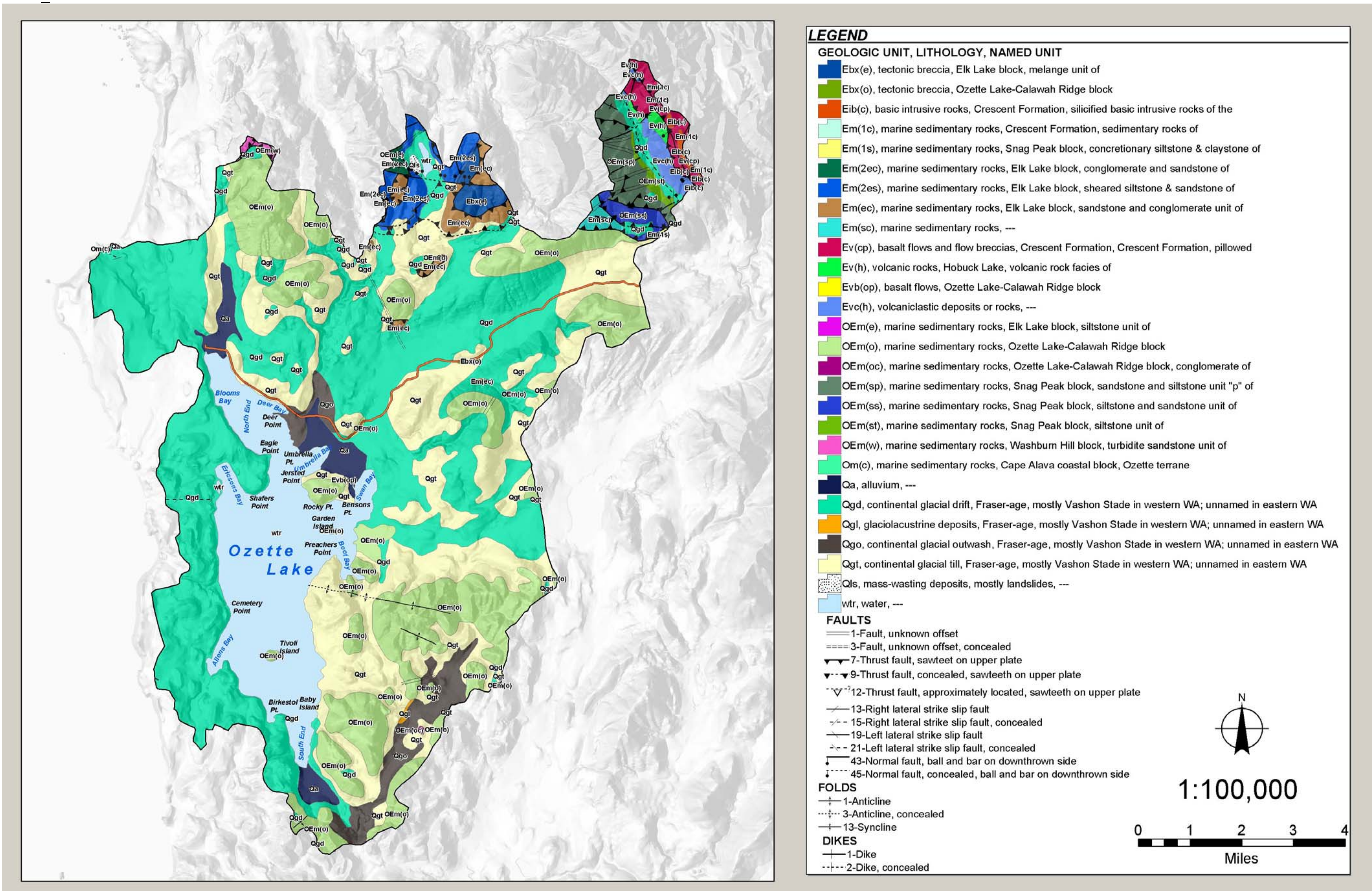

Figure 1.3. Ozette watershed geology (source: Schasse2003)

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1.3.2 Climate

The climate of the northwest Olympic Peninsula can be characterized as temperate coastal-marine, with mild winters and cool summers. The closest climate station to Lake Ozette is located at the Quillayute State Airport, approximately 12 miles to the south from the center of Lake Ozette (ranging from 6 to 22 miles from various points in the watershed). No long-term weather stations are located in the Ozette watershed (a new weather station was recently installed at the Ozette Ranger Station). The Quillayute climate station is the most representative of long-term conditions in the Ozette watershed, as compared to stations in Neah Bay, Tatoosh Island, or Forks. Most researchers (Bortleson and Dion 1979; Dlugokenski et al. 1981; Blum 1988; Jacobs et al. 1996) have used Quillayute, Washington climate data when describing Ozette climate patterns.

The following text was directly taken from the station description of the National Weather Service (NWS) climate station at the Quillayute State Airport (NOAA-National Climate Data Center [NCDC] 2005).

"Maritime air from over the Pacific has an influence on the climate [at Lake Ozette] throughout the year. In the late fall and winter, the low pressure center in the Gulf of Alaska intensifies and is of major importance in controlling weather systems entering the Pacific Northwest. At this season of the year, storm systems crossing the Pacific follow a more southerly path striking the coast at frequent intervals. The prevailing flow of air is from the southwest and west. Air reaching this area is moist and near the temperature of the ocean water along the coast which ranges from 45 degrees in February to 57 degrees in August. The wet season begins in September or October. From October through January, rain may be expected on about 26 days per month, from February through March, on 20 days, from April to June, on l5 days, and from July to September, on l0 days.

As the weather systems move inland, rainfall is usually of moderate intensity and continuous, rather than heavy downpours for brief periods. Gale force winds are not unusual. Most of the winter precipitation over the coastal plains falls as rain, however, snow can be expected each year [especially in the foothills surrounding Lake Ozette]. Snow seldom reaches depths in excess of l0 inches or remains on the ground longer than two weeks. Annual precipitation increases from approximately 90 inches near the coast, to amounts in excess of l20 inches over the coastal plains [and foothills surrounding Lake Ozette]. During the rainy season, temperatures show little diurnal or day-to-day change. Maximums are in the 40s and minimums in the mid-30s. A few brief outbreaks of cold air from the interior of Canada can be expected each winter. Clear, dry, cold weather generally prevails during periods of easterly winds. In the late spring and summer, a clockwise circulation of air around the large high pressure center over the north Pacific brings a prevailing northwesterly and westerly flow of cool, comparatively dry, stable air into the northwest Olympic Peninsula.

The dry season begins in May with the driest period between mid-July and mid-August. The total rainfall for July is less than .5 inch in one summer out of ten. It also exceeds 5 inches in one summer out of ten. During the warmest months, afternoon temperatures are in the upper 60s and lower 70s, reaching the upper 70s and the lower 80s on a few days. Occasionally, hot, dry air from the east of the Cascade Mountains, [funneled through the straits of Juan de Fuca], reaches this area and temperatures are in the mid- or upper-90s for one to three days. In summer and *early fall, fog or low clouds form over the ocean and frequently move inland at night, but generally disappear by midday [inland, but often persist throughout the day within a mile or three from the coast]. In winter, under the influence of a surface high pressure system, centered off the coast, fog, low clouds, and drizzle are a daily occurrence as long as this type of pressure continues."*

Average annual precipitation (by Water Year [WY]; October-September) at the Quillayute State Airport was 102.6 inches (260 cm) between 1967 and 2005, and ranged between 72.2 inches and 139.9 inches (183.4 and 355.3 cm; Figure 1.4). The bulk of this precipitation fell between October and April each year (i.e., the wet season) between 1967 and 2005, averaging 84 inches (231.4 cm) and ranging from 52.6 to 120 inches (133.6 to 304.8 cm; Figure 1.4). Summer precipitation (May – September; i.e., the dry season) during the same period averaged 18.1 inches (46 cm), ranging from 7.5 to 33.2 inches (19.1 to 84.3 cm; Figure 1.4). Average monthly precipitation ranges from a maximum of 29.1 inches (73.9 cm) in November to 2.2 inches (5.6 cm) in July (Figure 1.5). For the period of record at Quillayute on an annual basis, there are 209 days of the year with greater than 0.01 inches of precipitation, 148 days greater than 0.10 precipitation, 70 days greater than 0.50 precipitation, and 30 days with precipitation greater than 1.0 inches (0.03, 0.3, 1.3, and 2.5 cm).

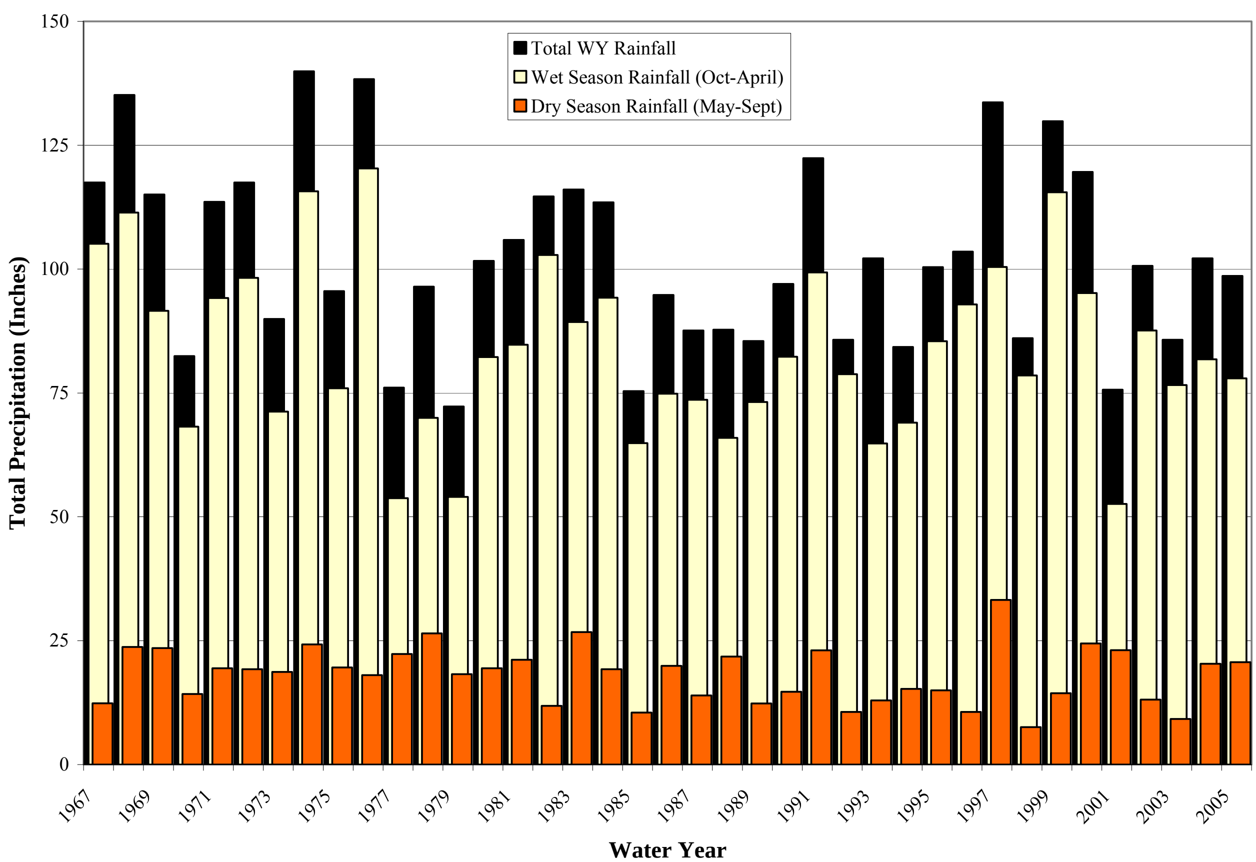

Figure 1.4. Total wet season, dry season, and annual precipitation by water year for Quillayute Airport weather station WY 1967 to WY 2005 (source: NOAA-NCDC 2005).

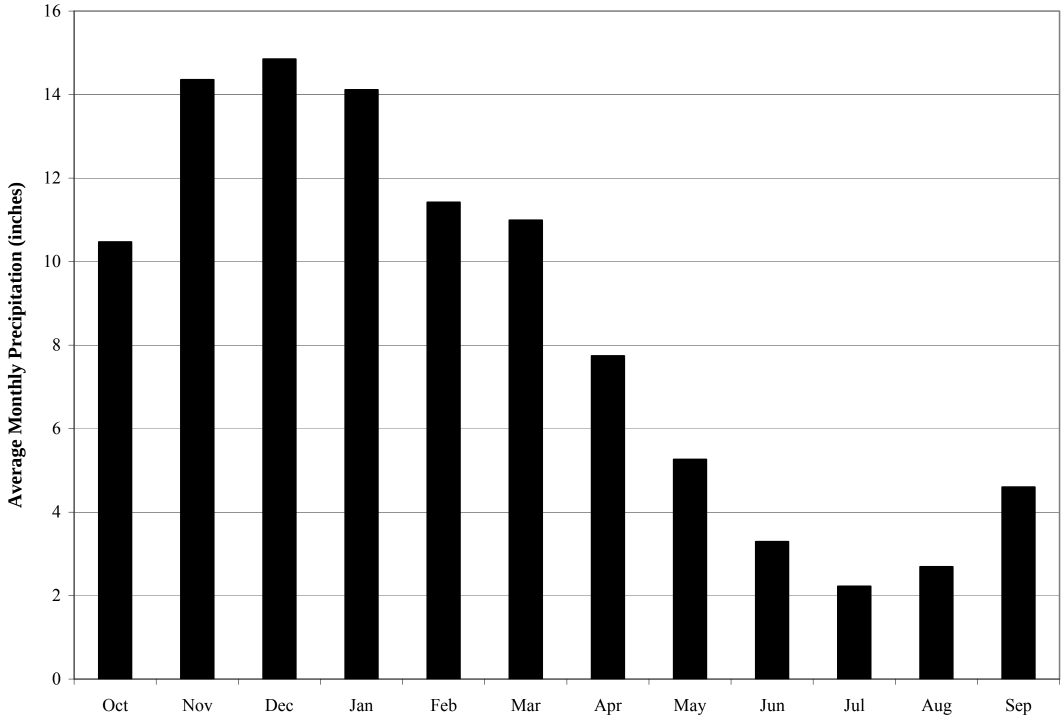

Figure 1.5. Average monthly precipitation for Quillayute Airport weather station WY 1967 to WY 2005 (source: NOAA-NCDC 2005)

While the data from the Quillayute State Airport are reliable and generally representative of the Lake Ozette watershed 12 miles (19.3 km) to the north, they do not define the existing north to south, west to east and elevational gradients of climate and precipitation on the northwest end of the Olympic Peninsula, and thus the high spatial heterogeneity of precipitation at the instantaneous to annual time steps. To shed some light on this heterogeneity, modeled precipitation data were acquired from the Spatial Climate Analysis Service (SCAS) at Oregon State University for the period 1967 to 2004. The PRISM (the Parameter-elevation Regressions on Independent Slopes Model) model was used to estimate annual precipitation (note: January to December) at various points in the Ozette watershed. This model uses point data, a digital elevation model, and other spatial data sets (including expert knowledge of rain shadows, temperature inversions, coastal effects, etc.) to generate gridded (4km) estimates of precipitation.

These data suggest that average annual precipitation at the Quillayute Airport is generally similar to low elevation points around the Lake Ozette watershed, such as the Ozette Ranger Station at the north end of Lake Ozette (Table 1.2 and Figure 1.6). However, annual precipitation gradually increases toward the east from Lake Ozette (e.g., Ozette Ranger Station to Coal Creek to Umbrella Creek to Big River at Royal), which is partially a result of elevational increases and orographic effects. Sharp increases in precipitation exist where large elevational gradients occur, such as in the headwaters of Big River above 1000 feet, where average precipitation is greater than 120 inches (Table 1.2 and Figure 1.6).

Table 1.2. PRISM modeled precipitation for various locations in the Ozette watershed for the period of 1967 through 2004.

ANNUAL PRECIPITATION 1967 TO 2004					
	Quil. Recorded	Quil. Modeled	South Creek	Siwash Creek	Crooked Creek
Elevation (feet)	192	192	80	200	120
Annual Avg (inches)	102.7	104.3	102.7	112.4	111.7
Annual Min (inches)	72.2	62.1	60.3	65.8	66.3
Annual Max (inches)	139.9	136.1	134.8	141.4	144.9
	Ranger Station	Coal Creek	Umbrella Crk.	Big at Royal	Big at Sekiu Mt.
Elevation (feet)	40	200	400	143	1788
Annual Avg (inches)	100.6	103.7	106.4	107.8	129.2
Annual Min (inches)	59.7	61.1	61.6	62.8	77.8
Annual Max (inches)	135.1	142.7	142.0	145.3	158.0

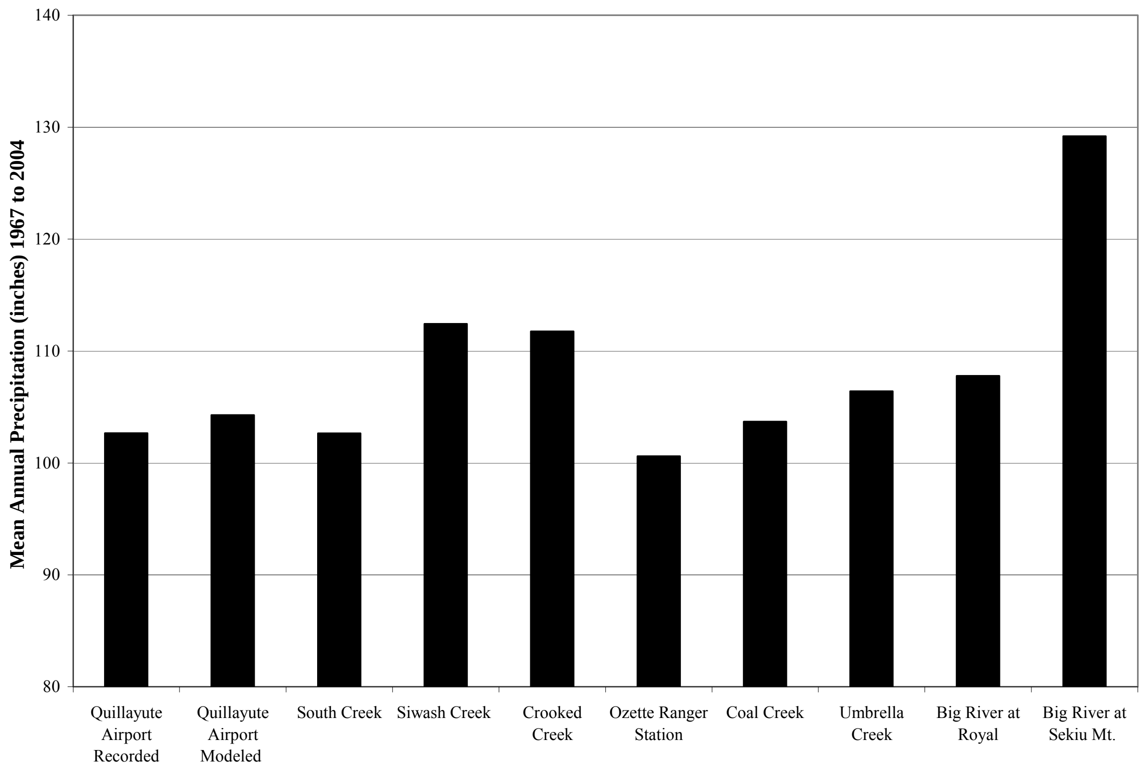

Figure 1.6. PRISM modeled mean annual precipitation (January through December) for various locations in the Ozette watershed for the period of 1967 through 2004.

Only one reliable precipitation data set inside the Lake Ozette watershed helps test the accuracy of these PRISM data. The National Park Service installed a continuous weather station at the Ozette Ranger Station in September 2003, which continuously records precipitation and records temperature, humidity, and solar radiation at the hourly time interval. This station allows for the direct comparison of annual precipitation for the two stations (Quillayute and Ozette) during Water Years (WY) 2004 and 2005. The annual precipitation total at Quillayute for WY 2004 was 102.15, while at Ozette the annual total was 89.54, a difference of 12.61 inches. For WY 2005, the annual precipitation total at

Quillayute was 98.61, while at Ozette was 91.68, a difference of 6.93 inches. Therefore, for at least these two water years, annual precipitation at Quillayute would over estimate precipitation at the Ozette Ranger Station. Modeled PRISM data indicates that on average Quillayute receives 2.1 more inches annually than Ozette Ranger Station.

At the regional scale, these annual data at Quillayute and Ozette initially suggest the presence of a south to north gradient in annual precipitation. However, rainfall data from Neah Bay 2E (average annual rainfall = 104.34 inches, 1948 to 1987) and the Quillayute Airport (average annual rainfall = 101.80 inches, 1966 to 2005) indicate that there is not a strong south to north gradient in annual or monthly precipitation. Differences in precipitation totals between Quillayute and Ozette were also present at monthly time scale over 2004 and 2005. Monthly total precipitation at Quillayute was generally higher than at Ozette, but exceptions did occur, especially during wet months (Figure 1.7). These data indicate that overall, Quillayute might receive slightly more precipitation than the Ozette Ranger Station, but that depending on differing weather patterns, storm tracks and physiographic positions, spatial variability in precipitation may be high enough to restrict development of consistent relationships without significant additional data.

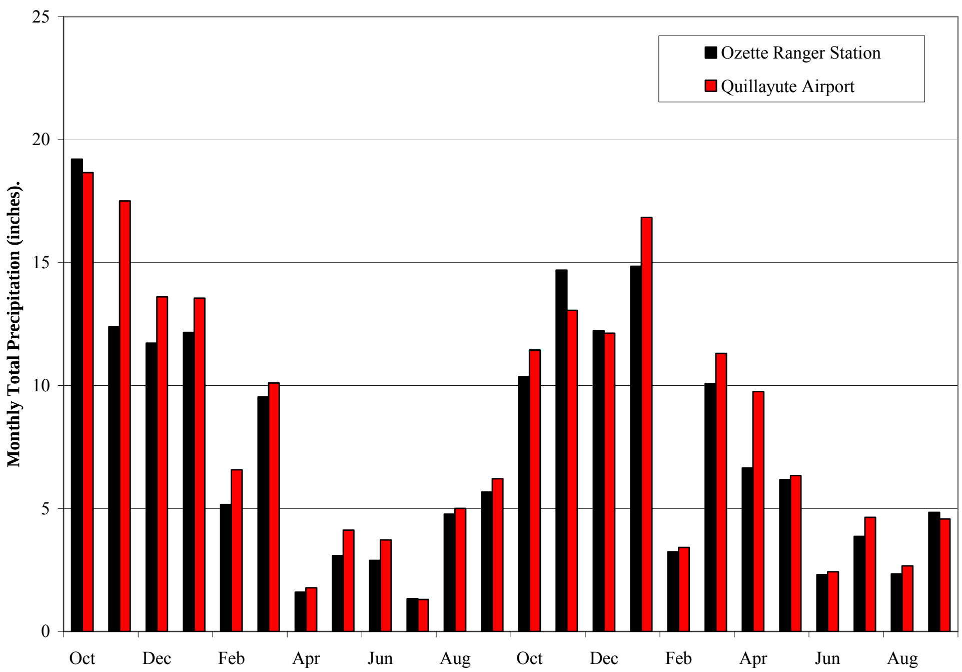

Figure 1.7. Monthly rainfall comparison, Quillayute versus Ozette for WY 2004 and 2005 (source: NOAA-NCDC 2005; ONP, unpublished data).

Regardless of specific comparisons that can be made between existing data in the region, there is obviously a lack of site-specific rainfall or climate data within the Lake Ozette watershed. While there are general trends that hold true for the region, such as similar patterns of monthly precipitation distribution, moderate variations in precipitation depths and intensities undoubtedly occur at the hourly and daily time scales on up to annual precipitation totals. This is especially true when factoring orographic effects on precipitation totals and intensity, wind effects on precipitation actually reaching the ground surface, and the effects of distance to coast and forest condition on moisture retention and fog drip. Due to the watershed's proximity to the coast, fog drip is likely a significant, but locally unquantified, contributor to overall ground surface precipitation. Vegetation cover and land use can significantly influence the magnitude of the fog drip component of the water cycle. The recently installed continuous weather station at the Ozette Ranger Station allows for a more local view of the weather parameters that may influence climate, local water balances, and lake levels, especially during the summer months. Figure 1.8 displays air temperature, relative humidity and shortwave radiation data for the summer 2004. Distinct diurnal patterns exist with temperature directly corresponding to radiation at the ground surface and humidity inversely relating to radiation level. On clear summer days, shortwave radiation is high, resulting in high day time temperatures near the ground and low relative humidity. Evaporation from Lake Ozette is presumed to be very high during these daytime conditions.

Following these clear summer days, summer nights bring lower temperatures and increased relative humidity, often as the marine layer and fog temporarily move inland. By the next day, often the fog burns off and the marine layer pushes back offshore. However, during other days, the marine layer fails to move off shore, which is often the case when temperatures are very hot inland pulling the cooler air in to replace hot rising air. During these foggy days, daytime temperatures are moderated by reduced shortwave radiation penetrating the low cloud surface and reaching the ground surface. Moderate temperatures and high humidity on these foggy days results in reduced potential for evaporation from Lake Ozette. Each summer at Lake Ozette varies in the degree that the coastal marine layer dominates local weather conditions over the lake. It is hypothesized that during typical summers with periodic precipitation events (Figure 1.4), moderately warm inland temperatures, and a general easterly flow of wind and pacific moisture (fog), evaporation from Lake Ozette is moderated by fog and periodic precipitation and runoff maintain the lake level at or above average summer lake levels. During drier summers dominated by more frequent winds from the east and northeast (westerly) and reduced precipitation, evaporation from Lake Ozette is enhanced and lake levels are not moderated by periodic precipitation and runoff, such as occurred during 2002 and 2003.

During a majority of the year at Quillayute (and Lake Ozette), but especially during the wet season, "*the prevailing flow of air is from the southwest and west. In the late spring and summer, a clockwise circulation of air around the large high pressure center over the north Pacific brings a prevailing northwesterly and westerly flow of cool, comparatively dry, stable air into the northwest Olympic Peninsula. Occasionally, hot, dry air from the east of the Cascade Mountains, [funneled through the Strait of Juan de Fuca], reaches this area*" (National Oceanic and Atmospheric Administration, National Climate Data Center 2005). Figure 1.9 displays a polar plot of average daily wind speed and <u>source</u> direction at the Quillayute Airport for the period 1966 to 2003. This wind rose indicates the percent of time the wind blew <u>from</u> a given direction over a range of wind velocities. The graph displays the overall general trend of wind and air flow from the west and southwest, with a counter trend of wind from the northeast, predominantly during periods of east/southeast wind through the Strait of Juan de Fuca. 41% of the time the average wind speed was calm between 1966 to 2003. Note units are in knots.

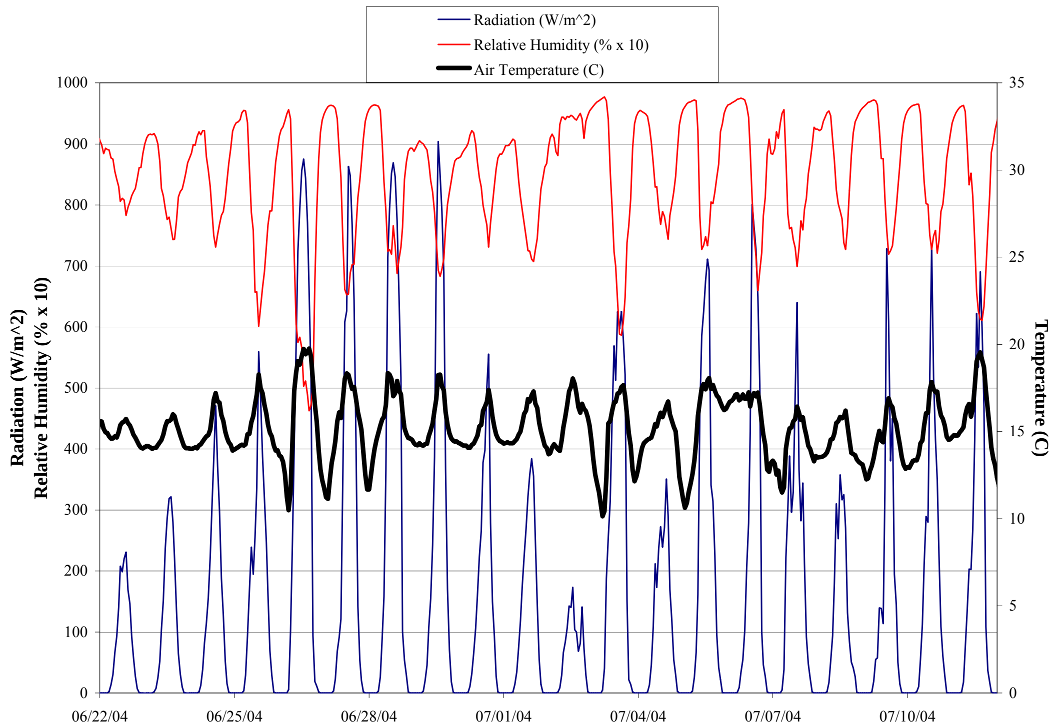

Figure 1.8. Ozette Ranger Station weather data for the early summer, 2004 (source: ONP, unpublished data).

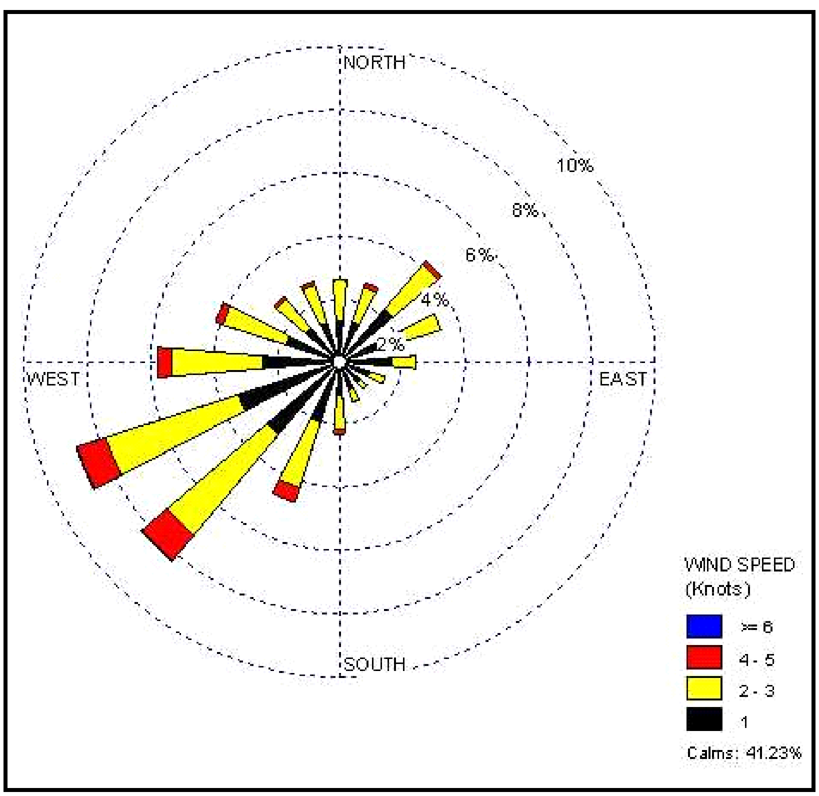

Figure 1.9. Rose plot of daily average wind speed and source wind direction at the Quillayute Airport 1966 to 2003 (adapted from Herrera 2005).

1.4 LAKE OZETTE ECOLOGICAL SETTING

Lake Ozette is a monomictic, mesotrophic lake, and is thermally stratified from April/May through October (Beauchamp and LaRiviere 1993). Summer time epilimnetic temperatures average 21°C. Dissolved oxygen levels remain greater than 8 mg/L above 70 m but were found to drop to approximately 4 mg/L at a depth of 80 m in September (Beauchamp and LaRiviere 1993; Bortleson and Dion 1979). The following is a summary of Meyer and Brenkman (2001) findings:

- pH levels ranged from 6.7 to 7.7
- Specific conductivity was relatively low and uniform throughout the water column
- Turbidity levels within the lake vary significantly depending upon time of year, sample location, and depth
- The highest chlorophyll concentrations are near the lake surface
- The lake's zooplankton community is comprised of nine crustacean and 15 rotifer taxa with the highest densities occurring in July

Meyer and Brenkman (2001) concluded that the water chemistry, nutrients, and zooplankton densities were within ranges documented for other sockeye lakes in Washington, British Columbia, and Alaska. Shoreline vegetation was surveyed in 1993 and 1994 and included approximately 24 plant taxa.

The Lake Ozette fish community includes a rich array of approximately 25 species of fishes presumed to be present (see Chapter 2). There are seven "species" of salmonids present in the lake system including: sockeye salmon (*Oncorhynchus nerka*), kokanee salmon (*Oncorhynchus nerka kennerlyi*), coho salmon (*Oncorhynchus kisutch*), chum salmon (*Oncorhynchus keta*), Chinook salmon (*Oncorhynchus tshawytscha*), rainbow/steelhead trout (*Oncorhynchus mykiss*), and cutthroat trout (*Oncorhynchus clarki*). Approximately 18 non-salmonid fish species are also thought or known to be present within the Lake Ozette watershed and they include the following: speckled dace (*Rhinichthys osculus*), coastrange sculpin (*Cottus aleuticus*), prickly sculpin (*Cottus asper*), reticulate sculpin (*Cottus perplexus*), riffle sculpin (*Cottus gulosus*), torrent sculpin (*Cottus rhotheus*), brook lamprey (*Lampetra richardsoni*), pacific lamprey (*Lampetra tridentata*), three-spine stickleback (*Gasterosteus aculeatus*), Olympic mudminnow (*Novumbra hubbsi*), peamouth (*Mylocheilus caurinus*), Tui chub[1] (*Gila bicolor*), northern pikeminnow (*Ptychocheilus oregonensis*), redside shiner (*Richardsonius balteatus*), American shad[2] (*Alosa sapidissma*), yellow perch[3] (*Perca*

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[1] Tui chub have been documented but no specimen samples have been collected; presumed present and introduced.

[2] Introduced species: American shad were not directly introduced into the Lake Ozette watershed. American shad were introduced into the Sacramento River system in 1871 and since that time their range has expanded north and they have recently been found in the Ozette watershed; although their numbers currently remain low.

[3] Introduced species: both yellow perch and largemouth bass were introduced to Lake Ozette in the 1920s

flavenscens), largemouth bass[3] (*Micropterus salmoides*), and brown bullhead (*Ictalurus nebulosus*)[4] (MFM 2000; Gustafson 1997; Mongillo and Hallock 1997; Jacobs et al. 1996; MFM unpublished fish captures). Several other species of fish use the estuarine portion of the lower Ozette River and likely include sturgeon (*Acipenser spp.*), marine cottids, marine flatfish, and surf smelt (*Hypomesus pretiosus*).

The Lake Ozette watershed is predominantly forested. Lake Ozette and Elk Lake are the largest unforested areas within the watershed. Other unforested areas also occur where bogs and open water wetlands naturally exist. The forest contained within the Ozette watershed can be characterized as a coastal temperate rainforest ecosystem. Sitka spruce (*Picea sitchensis*) and western hemlock (*Tsuga heterophylla*), are the dominant conifer species, followed by western redcedar (*Calocedrus decurrens*) pacific silver fir (*Abies amabilis*), Douglas fir (*Psuedotsuga mensiezii*), and western yew (*Taxus brevifolia*). Red alder (*Alnus rubra*) is the most prevalent deciduous tree, and is common along streams and disturbed sites. Vine maple (*Acer circinatum*) and bigleaf maple (*Acer macrophylla*) are also common in riparian areas, wetlands, and meadows. Schoonmaker et al. (1997) define this section of the Pacific coastal temperate rainforest as seasonal temperate rainforest, as compared to warm temperate rainforest to the south and perhumid temperate rainforest and sub-polar temperate rain forest zones to the north. It has been classified as seasonal due to less than 10% of the total rainfall occurring during summer months.

Understory vegetation in mature temperate rainforests is complex. In the Ozette watershed there are approximately 363 vascular plant species (Buckingham et al. 1995). Fungi and lichen are ubiquitous in areas of primary forest. They compose a significant fraction of the forest biomass and play an important role in nutrient cycling within the forest ecosystem. The lake and watershed contain a diverse assemblage of terrestrial and aquatic mammals, birds, and amphibians.

1.5 WATERSHED DISTURBANCE AND LAND USE

Natural disturbance in the Ozette watershed is primarily driven by winter storms. Wind and geomorphic events are considered the primary disturbance agents in coastal temperature rainforests (Alaback 1996). The size and age of the long-lived trees present when Europeans first began to settle the area is a testament to the pre-settlement disturbance regime in the watershed. Forest fires were infrequent, and mature spruce and cedar trees easily achieved ages of 400 years and older. Strong winter storms are common on the Pacific coast, and are the primary natural disturbance mechanism in coastal areas, frequently causing windthrow and toppling shallow-rooted trees (Alaback 1996). The “21 Blow” of January 29, 1921 toppled more than 8 billion board feet of timber. In addition, large magnitude (~magnitude 9) great earthquakes have been shown to recur at a 400-600 year frequency along this region of the Pacific Coast (Atwater and Hemphill-Haley 1997).

[4] One individual captured in the Ozette River on June 1, 2001, brown bullhead are assumed to have been introduced, although no documentation of this has been found.

Prior to European settlement, the area around Lake Ozette was occupied by Native Americans for thousands of years. The population of the Ozette Village, near the mouth of the Ozette River, decreased when natives were forced to move to Neah Bay so that their children could attend school in 1896 (Wray 1997). By 1914 there were only 17 natives remaining at Ozette and by 1932 there were only two (Wray 1997). Several prairies west of Lake Ozette were regularly burned by Native Americans to maintain open areas that attracted and fed game such as deer and elk. Swan (1869), who may have been the first white man to see Lake Ozette, describes journeying to the lake by trail with a group of natives from the Ozette village. In interviews in 1935 (Swindell 1941), Makah fishermen described fishing in the Ozette River, the lake, and the tributaries, using a variety of methods. Native American people undoubtedly affected their environment. However there is no evidence to indicate that significant anthropogenic watershed disturbance took place prior to European settlement.

Modern disturbance in the Ozette watershed is primarily driven by timber harvest, road construction and maintenance, residential and agricultural development, and stream clearing, including “stream improvement” projects and policies implemented by WDF and later WDNR.

1.5.1 Landownership

Each land parcel’s ownership in the Ozette watershed can be classified into one of the following categories: industrial forest, Washington Department of Natural Resources (WDNR), National Park Service (NPS), Ozette Reservation, Clallam County, small private (small forest, residential, and agriculture land owners), or undefined (no data or multiple landowners). Figure 1.10 depicts land ownership categories for the Lake Ozette watershed. Private lands including industrial forest and small private ownership types comprise about 74% of the basin. The NPS owns 15% of the basin, WDNR owns 10%, and the Makah Tribe owns about 1%. Clallam county and undefined land ownership comprises less than 1% of the watershed. Over 81% of the watershed’s land surface is zoned as commercial forest land.

Private timber companies and small private landowners own an average of 90% of the four largest tributaries to Lake Ozette and the Ozette River (Big River, Crooked Creek, Umbrella Creek, and Coal Creek). Ownership patterns vary between the four largest tributaries. Table 1.3 depicts the land ownership categories within the four largest Ozette watershed sub-basins. Private land ownership within the Coal Creek, Umbrella Creek, Big River, and Crooked Creek sub-basins comprises 92%, 93%, 92%, and 82% of the land area respectively. With the exception of Big River, zoning within these four sub-basins is 99 to 100% commercial forest.

Table 1.3. Land ownership types as a percentage of watershed area for the four largest Lake Ozette watershed sub-basins.

Sub-Basin	Clallam County	WDNR	Federal	Industrial Forest	Small Private	Undefined
Coal Creek	0.2%	6.3%	1.5%	91.8%	0.2%	0.0%
Umbrella Creek	0.3%	6.3%	0.2%	93.2%	0.1%	0.1%
Big River	0.2%	6.6%	0.3%	82.4%	9.7%	0.7%
Crooked Creek	0.0%	18.0%	0.2%	80.8%	1.0%	0.0%
TOTAL	**0.2%**	**9.1%**	**0.4%**	**85.3%**	**4.7%**	**0.3%**

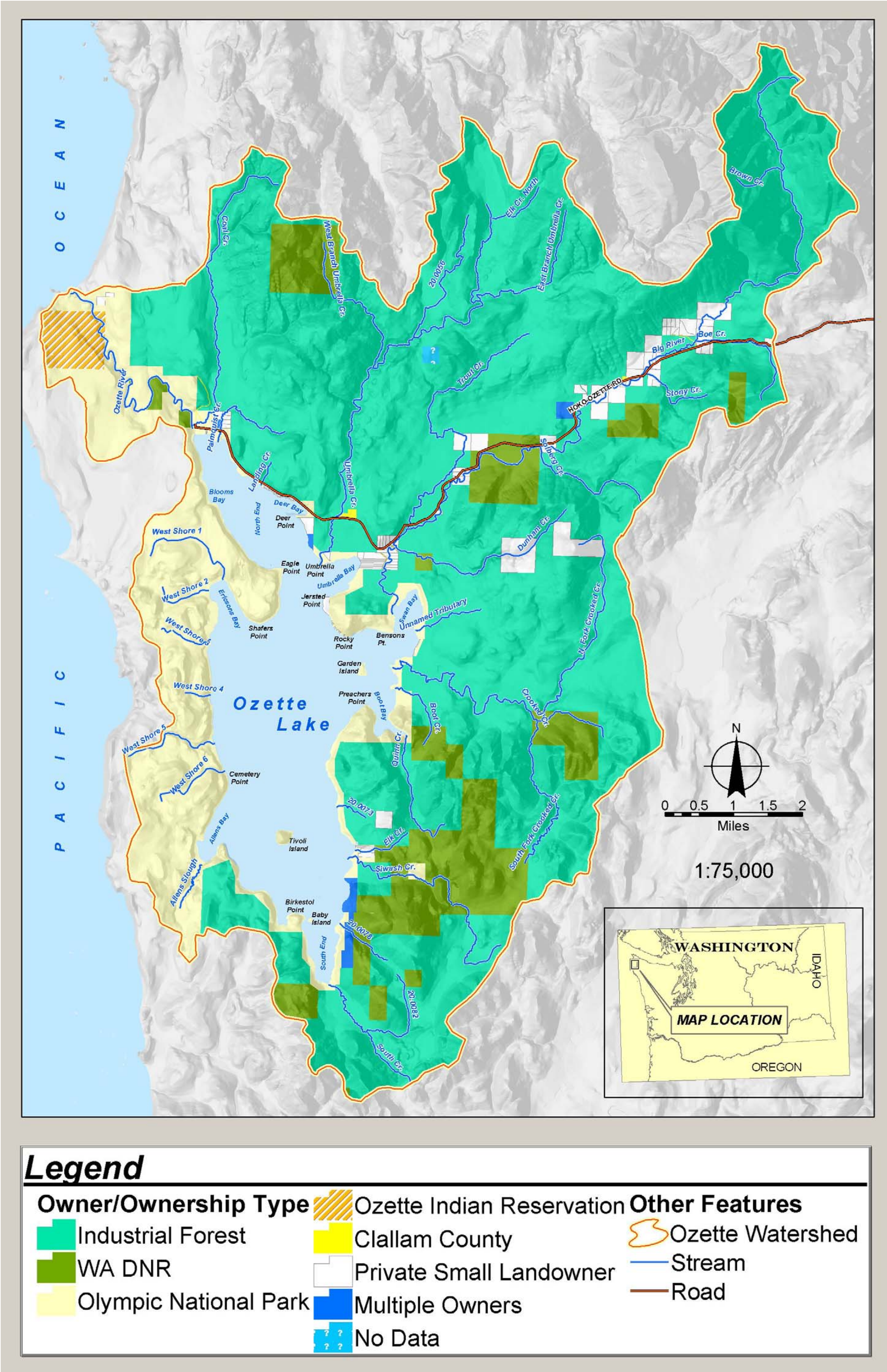

Figure 1.10. Ozette watershed landownership and landownership type.

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1.5.2 Settlement and Agricultural Development

Most of the Ozette watershed was ceded to the United States by the Makah Indian Tribe in the Treaty of Neah Bay in 1855. European settlement in the Ozette watershed began after the Treaty was signed. The Ozette area was opened to homesteading from 1890 until 1897. By 1892, 33 families occupied homesteads in the area (Jacobs et al. 1996). In 1893, the Ozette Reservation was established by Congress to protect the rights of 64 villagers living there (Wray 1997).

Settlement was concentrated along the shoreline of the lake and the gentle bottomlands of lower Big River, which was the primary route to civilization. Government Land Office (GLO) surveys conducted from 1892 to 1897 showed 39 homesteads along the lake and 29 additional homestead sites scattered throughout the watershed. Settlers cleared timber around their homes, and a wagon trail extended from Ozette to Clallam Bay. Settlement peaked near the turn of the century and declined after the creation of the Olympic Forest Reserve by President Cleveland in 1897. This caused an exodus of settlers, who had hoped for a road to bring development. By the time the land was reopened to settlement in 1907, timber companies rapidly consolidated their holdings, and very little additional settlement occurred. Big River has continued to slowly develop, while the lake shoreline has returned to forest, with the exception of a few parcels of private property within the boundaries of ONP. While the GLO maps at the turn of the century show 39 buildings around the lake, the 1935 USGS map shows only 10. Subsequent USGS maps show 11 buildings in 1956 and 21 in 1987.

In 1953, the area west of the lake was transferred to the National Park Service as a part of Olympic National Park. The lake and a thin strip along the eastern shoreline were added to the park in 1976 (Meyer and Brenkman 2001). Currently, the most developed portion of the shoreline of Lake Ozette is the area immediately surrounding the lake outlet. In addition to the ONP ranger facilities at the lake's outlet, there are 15 cabins/homes on lakefront parcels surrounding the lake. Starting in 1942, the area from the mouth of Coal Creek south to the current ONP campground was occupied by the U.S. Coast Guard, which performed beach patrols along the coastline. This area was developed into a resort in the 1950s, and was redeveloped into the ONP Ozette visitor center, ranger station, campground, and parking area in the 1980s. In addition to development at the lake outlet, there are two other vehicle access points to the lake at Swan Bay and Rayonier Landing, along the east side of the North End. Other developed private properties within the boundaries of ONP are reachable by boat or trail. The developed length of shoreline comprises approximately 1-2% of the total shoreline length.

Along Big River, agricultural and residential development have been confined to the lower 10 miles of the river. Most residential development along Big River is near the original wagon trail, which is now the only public road to Lake Ozette. GLO maps showed 8 developed homesteads along Big River in 1897. The 1935 USGS map shows 13 settlements, with 32 homes and other buildings, and about 288 acres of cleared land

(~2% of watershed area). The 1956 USGS map shows 12 settlements with 19 homes and other buildings, and 483 acres of cleared land (~3.3% of watershed area). The 1987 USGS map shows 34 homes or other buildings and 176 acres of cleared land (~1.2% of watershed area). Currently, about 245 acres of land (~1.7% of the watershed area) are cleared for residential or agricultural use, and there are approximately 62 houses and other buildings within the Big River valley. (Based on 2006 ortho photos, 42 tax parcels contain at least a home, building, or other improvement.) In agricultural areas, the riparian area and floodplain of the river were cleared of vegetation and converted to pasture. Currently, approximately 9,900 feet of Big River are adjacent to developed residential or agricultural land. Bank destabilization through these reaches has led to attempts to armor the river with automobiles, riprap, and wood, and in at least one location, an old side channel of the river has been filled in to create additional pasture (Emil Person, personal communication, verified with USGS maps and aerial photos).

1.5.3 Commercial Timber Harvest

Commercial timber harvest in the Ozette watershed began in the 1930s (Jacobs et al. 1996). Table 1.4, below, summarizes the percent of the watershed harvested, as reported in Herrera (2005) and Good et al. (2005). Values from Herrera have been adjusted to include the Ozette River and Coal Creek as part of the Ozette basin.

Table 1.4. Reported percent of Ozette basin clear-cut at least once since 1953 (source: Jacobs et al. 1996; Herrera 2006).

YEAR	1953	1964	1981	2003
Percent of basin logged	8.7%[1]	22.2%[2]	60%[1]	83.6%[2]

[1]It is not clear whether this calculation included the lake surface area in the basin area (Meier 1998).
[2]This calculation does not include lake surface in basin area calculations (Herrera 2005).

As part of this limiting factors analysis, a thorough review of aerial photos through time was conducted to accurately depict the logging history of the Ozette watershed, as well as major sub-basins within the watershed. Figure 1.11 depicts the percentage of old growth forest clear-cut through time for the Ozette watershed, as well as the Umbrella Creek, Big River, and Crooked Creek sub-basins. An additional analysis was conducted to determine the cumulative percentage of the forested watershed area where second growth forest has been clear-cut. As of 2006, within the Umbrella Creek, Big River, and Crooked Creek sub-basins, approximately 11.8%, 18.2%, and 11.2% of the second growth forests had been clear-cut, respectively, totaling approximately 14.4% of the second growth forest within the Ozette watershed as a whole.

Until the 1970s there were few regulations governing timber harvest. Streams were used for yarding corridors, riparian trees were removed, and sediment and slash inputs to streams were not regulated. Habitat degradation in Lake Ozette tributaries from commercial forest operations have long been implicated as major limiting factors affecting salmonid survival (USFWS 1965; Phinney and Bucknell 1975; Bortleson and Dion 1979; Dlugokenski et al. 1981; Blum 1988; WDF et al. 1994; Jacobs et al. 1996; Lestelle 1996; McHenry et al. 1996; MFM 2000; Smith 2000). Dlugokenski et al. (1981) noted that during their habitat surveys, trees were felled across Umbrella Creek and yarded through the channel; they also noted in one location in the mainstem where heavy equipment had been operating in the channel.

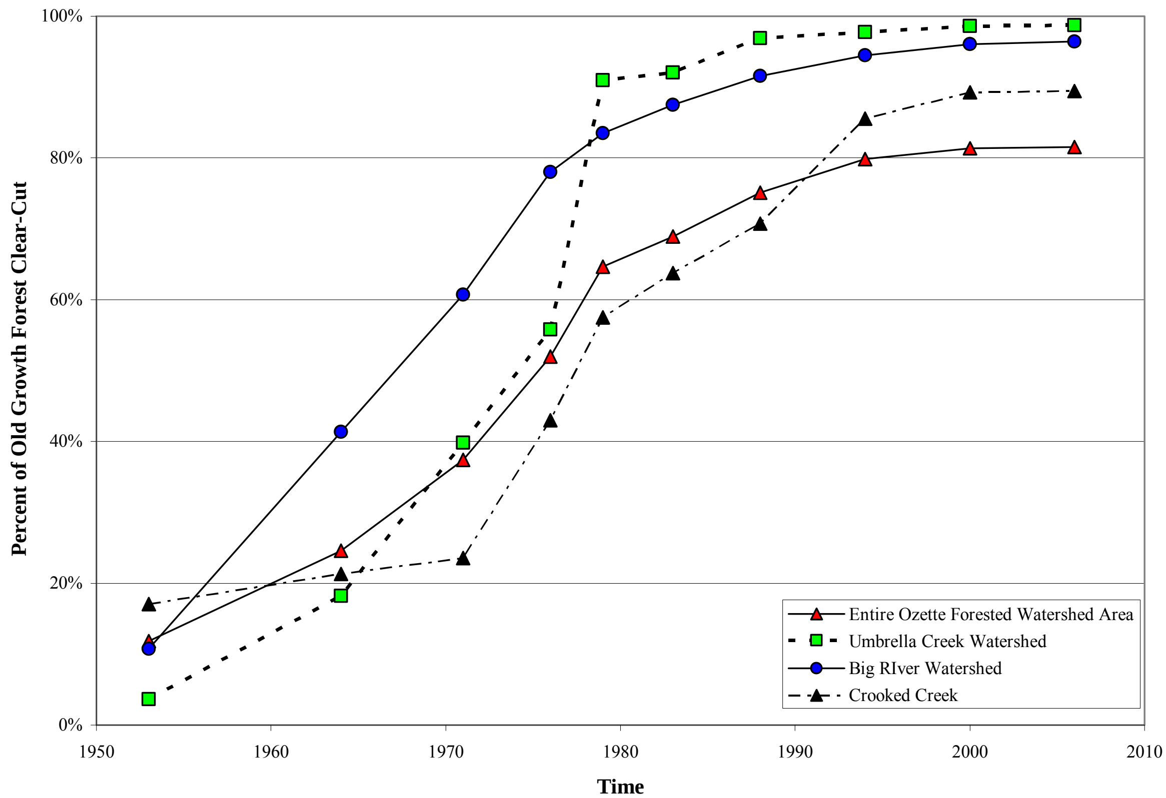

Figure 1.11. Percentage of old growth forest clear-cut through time for the entire forested portion of the Ozette watershed, as well as the Umbrella Creek, Big River, and Crooked Creek sub-basins.

1.5.4 Road and Railroad Construction

Lake Ozette in 1923 was described as being "*isolated*" by its location "*25 miles from Clallam Bay over an almost impassable road*" by Kemmerich (1926). The first road to Lake Ozette was completed in 1926 (Jacobs et al. 1996). Road and railroad building kept pace with timber harvest in the watershed, and road density continued to increase. In 1935, approximately 12.8 miles of road or railroad grade are shown on the USGS map. This increased to 25 miles in 1956, and by 1987 the USGS maps show 258.5 miles of road. Currently, there are about 341.3 miles of road and railroad grade identified on the WDNR GIS transportation coverage in the Ozette watershed, or about 4.4 miles of road per square mile (mi/mi^2) of land (Herrera 2006; note lake surface area not included in road density calculation).

A thorough review of aerial photos indicates that road densities are significantly higher than those depicted on USGS maps and the WDNR GIS transportation coverage, as well as recent estimates included in Herrera (2005; 2006). Road delineation using aerial photos and mapping in GIS resulted in the estimates of road length and road densities for major sub-basins depicted in Figure 1.12. In 2006, the total length of roads within the Ozette watershed was 417 miles. This road length results in an overall watershed road density of 5.5 mi/mi^2 (excluding the surface area of the lake). The 2006 ortho photo coverage indicates that road densities on non-federal land exceed 6 mi/mi^2 within the Ozette watershed.

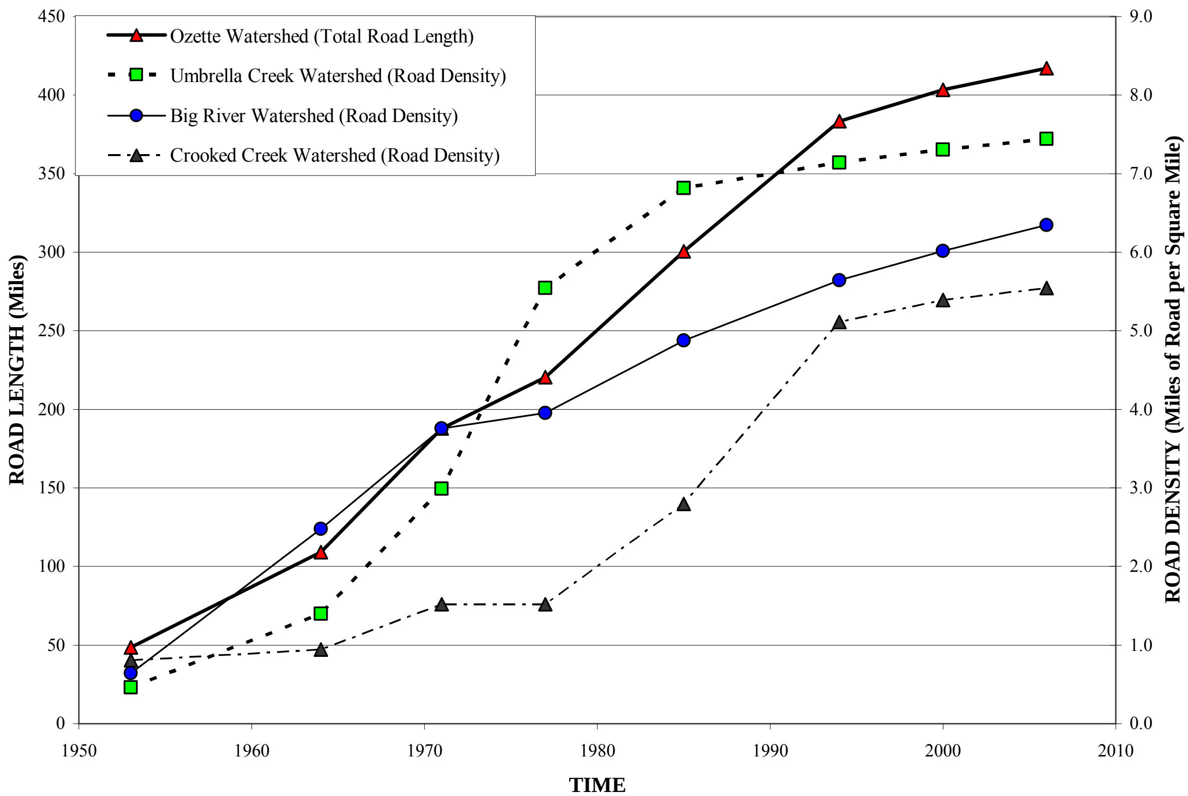

Figure 1.12. Ozette watershed road lengths and road densities for major sub-basins through time (road lengths based on aerial photo coverage; basin areas used in road density calculations were generated using a digital elevation model).

The Hoko-Ozette Road is the only significant public road in the area. It follows the original wagon trail to Ozette from Clallam Bay, and parallels Big River for approximately 7.8 river miles (Swan Bay Road to Nicolas Road). Within this reach, the road prism is frequently within the floodplain and channel migration zone of Big River. Kramer (1953) reported the road to be "*at times covered with flood waters*" during stream clearing activities in December 1952. Since then, the road has been raised repeatedly, but it still floods periodically. The road functions as a dike or levee during high water in some locations. Approximately 4,100 feet (1,250 meters) of bank hardening occurs along the county road and private property. Approximately 3.06 miles of riparian area are impacted by the road (road length within 200 feet of the bankfull edge of Big River; source: preliminary review of 2003 color aerial photos).

1.5.5 Stream Clearing History

It is unknown to what extent Native Americans cleared wood in the Ozette River prior to European settlement in the late-1800s. Charles Swan, possibly the first non-native to see Lake Ozette, was brought in by trail from the Ozette Village, near the mouth of the Ozette River. However, canoes were used on the lake, and may have been used on the Ozette River as well. Some historical accounts of homesteading describe the Ozette Indians ferrying settlers and goods to and from the mouth of the Ozette River. Stream clearing occurred, at least at a small scale, as early as the late-1800s in the Ozette and Big Rivers. Photos of the upper Ozette River from the late 1800's show no evidence of large wood above the Nylund homestead. One photo taken in the early 1900s shows cut logs in the river downstream of the ONP footbridge across Ozette River. In the lower Ozette River, a cedar logging operation was active in 1920s. By far the most significant directed stream clearing effort in the watershed took place in 1952, and was conducted by the Washington Department of Fisheries (Kramer 1953). A crew of eight men spent 63 operational days clearing log jams from the Ozette River, beginning August 7, 1952, and continuing through late October of the same year. A cat road was built along the river, and 26 separate log concentrations (Figure 1.13) were cleared or made passable (Kramer 1953). Many of the jams were described as being formed by erosion and blow-down of "*large over-ripe timber*" (Figure 1.14 and Figure 1.15). A 1964 aerial survey of the Ozette River from the mouth to the lake found that no log jams were present (USFWS 1965).

Immediately upon completing work in the Ozette River, the crew moved to Big River, where stream clearing took place from November 1 through December 19 (Figure 1.16) Heavy logging debris was reported to obstruct the river in the lower mile, which was not cleared because clearance equipment was "*not large enough to handle the heavy water-soaked logs*". Before stopping work due to flooding on December 19, the crew completed clearing about 3½ miles of stream between RM 2 and RM 6 of Big River (Kramer 1953). Umbrella Creek and Coal Creek were surveyed, and the need for clearance activities on Umbrella Creek was identified, however no work was completed at the time. It is not known if WDF conducted additional stream clearing activities in the Ozette watershed. Kramer's 1953 report does state though, that "*People of the area, especially the Lions Club of Sekiu, Neah Bay, and Clallam Bay, were very interested in this clearance project. They have assured us that they will assist us in keeping the river open after completion of clearance work*".

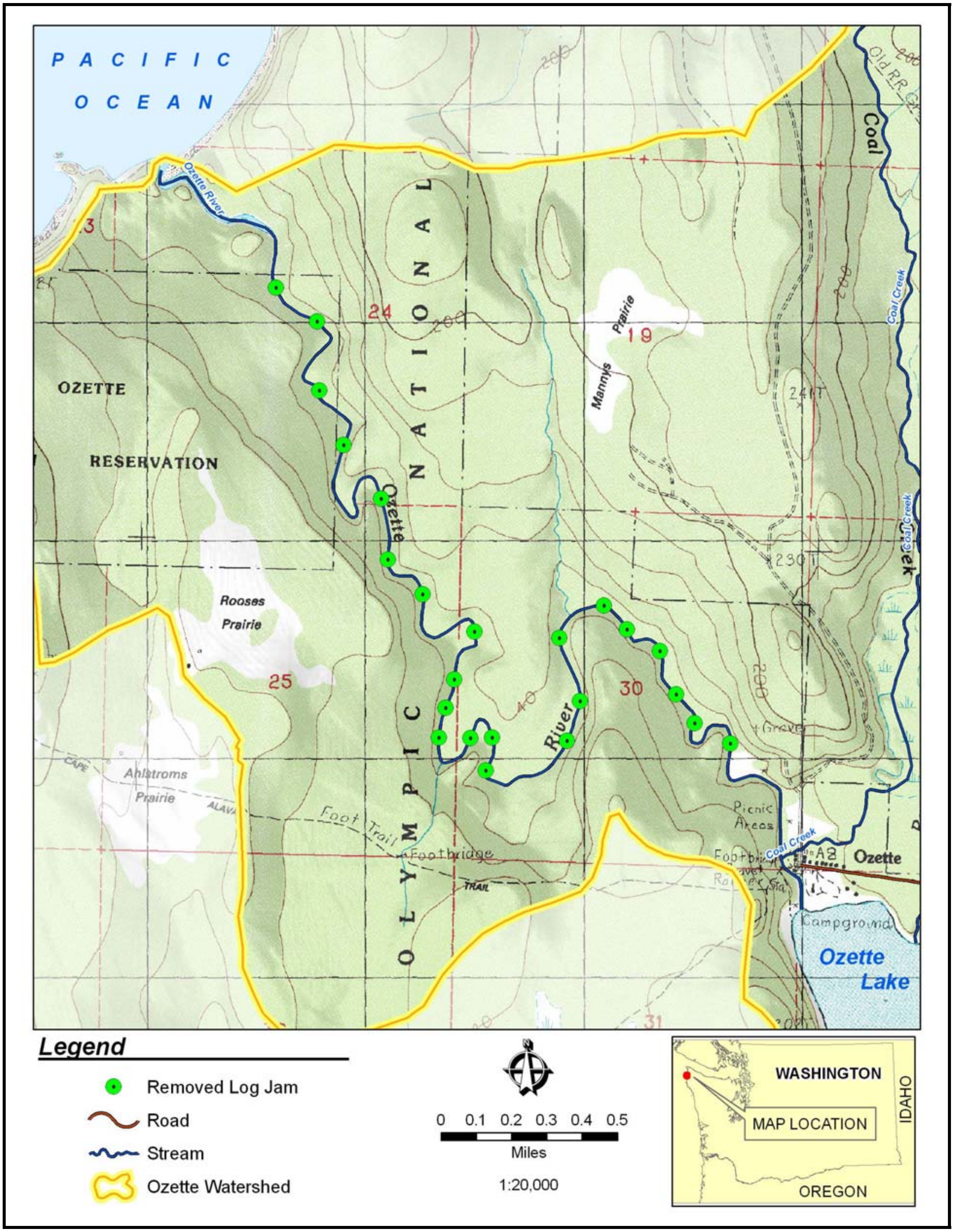

Figure 1.13. Map depicting the sites that logjams were cleared from the Ozette River (modified from Kramer 1953).

Figure 1.14. Example of typical logjam removed from Ozette River (source: Kramer 1953).

Figure 1.15. Debris racking on jam removed from the Ozette River (source: Kramer 1953).

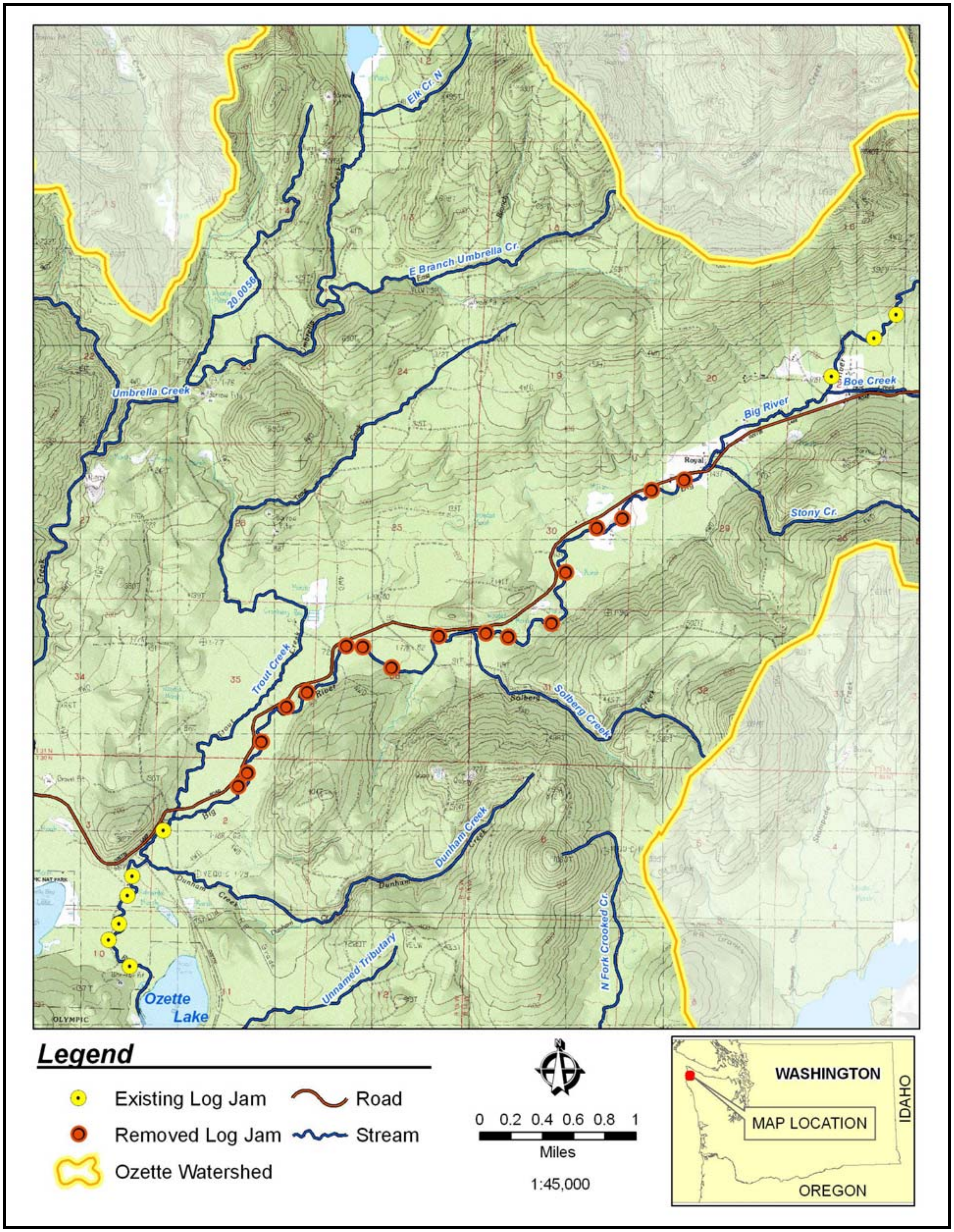

Figure 1.16. Map depicting existing and removed logjams in Big River in 1952 (modified from Kramer 1953).

Local residents continued to clear wood from the Ozette River sufficient to allow a small skiff to travel from the lake to the river mouth in the 1970s and 80s (Larry Sears, personal communication, 2005). ONP and the Makah Tribe continued to discuss a perceived need to remove wood from the river to improve fish passage through 1982 (Blum 1982, Contor 1982), but after surveying the river in 1985, they determined that fish passage was not obstructed by wood. Around the same time, the park stopped local residents from clearing wood in the Ozette River (Larry Sears, personal communication 2005).

After 1952, WDNR implemented stream clearing policies, and forest landowners were required to clear wood from streams when logging in the area. As with many Pacific Northwest watersheds, stream clearing became an integral part of forest practices, and was continued through the 1980s. Through much of the 1990's, cedar salvage and timber harvest operations continued to remove wood from channels, off-channel habitat, and riparian areas, although the rate declined steadily as regulations protecting instream and riparian areas developed.