KLAMATH NETWORK WATER QUALITY REPORT (PHASE II)

Skull Cave, Lava Beds National Monument, 1968

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EXECUTIVE SUMMARY

The Klamath Network (KLMN) is one of 32 National Park Service (NPS) networks responsible for developing vital signs-based monitoring programs for managing the long-term ecosystem health of the nation's parks. The park units of the Klamath Network are Crater Lake National Park (CRLA), Lassen Volcanic National Park (LAVO), Lava Beds National Monument (LABE), Oregon Caves National Monument (ORCA), Redwood National and State Parks (RNSP), and Whiskeytown National Recreation Area (WHIS). National Park Service networks are required to formulate Vital Signs Monitoring Plans, consisting of three phases: Phase I compiles background information and data on network park unit resources and presents conceptual models for each park unit ecosystem; Phase II provides an augmented Phase I and the selection and prioritization of vital signs; and Phase III will include the entire scope of information in Phases I and II, as well as the monitoring objectives, sampling designs and protocols, and data management and analysis procedures of a long-term vital signs monitoring program. The Klamath Network Phase II Water Quality Report is intended to provide an overview of the previous water quality related inventory and monitoring work conducted in each of the network's six park units and provide guidance in the direction of future monitoring objectives. The Phase II Report summarizes the activities undertaken to select vital signs to be used for monitoring the aquatic resources of Klamath Network park units.

The primary goal of the National Park Service Inventory & Monitoring (I&M) Program is to assess and monitor the long-term ecological health of park units. Other benefits of the program include the ability to detect change in resource condition and evaluate resource responses to management actions. Moreover, the program aims to create baseline knowledge of the condition of park unit resources for use by park unit scientists and those in academia or the private sector, and to create an effective method for data management, analysis, and reporting. Through information and data sharing the program hopes to increase public awareness of park unit activities and resources. The I&M program first focuses on inventories of park unit resources to assess the ecological health of the park units. While many aquatic resource-related inventories have been conducted within the Klamath Network, some fundamental inventories have not been completed. Then, given basic inventory data, a monitoring plan will be created to collect broad-based scientifically sound information on the current status and long-term trends in the health, composition, structure, and function of park unit ecosystems.

The I&M program was created through the Natural Resource Challenge, a method of improving natural resource stewardship in national parks. The Natural Resource Challenge requires managers to know the status or condition of natural resources under their stewardship and monitor long-term trends in those resources to conserve them unimpaired for future generations. Moreover, vital signs monitoring achieves the Category 1 goals found in the Government Performance and Results Act (GPRA) which requires that federal agencies account for money spent by reporting on the results of their activities.

To better understand and organize the information currently available about the aquatic resources of each park unit, the Klamath Network contracted the US Geological Survey to (1) compile background information on the primary aquatic resources of each network park unit, including past and current monitoring efforts, and (2) draft the Phase II Report. To date, over 100 aquatic inventory and monitoring related projects have occurred within Klamath Network park units and surrounding public lands. These projects include information on aquatic biota (e.g. amphibians, fishes, macroinvertebrates), baseline water quality (e.g. chemical and physical parameters), hydrological/ geological resources (e.g. surface flow, groundwater, geothermal/hydrothermal, ice in ice caves), recreation effects, land use impacts, and watershed restoration.

The Klamath Network, under the guidance of the National I&M Program, undertook the process of creating conceptual ecological models to help identify proposed candidate vital signs for selection and prioritization. Conceptual models formalize understanding of natural processes and facilitate a cross-discipline dialogue between scientists and resource managers. In addition, conceptual models provide an understanding of the structure, function, and interconnectedness of park unit ecosystems, enabling the identification of vital signs for assessing ecosystem health. Models were developed for freshwater and marine aquatic ecosystems found in Klamath Network park units. The conceptual modeling process also helped to identify many stressors that can potentially affect ecosystem components, patterns, and processes. Stressors, as defined by the I&M program, are forces of ecological change and can be of natural- or human-origin. The conceptual modeling process was particularly helpful in identifying proposed candidate vital signs that were not identified through other scoping processes.

The Klamath Network began in 1998 its scoping process to determine, or to prioritize, which vital signs the network should monitor. Initial park-specific Vital Signs Workshops were held between 1998 and 2003 to begin to identify stressors that potentially impact park unit ecosystems. These workshops were followed in 2004 by three network-wide workshops. The purpose of these workshops was to more specifically identify monitoring questions and vital signs associated with specific ecosystems and ecosystem categories (e.g., air, soil quality, hydrology, water quality, invasive species, etc.). The result of these workshops was the development of 172 monitoring questions and associated vital signs for the various park unit ecosystems. These monitoring questions and vital signs were sent out for review and prioritization by scientists/resource managers with research and management expertise related to park unit ecosystems; and two of the 10 most important network-wide vital signs monitoring questions identified were aquatic-resource focused. These two questions were: (1) what is the status and what are the trends of surface waters and pollutants; and (2) what is the status and what are the trends in structure, function and composition of locally limited (i.e., focal) aquatic communities?

The dominant theme during the initial identification of network-wide water quality issues was aquatic ecosystem health. The ability to (1) document improvement (or lack thereof) in the water quality of Clean Water Act section 303(d) listed impaired streams, and (2) the ability of park unit managers to document progress toward achieving GPRA goal 1.a4 (i.e., that parks have unimpaired water quality), underscored the importance of identifying a suite of vital signs useful for effective water quality assessment. The need to fully inventory aquatic resources and document baseline and reference water quality conditions also were identified as important objectives in the development of a vital signs-based long-term water quality monitoring program.

Detailed assessment and refinement of priority issues specific to Klamath Network water quality and the two aquatic resource-focused monitoring questions began in October 2004. The process was initiated by sending a questionnaire regarding aquatic resources and water quality to the Chief of Resources Management of each park unit. Park-specific information was sought in five basic categories: (1) identification of aquatic resources within park unit boundaries (i.e., marine, estuarine, lotic, lentic, palustrine, ice caves, and geothermal/ hydrothermal); (2) a list of water bodies of particular importance or interest to the park unit management; (3) a list of past and current water quality monitoring efforts; (4) a list of water resource management and/or land use issues that impact resources from either within or outside each park unit; and (5) qualification of the level of knowledge and experience of park unit staff in monitoring water quality. Questionnaire responses were summarized into preliminary park-specific Vital Signs Tables that included columns for: (1) Aquatic Resource; (2) Potential Resource Stressors; (3) Potential Indicators of Stress; (4) Potential Monitoring Options; and (5) Stressor Priority. The tables were reviewed and refined at an aquatic resources vital signs scoping session held in December 2004. Park unit staff identified the five most significant water quality resource management issues and aquatic resource stressors for each park unit (i.e., climate change, land use and non-recreational human impacts, introduced/invasive non-native biota, visitor recreational activities, and atmospheric deposition of nutrients and pollutants). In addition, the assessment process was instrumental for identifying indicators (or vital signs) of aquatic resource stress, relative to the five identified stressors, and potential monitoring options for quantifying ecosystem health and/or disturbance. The park-specific and network-level results of this process are discussed in detail on pages 57-85.

FIGURE 1: HORSESHOE LAKE, LASSEN VOLCANIC NATIONAL PARK

INTRODUCTION

The Klamath Network (KLMN) Water Quality Report is intended to provide a broad overview of aquatic resources at the network and park unit levels. Figure 1 is an example of one type of aquatic resource present in Klamath Network park units, and is representative of inland montane lakes within the network. The report begins with an overview of aquatic resources of the Klamath Network and includes identification of the locations of active monitoring stations in or near park units where various parameters (e.g., precipitation, evaporation, temperature, general water quality) are measured. This overview is followed by a general discussion of past and present water quality inventory, monitoring, and research activities in each park unit, a list of references associated with these activities, and a review of common (i.e., network-wide) water quality inventory, monitoring, and research themes related to these activities. Past and present monitoring and research programs of allied agencies in the KLMN region are then discussed followed by a detailed review of the Klamath Network Vital Signs Scoping Process and park-specific/network-level outcomes. The final section of the report presents park-specific responses to the Aquatic Resources and Water Quality Questionnaire solicited from each park unit.

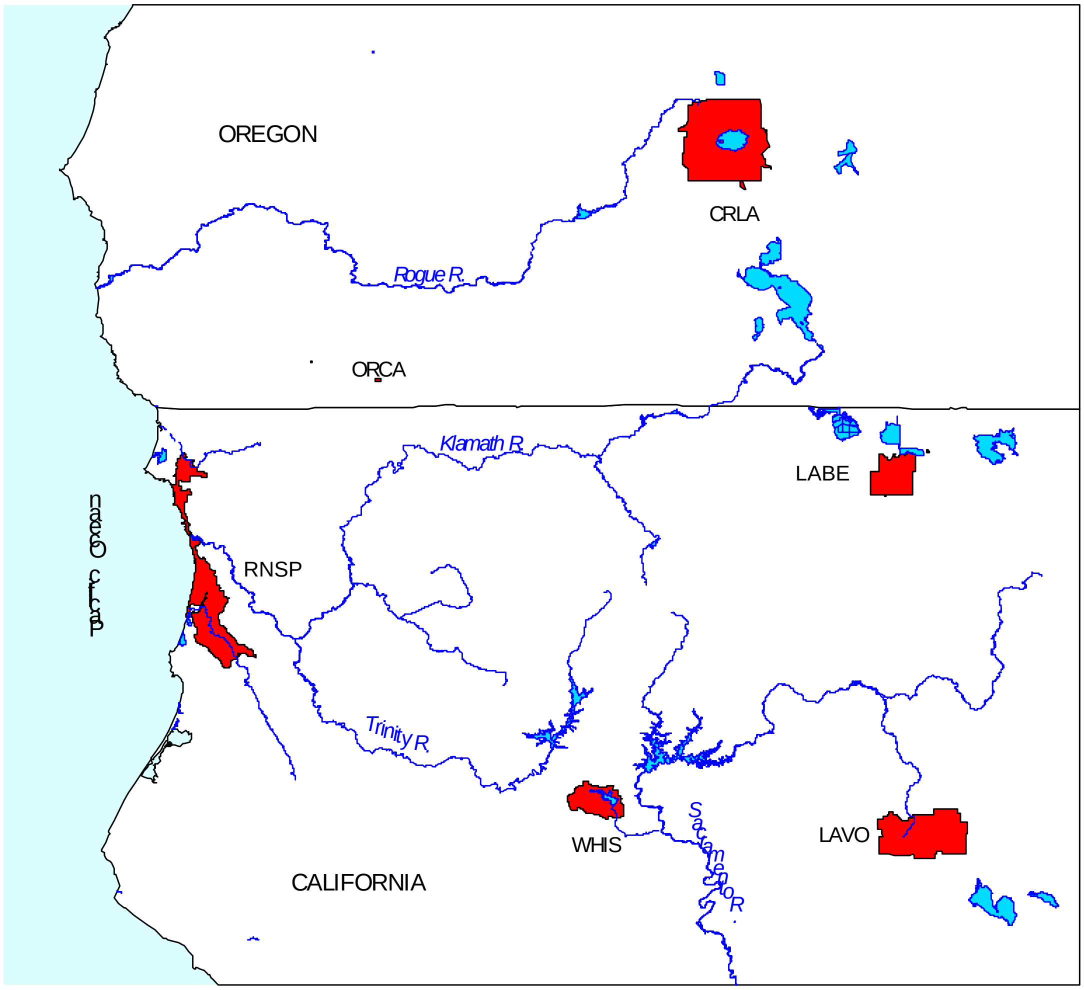


FIGURE 2: Klamath Network park units: Crater Lake National Park (CRLA), Lassen Volcanic National Park (LAVO), (Lava Beds National Monument (LABE), Oregon Caves National Monument (ORCA), Redwood National and State Parks (RNSP), and Whiskeytown National Recreation Area (WHIS). LAVO, LABE, and ORCA are the park units that have been selected for the current baseline inventory.

SECTION 1: OVERVIEW OF KLAMATH NETWORK AQUATIC RESOURCES

The Klamath Network park units (Figure 2) occur in a rugged region of exceptional and complex climate, topography, and geology; and the aquatic resources within the network are very diverse. Crater Lake National Park (Crater Lake) is responsible for managing the clearest and seventh deepest (592 m, 1942 ft) caldera lake in the world. In addition, Crater Lake contains deep lake thermal areas, small ponds outside of the Mt. Mazama caldera, numerous streams and springs, and several important wetland areas. Lassen Volcanic National Park (Lassen) includes the largest concentration of freshwater lentic systems in the network, with over 250 ponds and lakes (many of which have never been inventoried), as well as several major stream drainages, geothermal areas, and sphagnum bogs along lake margins. Lava Beds National Monument (Lava Beds) has limited surface water, although Tule Lake and the Tule Lake Wildlife Refuge are present near the northern border of the Monument. Lava Beds does, however, have approximately 28 known ice caves that are an important source of water for wildlife and, historically, for humans. Oregon Caves National Monument (Oregon Caves) is a small unit with only one stream, Cave Creek. The creek flows through the main cave and wet meadows, and seeps are present in the upper canyon of the creek. Parts of Cave Creek are directly affected by visitors touring the cave. Redwood National and State Parks (Redwoods) have marine and freshwater aquatic resources. Marine resources include over 60 km (36 mi) of coastal marine habitat extending 0.4 km (0.25 mi) offshore and coastal estuaries and lagoons. Freshwater resources include Redwood and Mill Creeks and their watersheds, and slope fens and seeps. Whiskeytown National Recreation Area (Whiskeytown) contains a large reservoir (Whiskeytown Lake) created by the damming of Clear Creek, as well as many perennial and intermittent tributary streams. Historically, mining was a common enterprise within WHIS and as a result acid mine drainage and mercury contamination are of major concern. WHIS also contains the only known global population of Howell's alkali grass (*Puccinellia howellii*) which is restricted to a mesosaline fen in the park.

National Park Service Water Resources Division Baseline Water Quality Inventory

The baseline water quality inventory is part of a National Park Service Water Resources Division program to develop baseline water-quality information for key resources in National Park Service units throughout the United States. A Klamath Network baseline inventory is in progress (i.e., 2005) at Lava Beds, Lassen, and Oregon Caves. The inventory is being conducted by personnel from the USGS Western Ecological Research Center located in Arcata, California. The following parameters have been measured for all water bodies selected for the inventory during the first of two sampling seasons scheduled to begin in 2005: alkalinity, dissolved oxygen, pH, specific conductance, temperature and discharge (where applicable). Additional parameters measured for select water bodies include fecal and total coliform, chloride, fluoride, nitrate and sulfate.

Outstanding Natural Resource Waters

There are no designated Outstanding Natural Resource Waters (ONRW) within the Klamath Network. Crater Lake National Park and network staff are, however, in the process of obtaining ONRW designation for Crater Lake from the Oregon Department of Environmental Quality.

The North Coast Regional Water Quality Control Board has identified Redwoods as a State Water Quality Protection Area as designated by the California State Water Board. Also, there are several Redwoods marine areas designated as Areas of Special Biological Significance by the State of California. The coast off Redwoods is part of a California Marine Sanctuary, and Redwoods has a California State Lands Commission Submerged Lands Lease to conduct resource management activities.

Wild and Scenic Rivers in the Klamath Network Region

(All of the information contained in this subsection is from the National Wild and Scenic Rivers website: http://www.nps.gov/rivers/wildriverslist.html.

1. Eel River:

    A. **Designated Reach:** January 19, 1981. From the mouth of the river to 100 yards below Van Ardsdale Dam. The Middle Fork from its confluence with the main stem to the southern boundary of the Yolla Bolly Wilderness Area. The South Fork from its confluence with the main stem to the Section Four Creek confluence. The North Fork from its confluence with the main stem to Old Gilman Ranch. The Van Duzen River from the confluence with the Eel River to Dinsmure Bridge.
    B. **Classification/Mileage:** Wild – 156 km (97 mi); Scenic – 45 km (28 mi); Recreational – 440 km (273 mi); Total – 642 km (398 mi).
    C. **Managing Agencies**: California Resources Agency, Bureau of Land Management; Six Rivers National Forest; Mendocino National Forest; Round Valley Reservation.

2. Klamath River:

    A. **Designated Reach:** January 19, 1981. From the mouth to 1,097 m (3,600 ft) below Iron Gate Dam. The Salmon River from its confluence with the Klamath to the confluence of the North and South Forks of the Salmon River. The North Fork of the Salmon River from the Salmon River confluence to the southern boundary of the Marble Mountain Wilderness Area. The South Fork of the Salmon River from the Salmon River confluence to the Cecilville Bridge. The Scott River from its confluence with the Klamath to its confluence with Schackleford Creek. All of Wooley Creek.
    B. **Classification/Mileage:** Wild – 19 km (12 mi); Scenic – 39 km (24 mi); Recreational – 403 km (250 mi); Total – 461 km (286 mi).
    C. **Managing Agencies**: California Resources Agency; Yurok Tribe; Hoopa Valley Indian Reservation; Klamath National Forest; Bureau of Land Management.

3. Smith River:

    A. **Designated Reach:** January 19, 1981 and November 16, 1990. The segment from the confluence of the Middle Fork Smith River and the North Fork Smith River to its mouth at the Pacific Ocean. The Middle Fork from its the headwaters to its confluence with the North Fork Smith River, including Myrtle Creek, Shelly Creek, Kelly Creek, Packsaddle Creek, the East Fork of Patrick Creek, the West Fork Patrick Creek, Little Jones Creek, Griffin Creek, Knopki Creek, Monkey Creek, Patrick Creek, and Hardscrabble Creek. The Siskiyou from its headwaters to its confluence with the Middle Fork, including the South Siskyou Fork of the Smith River. The South Fork from its headwaters to its confluence with the main stem, including Williams Creek, Eightmile Creek, Harrington Creek, Prescott Fork, Quartz Creek, Jones Creek, Hurdygurdy Creek, Gordon Creek, Coon Creek, Craigs Creek, Goose Creek, the East Fork of Goose Creek, Buch Creek, Muzzleloader Creek, Canthook Creek, Rock Creek, and Blackhawk Creek. The North Fork from the California-Oregon border to its confluence with the Middle Fork of the Smith River, including Diamond Creek, Bear Creek, Still Creek, the North Fork of Diamond Creek, High Plateau Creek, Stony Creek, and Peridotite Creek.

B. **Classification/Mileage:** Wild – 126 km (78 mi); Scenic – 50 km (31 mi); Recreational – 348 km (216 mi); Total – 524 km (325 mi).

C. **Managing Agencies**: California Resources Agency; Smith River National Recreation Area

4. Trinity River:

   A. **Designated Reach:** January 19, 1981. From the confluence with the Klamath River to 91 m (300 ft) below Lewiston Dam. The North Fork from the Trinity River confluence to the southern boundary of the Salmon-Trinity Primitive Area. The South Fork from the Trinity River confluence to the California State Highway 36 bridge crossing. The New River from the Trinity River confluence to the Salmon-Trinity Primitive Area.

   B. **Classification/Mileage:** Wild – 71 km (44 mi); Scenic – 63 km (39 mi); Recreational – 194 km (120 mi); Total – 327 km (203 mi).

   C. **Managing Agencies**: California Resources Agency; Hoopa Valley Indian Reservation; Yurok Tribe; Shasta-Trinity National Forest; Six Rivers National Forest; Bureau of Land management

Clean Water Act Section 303(d) Impaired Waters

Table 1 lists the 303(d) impaired waters within the Klamath Network. Redwood Creek and the Klamath River in Redwoods are listed due to impacts associated with upstream land use practices; in particular, road building, reduced land cover as a result of logging, and dams. In Whiskeytown, Willow Creek (associated with past mining activities) and designated swim beaches of Whiskeytown Lake are listed as 303(d) impaired waters. Whiskeytown Staff are in the process of having the swim beaches delisted. A full discussion of the CWA Section 303(d) listing and Total Maximum Daily Load (TMDL) program process can be found at the following EPA web site: http://www.epa.gov/owow/tmdl/ .

TABLE 1: KLAMATH NETWORK 303(d) LISTED IMPAIRED WATER BODIES.

303(d) Impaired Water	Pollutant/Stressor	TMDL Priority*
Klamath River (RNSP)	Temperature	High
	Nutrients	High
Redwood Creek (RNSP)	Temperature	Low
	Sedimentation/Siltation	Medium
Willow Creek (WHIS)	Metals	Low
Swim Beaches (WHIS)	Bacteria	Low

* See the EPA web site: http://www.epa.gov/owow/tmdl/ for a description of the TMDL (Total Maximum Daily Loads) process.

Aquatic Species of Special Concern

In 2002, the Klamath Network began an inventory of vascular plants and vertebrate species of special concern in network park units (Acker *et al.* 2001). Aquatic vertebrate species of concern at the network-level include nine amphibian, five reptile, and four fish species. The study plan for this inventory is available at: http://www1.nature.nps.gov/im/units/klmn/inventories/download_files/inventory_study_plan.doc.

SECTION 2: LOCATIONS OF ACTIVE MONITORING STATIONS IN THE KLAMATH NETWORK REGION

Tables 2-7 list the locations of geo-referenced climatic and hydrologic monitoring stations in or near Klamath Network park units. In addition to these monitoring stations, past water quality sampling sites in or near Lassen, Lava Beds, Oregon Caves and Whiskeytown are listed in a Horizon Report for each park unit (i.e., LAVO = NPS-WRD 1999a, pages 51-54; LABE = NPS-WRD 1999b, page 39; ORCA = NPS-WRD 1998, page 45; WHIS = NPS-WRD 2000, pages 45-47). Horizon Reports have not been completed for Crater Lake and Redwoods. The Horizon Reports are baseline water quality data inventories that detail historical water quality sampling and monitoring efforts in network park units. These reports have been developed by the National Park Service Water Resources Division and Service-wide Inventory and Monitoring Program. The network will emphasize verifying and geo-referencing additional locations and will link spatial files with corresponding tabular records in the NPS database for cataloging datasets and related metadata.

TABLE 2: DAILY PRECIPITATION MONITORING STATIONS AS OF 2005 IN THE NPS KLAMATH NETWORK REGION

Site	Latitude	Longitude	State
CRLA Headquarters	42.90000	-122.13333	OR
Crescent City	41.73333	-124.20000	CA
Crescent City 1N	41.76666	-124.06666	CA
Crescent City 1N	41.76666	-124.20000	CA
Crescent City 7ENE	41.78333	-124.08333	CA
Crescent City 7ENE	41.80000	-124.08333	CA
Crescent City 7ENE	41.80000	-124.23333	CA
Fort Dick	41.88333	-124.13333	CA
Fort Dick	41.88333	-124.15000	CA
Fort Dick	41.86666	-124.13333	CA
French Gulch	40.70000	-122.66666	CA
Klamath	41.51666	-124.03333	CA
LABE	41.73333	-121.51666	CA
Manzanita Lake-LAVO	40.53333	-121.56666	CA
Mineral	40.35000	-121.60000	CA
Mineral	40.35000	-121.58333	CA
Ono	40.48333	-122.61666	CA
Orick Prairie Creek Park	41.33333	-124.01666	CA
Orick Prairie Creek Park	41.36666	-124.01666	CA
Redding	40.58333	-122.40000	CA
Shasta Dam	40.71666	-122.46666	CA
Shingletown 2 E	40.50000	-121.26666	CA
Volta Power Station	40.46666	-121.56666	CA
Whiskeytown Reservoir	40.61666	-122.53333	CA
Williams 1 N	42.20000	-123.28333	OR

TABLE 3: HOURLY PRECIPITATION MONITORING STATIONS AS OF 2005 IN THE NPS KLAMATH NETWORK REGION

Site	Latitude	Longitude	State
Brandy Creek	40.61666	-122.70000	CA
CRLA Headquarters	42.90000	-122.13333	OR
Crescent City MNTC Station	41.75000	-124.20000	CA
Klamath	41.51666	-124.03333	CA
Mineral	40.35000	-121.60000	CA
Mineral	40.35000	-121.58333	CA
Sawyers Bar Ranger Station	41.30000	-123.98333	CA
Shasta Dam	40.50000	-121.26666	CA
Volta Power Station	40.46666	-121.56666	CA
Williams 1 N	42.20000	-123.28333	OR

TABLE 4: EVAPORATION MONITORING STATIONS AS OF 2005 IN THE NPS KLAMATH NETWORK REGION

Site	Latitude	Longitude	State
Brandy Creek	40.61666	-122.70000	CA
Crescent City MNTC Station	41.75000	-124.20000	CA
Klamath	41.51666	-124.03333	CA
Mineral	40.35000	-121.60000	CA
Mineral	40.35000	-121.58333	CA
Sawyers Bar Ranger Station	41.30000	-123.98333	CA
Shasta Dam	40.71666	-122.46666	CA
Volta Power Station	40.46666	-121.56666	CA
Whiskeytown Reservoir	40.61666	-122.53333	CA

TABLE 5: AIR TEMPERATURE MONITORING STATIONS AS OF 2005 IN THE NPS KLAMATH NETWORK REGION

Site	Latitude	Longitude	State
CRLA Headquarters	42.90000	-122.13333	OR
Crescent City	41.73333	-124.20000	CA
Crescent City 1N	41.76666	-124.06666	CA
Crescent City 1N	41.76666	-124.20000	CA
Klamath	41.51666	-124.03333	CA
LABE	41.73333	-121.51666	CA
Manzanita Lake-LAVO	40.53333	-121.56666	CA
Mineral	40.35000	-121.60000	CA
Mineral	40.35000	-121.58333	CA
Orick Prairie Creek Park	41.33333	-124.01666	CA
Orick Prairie Creek Park	41.36666	-124.01666	CA
Redding	40.58333	-122.40000	CA
Shasta Dam	40.71666	-122.46666	CA
Whiskeytown Reservoir	40.61666	-122.53333	CA

TABLE 6: DRINKING WATER INTAKES AS OF 2005 IN THE NPS KLAMATH NETWORK REGION

Site	Latitude	Longitude	Agency	State
Cave Junction-Illinois river	42.16111	-123.65000	City of Cave Junction	OR
Cave Junction Treatment Plant	42.15000	-123.63330	City of Cave junction	OR
Shasta Treatment Plant	40.58333	-122.48330	Shasta Comm Ser Dist	CA
Whiskeytown Reservoir	40.59917	-122.53830	Clear Creek Comm Ser Dist	CA
Whiskeytown Reservoir	40.59333	-122.46610	Shasta Comm Ser Dist	CA

TABLE 7: STREAM GAGING STATIONS AS OF 2005 IN THE KLAMATH NETWORK REGION

Site	Latitude	Longitude	Agency	State
Althouse Creek	42.08055	-123.51388	USGS	OR
Althouse Creek near Holland	42.10000	-123.52500	USGS	OR
Benner Creek	40.38388	-121.27333	USGS	CA
Butte Creek	40.64972	-121.27972	USGS	CA
Clear Creek at French Gulch	40.69500	-122.63555	USGS	CA
Clear Creek near Igo	40.51333	-122.52305	USGS	CA
Clear Creek near Shasta	40.62917	-122.56111	USGS	CA
East Fork Illinois River near Takilma	42.00278	-123.62500	USGS	OR
Elk Creek near Obrien	42.03166	-123.73666	BLM	OR
Elk Creek near Obrien	42.03167	-123.73666	USGS	OR
Illinois River at Kirby	42.19722	-123.65555	USGS	OR
Judge Francis Carr Powerhouse	40.64694	-122.62611	USGS	CA
Manzanita Creek-LAVO	40.53556	-121.57666	USGS	CA
Mill Creek near Mineral	40.35917	-121.50277	USGS	CA
South Fork Bailey Creek	40.47918	-121.59610	USGS	CA
Sucker Creek/Grayback Creek	42.15972	-123.47777	USGS	OR
Sucker Creek near Holland	42.15000	-123.46666	USGS	OR
Summit Creek near Mineral	40.36972	-121.53971	USGS	CA
West Fork Illinois River/Rock Creek	42.03888	-123.74722	USGS	OR
West Fork Illinois River near Obrien	42.06388	-123.71666	USGS	OR
West Fork Illinois River	42.05972	-123.72916	USGS	OR
Whiskeytown Lake	40.61750	-122.52527	USBR	CA
Whiskeytown Lake	40.61750	-122.52527	USGS	CA
Whiskeytown Lake	40.61666	-122.53333	USBR	CA
Windy Creek near Holland	42.13055	-123.36250	USGS	OR

SECTION 3: PAST INVENTORY, MONITORING, AND RESEARCH ACTIVITIES IN THE KLAMATH NETWORK PARK UNITS

In this section, past and ongoing water resources inventory, monitoring and research activities in each park unit are summarized based on information gathered from available project and study reports. A Horizon Report (or Technical Report of Baseline Water Quality Information and Analysis compiled by the National Park Service's Water Resources Division) has also been completed for four network park units (LAVO, LABE, ORCA, and WHIS). Each report contains information from several sources, including: (1) Storage and Retrieval (STORET) water quality database management system; (2) River Reach File (RF3); (3) Industrial Facilities Discharge (IFD); (4) Drinking Water Supplies (DRINKS); (5) Water Gages (GAGES); and (6) Water Impoundments (DAMS). Each report provides: (1) a complete inventory of all retrieved water quality stations and parameter data, and the entities responsible for data collection; (2) descriptive statistics and appropriate graphical plots of water quality data characterizing period of record, annual, and seasonal central tendencies and trends; (3) a comparison of the park's water quality data to relevant EPA and WRD water quality screening criteria; and (4) an Inventory Data Evaluation and Analysis (IDEA) to determine what Service-wide Inventory and Monitoring Program "Level I" water quality parameters have been measured within each study area. Core freshwater parameters include water temperature, specific conductance, pH, dissolved oxygen, qualitative assessment of flow/discharge at lotic sites, and qualitative assessment of stage/level at lentic sites. Marine/estuarine ecosystem core parameters include water temperature, dissolved oxygen, pH, conductivity, and salinity. Horizon Reports can be downloaded from the National Park Service's Water Resource Division web site at: (http://www.nature.nps.gov/water/horizon.htm).

Klamath Network park units have completed, at minimum, partial inventories of park unit-specific aquatic resources and short-term water quality sampling and monitoring of these resources. The descriptions of past inventory, monitoring, and research activities in each park unit also highlight future network-wide inventory, monitoring, and research needs. It is clear that not all aquatic resources in each park unit have been fully inventoried nor have present baseline water quality conditions been fully determined. These baseline conditions include documentation of the physical, chemical and biological characteristics of each water resource-type. Once these present baseline conditions are determined, appropriate resource sampling designs can then be used to more effectively monitor for potential resource-specific changes. The need for consistent freshwater inventory and monitoring techniques across park units has been identified as an important part of any network-wide program. Consistent sampling design and sample collection will facilitate the comparison and interpretation of water quality monitoring results among park units. Additional important future inventory and monitoring activities include: (1) development of a general monitoring program for Redwoods marine ecosystems; (2) inventories of wetland biota; (3) salmonid fisheries monitoring; (4) amphibian monitoring; and (5) benthic macroinvertebrate studies.

CRATER LAKE NATIONAL PARK (CRLA)

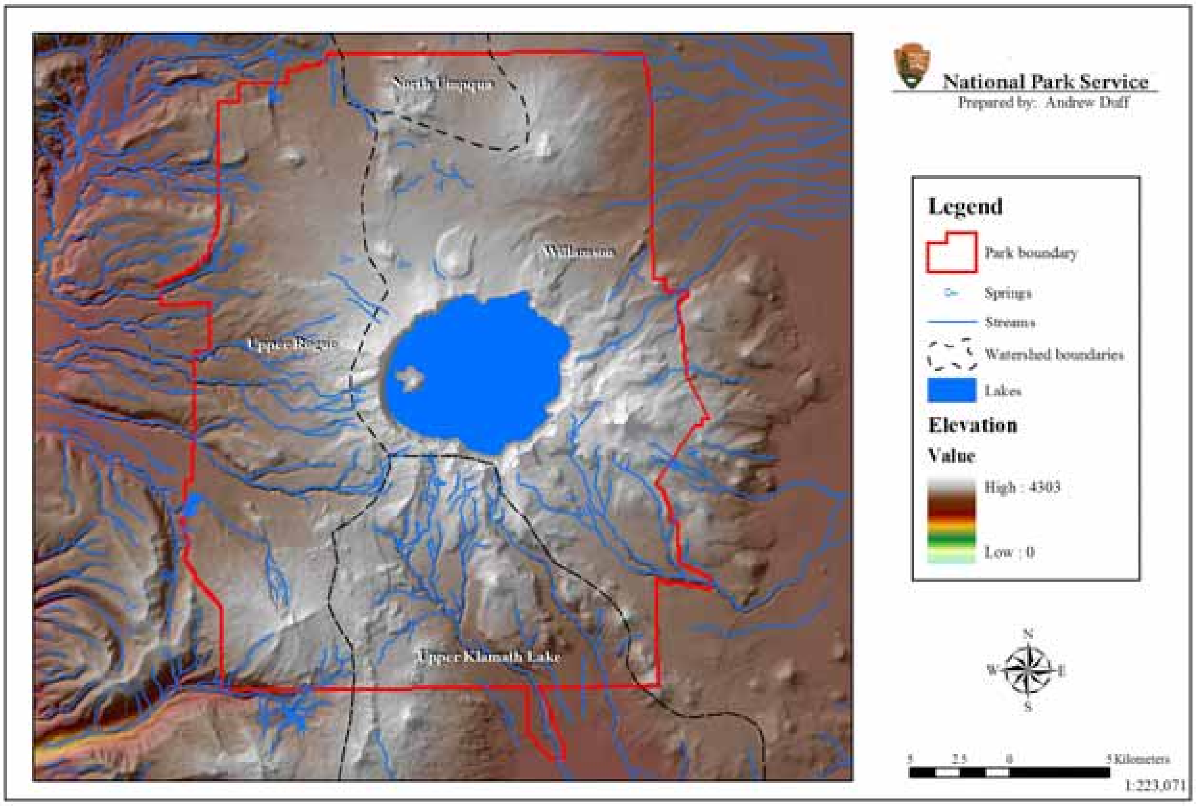


FIGURE 3: AQUATIC RESOURCES AND WATERSHED BOUNDARIES OF CRATER LAKE NATIONAL PARK, OREGON, NPS KLAMATH NETWORK

General Summary of Past Activities: *Crater Lake National Park has focused primarily on monitoring the water quality of Crater Lake. A long-term lake monitoring program has been active since 1983. Less comprehensive water quality inventories have been completed for ponds/lakes and streams located outside of the Mt. Mazama caldera. A Sun Creek bull trout restoration project and a survey of amphibians in the Whitehorse Ponds have also been initiated and/or completed*.

Crater Lake National Park (Figure 3) was established by Presidential Proclamation on May 22, 1902. The 74,140 ha (182,304 ac) park is located at the southern end of the Cascade Mountains in south-central Oregon. The park is dominated by a large natural caldera lake formed after the eruption of Mt. Mazama, approximately 7700 years ago (Ramsey et al. 2003; accessed June 6, 2005 at http://geopubs.wr.usgs.gov/i-map/i2790/i2790.pdf). The lake that is now in existence usually fluctuates seasonally between 1881 and 1882 m (573 – 574 ft) in surface elevation. However, fluctuations of up to five meters have been recorded (Redmond 1990). Crater Lake is the clearest and seventh deepest lake (592 m, 1942 ft) in the world, and has a strikingly deep blue color. Secchi disk clarity readings have been recorded as deep as 40 m (131 ft).

The water quality of Crater Lake and other freshwater resources in Crater Lake National Park has been an important management focus for over 100 years. Water quality monitoring of Crater Lake began in 1892 when Diller and Patton initiated the recording of Crater Lake water level (Larson 1987). Numerous inventory, monitoring, and research projects and programs have been completed or are being conducted within the caldera and focused on Crater Lake, or at sites located outside of the caldera.

Intra-Caldera Monitoring and Research

Monitoring and research activities from 1892-1984 that were designed to document the physical, chemical, and biological characteristics of Crater Lake are listed in Table 8. Most of these activities were of short duration and limited in scope (Larson 1987). A long-term Crater Lake water quality monitoring program, that is now 22 years old, was initiated in June 1983. Sampling has been most often conducted during July, August, and September, however, sampling also has been conducted in January, March, April, May, June, and October. Samples for the determination of lake water quality have been collected at predetermined depths from 0–550 m, and from intra-caldera springs (Larson 1987, 1990, 1996). Initially, up to 41 springs were sampled, but this number was reduced to five springs beginning in 1990. Water quality variables monitored as part of the long-term monitoring program (1983-present) are listed in Table 9. Introduced rainbow trout (*Oncorhynchus mykiss*) and kokanee salmon (*Oncorhynchus nerka*) have also been studied as part of the monitoring program. Detailed information concerning the long-term water quality monitoring program is available in Larson 1987, 1990, and 1996.

TABLE 8: HIGHLIGHTS OF CRATER LAKE MONITORING AND RESEARCH ACTIVITIES, 1892-1984 (FROM LARSON 1987)

Date	Activities
1892	Water level records initiated
1896	First scientific expedition (temperature and transparency)
1912	First chemical analysis (one sample from a depth of 2 m)
1913	Temperature, dissolved oxygen, Secchi disk, phytoplankton and zooplankton
1935	Optical properties (color)
1934-1936	Temperature, light transmission, and general floral and faunal surveys
1937-1940	Temperature, Secchi disk, and fish investigations
1938-1939	Secchi disk
1940	Temperature, dissolved oxygen, carbon dioxide, light transmission, nutrients and phytoplankton
1947/1950	Diatoms
1954	Secchi disk
1959	Morphometry
1960	Sediments evaluated
1961-1964	Stage height and temperature recorders installed, chemical analysis
1966	Temperature and general observations of surface current patterns
1967-1969	Distribution patterns and population dynamics of zooplankton, physical and chemical limnological characteristics, primary production and chlorophyll-a
1978-1981	General limnological characteristics with emphasis on phytoplankton distribution and abundance
1982-1984	Baseline monitoring program underway (physical, chemical, phytoplankton, with chemical and bacterial studies of caldera wall springs; hydrothermal springs located on lake bottom; sedimentation studies initiated

TABLE 9: CRATER LAKE AND INTRACALDERA SPRINGS WATER QUALITY VARIABLES MONITORED AS PART OF THE CRATER LAKE LONG-TERM MONITORING PROGRAM (1983-PRESENT)

Variable	Location
Temperature	Lake and Spring
Lake level	Lake
Secchi disk depth	Lake
Light transmission and penetration	Lake
pH	Lake and Spring
Alkalinity	Lake and Spring
Specific conductance	Lake and Spring
Dissolved oxygen	Lake
Total phosphorus	Lake and Spring
Orthophosphate	Lake and Spring
Nitrate-nitrogen	Lake and Spring
Total Kjeldahl nitrogen	Lake and Spring
Ammonia-nitrogen	Lake and Spring
Sulfate	Lake and Spring
Silica	Lake and Spring
Chloride	Lake and Spring
Sodium	Lake and Spring
Calcium	Lake and Spring
Magnesium	Lake and Spring
Potassium	Lake and Spring
Sulfur	Lake and Spring
Iron	Lake and Spring
Bacterial studies	Lake
Chlorophyll-a	Lake
Primary production (C^{14} light/dark bottles)	Lake
Phytoplankton (species, density, biomass)	Lake
Zooplankton (species, density, biomass)	Lake
Fish (species, abundance, biomass, spatial distribution, age, sex, growth, and food habits)	Lake
Hydrothermal processes studies	Lake

Extra-Caldera Monitoring and Research

The first observations documenting aquatic resources outside of the Crater Lake caldera were published in 1929 and 1935 in the park's Crater Lake Nature Notes publication. These articles identified and described, respectively, several mineral springs in the Annie Creek Canyon and six waterfalls that occurred at several locations in the park. Numerous articles in Crater Lake Nature Notes, survey reports, and articles published in peer-reviewed scientific journals have, since the publication of those two early articles, documented the diverse types of aquatic resources present in the park. The first survey of park streams was completed in 1947 (Wallis 1948). This survey, focused primarily on trout distribution, included 41 stations on 19 streams where water temperature, average station width and depth, and velocity were measured and stream habitat was described. A more extensive survey of park streams and springs was conducted in 1967-1968 (Frank and Harris 1969). These surveys recorded 106 flow measurements for 46 streams and 21 springs, and collected 45 water samples from a subsample of 17 streams and 21 springs. Eight samples were analyzed for a complete suite of water quality variables, and 37 samples were analyzed for a subset of variables. In 1981–1985, approximately 10 springs were sampled for water chemistry analysis (Thompson *et al*. 1987). The Whitehorse Ponds, a complex of 15 ponds located on Whitehorse Bluff, were inventoried and sampled in 1992 and 1993 to document their physical, chemical, and biological characteristics (Salinas *et al*. 1994). Additional activities have included: (1) incidental observations and projects designed to survey and investigate the distributions and life history characteristics of amphibian species in Crater Lake and at freshwater sites outside of the caldera (e.g., Farner 1947, Farner and Kezer 1953, Kezer and Farner 1955, Bergmann 1997); and (2) a project to eradicate brook trout (*Salvelinus fontinalis*) from and restore native bull trout (*Salvelinus confluentus*) in Sun Creek. The bull trout restoration project was initiated in 1992 in response to the precipitous decline within the park of this genetically distinct Pacific Northwest population due to encroachment of introduced nonnative brook trout. Fish surveys of all Klamath River basin tributaries within the park have also been conducted.

Horizon Report

No report is presently available.

Resource Management Water Quality Concern

1) Long-term clarity of Crater Lake and health of the lake ecosystem

See Attachment I for CRLA water quality, fisheries and streams inventory, monitoring, and research study references.

LASSEN VOLCANIC NATIONAL PARK (LAVO)

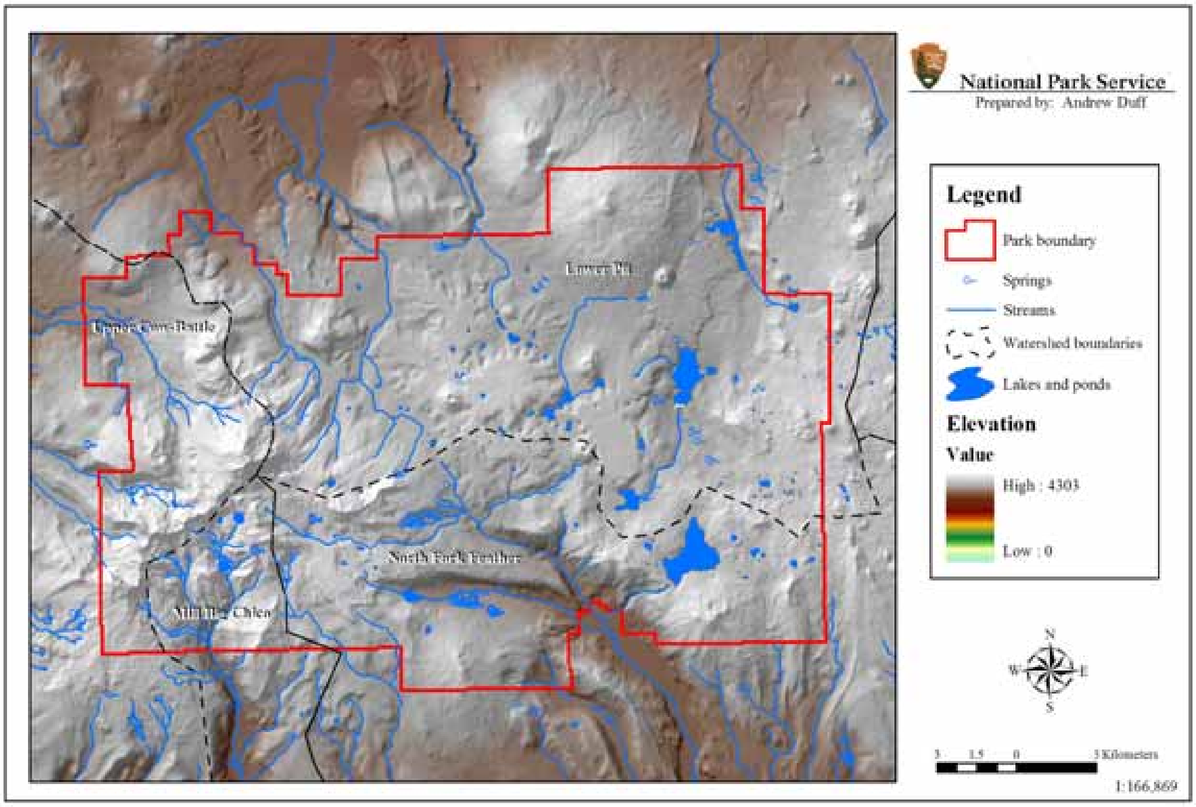


FIGURE 4: AQUATIC RESOURCES AND WATERSHED BOUNDARIES OF LASSEN VOLCANIC NATIONAL PARK, CALIFORNIA, NPS KLAMATH NETWORK

General Summary of Past Activities: *Surveys of Lassen Volcanic National Park ponds/lakes, wetlands and streams have focused primarily on documenting baseline ecological condition and developing management and research alternatives for these resources. The status of aquatic invertebrates, native amphibians and nonnative fish in Lassen lentic habitats has also been documented. Hydrothermal/geothermal resources have been continuously monitored since 1981, focusing on water quality characteristics, potential impacts of these resources on visitors, and potential visitor impacts on the resources.*

Lassen Peak and Cinder Cone National Monuments were established on March 6, 1907, and combined into Lassen Volcanic National Park (Figure 4) on August 9, 1916. The park is located in the southern most part of the Cascade Mountains in northeastern California, and is part of the Cascade Physiographic Province. The park is 43,047 ha (106,372 ac) in size, and the landscape is dominated by volcanic processes; Lassen Peak is the southernmost volcano in the Cascade Range. The park contains up to 277 permanent and ephemeral lentic water bodies. Portions of five drainage basins are located within the park, and four of the drainage basins (about 99% of the park) drain into the Sacramento River. Many lakes have been historically stocked with nonnative trout for recreational fishing and now contain self-propagating populations. Mill Creek, which has no dams blocking anadromous fish passage, is one of very few stream courses remaining in the Sacramento River drainage with biological integrity preserved.

There are several aquatic vertebrate and invertebrate taxa within Lassen that are on the federal and/or state lists as protected species. Kings Creek caddisfly (*Parapsyche extensa*) is a federal species of concern; the Modoc sucker (*Catostomus micorps*) is listed as endangered on both lists; and the Cascades frog (*Rana cascadae*) is listed as a federal and state species of concern.

Horizon Report

The retrieval of surface water quality data from six of the US Environmental Protection Agency's (EPA) national water resources databases included data generated by four agencies (i.e., National Park Service [NPS], US Geological Survey [USGS], EPA, and California Water Resources Control Board [CWRCB]; NPS-WRD 1999a). These data represent water quality analyses for samples collected from 281 sampling stations, of which 218 (NPS = 190, USGS = 14, EPA = 7, CWRCB = 7) were within the boundaries of Lassen. Park sampling stations (NPS-WRD 1999a, pages 51-54) were located at 29 lakes, 21 cold and hot streams, 60 hydrothermal sites, and 2 wetlands. Some sites had multiple sampling stations. A total of 169 water quality parameters (NPS-WRD 1999a, pages 55-57) were examined, although not all parameters were represented at all sampling locations. The period of time represented by these data from Lassen sampling sites was 1960-1994. The Horizon Report is available at: (http://nrdata.nps.gov/LAVO/nrdata/water/baseline_wq/docs/LAVOWQAA.pdf).

Lakes, Streams, and Wetlands

The first known survey of lakes in Lassen was documented in a report titled "1955 Lake Survey – Lassen Volcanic National Park" (author unknown). Wallis (1959) conducted a fishery resources survey of 22 lakes in 1958 with the purpose of developing a stocking plan for park lakes; the focus was primarily on the distributions of fish species and past stocking activities. Several lake surveys were conducted during the 1960's and data from these surveys have been summarized in the Baseline Water Quality Data Inventory and Analysis report described previously (NPS-WRD 1999a). At least 11 lakes were surveyed during this period of time. The objectives of these surveys were to determine the general ecological conditions of the lakes and to develop management and research alternatives for the park's lentic resources. In 1976, an extensive survey of Lassen lakes was completed (West 1976). A total of 162 lentic systems were surveyed, and of these 131 were sampled. Measurements and assessments included: (1) water temperature; (2) color; (3) clarity; (4) site depth (maximum and mean); (5) site bottom and shore type; (6) watershed condition; (7) site surface area; (8) presence and location of inlets and outlets; (9) fish presence; (10) presence of fish predators; and (11) relative abundance of aquatic invertebrates and vegetation. Additional lake survey activities included the physical and chemical analysis of seven Lassen lakes as part of the EPA's Western Lake Survey (Landers *et al*. 1987, Eilers *et al*. 1987); inventories of aquatic invertebrates (DeMartini, 1994); and amphibian surveys of 378 lentic sites as part of the Amphibian Research and Monitoring Initiative (Fellers *et al*. 2003). Stead *et al*. (2005), during the summer of 2004, also investigated the status of native amphibians and nonnative fish in Lassen lentic habitats (i.e., lakes, permanent and temporary ponds, wet meadows, and marsh/bogs; n=365). A new baseline water quality inventory of Lassen aquatic resources will begin in 2005, conducted by personnel of the USGS Western Ecological Research Center in Arcata, California.

Stream (cold and hot) and wetland survey data are available as part of the Baseline Water Quality Data Inventory and Analysis Report (NPS-WRD 1999a). Three reports document stream survey activities from 1963-1979 (Everest 1964, McClelland 1973, Thompson 1983), and three agencies (i.e., NPS, USGS, and CWRCB) have been responsible for collecting stream survey data from 1979-present. Two wetlands (Corral Meadows and Grassy Swale) were surveyed as part of the Lassen Park Summer 1979 Lake Surveys, and research has been conducted on the Drakesbad fen from 2002-2004 (Patterson and Cooper, in prep). Faculty members of the Department of Civil Engineering and Applied Mechanics, San Jose State University, conducted a sanitary survey of five park watersheds supplying water to campgrounds and park communities. The survey was completed in 1996, and provided data concerning types and sources of potential water source contamination to assist Lassen in complying with the USEPA Surface Water Treatment Rule established in 1989 (Williamson *et al*. 1997).

Hydrothermal/Geothermal Resources

Geothermal/hydrothermal resources in Lassen are situated primarily in the southwestern (e.g., Sulfur Works, Bumpass Hell, Little Hot Springs Valley) and southern (e.g., Devil's Kitchen, Drakesbad, Terminal Geyser) parts of the park (Thompson 1983). Waring (1915) reported the results of the first thermal water analyses of Lassen hot springs. Ten years later, Day and Allen (1925) reported the results of the chemical analyses of water from 23 Lassen hot springs. Since these early analyses, at least five surveys of hydrothermal resources have been conducted from 1963 to1981 (e.g., Lenn 1965 = 22 hot springs; Ghiorso 1980 = 34 hydrothermal sites; Thompson 1983 = 43 hydrothermal sites). Data from these surveys have been collected in the Baseline Water Quality Data Inventory and Analysis (NPS-WRD 1999a). Since 1981, the monitoring and chemical analyses of Lassen hydrothermal sites have been performed primarily by the USGS. According to USGS Fact Sheet 101-02 (Clynne *et al*. 2002), NPS personnel and USGS scientists monitor the physical and chemical characteristics of surface hydrothermal activity in the park to: (1) better understand the origin and evolution of the park's hydrothermal resources; and (2) protect park visitors from any potential hazards associated with visiting these features.

Fisheries Studies

1) Management of fishing and fish stocking in National Parks in California, 1975.
2) Management of high country lakes in the National Parks of California, 1976.
3) Snag Lake Management Report, 1976.

4) Summary of 1976 lake survey data relating to the status of trout fisheries in Lassen Volcanic National Park.
5) An analysis: Impacts of trout stocking upon recreational fishing and aquatic resources in Lassen Volcanic, Sequoia and Kings Canyon, and Yosemite National Parks, California, 1977.
6) Food Habits Analysis of Fish from Mountain Lakes in Lassen Volcanic National Park, California, 1977.
7) Aquatic resources of Lassen volcanic, Sequoia-Kings Canyon, and Yosemite National Parks, with special reference to trout stocking and the recreational fishery, 1978.
8) Status of the Manzanita Lake trout fishery, Lassen Volcanic National Park, 1998.
9) Surveys of the Sifford Lakes, Lassen Volcanic National Park, 2000.
10) FY04 Joint inventory of fishes, native amphibians, and invertebrates in all lakes and ponds of the park. Status of the trophy rainbow trout fishery at Manzanita Lake (Lassen Volcanic National Park) based on reports from angler survey boxes in 1994.

Resource Management Water Quality Concern

1) Deterioration of geothermal areas as a result of visitor impacts

See Attachment I for LAVO water quality, fisheries and lake monitoring, and research study references.

LAVA BEDS NATIONAL MONUMENT (LABE)

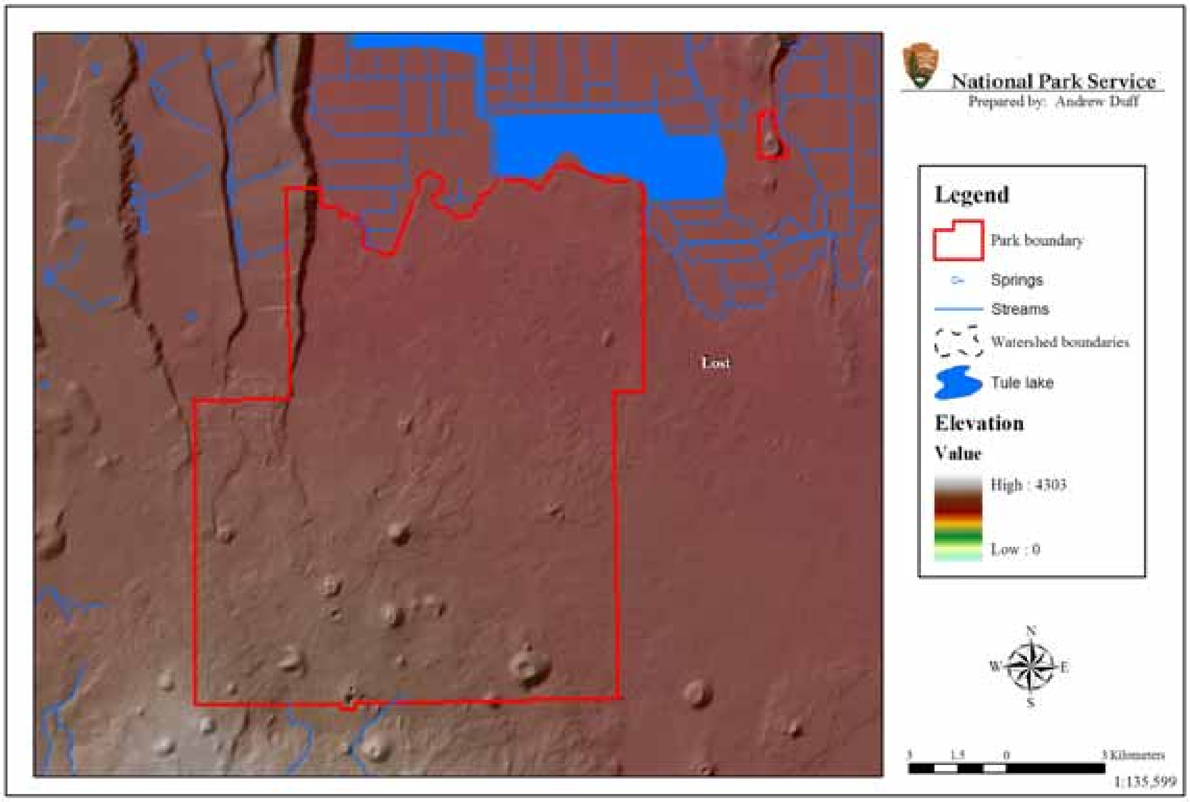


FIGURE 5: AQUATIC RESOURCES AND WATERSHED BOUNDARIES OF LAVA BEDS NATIONAL MONUMENT, CALIFORNIA, NPS KLAMATH NETWORK

General Summary of Past Activities*: Aquatic resource inventory, monitoring and research activities at Lava Beds National Monument have included surveys of ice cave baseline water quality, monitoring of ice depth, and monitoring of groundwater depth and availability. Lava Beds is also concerned about the potential effects of adjacent land use practices (e.g., agriculture and geothermal exploration and development) on park unit aquatic resources.*

Lava Beds National Monument (Figure 5) was established by Presidential Proclamation on November 21, 1925 to preserve for public enjoyment the area's dramatic volcanic geology (e.g., lava tubes, cinder cones, spatter cones, lava flows and other volcanic phenomena). Lava Beds was originally placed under the jurisdiction of the Department of Agriculture, U.S. Forest Service, and was transferred to the Department of the Interior on June 10, 1933.

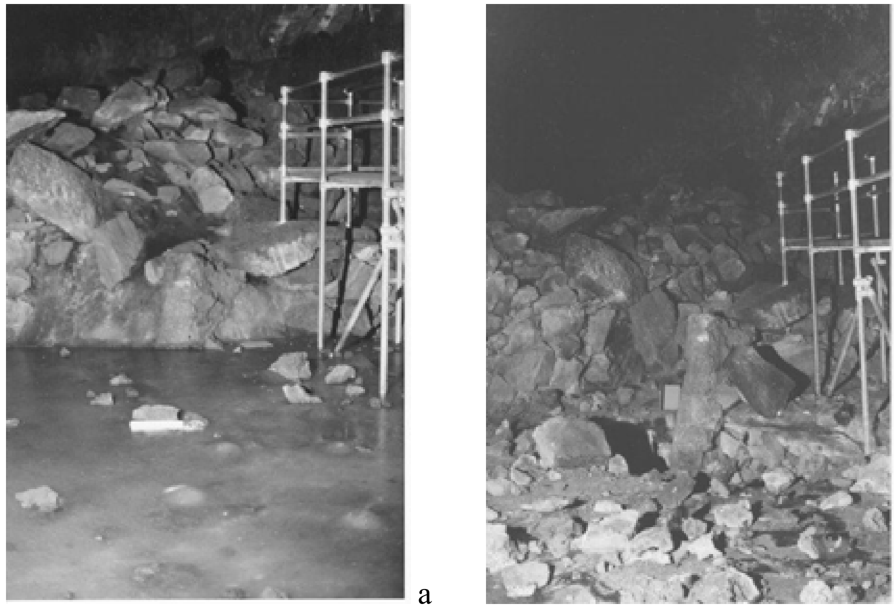
The 18,842 ha (46,560 ac) monument is located on the east-side of the Southern Cascade Mountains on the Modoc Plateau in northeastern California. The plateau is a volcanic platform generally ranging in elevation between 1219–1829 m (4,000-6,000 ft). Lava Beds lies on the northern flank of Medicine Lake Volcano. The volcano is a Pleistocene to Holocene shield volcano located about 48.3 km (30 mi) northeast of Mt. Shasta and the eruptive area of the Medicine Lake Volcano covers over 233 km^2 (900 mi^2). There is evidence of glaciation at the higher elevations of the volcano. LABE contains a range of Great Basin vegetation communities, including ponderosa pine forests, mountain mahogany/juniper, and sagebrush/bunchgrass.

Lava Beds currently has 502 documented lava tube caves with a total of 46.2 km (28.7 mi) of known passageways. Due to the porosity of lava soils, no permanent ponds, lakes, streams or wetlands are found within the monuments boundary. However, 28 caves within the monument are documented to contain ice and water, and seasonal (intermittent-ephemeral) ponds can be formed after heavy precipitation events. Many of the ice caves are important water sources for wildlife and have been historically used by humans (e.g., indigenous groups, ranchers and moonshiners). Fourteen species of bats and a number of bird species utilize the ice caves as sources of water. Two of the bat species include Townsend's big eared bat (*Corynorhinus townsendii*) which is a species of concern, and the largest northern migratory United States colony of the Mexican free-tail bat (*Tadarida brasiliensis*).

There are no distinct aquifers in the area, so there is uncertainty about the source, quantity and movement of groundwater in Lava Beds. One groundwater well, located at the monument headquarters, provides water for all staff and visitors. The U.S. Geological Survey is monitoring groundwater at five wells, four in the monument and one outside the monument boundary. There appears to be some groundwater drawdown due to agricultural land use near the monument. The National Park Service Water Resources Division also is helping to evaluate the status of groundwater at Lava Beds.

In 1999, a Student Conservation Associate conducted the first water sampling of 14 Lava Beds ice caves. Between 1990 and the present, eight ice cave floors have been monitored for changes in ice depths by the Cave Research Foundation. In 1999, the ice in Merrill Ice Cave, one of the larger ice resources in the monument, began to melt with the formation of a hole in the center of the ice floor (Figure 6). By 2001, the entire ice resource had practically disappeared. It is paramount that an ice/water quality baseline be established before possible future losses occur in other caves.

The Glass Mountain Known Geothermal Resource Area (KGRA) is located adjacent to Lava Beds to the south. The KGRA allows the Bureau of Land Management to conduct competitive lease sales for geothermal exploration. In the past there has been exploratory drilling for geothermal resources in the Medicine Lake area up to the southern boundary of the monument. Although it is unlikely that any wells will be drilled in the monument, outside activity could have an impact on Lava Beds. There could be a drawdown of the groundwater table in addition to the vibration and disturbance caused by the drilling rigs and support activities.



a b

FIGURE 6: MERRILL CAVE ICE FLOOR IN (a) 1990 AND (b) 1999, LAVA BEDS NATIONAL MONUMENT

Horizon Report

A Horizon Report (NPS-WRD 1999b) is available for Lava Beds at: (http://nrdata.nps.gov/LABE/nrdata/water/baseline wq/docs/LABEWQAA.pdf). Data were collected for 131 water quality parameters (pages 40-41 of the report) from 23 sampling stations (page 39 of the report), 1966 through 1992. The stations were outside of the park unit boundary and associated with Tule Lake. The U.S. Geological Survey and the National Park Service were responsible for the water quality sampling summarized in this report.

Ice and Water Resource Monitoring

1) Ice cave studies
2) Groundwater study
3) Water quality inventory within ice caves (KLMN-FY05, Chris Currens, USGS WERC). Beginning in 2005, water sampling at Lava Beds will occur in 12 of the 28 known ice caves. Sampling will occur in caves identified as primary ice resources for the monument. The selection of caves will also be based on ease of access, technician safety, and cave resource sensitivity
4) Ice levels in eight ice caves have been monitored since 1990 by Cave Research Foundation
5) Ice cave geomorphology
6) Effects of geothermal exploration and development

7) Assess effects of adjacent land use practices on park unit resources (agricultural use, insecticides/pesticides; accumulation within Tule Lake; Tule Lake NWR management/land use)

Resource Management Water Quality Concerns

1) Loss of ice in permanent ice caves and water in seasonal wet caves
2) Lack of data on groundwater supply and possible drawdown effects
3) Lack of basic water quality inventory of intermittent-ephemeral ponds

See Attachment I for LABE water quality inventory, monitoring, and research study references.

OREGON CAVES NATIONAL MONUMENT (ORCA)

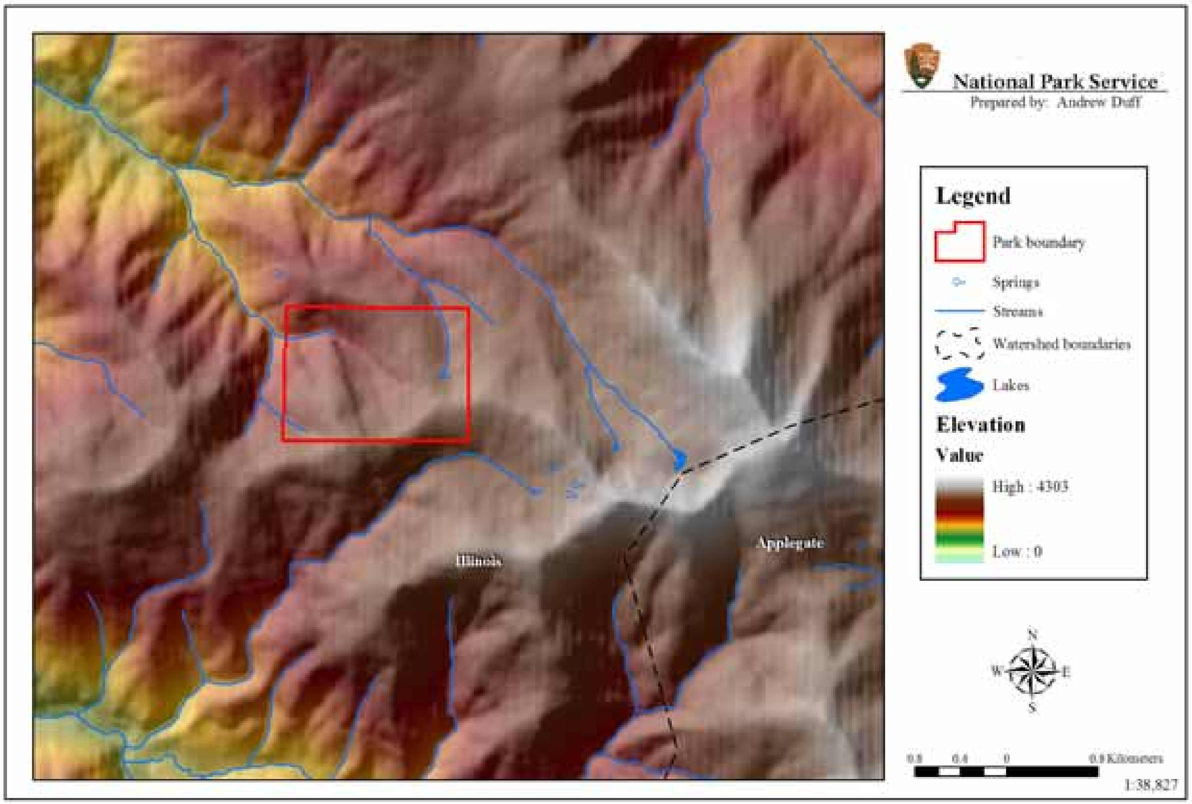


FIGURE 7: AQUATIC RESOURCES AND WATERSHED BOUNDARIES OF OREGON CAVES NATIONAL MONUMENT, OREGON, NPS KLAMATH NETWORK

General Summary of Past Activities: *Oregon Caves National Monument has focused on documenting the baseline water quality of pools, springs and streams in or near the park unit cave system. The physical characteristics and magnitude of potential direct human impacts on park unit aquatic resources also have been inventoried and continue to be monitored.*

Oregon Caves National Monument (Figure 7) was established on July 12, 1909, under the U.S. Forest Service, specifically to protect the cave system. It was transferred to the National Park Service on August 10, 1933. In February 1992, a large portion of the developed area in the monument was listed in the National Register of Historic Places. Oregon Caves (194 ha; 480 ac) is located in the Siskiyou/Klamath bioregion of southwestern Oregon. Although Oregon Caves is a small unit, its forest communities are a diverse representation of the larger bioregion. Old growth Douglas fir, white fir and oak forests cover the majority of the monument, providing diverse microhabitats for the monument's nearly 500 plant species, and an estimated 5,000 animal and 2,000 fungal species; which are among the highest catalogued biota per acre for any national park unit (John Roth, ORCA, personal communication). Federally threatened and endangered species that reside in or utilize the monument include the northern spotted owl, bald eagle, and peregrine falcon. Two of the 20 federal and state species of concern in the monument are the Del Norte Salamander (*Plethedon elongates*) and Western Toad (*Bufo boreas*). The amphibian species are, respectively, a species of concern and a sensitive species in the State of Oregon. The cave pools, springs and streams of Oregon Caves are considered important water resources for wildlife.

Horizon Report

A Horizon Report (NPS-WRD 1998) for Oregon caves is available at: (http://nrdata.nps.gov/ORCA/nrdata/water/baseline_wq/docs/ORCAWQAA.pdf). Water quality data catalogued in this report were provided by the Washington Department of Ecology, US Forest Service-Region 6, US Geological Survey, National Park Service, and US Environmental Protection Agency-Region 10. Nineteen sampling stations (page 45 of the report) were located in the park unit; 11 in the cave and 8 outside of the cave. A total of 30 water quality parameters (page 46 of the report) were measured and sampled. The period of sampling was 1966 and 1992-1993.

Cave Inventory

According to Roth (1994), the first comprehensive inventory of any large federally managed cave in the US was completed at Oregon Caves by Earthwatch Institute volunteers prior to 1994. The physical characteristics and magnitude of potential direct human impacts (as indicated by the presence of "cave slime" or *actinomycetes* bacteria) on Oregon Caves were inventoried.

Aquatic Studies

1) ORCA sample collection, 1992-1993, baseline water quality inventory of waters in or near the cave system;
2) Within-cave water quality study of Cave Creek (ongoing by John Salinas, Rogue Valley Community College)
3) Water quality inventory (KLMN-FY05, Chris Currens, USGS WERC)

Resource Management Water Quality Concerns

1) Decline in water quality due to human-caused organic enrichment, calcite solubility index, and turbidity
2) Changes in water volume and timing of cave infiltration
3) Contamination of Cave Creek (the primary water resource at ORCA), cave springs and other surface streams due to drain field pollution and pavement-derived hydrocarbon particulate input
4) Changes in the caves environment (including Cave Creek and various springs located inside the cave) due to manipulation of the primary cave's environment (i.e., modified cave opening and lighted walkway
5) Visitor use

6) Protection, preservation, restoration and interpretation of cave and karst are of primary importance to the park unit.

See Attachment I for ORCA water quality inventory, monitoring, and research study references.

REDWOOD NATIONAL AND STATE PARKS (RNSP)

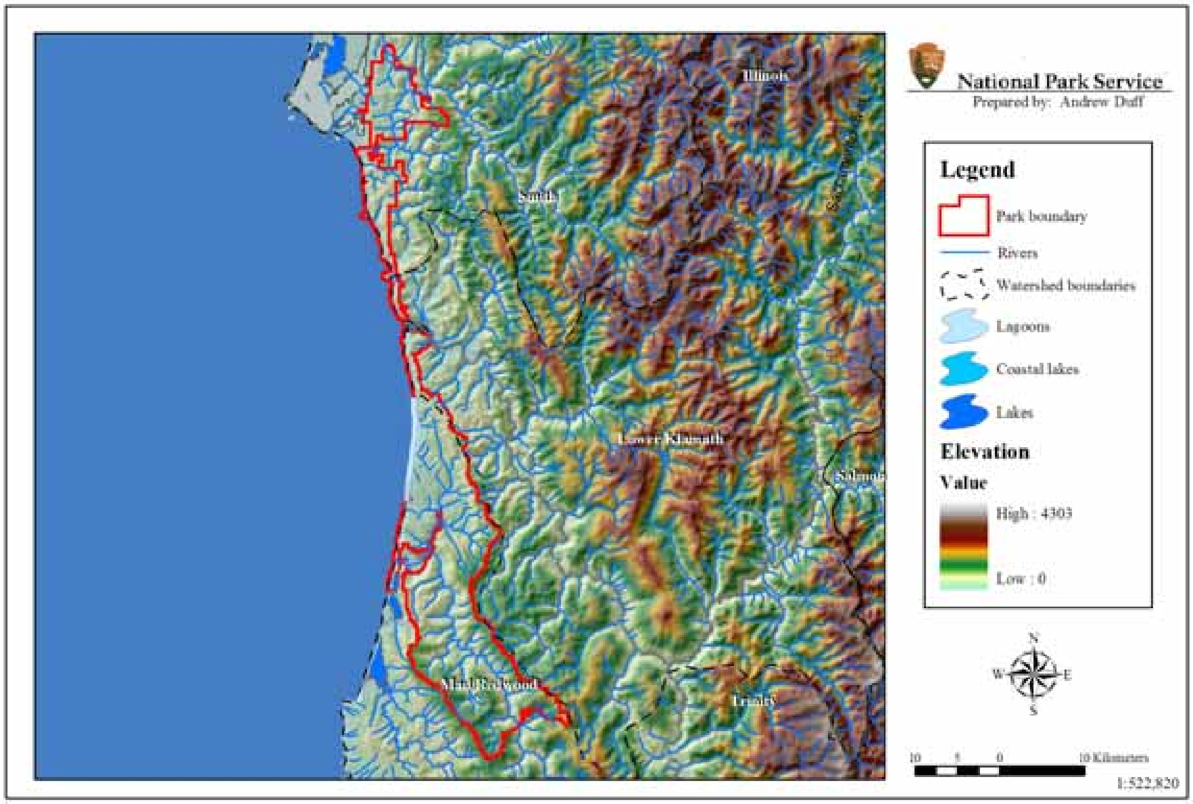


FIGURE 8: AQUATIC RESOURCES AND WATERSHED BOUNDARIES OF REDWOOD NATIONAL AND STATE PARKS, CALIFORNIA, NPS KLAMATH NETWORK

General Summary of Past Activities*: Redwood National and State Parks has monitored steam surface flow and sediment transport and deposition since 1972. The focus of these activities has been the long-term geomorphic and hydrologic monitoring of park unit freshwater lotic systems with emphasis on: (1) impacts due to human-related activities such as logging and road building; (2) water quality issues related to Clean Water Act section 303(d) impaired stream segments (i.e., Redwood Creek and Klamath River); (3) the impact of human-related activities on anadromous salmonids in park unit streams; and (4) the status of native amphibians in park unit lotic habitats. The status and trends of Redwoods marine ecosystems have been minimally examined. However, coastal and intertidal inventories are underway that are designed to assess, in part, human and invasive species impacts, offshore sediment budget, and potential impacts of perturbations such as oil spills to marine ecosystems.*

Redwood National Park was established on October 2, 1968. It was designated a World Heritage Site on September 5, 1980, and a Biosphere Reserve on June 30, 1983. Redwood National Park joined three California State Parks (Prairie Creek Redwoods State Park, Del Norte Coast Redwoods State Park, and Jedediah Smith Redwoods State Park) as one cooperative management unit of the National Park Service and California

Department of Parks and Recreation. In May 1994, Redwood National Park became Redwood National and State Parks (Figure 8), which contains approximately 45% of all remaining old-growth redwood forest in California. The parks are 42,701 ha (105,516 ac) in size arrayed along the Pacific Coast of northern California. The western boundary of Redwoods extends 0.4 km (0.25 mi) beyond the mean high tide line of the Pacific Ocean and the National Park Service has jurisdiction over the waters, intertidal lands, and submerged lands in this area. The coastal jurisdiction of state parklands extends 0.3 km (0.19 mi) west of the ordinary high-water mark of the Pacific Ocean. Elevations within the park range from below sea level to 996 m (3,268 ft).

The aquatic resources of Redwoods consist of over 60 km (36 mi) of marine coastal habitat and 547 km (340 mi) of USGS blue-line (first order) streams. Redwood Creek and its associated watersheds dominate the southern part of the park. The Klamath River is in the northern part of the park and the Klamath River estuary is the only part of the drainage contained within the park boundary. Redwood Creek supports a number of native salmonid species (i.e., cutthroat trout [*Oncorhynchus clarki*], coho salmon [*Oncorhynchus kisutch*], steelhead [*Oncorhynchus mykiss*], and chinook salmon [*Oncorhynchus tshawytscha*]) that are monitored on an annual basis. Green sturgeon (*Acipenser medirostris*), Klamath smallscale sucker (*Catostomus rimiculus*), and the tidewater goby (*Eucyclogobius newberryi*) are threatened and endangered fish species that also are monitored on an annual basis within the park. The park also supports a number of additional threatened and endangered species (see Appendix E of the KLMN Phase I Report).

The Redwood National Park Act as amended in 1978 gave the Secretary of the Interior the authority to reduce the impacts of upstream sedimentation and to rehabilitate areas that have been subject to timber harvesting in the past. Due to the nature of Franciscan rocks, the steepness of many slopes, the amount of precipitation, and the exposure of soil and bedrock from intensive logging, stream erosion and sedimentation have had and continue to have a profound impact on Redwoods lotic resources. The lower 40% of Redwood Creek is within the park and the upper 60% is on private land that has been logged. As a result of past land use and flood events, Redwood Creek is currently 303(d) listed under the Clean Water Act due to excessive sediment and warm water temperatures.

Long-term geomorphic and hydrologic monitoring continues to be a priority on Redwood Creek and other creeks within Redwoods. Monitoring parameters include stream discharge, sediment transport, turbidity, temperature, channel stability, changes in pool and riffle distribution, pebble count and facies changes in streambed deposits. It may be difficult to determine the exact source of turbidity and sedimentation, but the primary sources appear to be the various impacts of logging roads inside and outside of the park. In cooperation with private landowners, park staff assists in surveying roads on private lands. Park staff also provides input to proposed Timber Harvest Plans in an attempt to minimize erosion. A project funded by the Environmental Protection Agency to evaluate the differences in the duration of turbidity for small streams with different disturbance levels was recently completed.

Road restoration has been a major undertaking at the park. This effort has restored many of the old logging roads and reduced landslide activity in those areas. However, most roads open to visitor traffic are gravel and subject to erosion. Adequate maintenance and upgrading of road drainage structures, culverts and other road features are concerns.

Redwoods coastal resources are largely unexamined and their condition is presently unknown. Redwoods and Humboldt State University are cooperatively conducting an inventory of coastline resources. The goal of the project is to assess the marine resources, including habitat type, vegetation types, and algal, invertebrate, and fish diversity along the park's 36 miles of accessible coastline.

Horizon Report

No report is presently available.

Fisheries Studies

1) Redwood Creek:
   a. Invertebrate drift and juvenile salmonid habitat of the Redwood Creek watershed: 1981
   b. Downstream migration, growth and condition of juvenile fall chinook salmon in Redwood Creek, Humboldt County, California: 1985
   c. Juvenile salmonid habitat of the Redwood Creek basin, Humboldt County, California: 1988
   d. Fish food habits and their interrelationships in lower Redwood Creek, Humboldt County, California: 1987
   e. Fish food habits in the Redwood Creek estuary: 1990
   f. Redwood Creek basin coho salmon (*Oncorhynchus kisutch*) summary reports: 1994
   g. Redwood Creek basin fisheries summary: 1980-1994
   h. Redwood Creek basin spawning and carcass surveys and annual reports: 1991-1992, 1993-1994, 1996-1997, 1997-1998, 2000-2001, 2002-2003
   i. Redwood Creek estuary flood history, sedimentation and implications for aquatic habitat: 1983
   j. Redwood Creek estuary monitoring and management: 1990, 1993, 1997-1999, 2002, 2003
   k. Redwood Creek fish and amphibian distribution data [collection]
   l. Redwood Creek summer steelhead trout survey: 1991, 1992, 1998, 1999, 2002
2) Prairie Creek
   a. Effects of fine sediment on salmonid redds in Prairie Creek, a tributary of Redwood Creek, Humboldt County, California: 1991
   b. Smolt production from Prairie Creek Hatchery juvenile coho reared in an Arcata wastewater-seawater pond: October 1992-May 1993
   c. Prairie Creek salmon restoration: 1992-1993
   d. Anadromous salmonid escapement and downstream migration studies in Prairie Creek, California: 1995-1996

    e. Prairie Creek salmon redd composition, escapement and migration studies, Humboldt County, California: 1996-1997
    f. Effects of sediments from the Redwood National Park bypass project (CALTRANS) on anadromous salmonids in Prairie Creek State Park: 1995-1998
    g. Effects of sedimentation on incubating coho salmon, (*Oncorhynchus kisutch*) in Prairie Creek, California: 1998
    h. Prairie Creek: Survival, growth and movement of juvenile coho salmon (*Oncorhynchus kisutch*) over-wintering in alcoves, backwaters, and main channel pools: 2001
    i. Abundance and survival rates of juvenile coho salmon (*Oncorhynchus kisutch*) in Prairie Creek: 2002
3) Klamath River
    a. Klamath River chinook salmon: use of radio telemetry to study adult upriver migration: 1982
    b. Klamath River estuary: utilization by juvenile chinook salmon (*Oncorhynchus tshawytscha*): 1986
    c. Assessment of fish habitat types within the Klamath River estuary: annual performance report: 1992
    d. Assessing the effects of moderately elevated fine sediment levels on stream fish assemblages: 2000
4) Coyote Creek Spring Pond brook trout removal: 1999, 2001, 2002
5) Fish habitat inventory for lower Lost Man Creek: 1990
6) Habitat utilization by 1987 and 1988 cohorts of chinook salmon from emergence to out-migration in Hurdygurdy Creek, California
7) Mill Creek monitoring program: juvenile salmonid monitoring on the east and west branches of Mill Creek: 1994
8) Smith River adult fish survey: 1997
9) Hoopa Valley Indian Reservation inventory of reservation waters, fish rearing feasibility study and a review of the history and status of anadromous fishery resources of the Klamath River Basin: 1979
10) Effects of large organic debris on channel morphology and process, and anadromous fish habitat in steep, montane coastal redwood environments: 1980
11) Large organic debris and anadromous fish habitat in the coastal redwood environment: the hydrologic system: 1983
12) Fish distribution survey reports: FY2000, FY2001, FY2002
13) Spawning survey results: 1983-1990
14) Tidewater goby surveys and reports: 1997, 1998, 2002

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Beneficial Water Uses

Table 10 shows the beneficial uses of water in Redwoods as identified by the North Coast Regional Water Quality Control Board (NCRWQCB).
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TABLE 10: BENEFICIAL USES OF WATER WITHIN REDWOOD NATIONAL AND STATE PARKS (NCRWQCB)

Acronym	Definition
AGR	Agricultural Supply
COLD	Cold Freshwater Habitat
COMM	Commercial and Sport fishing
EST	Estuarine Habitat
FRSH	Freshwater Replenishment
GWR	Groundwater recharge
IND	Industrial Service Supply
MAR	Marine Habitat
MIGR	Fish Migration
MUN	Municipal Supply
NAV	Navigation
PROC	Industrial Process Supply
RARE	Preservation of Rare and Endangered Species
REC 1	Contact Water Recreation
REC2	Non-contact Water Recreation
SHELL	Shellfish Harvesting
SPWN	Fish Spawning
WARM	Warm freshwater habitat
WILD	Wildlife Habitat

Wildlife Monitoring

1) Redwood Creek estuary salmonid monitoring for adult spawning and juveniles
2) Redwood Creek monitoring for deformed amphibians
3) Marine mammal carcass monitoring (ongoing)
4) Marbled murrelet, snowy plover and brown pelican monitoring

Resource Management Water Quality Concerns

1) Freshwater

   A) Effects of adjacent land use, in particular, logging on water quality
   B) Water quality issues related to Clean Water Act (CWA) Section 303(d) impaired stream segments (i.e., Redwood Creek sedimentation/siltation and temperature, and Klamath River nutrients and temperature)

C) Water quality of Redwood Creek watershed related to sediment transport trends, water and suspended-sediment discharge, and water chemistry and aquatic biology
D) Impacts of recreational catch and release fishing on threatened salmonid species

Note: a full discussion of the CWA Section 303(d) listing and Total Maximum Daily Load (TMDL) program process can be found at the following EPA web site: http://www.epa.gov/owow/tmdl/

2) Marine

A) Completion of coastal and intertidal inventories including assessments of human impacts, invasive species, offshore sediment budget and potential hazards such as oil spills
B) Compliance of near- and offshore water quality with State Water Quality Control Board standards
C) The impact of river flow output (e.g., Klamath River plume) on coastal habitat, productivity, and water chemistry
D) The potential presence of contaminants in the near- and offshore waters
E) Lack of complete inventories from most marine habitats (Table 11)

TABLE 11: MARINE INVENTORY NEEDS AT REDWOOD NATIONAL AND STATE PARKS

Pelagic	Fish Marine Mammals Marbled Murrelet Brown Pelicans
Subtidal	Habitat Typing (rock, sand, kelp) Bathymetry Near Shore Currents and Wave Action Fish Distribution
Intertidal	Habitat Typing (rock, sand) Invertebrates, Plants, Fish (Distributions and Abundances) Large Woody Debris Visitor Use
Estuary	Substrate Typing (rock, sand, mud) Aquatic Plants Bathymetry

See Attachment I for RNSP watershed monitoring, water quality, and fisheries inventory, monitoring and research study references.

WHISKEYTOWN NATIONAL RECREATION AREA (WHIS)

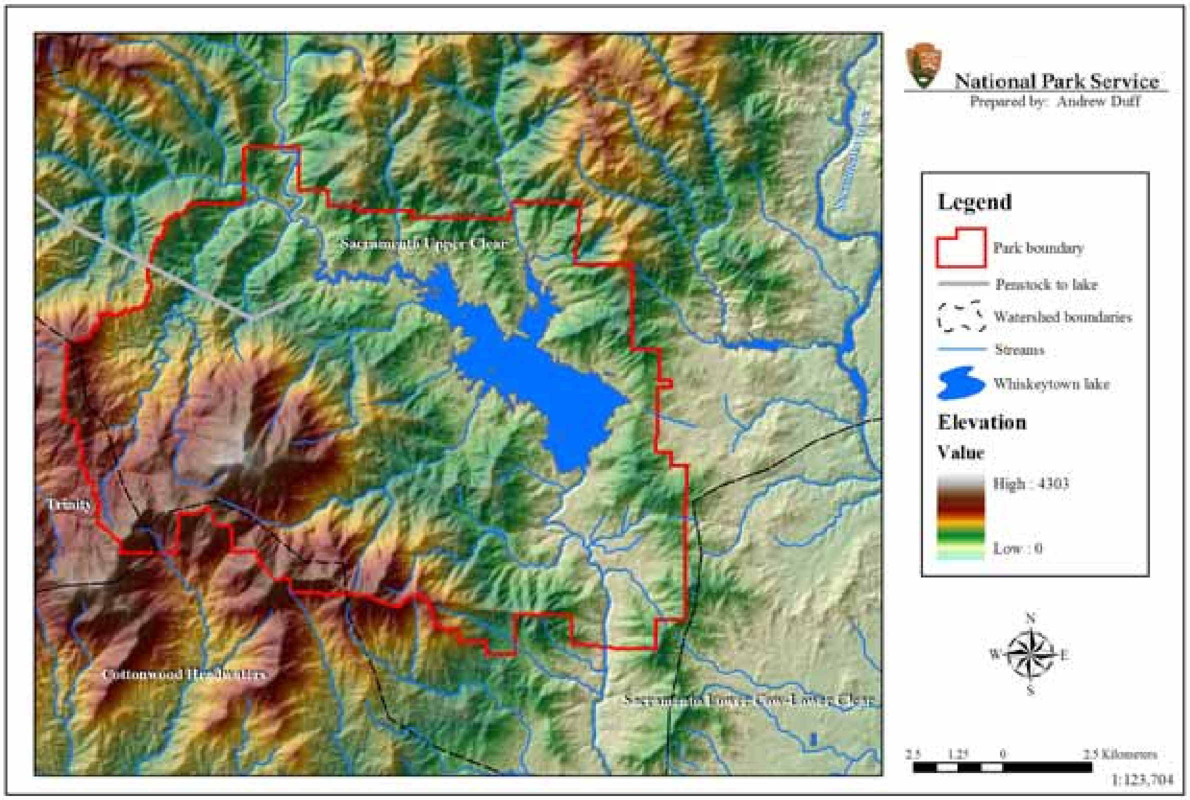


FIGURE 9: AQUATIC RESOURCES AND WATERSHED BOUNDARIES OF WHISKEYTOWN NATIONAL RECREATION AREA, CALIFORNIA, NPS KLAMATH NETWORK

General Summary of Past Activities*: Aquatic resource inventory, monitoring and research activities at Whiskeytown National Recreation Area have focused on the water quality of Whiskeytown Lake and its inlet and outlet streams. Water quality sampling has emphasized documentation of potential resource perturbation due to: (1) human recreation activities and waste disposal; (2) point source pollution due to past mining activities and practices; (3) point source pollution due to clandestine-illegal marijuana cultivation; and (4) impacts due to logging and road building. Additional projects have been initiated or completed to: (1) assess the baseline water quality, biology and habitat conditions of the major Whiskeytown watersheds; (2) demonstrate the potential for watershed restoration; (3) determine the status of amphibians and turtles; and (4) survey the status of and potentially restore anadromous salmonids in Clear Creek.*

Whiskeytown National Recreation Area (Figure 9) was authorized by Congress on November 8, 1965 ("…to provide…for the public outdoor recreation use and enjoyment of Whiskeytown reservoir and surrounding lands…") and established on October 21, 1972. Whiskeytown is the only unit of the Whiskeytown-Shasta-Trinity National Recreation Area administered by the National Park Service; the Shasta and Trinity units are administered by the US Forest Service. The Whiskeytown unit (17,198 ha; 42,497 ac) is located at the northern end of the Sacramento Valley, eight miles west of Redding, California, and Whiskeytown Lake is surrounded by shrubland, oak woodland, and montane forests.

Whiskeytown Lake was created by the Bureau of Reclamation in 1962, when the Clair A. Hill Whiskeytown Dam, blocking Clear Creek, was completed. The reservoir at full capacity contains 29,604 ha-m (240,000 ac-ft) of water and serves as the domestic water supply for the California cities of Redding, Old Shasta, Centerville, Keswick, and Happy Valley. It is also one of several reservoirs that store water for the Central Valley Project. Seven major streams empty directly into the reservoir: Clear, Mill, Brandy, Crystal, Boulder, Willow and Whiskey Creeks. Intermittent streams abound throughout the park unit, and many springs are found at higher elevations.

Whiskeytown has approximately 850,000 visitors annually, with the majority of visitation concentrated in and around the reservoir. Sailing, skiing, fishing, swimming, and kayaking are popular recreational activities. There are two permanent marinas, one additional boat launch site, three designated campgrounds, two developed day use beaches, and numerous smaller beaches along the reservoir. The reservoir is stocked annually with both native and non-native fishes by the California Department of Fish and Game.

Horizon Report

Surface water quality data for Whiskeytown were collected by eight agencies (i.e., California Department of Fish and Game, California Department of Health Services, California Department of Water Resources, California Water Resources Control Board, National Park Service [WHIS and Water Resources Division], UC Davis, USDI Bureau of Reclamation, and US Geological Survey), between 1962-1998 (NPS-WRD, 2000). Numerous sites throughout the reservoir (Whiskeytown Lake), as well as 12 streams, 4 springs, and 2 mines (NPS-WRD 2000, pages 45-47) were sampled during this time period. A total of 128 stations were sampled and all but 17 stations were either sampled once or intensively for a single-year (NPS-WRD 2000). The 17 relatively long-term stations were located at numerous sites around the reservoir, or on Clear and Willow Creeks. Many of the 203 parameters assessed between 1962-1998 (NPS-WRD 2000, pages 48-51) were potential indicators of water quality problems associated with (1) human recreational activities and waste disposal, and (2) point source pollution due to past mining activities and clandestine-illegal marijuana cultivation. These water quality parameters continue to be monitored (1999-present). A Horizon Report for WHIS is available at:
(http://nrdata.nps.gov/WHIS/nrdata/water/baseline_wq/docs/WHISWQAA.pdf).

Additional Activities

Water quality related activities at Whiskeytown also include four recent projects not covered by the NPS-WRD (2000) Report. In 1996, Whiskeytown began a cooperative watershed restoration partnership with Shasta College and Salix Applied Earthcare, a natural resource consulting firm, both located in Redding, California. The cooperative project was titled "Watershed Restoration and Logging Road Removal Project in the Paige Bar Demonstration Watershed" and was designed, in part, to demonstrate the capacity for restoring watershed water quality and fish habitat. The project received the National Park Foundation Environmental Conservation Award in 1999. USGS Project CA598 was designed to identify and characterize contaminant "hot spots" in Whiskeytown due to past mining activities, and to examine the potential adverse effects of mercury and other heavy metals on aquatic biota. This project, begun in April, 2002, examined 15 sites throughout Whiskeytown and concluded in September, 2004 (Hothem *et al*. 2002-2004). In February, 2004, USGS Project 9VL22 was initiated to assess the aquatic biology, habitat, and water quality conditions of the major Whiskeytown watersheds (May and Brown 2004-2006). This project will conclude in September, 2006. In 2002, USGS personnel surveyed and inventoried the presence of amphibians and turtles in 12 Whiskeytown streams and one pond. Amphibians and turtles were again surveyed and inventoried in 2004, in nine Whiskeytown streams and one pond, and in five arms of the reservoir. Fisheries activities in Clear Creek at Whiskeytown have been associated with a larger effort concerning the restoration of anadromous fish in the Sacramento River drainage area (NMFS 1997, USFWS 2001, CDFG 2002).

Resource Management Water Quality Concerns

1) ArcGIS feature datasets of aquatic resources within the park unit boundary have yet to be completed
2) Disturbance and contamination of stream habitats due to clandestine-illegal marijuana cultivation
3) Introduction of nonnative fish and wildlife (particularly bullfrogs) species
4) Spread of exotic plant species within Whiskeytown Lake

See Attachment I for WHIS water quality and fisheries inventory, monitoring and research study references.

Section 4: Water Quality Monitoring and Research Programs of Allied Agencies Relevant to Klamath Network Park Units

This section describes past and ongoing research or monitoring programs in the Klamath Network region. Many of these programs could provide funding, protocols, or partnership opportunities for the Klamath Network as it develops its water quality monitoring program.

A. **US Environmental Protection Agency (USEPA), Environmental Monitoring and Assessment Program (EMAP) - Surface Waters - Western Pilot Study, USEPA (with collaborators). Project Dates: 2000–2005:** The Western Pilot study is the Surface Waters component of the USEPA Western Geographic Study through the EMAP Program. The program goal is to answer questions about the importance of stressors and the extent of their effects on ecological condition of wadeable streams; the objective is to develop monitoring tools to estimate the ecological condition of surface waters across the Western US. Project methodology includes sampling of water chemistry, stream discharge, periphyton, sediment, benthic macroinvertebrates, fish, and physical habitat characteristics. Contact: David Peck, USEPA, Corvallis, OR. Phone: 541-754-4426, E-mail: peck.david@epa.gov.

B. **US Environmental Protection Agency (USEPA), Environmental Monitoring and Assessment Program (EMAP) – National Coastal Assessment, USEPA (with collaborators). Project Dates: 1990–2003:** The USEPA National Coastal Assessment has conducted estuarine monitoring in all 23 coastal States and Puerto Rico (accounting for 99.8% of estuarine acreage in the continental US and Puerto Rico). Data from several regional and national programs conducted by NOAA, USGS and the USFWS are included in the assessment of coastal condition. The West Coast of the US was assessed in 1999 and 2000, and the assessment was extended in 2003 to cover the continental shelf. Marine biota (plankton, benthos, and fish) and environmental parameters associated with water quality, sediment quality, and tissue bioaccumulation were sampled. The first and second Coastal Assessment Reports can be accessed using the following website link: http://www.epa.gov/owow/oceans/nccr2/index.html. Contact: J. Kevin Summers, US EPA. Phone: 850-934-9201, summers.kevin@epamail.epa.gov.

C. **National Oceanic and Atmospheric Administration (NOAA), with the Western Regional Climate Center (Desert Research Institute). Climate Reference Network. Project Dates: implemented in 2004:** The Climate Reference Network is a network of climate stations being established, with the help of the Western Regional Climate Center, as part of a NOAA initiative. The goal of this project is to monitor long-term precipitation and temperature observations to investigate present and future climate change. If fully implemented, the network will have about 250 sampling stations nationwide. Many of these stations are being established in national parks. Contact: John Jensen, Program Manager, NOAA. Phone: 828-271-4475, E-mail: John.A.Jensen@noaa.gov.

D. **US Geological Survey (USGS), Amphibian Research and Monitoring Initiative (ARMI), with NPS, FWS, BLM. Project Dates: 2000–ongoing:** In response to growing awareness of amphibian declines and malformations, the USGS ARMI program was initiated by the United States Congress in 2000 to monitor trends in amphibian populations on Department of Interior (DOI) lands; and to research the cause of amphibian declines. While intensive monitoring will be focused on DOI lands, ARMI will also provide a framework for other agencies outside of DOI lands for incorporating amphibian monitoring data. Partnerships with other DOI agencies include a nationwide Fish and Wildlife Service survey for contaminants that may induce malformations in amphibians on 48 National Wildlife Refuges in 31 states. Contact: Mike Adams, Wildlife Biologist, USGS Forest and Rangeland Ecosystem Science Center (FRESC) Corvallis, OR. Phone: 541-758-8857, E-mail: Michael_adams@usgs.gov.

E. **US Geological Survey (USGS), National Water Quality Assessment Program (NAWQA) – Sacramento River Basin Study. Project Dates: 1994–1998:** The Sacramento River water quality assessment, covering the river's nearly 75,000 sq km (27,000 sq mi) drainage basin, is the largest within the State of California. The study was divided into 5 physiographic provinces: the Sacramento Valley, the Sierra Nevada, the Coast Ranges, the Cascade Range and the Modoc Plateau. The major use of Sacramento River water is for agriculture (58%), environmental management (32%), urban land use (6%), and other (4%). A suite of water quality parameters were measured including temperature, pH, dissolved oxygen, specific conductance, major cations and anions, metals, suspended sediment, bed sediment, discharge, and fish tissue samples for contaminants. The major issues within the basin are elevated concentrations of trace metals, especially from abandoned mines (WHIS); pesticide contamination of surface water and potential contamination of ground water (LABE, LAVO, WHIS); nitrate contamination of ground water (LABE, LAVO, WHIS); and urban runoff and volatile-organic-chemical contamination. Contact: Joseph Domagalski, USGS, Sacramento, CA. Phone: 916-278-3077, E-mail: joed@usgs.gov.

F. **US Geological Survey (USGS), National Stream-gaging Program (NSP), with Federal, State, and Local agencies. Project Dates: variable and ongoing:** The USGS has been collecting streamflow information since 1887. The NSP, which partners with many agencies, monitors flows on major and minor streams at nearly 7,000 stations throughout the US. Streamflow gaging stations provide data that can be used for planning and operating water resources projects, flood warning and control operations, and long-term background information about changes in streamflow in response to climate and changes in land use. Contact: Mike Norris, USGS, Phone: 703-648-5304, E-mail: mnorris@usgs.gov.

G. **US Geological Survey (USGS), Forest and Rangeland Ecosystem Science Center (FRESC), Project: Development of monitoring protocols for mountain lakes and ponds at North Cascades National Park Service Complex:** This project began in 2001 with the purpose of developing a sampling protocol for mountain ponds and lakes. The NPS North Coast and Cascades Network is the project partner and this protocol has been developed for all park units in this network. The protocol also has been written as a document that can be used by any agency, institution or group (e.g., KLMN) interested in sampling montane lentic ecosystems. The protocol is in press and will be published as stand-alone chapter of a USGS Techniques and Methods document (Techniques and Methods 2-A2). Contact: Robert Hoffman, USGS FRESC (Phone: 541-750-1013, E-mail: robert_hoffman@usgs.gov) and Gary Larson, USGS FRESC (Phone: 541-750-1032, E-mail: gary_l._larson@usgs.gov).

H. **US Forest Service (USFS) and Bureau of Land Management (BLM) Watershed Analyses. Approximately 1995–present:** Watershed analyses have been conducted by the USFS National Forests and BLM Districts throughout the KLMN region. These analyses are part of the process of implementing ecosystem management as directed by the Northwest Forest Plan. USFS National Forests include: Fremont-Winema, Klamath, Rogue River-Siskiyou, Shasta-Trinity, and Six Rivers; BLM Districts include: Coos Bay, Lakeview, and Medford. Over 76 watersheds have been analyzed since 1995. Each watershed analysis includes the characterization of current and reference conditions in 14 basic categories: (1) human uses; (2) roads; (3) climate; (4) erosion processes; (5) soil productivity; (6) vegetation density and vigor; (7) plant species and habitats; (8) fire; (9) terrestrial wildlife species and habitats; (10) hydrology; (11) stream channel; (12) water quality; (13) riparian areas; and (14) aquatic wildlife species and habitats. Many of the watershed analyses reports are available at each USFS National Forest and BLM District internet web site.

I. **Northwestern California/Klamath Bioregion Environment Information Sources:** This is an internet website hosted by the Humboldt State University Library at http://library.humboldt.edu/~rls/NorCalEnv.htm#water. The site provides clickable links to environmental data made available by various entities throughout the Klamath Region. Water resources/water quality site links include: (1) California Data Exchange Center; (2) California Nevada River Forecast Center; (3) EPA – Established TMDLs; (4) Hydro-Climatic Data Network; (6) Klamath Resource Information System (KRIS) Web Bibliography; (7) National Water Information System (NWISWeb) Data for California (USGS); (8) Regional Assessment of Stream Temperatures Across Northern California and Their Relationship to Various Landscape-Level and Site-Specific Attributes; (9) Surf Your Watershed; (10) Water Data Library (California Department of Water Resources); and (11) Water Resources Data: California (USGS).

J. **California Department of Fish and Game Stream Bioassessment Procedure:** The mission of the California Department of Fish and Game's Aquatic Bioassessment Laboratory is to use biology in the management and assessment of California water quality. This procedure utilizes aquatic invertebrates for the rapid bioassessment of stream water quality. Background information and the bioassessment procedure are available at http://www.dfg.ca.gov/cabw/cabwhome.html.

K. California North Coast Watershed Assessment Program: The development of this interagency program was initiated in 1999 by the California Resources Agency and the California Environmental Protection Agency. The California agencies participating in this program are (1) Department of Fish and Game, (2) Department of Forestry and Fire Protection, (3) Division of Mines and Geology, (4) Department of Water Resources, and (5) North Coast Water Quality Control Board. The program purpose is "to develop consistent, scientifically credible information to guide landowners, agencies, watershed groups, and other stakeholders in their efforts to improve watershed and fisheries conditions." Detailed information about this program is available at http://www.ncwatershed.ca.gov.

SECTION 5: NETWORK-WIDE SCOPING, IDENTIFICATION, AND PRIORITIZATION OF VITAL SIGNS FOR AQUATIC RESOURCE MONITORING

A. PURPOSE, NEED, AND APPROACH

The Klamath Network is in the process of developing a long-term water quality monitoring plan for its park units. Development of the water quality monitoring plan follows the guidance given in a May 2002 Memorandum to National Park Service Regional I&M Coordinators. The memo outlines the three-phase approach for developing a monitoring plan. Phase 1 of the network's water resources and water quality assessment provides introductory and background resource and quality information for each park unit in the network. Phase 2 provides a more in-depth review of the aquatic resources and past water quality inventory, monitoring, and research activities in each park unit; and discusses the process of identifying and prioritizing specific "vital signs indicators" (i.e., indicators of ecosystem health) to be monitored as part of a long-term water quality monitoring program. Phase 3 details the steps required to implement an integrated long-term monitoring program including development of: (1) monitoring objectives for each priority vital sign; (2) sampling protocols and sampling designs; and (3) a plan for data management, analysis and reporting.

Water quality was identified during the Klamath Network's general ecosystems vital signs scoping process as an important element of the overall health of the network's diverse ecosystems. The network also identified the need for a working water quality subgroup of the Science Advisory Committee (SAC). The subgroup was given the task of making recommendations concerning water quality issues and implementing tasks that the committee considered significant. Their first assignment was to recommend additional Phase I basic water quality inventories for three network park units (LAVO, LABE, and ORCA) based upon a preliminary evaluation of existing water quality information and its currency by the National Park Service Water Resources Division. The second task for the subgroup was to develop and write a Phase I Water Quality Report. The network decided, based upon existing network expertise and available time, to produce the Phase I Report in-house, with technical assistance from the park units. The network did not identify the need to hold a separate water quality scoping and/or vital signs meeting to gather park-specific water quality information. Rather, the identification of general water quality vital signs was incorporated as one of the tasks of the Aquatic Group participating in the network's third Vital Signs Workshop held May 4-6, 2004. The purpose of this workshop was to identify Level 1 and Level 2 Categories of the National Vital Signs Framework and to provide examples of vital signs and their measurement associated with these categories (see Table 12). A meeting focusing on identifying more specific water quality vital signs for each network park unit was completed on December 1, 2004.

B. VITAL SIGNS SCOPING

The Klamath Network began its vital signs monitoring scoping process in 1998. A detailed account of the process and key findings were reported in Sarr *et al*. (2004).

Initial park-specific Vital Signs Workshops were held between 1998 and 2003 to begin to identify stressors that potentially impact park unit ecosystems. These workshops were followed in 2004 by three network-wide workshops: (1) Marine (January 27-28); (2) Geology/Soils (March 1-4); and (3) Level 1 and 2 Categories of the National Vital Signs Framework (May 4-6). The purpose of these workshops was to identify general monitoring questions and broad-scale vital signs associated with specific ecosystems and categories (see Sarr *et al*. 2004, Appendix G, pages 4-17 including Table 1, pages 16-17, for a complete list of National Vital Signs Framework Categories). Detailed results of the May 4-6 workshop specific to Klamath Network park units can be reviewed in Sarr et al. 2004, Appendix G, Tables 2-7, pages 18-46.

General Water Quality Vital Signs Identified during the May 2004 Scoping Process

The dominant theme during the initial identification of network-wide general water quality vital signs was aquatic ecosystem health. The ability to (1) document improvement (or lack thereof) in the water quality of Clean Water Act section 303(d) listed streams, and (2) the ability of park unit managers to document progress toward achieving GPRA goal 1.a4 (i.e., that park units have unimpaired water quality) underscored the importance of identifying a suite of vital signs useful for effective water quality assessment. The need to fully inventory aquatic resources and document baseline and reference water quality conditions also were identified as important objectives in the development of a vital signs-based long-term water quality monitoring program. The vital signs initially identified included:

- **Watershed budgets:** A watershed budget is one method for monitoring water quality. It is an accounting of the inputs and outputs of water, nutrients, sediments, and chemicals passing through a particular watershed; and budgets vary considerably among watersheds. Typical monitored parameters include the concentration of major ions and isotopes, stream flow, groundwater hydrology, and continuous water temperature.
- **Continuous water temperature measurement:** Water temperature can be a useful indicator of the status and trends of aquatic ecosystems. Change in water temperature can be indicative of ecosystem impact due to climate change or other anthropogenic-derived perturbations. However, the intermittent monitoring of temperature can be problematic due to the significant temporal variation of temperature. Use of continuous recording devices is a preferred means of eliminating time-associated sampling variation.
- **Groundwater quantity and quality:** This vital sign refers to the monitoring of groundwater level and chemistry (including contamination). Monitored parameters include groundwater level and volume, pH, temperature, conductivity, trace organic compounds and metals. Samples for analysis are obtained through purging and sampling groundwater wells.
- **Reservoir elevation.** Lakes that are hydrologically managed (i.e., water impounded by a dam) will have fluctuating water levels that can potentially affect lake food webs and ecosystem function. Therefore, changes in water surface

elevation and storage capacity, as well as water inflow and discharge should be part of the long-term monitoring of reservoirs.

- **River invertebrate assemblages.** The composition of an invertebrate assemblage can be a useful indicator of water quality; and may change in response to the presence of exotic species, as well as changes in sedimentation rate, nutrient loading, composition of predator population, and climate. Two methods can be used to identify and document change: (1) comparing the species of a measured assemblage structure with species that may be indicative of a particular water quality condition (e.g., Stribling *et al*. 1998), and (2) using multivariate analysis to compare a predicted invertebrate assemblage structure to a measured structure (e.g., Hawkins *et al*. 2001, Lewis *et al*. 2001).
- **Hydrology of springs and seeps (cold and hot):** This vital sign includes documenting the location, volume, duration, and seasonality of flow of springs and seeps. Parameters are quantified by calculating physical/geometric metrics (i.e., water depth [maximum, minimum, average]; site length, and width) and discharge (flow quantity, duration, and peak) at each spring or seep.
- **Stream flow/discharge:** Stream flow is the measure of the flow of water in a stream at a specific time relative to (1) watershed routing mechanisms and water quality, (2) watershed land-use activities, and (3) natural and point-source discharges within the watershed. Stream discharge (Q) is defined as the unit volume of water passing a given point on a stream or river over a given time. It is typically expressed in cubic feet per second (cfs) or cubic meters per second (cms) and is based on the equation: $Q = A*V$, where A is the cross-sectional area of the stream at the measurement point and V is the average velocity of water at that point.
- **Water chemistry:** Information from monitoring water chemistry is used to evaluate water quality with respect to stressors such as atmospheric deposition, nutrient enrichment, and inorganic contaminants. The following parameters and ions are usually monitored: alkalinity, ammonia, bicarbonate, carbonate, calcium, chloride, fluoride, trace metals, nitrate, pH, potassium, silica, sodium, sulfate, total dissolved solids, total suspended solids, total nitrogen, and total phosphorous. In streams, concurrent discharge measurements allow data to be presented as mass flow (e.g., g/hr).
- **Algal species composition and biomass:** Algal species composition refers to the kinds of species present in a body of water. Algal biomass refers to the combined mass of the species. Certain species can indicate changes in water column nutrient input or water temperature. Algal composition is measured by examining algal assemblages, whereas algal biomass can be measured using chlorophyll ą concentrations or Secchi disk water clarity measurements.
- ***Escherichia coli (E. coli*)**:** The presence of *E. coli* in a water sample is an indicator of fecal contamination. This bacterium can cause gastrointestinal distress and illness in humans and can be contracted by drinking contaminated water or by swimmers recreating in contaminated swimming areas. Determination of *E. coli* contamination is based on the density of the indicator organism in a

water sample. The EPA requires that the concentration of *E. coli* in a water sample be no more than a geometric mean of 126 *E. coli* per 100 ml of fresh water, or 260 *E. coli* per 100 ml for any single sample.

- **Exotic aquatic species community structure and composition:** Introduced exotic aquatic species can affect the ecosystem dynamics of a water body and negatively impact naturally occurring native biota in affected systems. Monitoring the distribution (geographical location), abundance (number at each sampling location), and spread of exotic species can help managers understand the potential environmental consequences of these organisms. Introduced exotic species of concern include fish (e.g., kokanee [*Oncorhynchus nerka*] in Crater Lake and brook trout [*Salvelinus fontinalis*] in western montane lakes and streams), as well as invertebrates (e.g., the New Zealand mud snail [*Potamopyrgus antipodarum*]).
- **Native aquatic species community structure, composition, stability and genetic integrity:** This vital sign is associated with the overall health of native biota in water bodies of interest. Monitored parameters include the determination of the condition of native biotic communities based on metrics of species richness, composition, and trophic status, relative abundance, presence/absence, and genetics.
- **Atmospheric deposition (wet and dry) of nitrogen, sulfur, and all major anions and cations:** Atmospheric deposition is the process whereby air-borne particles, aerosols, and gases move from the atmosphere to the earth's surface. This vital sign is quantified by measuring snow-pack chemistry and direct measurements of wet (NADP/NTN) and dry (CASTNet) deposition. Fire (e.g., wildfire or controlled burns) also is a source of atmospheric deposition of pollutants, and can reduce visibility in KLMN park units.
- **Basic climatological measurements:** Monitoring parameters associated with this vital sign will help park unit managers identify potential climate change. Basic climatological measurements include: temperature (maximum, minimum, and average), precipitation, relative humidity, wind velocity and pattern, surface pressure, as well as snow cover, depth and water equivalent. The following are recommended standard metrics for these climatological variables: air temperature (°C), surface wind (m/s), and atmospheric humidity/water vapor (as percent, mixing ratio in g H_2O/kg-air, or concentration in g H_2O/m^3), surface pressure (hectopascals [hPa] or millibars [mb]), snow cover and depth (water equivalent per km^2 and/or percent of area for cover and mm/cm for depth).
- **Stream sediment transport.** Sediment data, both suspended and bedload, are required for the evaluation of stream sediment yield with respect to (1) background environmental conditions (geology, soils, climate, runoff, topography, ground cover, and size of drainage area), (2) historic and current land use, and (3) erosion and deposition in channel systems. Additionally, understanding the temporal distribution of sediment concentration, size characteristics, and transport rates is crucial to the management of in-stream aquatic communities and riparian ecosystems. Standardized sediment sampling methods and the frequency of collection will be dictated by the hydrologic and

sediment characteristics of the water body to be sampled, the required accuracy of the data, the funds available, and the proposed use of the collected data.

Also during the May 2004 vital signs scoping meeting, the Level 1 category, water, was divided into three Level 2 subcategories (i.e., hydrology, subterranean, and water quality). General conceptual models of freshwater and marine ecosystems (e.g., Attachment III, pages 146-154) were used by participants to help organize and frame the discussions of ecosystem processes, dynamics, and linkages. Out of these discussions, general, broad-scale monitoring questions were developed and associated vital signs were identified for each Level 2 subcategory. The outcome of this process is presented in Table 12. Full details of the results of the May 2004 meeting are available in Appendix G of Sarr *et al*. (2004). These general monitoring questions and vital signs were assessed and refined (i.e., narrowed) during subsequent scoping meetings (see pages 55-85 and Tables 14-24).

TABLE 12: BROAD-SCALE MONITORING QUESTIONS AND POTENTIAL VITAL SIGNS FOR WATER, A NATIONAL FRAMEWORK LEVEL 1 CATEGORY (SAC = SCIENCE ADVISORY COMMITTEE), NPS KLAMATH NETWORK VITAL SIGNS SCOPING WORKSHOP, MAY 4-6, 2004

Subcategories (Level 2)	Monitoring Question	Vital Sign (Klamath)	Question Identified by	Comments
Hydrology	What is the effusion rate of groundwater into the surface environment? (geothermal)?	Groundwater dynamics (discharge)	Process	
	What types of groundwater changes are occurring in network park units?	Aquifers (depth volume variability)	Aquatic	
		Hyporheic zones	Aquatic	
	What is happening with the hydrological cycle?		Terrestrial	
	What are trends in soil moisture across vegetation habitats?	Evapotranspiration	Terrestrial	
	What is the status and what are the trends of hydrothermal output into aquatic system?	Water chemistry	Process	
	What impact does seepage have on groundwater quality?	Groundwater (discharge and composition)	SAC	
	What is the status and what are the trends of water flow (water supply) in network park units?	Water flow	SAC	
		Water supply	Process, Aquatic	
Subterranean	How are changes in water and ice quantity, rates, and quality affecting erosion, deposition, and biota?	Water Flow (quantity)	Cave, Aquatic	
		Distribution (Water/Ice Budget)	Cave, Aquatic	
		Crustaceans and worms	Cave, Aquatic	

Subcategories (Level 2)	Monitoring Question	Vital Sign (Klamath)	Question Identified by	Comments
		Water Chemistry (quality)	Cave, Aquatic	
		Microorganisms	Cave	
Water Quality	What is the status and what are the trends of point source pollution inputs?	Pollutants (inorganic)	Process, Marine	
	What is the status and what are the trends of non-point source pollution inputs?	Pollutants (organic)	Marine	
		Water chemistry	Process, Aquatic	
		Nutrient levels	Whiskeytown	
	What is the status and what are the trends of watercraft emissions?	Hydrocarbon deposition	SAC	
	What is the status and what are the trends of aquatic biological communities?	Aquatic organisms	Aquatic	benthic algae, canopy cover, macroinvertebrates, freshwater mussels, substrate
		Water (physical)	Aquatic	
	When and how much water is occurring in ephemeral systems and can we detect a change over time?	Vernal pools	Terrestrial	
		Ephemeral streams	SAC	
		Littoral ponds (Crater Lake)	SAC	
		Seasonal wet meadows (LAVO))	SAC	
		Snow melt beds	SAC	
	Are the sizes and distributions of perennial water bodies (streams, lakes, snow fields, springs, wetlands) changing over time?	Distribution of water bodies	Aquatic	

Subcategories (Level 2)	Monitoring Question	Vital Sign (Klamath)	Question Identified by	Comments
Water Quality	What is the extent of material, biological, and chemical pollution in the marine ecosystem?		Marine	
	What is the status and what are the trends of marine trash (material trash)?	Seabirds	Marine	Percent of beached marine seabird carcasses with attached debris
	What is the status and what are the trends of marine mammals (?):	Marine mammals	Marine	percent of beached marine mammal carcasses with attached debris
	What are the impacts of terrestrial sources of intertidal pollution (?):			
	-oil	Oil Seabirds	Marine	Presence/absence of oiled beach marine seabird carcasses
		Marine mammals	Marine	Presence/absence of oiled beach marine mammal carcasses
	-river discharged pollution	Pollutants	Marine	Similar water quality testing as done by State Water Quality Control Board
	-salinity	Surface salinity	Marine	Annual and seasonal variations in open ocean and estuary

Subcategories (Level 2)	Monitoring Question	Vital Sign (Klamath)	Question Identified by	Comments
Water Quality	-turbidity/clarity	Turbidity	Marine, VSA	NTUs, light penetration in estuary, intertidal and subtidal zones, extent of turbid river plumes
	What is the status and what are the trends of sea surface and subsurface water temperature?	Sea surface and subsurface water temperature	Marine	Annual and seasonal variations of water samples in open ocean
	What is the status and what are the trends of dissolved oxygen in estuarine ecosystems?	Dissolved oxygen	RNSP, Marine	Annual and seasonal variations of water samples in estuary
	What are the effects of upstream management on estuaries (dams, flow regulation, water quality)?	Water temperature (estuary)	Marine	Annual and seasonal variations of water samples in estuary
		Chlorophyll ą	Marine	Annual and seasonal variations of water samples in estuary
		Coliform bacteria	Marine	Annual and seasonal variations of water samples in estuary
		Herbicides associated with forestry application	Marine	Annual and seasonal variations of water samples in estuary
	What are the effects of upstream management on estuaries (land use)?	Dissolved oxygen (estuary)	Marine	Annual and seasonal variations in estuary

Priority Water Quality Vital Signs Associated with Monitoring Questions

In October 2004 the Klamath Network began the detailed assessment and refinement (i.e., narrowing) of the general water quality monitoring questions and vital signs identified during the May 2004 workshops. The process was initiated by sending an Aquatic Resources and Water Quality Questionnaire (see Attachment II) to the Chief of Resources Management of each park unit. Park-specific information was sought in five basic categories: (1) identification of aquatic resources within park unit boundaries (i.e., marine, estuarine, lotic, lentic, palustrine, ice caves, and geothermal/hydrothermal); (2) a list of water bodies of particular importance or interest to the park unit management; (3) a list of past and current water quality monitoring efforts; (4) a list of water resource management and/or land use issues that impact resources from either within or outside each park unit; and (5) qualification of the level of knowledge and experience of park unit staff in monitoring water quality. All park units except ORCA were able to complete and return the questionnaire. Answers to the questionnaire categories were summarized into preliminary park-specific Vital Signs Tables that included columns for: (1) Aquatic Resource; (2) Potential Resource Stressors; (3) Potential Indicators of Stress; (4) Potential Monitoring Options; and (5) Stressor Priority. (The Oregon Caves Vital Signs Table was completed at the December 1, 2004 scoping session described below.)

The preliminary Vital Signs Tables were presented to representatives of each park unit at the Klamath Network Inventory and Monitoring Program Board of Directors Meeting (FY05) in Ashland, Oregon, December 1, 2004. A Water Quality Vital Signs Scoping Session was held in the afternoon at which time the Vital Signs Tables were reviewed and refined. Session participants (Table 13) were separated into three working groups: (1) Crater Lake and Lassen; (2) Lava Beds and Redwoods; (3) Oregon caves and Whiskeytown. The objectives of the small groups were, for each park unit, to: (1) identify specific water quality vital signs, ecosystem stressors associated with each vital sign, and associated monitoring options; and (2) prioritize aquatic resource vital signs. Final park-specific Vital Signs Tables were then developed based on feedback from the small groups (Tables 14-20).

TABLE 13: PARTICIPANTS AT THE NPS KLAMATH NETWORK WATER QUALITY VITAL SIGNS SCOPING MEETING, ASHLAND, OREGON, DECEMBER 1, 2004

Participant	Affiliation
David Anderson	RNSP
Jon Arnold	LAVO
Larry Bancroft	CRLA
Mac Brock	CRLA
Mark Buktenica	CRLA
Chris Currens	USGS WERC
Paul DePrey	WHIS
Scott Girdner	CRLA
David Hays	LABE
Robert Hoffman	USGS FRESC
Terry Hofstra	RNSP
Louise Johnson	LAVO
David Larson	LABE
Mary Ann Madej	USGS WERC
Tom Marquette	RNSP
Brian Rasmussen	WHIS
John Roth	ORCA
Howard Sakai	RNSP
Robert Truitt	KLMN

The Vital Signs Tables created during this process include monitoring options useful in detecting potential resource change due to stress of natural or anthropogenic origin. These suggested options are not intended as a complete list of potential monitoring procedures useful for detecting ecosystem change, and the list of options can be amended as necessary during future program assessments. In addition to these options, several field measured parameters will be required as part of any monitoring program. These required parameters include: (1) water temperature; (2) specific conductance (as well as salinity in marine systems); (3) pH; and (4) dissolved oxygen. At flowing sites, some measure of qualitative flow will be required, and an estimate of water body stage or level will be required at non-flowing/still freshwater sites. Additional required parameters at marine sites include tidal stage and estimated wave height. Guidance concerning these required parameters is available in the National Park Service Water Resources Division draft document titled "Vital Signs Long-term Aquatic Monitoring Projects: Part C, Draft Guidance on WRD Required and Other Field Parameter Measurements, General Monitoring Methods and some Design Considerations in Preparation of a Detailed Study Plan (August 2003)." This document is available on the National Park Service Inventory and Monitoring Program website at: http://science.nature.nps.gov/im/monitor/protocols/wqPartC.doc.

C. PARK-LEVEL VITAL SIGNS TABLES

Crater Lake National Park (CRLA)

Crater Lake aquatic resources occur within and outside of the Mt. Mazama caldera. Crater Lake is the focus of most park visitors, and a long-term monitoring program of lake and inner-caldera streams and springs water quality has been active since June, 1983. Geothermal sites deep in Crater Lake are also identified as an important resource within the caldera. Freshwater resources outside of the caldera include: (1) relatively small and shallow ponds, lakes, and wetlands; (2) Sphagnum Bog Research Natural Area; and (3) numerous streams and springs. Vital Signs for Crater Lake, inner-caldera streams and springs, and lentic systems outside of the caldera, in order of priority, are: (1) climate change (e.g., temperature and precipitation regimes); (2) presence and extent of native/ introduced (invasive) aquatic biota; (3) atmospheric deposition of nutrients and pollutants; and (4) visitor use impacts - recreation and motorized boat use on Crater Lake. Vital Signs for perennial streams and springs outside of the caldera, in order of priority, are: (1) presence and extent of native/introduced (invasive) aquatic biota; (2) atmospheric deposition of nutrients and pollutants; and (3) land and non-recreational human use impacts – park operations. Cattle trespass is identified as a potential vital sign of Sphagnum Bog RNA. There is also concern that geothermal exploration near the CRLA boundary could negatively impact geothermal sites within the caldera. A detailed summary of Crater Lake aquatic resource vital signs, potential stress indicators, and associated monitoring options is presented in Table 14A-D.

Lassen Volcanic National Park (LAVO)

Aquatic resources in Lassen can be grouped into two categories: (1) ponds and lakes, wetlands, and streams; and (2) geothermal/hydrothermal features such as hot springs and streams, fumaroles, and mudpots. Ponds and lakes, wetlands, and streams are grouped together because the same stressors impact each resource-type. Vital signs of lentic and lotic resources, in order of priority, are: (1) climate change (e.g., temperature and precipitation regimes); (2) atmospheric deposition of nutrients and pollutants (3) presence and extent of native/introduced (invasive) aquatic biota (esp., non-native trout and charr); and (4) Visitor use impacts - recreational (e.g., hiking, backpacking and camping) and non-recreational (park operations, e.g., parking lot and road maintenance, and various construction projects). Visitor use impacts - recreational is identified as the major vital sign of geothermal/ hydrothermal resources in Lassen. Geothermal/hydrothermal resources have been and continue to be monitored as part of the USGS Volcano Monitoring Program. A detailed summary of Lassen aquatic resource vital signs, potential stress indicators, and associated monitoring options is presented in Table 15A-B.

Lava Beds National Monument (LABE)

No permanent surface freshwater resources exist within the boundaries of Lava Beds; however, a few intermittent-ephemeral ponds occur. Aquatic resources in Lava Beds occur primarily as ice and water in permanent ice caves and seasonal wet caves, and groundwater. Stressors of these resources include reduced precipitation associated with increased air temperatures and evaporation, and decreased relative humidity in caves. These changes could subsequently decrease the amount of ice in caves and the availability of water for Lava Beds biota. Since water is a precious commodity in Lava Beds, any change in water availability due either to stress of natural or anthropogenic origin could be quite detrimental to Lava Beds ecosystems. Stressors of anthropogenic origin include impacts due to climate change, geothermal exploration, agricultural land use (esp., irrigation and use of chemicals), and timber harvest just outside of the Lava Beds boundary. The priority vital signs for Lava Beds aquatic resources are: (1) climate change (e.g., temperature and precipitation regimes); (2) groundwater; (3) agricultural chemicals in cave ice and water; and (4) extent of impact on water quality of activities associated with park unit development, visitor use, and water runoff from roads. A detailed summary of Lava Beds aquatic resource vital signs, potential stress indicators, and associated monitoring options is presented in Table 16A-D.

Oregon Caves National Monument (ORCA)

The aquatic resources of Oregon Caves consist of an in-cave stream and springs, and surface streams. Stressors to in-cave resources include: (1) impacts due to climate change; (2) human actions that modify the cave environment, especially modification of cave openings; (3) visitor use impairments due to the introduction of inorganic and organic contaminants; (4) manipulation of the cave environment through the introduction of artificial light; (5) subsequent increase in algal growth in the cave and the introduction of contaminants (e.g., bleach) during cave algae control efforts; and (6) decrease in the amount and availability of in-cave water due to withdrawal of water from surface streams for fire suppression. Surface streams are susceptible to the effects of climate change, catastrophic fire, and debris flows. Cave Creek, a primary stream flowing through Oregon Caves, is also particularly susceptible to contamination by drain field leaching. The presence of grazing cattle near Oregon Caves' streams may also contribute to the potential contamination of the Oregon Caves water supply. The priority vital signs of Oregon Caves' aquatic resources are: (1) drain field contamination of Cave Creek; (2) cave environment relative to the modified cave opening; (3) visitor usage; and (4) cave environment relative to introduction of artificial light. A detailed summary of Oregon Caves' aquatic resource vital signs, potential stress indicators, and associated monitoring options is presented in Table 17A-B.

Redwood National and State Parks (RNSP)

Freshwater and marine aquatic resources are present in Redwoods. Freshwater resources include impaired streams (i.e., Redwood Creek and Klamath River), numerous unimpaired streams (e.g., Godwood Creek, Hayes Creek, Little Lost Man Creek, Mill Creek, Upper Prairie Creek, and Smith River), and small ponds and wetlands. Marine resources include the intertidal and offshore coastal zones, the estuaries of Redwood Creek and Klamath River, several lagoons (i.e., Espa, Lagoon Creek, and Freshwater), and coastal ponds at Enderts Beach.

Redwood Creek and Klamath River are listed under section 303(d) of the Clean Water Act for high water temperature and unacceptable levels of sedimentation and nutrients (see Table 1). Additional stressors include: (1) the presence of introduced invasive species; (2) upstream land use activities (e.g., timber harvest, use of herbicides, and controlled burns); (3) highway- and levee-related perturbations (e.g., road and culvert failures, runoff and toxic spills, and levee maintenance); (4) contamination from septic system leaching and illegal garbage/trash dumping; and (5) riparian/bank disturbance associated with recreational fishing. Park watershed rehabilitation activities and in-channel gravel extraction additionally impact Redwood Creek. The unimpaired sites will be useful for determining baseline water quality characteristics and range of natural variation of Redwoods streams. Immediate stressors to these systems include runoff and toxic spills from State Highway 229 and U.S. Highway 101 and groundwater draw-down at the Mill Creek Campground.

Stressors affecting marine resources vary according to resource-type. Intertidal and offshore coastal areas can be affected by: (1) climate change and climatic events such as El Niño; (2) offshore oil spills and the dumping of garbage/plastics; (3) reduced downstream sediment transport due to the presence of Klamath River dams; and (4) commercial fishing of smelt and rockfish. Estuaries are affected by changes in hydrology, increased water temperatures, runoff and spills from US Highway 101, and the removal and illegal cutting of wood. The Redwood Creek estuary is also impacted by human activities that degrade riparian habitat, and by dairy farming and flood control projects. Lagoons and coastal ponds can be stressed by human-related perturbations associated with road drainage and maintenance, park development, and potential toxic contamination from an old mill site. The presence or possible introduction of various non-native invasive species (e.g., algae and invertebrates, European beachgrass, and numerous other exotic plants, etc.) can affect all marine resource-types.

The priority vital signs for Redwoods freshwater resources are: (1) 303(d) listed streams (Redwood Creek and Klamath River); (2) upstream land cover and use; (3) recreational fishing; and (4) presence and extent of introduced exotic biota. The priority vital signs for Redwoods marine resources are: (1) commercial fishing; (2) extent of impacts on water quality due to human activities related to flood control and dairy farming (Redwood Creek only); (3) presence and extent of invasive biota; and (4) presence and extent of pollutants (e.g., oil) and garbage/plastics offshore and on beaches. A detailed summary of Redwoods aquatic resource vital signs, potential stress indicators, and associated monitoring options is presented in Tables 18A-C and 19A-C.

Whiskeytown National Recreation Area (WHIS)

Whiskeytown aquatic resources include Whiskeytown Lake, perennial streams, mineral springs, permanent and intermittent small-shallow ponds, and marshes. Water related activities (e.g., boating, sailing, water skiing, kayaking, swimming, fishing, etc.) are the primary recreational focus of visitors to Whiskeytown Lake and are potential stressors of reservoir water quality. Additional stressors related to human activity include: park unit sewage treatment and wastewater discharge by surrounding communities; marijuana farming and heavy metals contamination from past mining operations on the upstream sections of reservoir tributaries; and water level fluctuations caused by reservoir dam operations. As is the case with many large water bodies in the western USA, the introduction of non-native invasive floral and faunal species impact the native biota of Whiskeytown Lake. Impacted perennial streams have been affected by human-related activity (e.g., past mining operations; treatment and disposal of human waste; marijuana farming; recreation; deteriorating abandoned logging roads; gravel injection and waste rock disposal; prescribed/natural fires and related activities; floods; and introduced non-native invasive biota). The unimpaired perennial streams in Whiskeytown can be used to determine baseline lotic water quality conditions and range of natural variation. However, these streams can also be affected by perturbations of natural and anthropogenic origin. Whiskeytown also contains a complex of mineral springs that supports a small, indigenous population of Howell's alkali grass (*Puccinellia howellii*), which is listed by the California Native Plant Society as rare and endangered. Stressors to this resource include: (1) littering and garbage dumping, trampling, and off-road vehicle use); (2) change in hydrology; (3) State Highway 299 maintenance and contamination/pollution due to vehicle use and accidents; and (4) potential invasion by saltgrass (*Distichlis spicata*). Little is known about the various permanent and intermittent small-shallow ponds and marshes that occur in Whiskeytown. They, like the unimpaired perennial streams, are susceptible to various types of stress of natural and anthropogenic origin. The priority vital signs of Whiskeytown aquatic resources are: (1) extent of human impacts such as heavy metals contamination associated with from past mine operations and tailings; (2a) park unit sewage treatment and disposal; (2b) septic tanks, garbage/trash, and marijuana farming; and (3) extent and occurrence of natural and prescribed fire. A detailed summary of Whiskeytown aquatic resource vital signs, potential stress indicators, and associated monitoring options is presented in Table 20A-E.

TABLE 14: CRATER LAKE NATIONAL PARK VITAL SIGNS TABLES

A: Crater Lake and inner-caldera streams and springs; ponds, lakes and wetlands outside of caldera

Priority	Vital Sign	Potential Stress Indicators	Potential Monitoring Options
3	**Atmospheric deposition of nutrients and pollutants**	**Change in the concentrations of air-borne nutrients (esp., nitrogen and phosphorus) and pollutants in water samples**	**A. Continue Crater Lake Long-term Monitoring Program B. Quantify selected physical, chemical and biological characteristics of lentic systems outside of the caldera C. Wet/dry chemistry: (a) rain and snow precipitation; (b) snow core D. Measure pollutants of interest in tissue samples E. Rapid bioassessment of impact using aquatic macroinvertebrates as indicators**
2	**Presence and extent of native/ introduced (invasive) aquatic biota**	**Impacts such as change in the distributions, abundances, percent area occupied (PAO), and community organization and structure of native and introduced aquatic species**	**A. Quantify the distributions, abundances, and community organization and structure of native and introduced (invasive) aquatic biota**
4	**Visitor use impacts – recreational (e.g., hiking, back-packing, camping) on non-caldera sites and motorized boat use on Crater Lake**	**Change in rates of sedimentation, aquatic macroinvertebrate occurrence (species and community composition), shoreline/riparian impact, and presence of hydrocarbons**	**A. Quantify, map, and photo-archive shoreline condition of non-caldera sites B. Collect sediment cores to document historical and contemporary sedimentation rates C. Quantify macroinvertebrate species distribution and community composition in all aquatic habitats at each site and use rapid bioassessment methods to identify and quantify impact D. Measure chlorophyll-a concentration in phytoplankton and periphyton E. Analyze Crater Lake water for hydrocarbons**
1	**Climate change (e.g., temperature and precipitation regimes)**	**Change in parameters such as water temperature, precipitation, water-level, ozone, UVB radiation, etc.**	**A. Measure water temperature, precipitation, water-level, ozone, UVB radiation, etc.**

B: Sphagnum Bog Research Natural Area

Priority	Vital Sign	Potential Stress Indicators	Potential Monitoring Options
	All vital signs in 1A plus cattle trespass	**Change in the physical, chemical and biological characteristics of the bog**	**A. Quantify physical, chemical and biological characteristics, range of natural variation, and monitor for change**

TABLE 14: CRATER LAKE NATIONAL PARK VITAL SIGNS TABLES CONTINUED

C: Perennial streams and springs outside of the caldera.

Priority	Vital Sign	Potential Stress Indicators	Potential Monitoring Options
1	**Presence and extent of native/ introduced (invasive) aquatic biota**	**Change in the distributions, abundances, percent area occupied (PAO), and community organization and structure of native and introduced aquatic species**	**A. Quantify the distributions, abundances, community organization and structure of native and introduced (invasive) aquatic biota**
2	**Atmospheric deposition of nutrients and pollutants**	**Change in the concentrations of air-borne nutrients (esp., nitrogen and phosphorus) and pollutants in water samples**	**A. Quantify selected physical, chemical and biological characteristics of lotic systems B. Wet/dry chemistry: (a) rain and snow precipitation; (b) snow core C. Measure periphyton chlorophyll-a concentration D. Measure pollutants of interest in tissue samples E. Rapid bioassessment of impact using aquatic macroinvertebrates as indicators**
3	**Land and non-recreational human use impacts – Park operations (construction, road and parking lot maintenance)**	**Change in rates of sedimentation, aquatic macroinvertebrate occurrence (species and community composition), shoreline/riparian impact, increase in hydrocarbons and other pollutants related to construction activities, and parking lot and road maintenance**	**A. Collect sediment cores to determine historical and contemporary sedimentation rates B. Quantify species distribution and composition in all aquatic habitats C. Rapid bioassessment of impact using aquatic macroinvertebrates as indicators D. Analysis of stream water and runoff from parking lots and roads for hydrocarbons and other potential pollutants E. Measure periphyton chlorophyll-a concentration**

D: Subsurface geothermal sites in Crater Lake

Priority	Vital Sign	Potential Stress Indicators	Potential Monitoring Options
	Subsurface geothermal vents	**Change in chemistry, discharge, temperature, etc. due to geothermal exploration near Park boundary**	**Quantify baseline conditions and natural variation of chemistry, flow and discharge, temperature, bacteria, and other associated biota**

TABLE 15: LASSEN VOLCANIC NATIONAL PARK VITAL SIGNS TABLES

A: Ponds, lakes, wetlands and perennial streams

Priority	Vital Sign	Potential Stress Indicators	Potential Monitoring Options
2	**Atmospheric deposition of nutrients (esp., nitrogen and phosphorus) and pollutants**	**Change in the concentrations of nutrients and pollutants**	**A. Wet/dry chemistry: (a) rain and snow precipitation; (b) snow core** **B. Chemical analysis of water samples with emphasis on nutrients** **C. Tissue sample analysis to determine concentrations of pollutants** **D. Measure chlorophyll-a concentration in phytoplankton and periphyton** **E. Rapid bioassessment of impact using aquatic macroinvertebrates as indicators**
3	**Presence and extent of native/ introduced (invasive) aquatic biota**	**Change in the distributions, abundances, percent area occupied (PAO), and community organization and structure of native and introduced aquatic species**	**A. Quantify the distributions, abundances, and community organization and structure of native and introduced (invasive) aquatic biota**
4	**Visitor use impacts – recreational (e.g., hiking, backpacking, camping) and land and non-recreational human use impacts - Park operations (e.g., construction, road and parking lot maintenance)**	**Change in sedimentation rates, aquatic macroinvertebrate occurrence (species and community composition), shoreline/riparian impact, and increase of pollutants**	**A. Collect sediment cores to determine historical and contemporary sedimentation rates** **B. Quantify macroinvertebrate species distribution and community composition in all aquatic habitats** **C. Rapid bioassessment of impact using aquatic macroinvertebrates as indicators** **D. Analysis of stream water and runoff from parking lots and roads for hydrocarbons and other pollutants** **E. Measure chlorophyll-a concentration in phytoplankton and periphyton**
1	**Climate change (e.g., temperature and precipitation regimes)**	**Change in parameters such as water temperature, precipitation, water-level, ozone, UVB radiation, etc.**	**A. Measure precipitation, water temperature, water-level, flow rates, UVB radiation, ozone, etc.**

TABLE 15: LASSEN VOLCANIC NATIONAL PARK VITAL SIGNS TABLES CONTINUED

B: Geothermal/hydrothermal

Priority	Vital Sign	Potential Stress Indicators	Potential Monitoring Options
	Visitor use impacts - recreational	**Change in measured parameters (e.g., water chemistry and temperature, flow, discharge, etc.)**	**A. Continue on-going monitoring as part of USGS Volcano Monitoring Program**

TABLE 16: LAVA BEDS NATIONAL MONUMENT VITAL SIGNS TABLES

A: Permanent ice caves

Priority	Vital Sign	Potential Stress Indicators	Potential Monitoring Options
1	Climate change (e.g., temperature and precipitation regimes) In cave air currents and movement	Change in air temperature and relative humidity in caves	A. Identify and quantify ice sources B. Measure air temperature, relative humidity, and ice-levels in caves C. Chemical analysis of ice samples for basic water quality and concentrations of hydrocarbons and agricultural chemicals of interest
3	Agricultural chemicals in cave ice and water	Change in ice chemistry and ice levels in caves	
4	Extent of impact on water quality of activities associated with park unit development, visitor usage, and water runoff from roads	Increase in the concentrations of agricultural chemicals and hydrocarbons in ice and water in caves	

B: Seasonal ice caves

Priority	Vital Sign	Potential Stress Indicators	Potential Monitoring Options
	Physical, chemical and biological characteristics of caves	Change in characteristics of caves due to nearby geothermal exploration and agricultural activities	A. Measure air temperature, relative humidity, and available water in caves B. Identify biota residing in or using caves and quantify resident community organization and structure and rates of use by non-resident biota C. Quantify physical characteristics of caves and quality of available water (including concentrations of agricultural chemicals of interest)

C: Intermittent ephemeral ponds

Priority	Vital Sign	Potential Stress Indicators	Potential Monitoring Options
	Climate change (e.g., temperature and precipitation regimes)	Change in the timing, longevity and physical characteristics of ponds	A. Identify and inventory ponds B. Quiantify timing, longevity and physical characteristics of ponds C. Quantify water quality (esp., chemistry and biology)

D: Groundwater

Priority	Vital Sign	Potential Stress Indicators	Potential Monitoring Options
2	Groundwater	Change in the availability, depth and quality of groundwater due to nearby geothermal exploration, agricultural activities (esp., irrigation and chemical use) and timber harvest	A. Quantify the physical and chemical characteristics of groundwater throughout the Park

TABLE 17: OREGON CAVES NATIONAL MONUMENT VITAL SIGNS TABLES

A: In-cave stream and springs

Priority	Vital Sign	Potential Stress Indicators	Potential Monitoring Options
2	**Cave environment** **Climate change (e.g., temperature and precipitation regimes)**	**Changes in cave environment (including air temperature, evaporation rates, relative humidity and concentrations of total carbonates, chloride and total dissolved solids) due to modification of cave opening**	**A. Measure air temperature, evaporation, relative humidity and concentrations of total carbonates, chloride and total dissolved solids** **B. Identify and quantify the abundance of cave-adapted biota** **C. Quantify timing and extent of snowmelt** **D. Monitor calcite solubility**
3	**Visitor use impacts - recreation**	**Change in the presence and amount of litter and organic contaminants (e.g., lint)**	**A. Identify and quantify presence of litter and organic contaminants and monitor for change**
4	**Cave environment (esp., light)**	**Effect of the timing and duration of artificial light on cave-adapted biota and potential increase in abundance of light-adapted biota**	**A. Measure timing and duration of artificial light** **B. Identify and quantify the presence and abundance of cave- and light-adapted biota**
	In-cave algae (and its control)	**Increase in the presence and concentrations of sodium hypochlorite and hydrogen peroxide in water samples**	**A. Measure presence and concentrations of sodium hypochlorite and hydrogen peroxide in water samples**
	Use of surface water for fire suppression	**Change in flow rates and availability (i.e., quantity) of water in cave stream and springs**	**A. Measure flow and discharge of cave stream and springs**

B: Perennial surface streams

Priority	Vital Sign	Potential Stress Indicators	Potential Monitoring Options
1	**Drain field contamination of Cave Creek**	**Increase in nitrate, orthophosphate and fecal coliform concentrations, and changes in the presence of aquatic macroinvertebrate species and community composition**	**A. Measure nitrate, orthophosphate and fecal coliform concentrations in water samples** **B. Identify and quantify macroinvertebrate species distribution and community composition in Cave Creek; use rapid bioassessment methods to identify change**
	Debris flows and catastrophic fire	**Increase in bank and channel erosion, sediment input and loss of water clarity**	**A. Measure channel longitudinal profile, frequency and distribution of upwelling zones, flow and discharge rates, bedload, and concentrations of suspended and total dissolved solids**
	Port Orford cedar root rot	**Presence of the fungus *Phytopthera lateralis* and dead trees**	**A. Identify, quantify, and monitor vegetation patterns and number and distribution of dead trees**
	Climate change	**Change in the timing, depth and duration of snow pack and quantity of surface water**	**A. Measure the timing, depth and duration of snow pack** **B. Measure flow and discharge rates of streams**
	Cattle grazing near water supply	**Presence of *Giardia* and *Cryptosporidium* in water supply**	**A. Monitor for presence of *Giardia* and *Cryptosporidium* in samples from water supply**

TABLE 18: REDWOOD NATIONAL AND STATE PARKS VITAL SIGNS TABLES (FRESHWATER)

A: Impaired perennial streams (Redwood Creek and Klamath River)

Priority	Vital Sign	Potential Stress Indicators	Potential Monitoring Options
1	303(d) listed for high water temperatures, nutrients and sedimentation/siltation Presence and extent of invasive aquatic biota (i.e., catfish)	Change in the physical, chemical, and biological characteristics of streams including: (1) water temperature, (2) sedimentation rate and clarity, (3) flow and discharge rates, (4) nitrogen concentration, (5) primary productivity, (6) presence and abundance of native and invasive biota, (7) presence and concentrations of herbicides, (8) presence of highway and motor vehicle derived contaminants, (9) presence of bacterial indicators of fecal contamination; related to timber harvest, herbicide application, removal and lack of woody debris, and controlled burns	A. Rapid bioassessment of impact using aquatic macroinvertebrates as indicators B. Water temperature monitoring C. Measure suspended sediment and turbidity, bedload, flow and discharge D. Mainstem cross-sections E. Quantify status and trends of native and invasive biota (esp., anadromous fish, catfish, amphibians) F. Measure nitrogen concentration and bacterial indicators of fecal contamination near suspected septic drain field effluent G. Quantify status and trends of water chemistry and assessment of presence of highway and motor vehicle derived contaminants
2	Upstream land cover and use Condition of roads (i.e., road failures and Hwy 101 bypass runoff and spills Private septic systems and illegal dumping of garbage and trash Park watershed rehabilitation activities and gravel removal (Redwood Creek only)		
3	Recreational fishing Levee maintenance		

B: Unimpaired perennial streams (e.g., Godwood, Upper Prairie, and Hayes Creeks; Smith River)

Priority	Vital Sign	Potential Stress Indicators	Potential Monitoring Options
	Useful as reference sites for baseline water quality data and determination of range of variability Groundwater draw-down at Mill Creek Campground Hwy 199 and 299 runoff and spills	Change in the physical, chemical, and biological characteristics of streams including: (1) water temperature, (2) sedimentation rate and clarity, (3) flow and discharge rates, (4) nitrogen concentration, (5) primary productivity, (6) presence and abundance of native biota, (7) occurrence of invasive biota (8) salmonid spawning activity and recruitment, (9) abundance of large woody debris	A. Quantify water temperature, sediment, turbidity, bedload, flow and discharge B. Rapid bioassessment of impact using aquatic macroinvertebrates, fish and freshwater mussels as indicators C. Sample large woody debris D. Quantify status of anadromous and resident fish, and native amphibians E. Quantify fish carcasses and redds F. Water table monitoring G. Quantify selected water quality parameters

TABLE 18: REDWOOD NATIONAL AND STATE PARKS VITAL SIGNS TABLES (FRESHWATER CONTINUED)

C: Freshwater ponds and wetlands (Marshall Pond, small ponds at Gold Bluffs Beach)

Priority	Vital Sign	Potential Stress Indicators	Potential Monitoring Options
4	**Atmospheric deposition of nutrients and other pollutants, and air quality** **Presence and extent of introduced exotic plants, bullfrogs, and fish** **Former mill site**	**Change in the physical, chemical and biological characteristics of ponds and wetlands beyond natural variation**	**A. Quantify water quality conditions and range of variation** **B. Quantify community composition of aquatic biota and determine extent of presence of introduced biota** **C. Quantify trends of native amphibians** **D. Rapid bioassessment of impact using aquatic macroinvertebrates as indicators**

TABLE 19: REDWOOD NATIONAL AND STATE PARKS VITAL SIGNS TABLES (MARINE)

A: Intertidal and offshore coastal

Priority	Vital Sign	Potential Stress Indicators	Potential Monitoring Options
	Climate change and events (e.g., El Niño; temperature and precipitation regimes)	**Change in ocean processes (e.g., upwelling, wave action, nearshore currents), water and air temperature, ozone, UVB radiation**	**A. Quantify trends of wave action, nearshore currents and upwelling, and monitor for change beyond natural range of variation** **B. Measure water and air temperatures, ozone, UVB radiation** **C. Quantify trends of seabirds/shorebirds and coastal invertebrates and use indicator species for rapid bioassessment of impacts** **D. Quantify distribution of sediment composition and particle size, and trends of sediment flux** **E. Quantify trends of smelt and rockfish populations** **F. Status and trends of ocean and tidal water chemistry** **G. Quantify trends of native and introduced/ invasive biota**
4	**Presence and extent of pollutants (e.g., oil) and garbage/plastics offshore and on beaches**	**Catastrophic mortality of shorebirds and marine biota**	
3	**Presence and extent of invasive biota (e.g., European beachgrass, invertebrates, algae, etc.)**	**Increase in presence of invasive species concordant with decline in native species**	
	Sediment flux from Klamath River dams		
1	**Commercial fishing activities (e.g., smelt, nearshore rockfish fishery**	**Change in smelt and rockfish abundances**	

B: Lagoons (Espa, Lagoon Creek, Enderts Beach pond)

Priority	Vital Sign	Potential Stress Indicators	Potential Monitoring Options
	Sedimentation due to roads, culverts, road drainage and Park development	**Increase in sedimentation rate and decrease in water-level and depth**	**A. Measure water-level and depth** **B. Quantify plant community composition and monitor for change** **C. Quantify trends of water quality and presence of toxins** **D. Quantify trends of native and introduced/invasive biota; also trends of amphibians (primarily anurans)**
	Water contamination from old mill site	**Presence of toxins in water and tissue samples**	
	Presence and extent of introduced/invasive species (e.g., fish stocking and aquatic weeds)	**Presence of introduced/invasive species with concordant decrease in native biota**	

TABLE 19: REDWOOD NATIONAL AND STATE PARKS VITAL SIGNS TABLES (MARINE CONTINUED)

C: Estuaries (Redwood Creek, Klamath River)

Priority	Vital Sign	Potential Stress Indicators	Potential Monitoring Options
2	**Presence and extent of invasive species/exotic grasses (e.g., canary grass)** **Hydrological changes and increased water temperatures** **Extent of impacts on water quality due to human impacts related to flood control and dairy farming (Redwood Creek only)** **Extent of illegal woodcutting** **Hwy 101 bypass runoff and spills**	**Increase in the presence of invasive species/exotic grasses and decrease in native species (including threatened and endangered species)** **Continued degradation of riparian habitat** **Change in sediment deposition, water temperature and flow, and distribution of large woody debris** **Presence of bacterial indicators of fecal contamination (Redwood Creek only)** **Presence of highway and motor vehicle derived contaminants**	**A. Sample sediment and quantify trends of sediment deposition** **B. Quantify extent of Canary grass** **C. Quantify selected riparian habitat parameters** **D. Sample large woody debris** **E. Water temperature and flow monitoring** **F. General water quality monitoring (esp., bacterial indicators of fecal contamination, Redwood Creek only)** **G. Quantify trends of native and introduced/invasive species** **H. Determine the presence of and quantify trends of highway and motor vehicle derived contaminants**

TABLE 20: WHISKEYTOWN NATIONAL RECREATION AREA VITAL SIGNS TABLES

A: Whiskeytown Lake (Reservoir)

Priority	Vital Sign	Potential Stress Indicators	Potential Monitoring Options
	Visitor use -recreation: terrestrial, boating, swimming and other water-related activities Extent of upstream marijuana farming	Beach and shoreline erosion Increase in: bacterial indicators of fecal contamination, nitrogen and phosphorus due to fertilizer use, herbicides and pesticides, and petroleum-based contaminants	A. Quantify trends of selected water quality parameters (esp., nutrients and hydrocarbons) B. Measure concentrations of fecal indicator bacteria C. Measure concentrations of herbicides and pesticides in tissue samples (highest trophic-level possible) D. Document presence of petroleum-based discharges on water surface E. Measure indicators of beach/shoreline erosion (vegetation and trail impact mapping, photo-archive, sediment cores)
2a	Park sewage treatment and waste water discharge of surrounding communities	Increase in concentrations of nitrate and phosphorus and presence of bacterial indicators of fecal contamination	A. Measure nitrate and phosphorus concentrations near potential discharge sites and test for fecal indicator bacteria
	Presence and extent of native/ introduced (invasive) aquatic biota	Increase in occurrence and abundance of invasive species	A. Quantify trends of invasive species: presence, abundance, rates of recruitment and mortality
	Water level fluctuations due to reservoir operations and evaporation	Increase in nearshore sedimentation, change in beach profiles and aquatic macroinvertebrate species presence and community organization	A. Measure total dissolved solids and rates of sedimentation B. Photo-archive and map beach profiles C. Monitor reservoir water-level D. Quantify macroinvertebrates species distribution and community organization in all nearshore habitats; assess using rapid bioassessment methods
	Presence of the dam	Disruption of native salmonid passage into upper reaches of reservoir tributaries	A. Measure presence and abundance of salmonids below and above dam
	Concentrations of heavy metals	Presence and increase in concentrations of heavy metals in reservoir water	A. Measure concentrations of heavy metals (e.g., mercury, cadmium, nickel, iron, and arsenic) in tissue samples (highest trophic-level possible)

TABLE 20: WHISKEYTOWN NATIONAL RECREATION AREA VITAL SIGNS TABLES (CONTINUED)

B: Impaired perennial streams

Priority	Vital Sign	Potential Stress Indicators	Potential Monitoring Options
1 2b	**Human impacts including:** - mine operations and tailings - septic tanks, garbage, trash and marijuana farming - visitor usage (e.g., horses and mountain bikes)	Increase in concentrations of heavy metals, nitrogen, phosphorus, herbicides and pesticides; presence of fecal indicator bacteria; change in sedimentation rate, water clarity and temperature; soil compaction leading to lower infiltration rates; increase in the presence of litter and trash	A. Quantify trends of selected water quality parameters (esp., nitrogen, phosphorus. pH, conductivity, total dissolved solids) B. Measure concentrations of fecal indicator bacteria C. Monitor for the presence of oil products and other hazardous wastes, litter and trash D. Measure sedimentation rate, turbidity, bedload, water temperature E. Photo-archive and map shoreline soil compaction F. Quantify macroinvertebrate species distribution and community organization in all aquatic habitats; assess using rapid bioassessment methods G. Measure heavy metals concentrations in tissue samples
	Gravel injection; sedimentation due to roads and deteriorating condition of abandoned logging roads; waste rock disposal	Change in sedimentation rates, channel morphology, flow regime, biota, and metals content	A. Measure suspended and total dissolved solids, turbidity, bedload, water temperature and pH B. Measure channel morphology (e.g., pool/riffle sequence, channel width/depth profiles) C. Measure heavy metals concentrations in tissue samples (highest trophic-level possible)
	Species of concern and presence and extent of invasive species	Decline in species of concern	A. Quantify trends of species of concern and invasive species: presence, abundance, rates of recruitment and mortality B. Quantify condition of habitat quality for species of concern
3	Fire occurrence and extent: prescribed burns, natural wildfires, construction of fuel breaks, other fire-related activities	Change in physical, chemical, and biological characteristics of streams	A. Measure sedimentation rate, turbidity, bedload, water temperature B. Measure channel morphology (e.g., pool/riffle sequence, channel width/depth profiles) C. Measure water chemistry (esp., nitrogen) D. Rapid bioassessment of impact using aquatic macroinvertebrates as indicators
	Floods (natural and due to water release from dam)	Change in water temperature and concentrations of heavy metals	A. Measure water temperature and heavy metal concentrations

C: Unimpaired perennial streams

Priority	Vital Sign	Potential Stress Indicators	Potential Monitoring Options
	Impacts of natural and anthropogenic origin	Change in physical, chemical and biological characteristics of streams beyond range of natural variation	A. Quantify selected characteristics of streams B. Quantify trends of species of concern and invasive species : presence, abundance, rates of recruitment and mortality

TABLE 20: WHISKEYTOWN NATIONAL RECREATION AREA VITAL SIGNS TABLES (CONTINUED)

D: Complex of mineral springs and Howell's alkali grass (*Puccinellia howellii*)

Priority	Vital Sign	Potential Stress Indicators	Potential Monitoring Options
	Hwy 299: accidents, construction, maintenance, hydrocarbon pollution, and other contaminants **Visitor use: litter and garbage dumping, vehicle parking and off-road use, trampling** **Hydrology** **Invasion and exclusion by salt-grass (*Distichlis spicata*)**	**Decline in already small population size of indigenous Howell's alkali grass**	**A. Quantify selected characteristics of the Howell's alkali grass population and saltgrass (esp., inventory, map, and photo-archive)** **B. Monitor hydrology of springs** **C. Quantify visitor use and types of pollution; monitor for change**

E: Permanent small-shallow ponds, intermittent ephemeral ponds, marshes

Priority	Vital Sign	Potential Stress Indicators	Potential Monitoring Options
	Impacts of natural and anthropogenic origin	**Change in the physical, chemical and biological characteristics of these resources beyond the range of natural variation**	**A. Quantify selected physical, chemical, and biological characteristics**

D. NETWORK-LEVEL VITAL SIGNS ASSESSMENT

Priority Aquatic Resource Monitoring Questions

Two of the 10 most important network-wide vital signs monitoring questions identified at a Klamath Network meeting in Redding, California, April 27-28, 2005, were aquatic resource-focused. The top 10 monitoring questions (out of 172 monitoring questions and associated vital signs) were selected based on the total rating assigned to them by the individuals who participated in the Klamath Network vital signs/monitoring question rating process.

The two aquatic resources monitoring questions are:

1) What is the status and what are the trends of surface waters and pollutants, and
2) What is the status and what are the trends in structure, function and composition of locally limited (i.e., focal) aquatic communities?

The vital signs for each question are, respectively:

1) Water quality characteristics of surface and subterranean freshwater resources, and marine resources; and
2) Aquatic biota and communities.

Aquatic Resource Vital Signs Categories

Five general vital signs categories (Table 21) were identified from the park unit Vital Signs Tables (Tables 14-20, pages 61-73) as potentially affecting Klamath Network park unit freshwater resources: (1) atmospheric deposition of nutrients (e.g., nitrogen and phosphorus) and pollutants (e.g., mercury, persistent organics flame retardants, water-repellent coatings, etc.); (2) presence and extent of native/introduced (invasive) aquatic biota (e.g., bullfrogs, exotic fish, invertebrates, algae, etc.); (3) climate change (e.g., changes in air and water temperature regimes and the timing and longevity of precipitation events and snow pack, etc.); (4) visitor use impacts - recreational; and (5) land and non-recreational human use impacts. Visitor use impacts - recreational was divided into four types of impact subcategories ranging from general impacts in the more developed and maintained areas in park units to backcountry impacts caused by activities such as hiking, backpacking, and camping. The land and non-recreational human use impacts category was divided into 15 types of impacts subcategories representing activities that include road construction and maintenance, treatment and deposition of human waste, dam operation and maintenance, agriculture, and past and present resource extraction operations (e.g., mining, timber harvest, geothermal exploration). A relatively high number of vital signs categories and subcategories (Table 22) were associated with lentic (12 of 22; 55%), lotic (15 of 22; 68%), and unique water resources (10 of 22; (45%). Lotic systems were also identified as especially associated with land and non-recreational human use impact subcategories (i.e., 10 of 15 compared to 6 of 15 for lentic and unique water resources; Table 22). The vital sign categories and subcategories associated with cave water resources (e.g., ice, streams and springs) were climate change, visitor use, manipulation of the cave environment, park unit operations and nearby agricultural activities, and activities associated with fire suppression. Geothermal/hydrothermal resources were identified as being generally affected by visitor use and geothermal exploration near, yet beyond park unit boundaries.

The three Redwoods marine resource-types were identified as being variously associated with three of the five general vital signs categories: (1) climate change; (2) presence and extent of native/introduced (invasive) aquatic biota; and (3) land and non-recreational human use impacts (Table 23). The land and non-recreational human use impacts category was divided into nine types of impact subcategories. Climate change was identified as only associated with the intertidal/coastal offshore resource-type, whereas the presence and extent of native/introduced (invasive) aquatic biota was an important vital sign for lagoons and estuaries. Each resource-type was identified as being susceptible to two or more types of land and non-recreational human use impacts.

TABLE 21: GENERAL VITAL SIGNS CATEGORIES AND SUBCATEGORIES AND THEIR APPLICABILITY IN EACH KLAMATH NETWORK PARK UNIT

Vital Sign	CRLA	LAVO	LABE	ORCA	RNSP	WHIS
1. Atmospheric deposition of nutrients and pollutants	X	X			X	X
2. Presence & extent of native/introduced (invasive) aquatic biota	X	X			X	X
3. Climate change (e.g., temperature & precipitation regimes)	X	X	X	X		X
4. Visitor use impacts – recreational						
A. General impacts		X	X	X		
B. Hiking, backpacking, camping, horses, mountain bicycles	X	X				X
C. Motorized boats and boat-related activities	X					X
D. Swimming, fishing, etc.					X	X
5. Land & non-recreational human use impacts						
A. Park operations (construction, development, parking lot/road and levee maintenance)	X	X	X	X	X	X
B. Roads: construction, maintenance, failure, culverts, runoff and spills	X	X	X		X	X
C. Past mining operations/heavy metals						X
D. Dam operations, water-level and sediment flux						X
E. Sewage treatment, wastewater discharge, septic and drain field contamination				X	X	X
F. 303(d) listed water bodies					X	
G. Former mill site and operations					X	
H. Fire: wild and prescribed; suppression				X	X	X
I. Timber harvest and operations (including herbicide application)			X		X	
J. Agriculture: contamination by fertilizers, herbicides and pesticides; irrigation			X			X
K. Manipulation of cave environment (esp., light and control of algae)				X		
L. Geothermal exploration and activities near Park boundary	X		X			
M. Litter and garbage dumping					X	X
N. Vehicle parking and off-road use						X
O. Impacts associated with cattle (grazing and trespass)	X			X		

TABLE 22: GENERAL VITAL SIGNS CATEGORIES AND SUBCATEGORIES AND THEIR APPLICABILITY TO EACH FRESHWATER RESOURCE-TYPE IN KLAMATH NETWORK PARK UNITS [P = PERMANENT; GEO/HYDRO = GEOTHERMAL/HYDROTHERMAL; UNQRES = UNIQUE RESOURCE INCLUDING INTERMITTENT EPHEMERAL PONDS AND SEASONAL ICE CAVES (LABE), MINERAL SPRINGS COMPLEX (WHIS), AND SPHAGNUM BOG RESEARCH NATURAL AREA (CRLA)]

Vital Sign	pLentic	pLotic	Geo/Hydro	Caves	unqRes
1. Atmospheric deposition of nutrients and pollutants	X	X			X
2. Presence & extent of native/introduced (invasive) aquatic biota	X	X			X
3. Climate change (e.g., temperature & precipitation regimes)	X	X		X	X
4. Visitor use impacts – recreational					
A. General impacts			X	X	
B. Hiking, backpacking, camping, horses, mountain bicycles	X	X			X
C. Motorized boats and boat-related activities	X				
D. Swimming, fishing, etc.	X	X			
5. Land & non-recreational human use impacts					
A. Park operations (construction, development, parking lot/road and levee maintenance)	X	X		X	
B. Roads: construction, maintenance, failure, culverts, runoff and spills		X			
C. Past mining operations/heavy metals	X	X			
D. Dam operations, water-level and sediment flux	X	X			
E. Sewage treatment, wastewater discharge, septic and drain field contamination	X	X			
F. 303(d) listed water bodies	X				
G. Former mill site and operations	X				
H. Fire: wild and prescribed; suppression		X		X	
I. Timber harvest and operations		X			X
J. Agriculture: fertilizers, herbicide and pesticide contamination, irrigation		X		X	X
K. Manipulation of cave environment (esp., light and control of algae)				X	
L. Geothermal exploration and activities near Park boundary			X		X
M. Litter and garbage dumping		X			X
N. Vehicle parking and off-road use					X
O. Impacts associated with cattle (grazing and trespass)		X			X

TABLE 23: GENERAL VITAL SIGNS CATEGORIES AND SUBCATEGORIES AND THEIR APPLICABILITY TO THREE GENERAL TYPES OF MARINE RESOURCES AT REDWOOD NATIONAL AND STATE PARKS, KLAMATH NETWORK

Vital Sign	Intertidal/ Coastal Offshore	Lagoons	Estuaries
1. Climate change (e.g., temperature and precipitation regimes, El Nino)	X		
2. Presence & extent of native/introduced (invasive) aquatic biota		X	X
3. Land & non-recreational human use impacts			
A. Oil spills	X		
B. Litter and garbage dumping	X		
C. Sediment flux (dams)	X		
D. Commercial fishing	X		
E. Sedimentation (roads, runoff, spills and culverts)		X	X
F. Contamination from old mill site		X	
G. Flood control levees			X
H. Dairy farming			X
I. Illegal woodcutting			X

Vital Signs Prioritization

Vital signs were prioritized for each park unit by staff at each park unit relative to the perceived importance of including each vital sign category as part of an aquatic resources monitoring program. The prioritization of vital signs varied among the units (Table 24):

1. Crater Lake identified each of the five general vital signs as important for monitoring the park's lentic and lotic resources;
2. Lassen did not identify any of the land and non-recreational human use impact subcategories as potentially affecting the park's water resources;
3. Climate change was identified as the top priority vital sign at Lava Beds, followed by four types of land and non-recreational human use impacts (i.e., park unit operations, timber harvest/operations, agriculture, and geothermal exploration);
4. Land and non-recreational human use impacts (esp., associated with human waste disposal and timber harvest), climate change, and visitor use impacts – recreational (i.e., general impacts) were identified as priority vital signs for Oregon Caves;
5. Redwoods did not identify atmospheric deposition of nutrients and pollutants as a priority vital sign for the park's freshwater and marine resources;
6. The only vital sign identified as important for Whiskeytown aquatic resources was land and non-recreational human use impacts and included three priority subcategories (i.e., past mining operations, dam operation and water-level flux, and impacts due to fire and fire suppression).

TABLE 24: PRIORITY RATINGS FOR EACH OF FIVE GENERAL AQUATIC RESOURCE VITAL SIGN CATEGORIES AND SUBCATEGORIES. RATINGS FOR EACH KLAMATH NETWORK PARK UNIT ARE FROM 1-4 WITH 1 BEING THE HIGHEST PRIORITY. THE TWO CRLA RATINGS ARE LENTIC/LOTIC; THE TWO RNSP RATINGS ARE FRESHWATER/MARINE; THE TWO WHIS RATINGS ARE DAM OPERATIONS/WATER-LEVEL FLUX.

Vital Sign	CRLA	LAVO	LABE	ORCA	RNSP	WHIS
1. Atmospheric deposition of nutrients and pollutants	3 / 2	2				
2. Presence & extent of native/introduced (invasive) aquatic biota	2 / 1	3			4 / 2	
3. Climate change (e.g., temperature and precipitation regimes)	1 / -	1	1	2	- / 3	
4. Visitor use impacts – recreational	4 / -					
A. General impacts				3		
B. Hiking, backpacking, camping, horses, mountain bicycles		4				
C. Motorized boats and boat-related activities						
D. Swimming, fishing, etc.					3 / -	
5. Land & non-recreational human use impacts					- / 1	
A. Park operations (construction, development, parking lot/road and levee maintenance)	- / 3		4			
B. Roads: construction, maintenance, failure, culverts, runoff and spills						
C. Past mining operations/heavy metals						1
D. Dam operations, water-level and sediment flux					- / 4	2a / 2b
E. Sewage treatment, wastewater discharge, septic and drain field contamination				1		
F. 303(d) listed water bodies					1 / -	
G. Former mill site and operations						
H. Fire: wild and prescribed; suppression					2a / -	3
I. Timber harvest and operations (including herbicide application)			2a	2	2b / -	
J. Agriculture: fertilizers, herbicide and pesticide contamination, irrigation			3			
K. Manipulation of cave environment (esp., light and control of algae)						
L. Geothermal exploration and activities near Park boundary			2b			
M. Litter and garbage dumping						
N. Vehicle parking and off-road use						
O. Impacts associated with cattle (grazing and trespass)						

An index was created to determine the perceived importance of each general vital sign category at the network-level. The index was calculated for each vital sign by adding the priority rating (i.e., 1–4, with 1 being the highest priority) assigned to the vital sign by each park unit (Table 24). If a park unit did not assign a rating to a vital sign then a rating of 5 was assigned to that vital sign for that unit. If a park unit assigned two or more ratings to a vital sign (e.g., CRLA atmospheric deposition = 3/2; LABE land and non-recreational human use impacts = 4/2a/3/2b; Table 24) then the ratings for that vital sign were averaged. The average index for all park units for each general vital sign was calculated as:

1. [CRLA + LAVO + LABE + ORCA + RNSP + WHIS]/6 park units.

For example:

1. atmospheric deposition = [(3+2/2)+2+5+5+5+5]/6 = **4.1**,

2. land use = [3+5+(4+2+3+2/4)+(1+2/2)+(1+4+1+2+2/5)+(1+2+2+3/4)]/6 = **2.7**.

Two basic groups of vital signs were identified based on the calculation of the average index for each of the five general vital signs: (1) climate change and land and non-recreational human use impacts scored 2.7; and (2) presence and extent of native/introduced (invasive) aquatic biota, visitor use impacts - recreational, and atmospheric deposition scored between 3.8 and 4.1.

1. Climate change: mean = 2.7; median = 1.5; 5 of 6 park units
2. Land use impacts: mean = 2.7; median = 2.4; 5 of 6 park units
3. Native/introduced biota: mean = 3.8; median = 4.0; 3 of 6 park units
4. Visitor use impacts - recreational: mean = 4.0; median = 4.0; 4 of 6 park units
5. Atmospheric deposition: mean = 4.1; median = 5.0; 2 of 6 park units.

Monitoring Questions, Potential Indicators of Resource Stress, and Associated Monitoring Options

A monitoring question was developed for each of the five general aquatic resource vital signs categories. Each question was general in scope so as to be applicable to each park unit. Next, a list of potential stress indicators (i.e., characteristics that can be measured and are useful indicators of change and/or perturbation) for each vital sign category was created by compiling and synthesizing indicators from each park-specific Vital Signs Table (Tables 14-20). Indicators were chosen that could be used to answer each monitoring question. Finally, a list of potential monitoring options consisting of a parameter or set of parameters to be sampled and useful for quantifying resource change and/or perturbation was also created by compiling and synthesizing responses from the park-specific Vital Signs Tables. This process created a relatively detailed outline of potential stress indicators and monitoring options. Indicators and monitoring options can be revised and refined as necessary during the development of the Klamath Network water quality monitoring program.

1. **Basic information** that would be helpful to have for each resource-type prior to implementation of a monitoring program:

    A. Complete inventory (or as complete as possible) of sites in each park unit.

    B. Status and trends:
        1) Analyze data to elucidate the present physical, chemical and biological characteristics of (at least) a subset of sites; and
        2) Determine the present variability among sites.

    C. Identify sites potentially not affected by impacts due to recreational visitor use, park unit operations, or nearby past and present land use activities. These sites will be potentially useful for determining, at least in a relative sense, the characteristics and variation among ‘pristine’ sites to which impacted sites can be compared.

2. **Climate change (e.g., temperature and precipitation regimes)**:

    A. Monitoring question: What impacts do global and local changes in climate have on Klamath Network park unit aquatic resources (especially regarding such parameters as the timing and extent of precipitation, water and air temperature ranges, air currents, relative humidity, evaporation rates, ozone-levels, and UVB radiation flux and attenuation); and how do these impacts affect resource condition, quality, and ecosystem dynamics?

    B. Indicators of stress:

        1) Change in climate-related parameters such as (a) water and air temperature, (b) relative humidity, (c) timing and amount of precipitation (rain and snow), (d) water-level, (e) flow and discharge rates, (f) ozone levels, (g) UVB radiation flux and attenuation, and ocean processes (e.g., upwelling, wave action, nearshore currents);
        2) Change in the timing, longevity and physical characteristics of intermittent ephemeral ponds (primarily at LABE).

    C. Monitoring Options:

        1) Measure water and air temperature, relative humidity, precipitation, water-level, flow and discharge rates, ozone levels, and UVB radiation flux and attenuation;
        2) Quantify trends of wave action, upwelling, and nearshore currents; and measure for change beyond normal statistical variation;
        3) Quantify the timing, depth, and duration of snow pack; and the timing and extent of snow melt;
        4) Identify and quantify ice sources and intermittent ephemeral ponds (LABE);

5) Determine extent of ice sources and measure ice-levels, evaporation rates, concentrations of total carbonates and calcite solubility (LABE and ORCA);
6) Quantify the timing, longevity and physical characteristics of intermittent ephemeral ponds (LABE).

3. **Land and non-recreational human use impacts** (subcategories to which indicators apply are in brackets; see Tables 21– 24 for list of subcategories):

A. Monitoring question: How do land use activities (past, present and within and outside of Klamath Network park units) affect park unit aquatic resources; and how do these activities impact resource condition, quality, and ecosystem dynamics?

B. Indicators of stress:

1) Change in sedimentation/siltation and turbidity [A, B, D, F, H, I];
2) Changes in the distributions and composition of aquatic biota [A, D, E, H, I, L];
3) Disturbance (e.g., trampling, rutting, erosion) of stream banks and channels, pond and lake shorelines and wetted areas [A, N, O];
4) Presence of and/or change in the concentrations of hydrocarbons and other motor vehicle derived contaminants [A, B, N];
5) Change in water temperature and dissolved oxygen level [B, F, I, L];
6) Change in channel morphology (e.g., bank and channel erosion), as well as flow and discharge rates [B, H, I, L];
7) Presence of and/or change in the concentrations of heavy metals and other contaminants (e.g., herbicides, pesticides, dioxin) [B, C, G, I, J];
8) Disruption of native anadromous salmonid passage [D];
9) Change in nutrients (e.g., nitrogen and phosphorus) and primary productivity [B, E, F, I];
10) Presence of and/or change in bacterial indicators of fecal contamination, *Giardia*, and *Cryptosporidium* [E, O];
11) Change in the depth and quantity of groundwater [J];
12) Presence of and/or change in the abundance of light-adapted biota as well as contaminants such as hydrogen peroxide and sodium hypochlorite in caves [K];
13) Presence of and/or change in the amount of litter and garbage at or near resource sites [M].

C. Monitoring Options:

1) Collect sediment cores to determine historical and contemporary sedimentation rates; measure turbidity, bedload, flow and discharge rates, water-level [A, B, D, F, H, I];
2) Measure water temperature, dissolved oxygen level, and nutrient and chlorophyll-ą concentration [A, B, E, F, I, J, L];

3) Quantify the presence and composition of aquatic biota, and use rapid bioassessment methods to identify and quantify impact [A, B, D, E, H, I, L];
4) Quantify the presence and concentrations of heavy metals and other contaminants (e.g., herbicides, pesticides, dioxin, hydrogen peroxide, sodium hypochlorite) in water and /or tissue samples [C, G, I, J, K];
5) Analyze water samples for hydrocarbons and other motor vehicle derived contaminants [A, B, N];
6) Quantify the presence and concentrations of bacterial indicators of fecal contamination, *Giardia*, and *Cryptosporidium* in water samples [E, O];
7) Quantify the abundances of light-adapted biota in caves [K];
8) Measure groundwater depth and quantity [J];
9) Map and photo-archive beach, shoreline, bank and channel profiles and monitor for disturbance (e.g., trampling, soil compaction, rutting, erosion, de-vegetation) [D, N, O];
10) Measure ice-levels and the quantity and availability of water in caves [L];
11) Measure the presence and amount of litter and garbage at or near resource sites [M].

4. **Presence and extent of native/introduced (invasive) aquatic biota**:

A. Monitoring question: What impact do introduced/invasive non-native aquatic biota have on the distributions and survival of native aquatic biota, and on the biotic community and ecosystem dynamics of Klamath Network park unit aquatic resources?

B. Indicators of stress:

1) Change in the (a) distributions, (b) abundances, (c) percent area occupied (PAO), and (d) community organization and structure of native and non-native introduced/invasive biota of concern

C. Monitoring Options:

1) Quantify trends of native and introduced (invasive) aquatic biota including: (a) distributions, (b) abundances, (c) PAO, (d) community organization and structure, and (e) rates of recruitment and mortality;
2) Quantify the condition and quality of the habitats occupied by native biota of concern.

5. **Visitor use impacts - recreational** including (a) tour-related impacts, (b) hiking, backpacking and camping, (c) stock (horse) and mountain bicycle use, (d) swimming, sun-bathing, and picnicking, (e) recreational fishing, and (f) motorized boats and boat-related activities:

   A. Monitoring question: How do the recreational activities of visitors affect Klamath Network park unit aquatic resources, and how do these activities impact resource condition, quality, and ecosystem dynamics?

   B. Indicators of stress:

      1) Change in shoreline/bank erosion and concomitant change in nearshore sedimentation rates and siltation;
      2) Change in shoreline/ bank soil compaction, trampling, and de-vegetation;
      3) Change in the distributions and composition of aquatic macroinvertebrates;
      4) Presence of and/or change in the concentrations of bacterial indicators of fecal contamination;
      5) Presence of and/or change in the amounts of litter and inorganic/organic contaminants.

   C. Monitoring Options:

      1) Quantify shoreline/bank condition and measure, map, and photo-archive indicators of erosion and impact (e.g., (a) sedimentation/ siltation; (b) soil compaction; (c) de-vegetation);
      2) Collect sediment cores to document historical and contemporary sedimentation rates;
      3) Measure water clarity and turbidity;
      4) Quantify macroinvertebrate species presence and composition in all aquatic habitats;
      5) Measure chlorophyll-ą concentration in phytoplankton and periphyton samples (as a proxy for primary productivity);
      6) Determine in water samples the presence and concentrations of bacterial indicators of fecal contamination;
      7) Quantify the presence and amount of litter, as well as inorganic/organic contaminants in caves, and monitor for change.

6. **Atmospheric deposition** of nutrients (e.g., nitrogen and phosphorus) and pollutants (e.g., mercury, persistent organics, flame retardants, water-repellent coatings, etc.):

   A. Monitoring question: How does the atmospheric deposition of nutrients and other contaminants affect the water quality and ecosystem dynamics of Klamath Network park unit aquatic resources?

B. Indicators of stress:

1) Presence of and/or change in the concentrations of air-borne nutrients and pollutants;
2) Change in primary productivity;
3) Change in the presence and composition of aquatic macroinvertebrates, especially species negatively affected by air-borne pollutants.

C. Monitoring Options:

1) Wet/dry chemistry: (a) rain and snow precipitation samples; (b) snow core samples;
2) Analyze water samples for nitrogen and phosphorus concentrations;
3) Analyze tissue samples (highest trophic-level possible) for the presence and concentrations of pollutants of interest;
4) Determine the concentration of chlorophyll-ą in phytoplankton and periphyton samples (as a proxy for primary productivity);
5) Determine the presence and composition of aquatic macroinvertebrates, and use rapid bioassessment methods to identify and quantify impact.

References Cited

Acker, S., Brock, M., Furhmann, K., Gibson, J., Hofstra, T., Johnson, L., Roth, J., Sarr, D., and Starkey, E., 2001, A study plan to inventory vascular plants and vertebrates: Klamath Network, National Park Service. Report prepared for the Klamath Network of the National Park Service. 115 p.

Bergmann, S.A., 1997, Breeding-site characteristics of pond-breeding amphibians at Whitehorse Ponds, Crater Lake National Park: Corvallis, Oregon State University Senior Thesis, 41 p.

CDFG. 2002. Sacramento River spring-run chinook salmon: 2001 Annual Report. Prepared for the Fish and Game Commission by California Department of Fish and Game, Habitat Conservation Division, Native Anadromous Fish and Watershed Branch. 29 p.

Clynne, M.A., Janik, C.J., and Muffler, L.J.P., 2002, Hot Water in Lassen Volcanic National Park–Fumaroles, Steaming Ground, and Boiling Mudpots: U.S. Geological Survey Fact Sheet 101-02.

Day, A.L., and Allen, E.T., 1925, The volcanic activity and hot springs of Lassen Peak: Carnegie Institute of Washington Publication 360, 190 p.

Eilers, J.M., Kanciruk, P., McCord, R.A., Overton, W.S., Hook, L., Blick, D.J., Brakke, D.F., Kellar, P.E., DeHann, M.S., Silverstein, M.E., and Landers, D.H., 1987, Characteristics of Lakes in the Western United States, Volume II, Data Compendium for Selected Physical and Chemical Variables: EPA-600/3-86/054b, US Environmental Protection Agency, Washington, DC: 425 p.

Everest, F.H., 1964, A survey of Horseshoe and Snag Lakes and their tributaries, Lassen National Park, June-September, 1963. Part 1 of a project by Humboldt State College, Arcata, CA: Memorandum of Agreement No. 14-10-0434-1434: 47 p.

Farner, D.S., 1947, Notes on the food habits of the salamanders of Crater Lake, Oregon: Copeia 1947(4), p. 259-261.

Farner, D.S., and Kezer, J., 1953, Notes on the amphibians and reptiles of Crater Lake National Park: American Midland Naturalist 50, p. 448-462.

Fellers, G., Covay, K., and Lico, M., 2003, Apex Site Monitoring, Amphibian Research and Monitoring Initiative.

Frank, F.J., and Harris, A.B., 1969, Water-resources appraisal of Crater Lake National Park, Oregon: US Geological Survey Water Resources Division Open-File Report, 26 p.

Ghiorso, M.S., 1980, Studies in natural solid-liquid equilibrium: University Microfilms, Ann Arbor, MI, University of California, Berkeley, PhD Dissertation, p. 138-371.

Hawkins, C.P., and Carlisle, D.M., 2001, Use of predictive models for assessing the biological integrity of wetlands and other aquatic habitats, Pages 59-111 *In* RB Rader, DP Baltzer and SA Wissinger (eds.), Bioassessment and Management of North American Freshwater Wetlands, John Wiley & Sons, Inc., New York.

Kezer, J., and Farner, D.S., 1955, Life history patterns of the salamander *Ambystoma macrodactylum* in the High Cascade Mountains of Southern Oregon: Copeia 1955(2), p. 127-131.

Landers, D.H., Eilers, J.M., Brakke, D.F., Overton, W.S., Kellar, P.E., Silverstein, M.E., Schonbrod, R.D., Crowe, R.E., Linthrust, R.A., Omernik, J.M., Teague, S.A., and Meier, E.P., 1987, Characteristics of Lakes in the Western United States, Volume I, Population Descriptions and Physico-Chemical Relationships: EPA/600/3-86/054a, US Environmental Protection Agency, Washington, DC, 176 p.

Larson, G.L., 1987, A review of the Crater Lake limnological programs. In Boyle, TP (ed), New Approaches to Monitoring Aquatic Ecosystems: ASTM STP 940, American Society for Testing and Materials, Philadelphia, p. 58-69.

Larson, G.L., 1990, Status of the ten-year limnological study of Crater Lake, Crater Lake National Park. Pages 7-18 *in* E.T. Drake, G.L. Larson, J. Dymond, and R. Collier, eds., Crater Lake, An Ecosystem Study: Pacific Division, American Association for the Advancement of Science, San Francisco, Calif.

Larson, G.L., 1996, Development of a ten-year limnological study of Crater Lake, Crater Lake National Park, Oregon, USA: Lake and Reservoir Management 12, p. 221-229.

Lenn, R., 1965, U.S. Geological Survey Chemical Analysis: Drakesbad, Devil's Kitchen, Little Hot Springs Water Samples (Lassen Volcanic National Park): Report. National Park Service, Mineral, CA.

Lewis, P.A., Klemm, D.J., and Thoeny, W.T., 2001, Perspectives on use of a multimetric lake bioassessment integrity index using benthic macroinvertebrates: Northeastern Naturalist 8, p. 233-246.

McClelland, E.J., 1973, A brief field survey of Lassen Volcanic National Park: U.S. Geological Survey, Water Resources Division.

Mitsch, W.J., and J.G. Gosselink., 2000, Wetlands, 3rd ed.: John Wiley & Sons, New York. 920 p.

National Park Service-Water Resources Division, 1998, Baseline Water Quality Data Inventory and Analysis: Oregon Caves National Monument: Technical Report NPS/NRWRD/NRTR-98/186, Water Resources Division and Servicewide Inventory and Monitoring Program, Fort Collins, CO, 361 p.

National Park Service-Water Resources Division, 1999a, Baseline Water Quality Data Inventory and Analysis: Lassen Volcanic National Park: Technical Report NPS/NRWRD/NRTR-99/244, Water Resources Division and Servicewide Inventory and Monitoring Program, Fort Collins, CO, 733 p.

National Park Service-Water Resources Division, 1999b, Baseline Water Quality Data Inventory and Analysis: Lava Beds National Monument: Technical Report NPS/NRWRD/NRTR-99/214, Water Resources Division and Servicewide Inventory and Monitoring Program, Fort Collins, CO, 227 p.

National Park Service-Water Resources Division, 2000, Baseline Water Quality Data Inventory and Analysis: Whiskeytown National Recreation Area: Technical Report NPS/NRWRD/NRTR-2000/257, Water Resources Division and Servicewide Inventory and Monitoring Program, Fort Collins, CO, 799 p.

NMFS. 1997. NMFS proposed recovery plan for the Sacramento River winter-run chinook salmon. National Marine Fisheries Service, Southwest Region, Long Beach, California.

Patterson and Cooper, In preparation, Research on the Drakesbad fen, 2002-2004.

Ramsey, D.W., Dartnell, P., Bacon, C.R., Robinson, J.E., and Gardner, J.V., 2003, Crater Lake Revealed: U.S. Geological Survey, Geologic Investigations Series I-2790.

Redmond, K.T., 1990, Crater Lake climate and lake level variability, Pages 127-142 I*n* E.T. Drake, G.L. Larson, J. Dymond, and R. Collier, eds., Crater Lake, An Ecosystem Study: Pacific Division, American Association for the Advancement of Science, San Francisco, Calif.

Roth, J., 1994, Taking inventory at Oregon Caves: Crater Lake Nature Notes 25.

Salinas, J., Truitt, R., and Hartesveldt, D.J., 1994, Whitehorse Ponds, Crater Lake National Park, limnological and vascular plant survey, 1993: Final Report, RCC-9404.

Sarr, D., Odion, D., Truitt, R.E., Beever, E., Shafer, S., Duff, A., Smith, S.B., Bunn, W., Rocchio, J., Sarnat, E., Alexander, J., and Jessup, S., 2004, Vital Signs Monitoring Plan for the Klamath Network, Phase I Report: NPS-Klamath Network Inventory and Monitoring Program, Ashland, OR, 106 p. + 11 Appendices.

Simenstad, C., Jay, D., McIntire, C.D., Nehlsen, W., Sherwood, C., and Small, L., 1984a, The Dynamics of the Columbia River Estuarine Ecosystem, Volume I. Columbia River Estuary Data Development Program. Pages 1-338.

Simenstad, C., Jay, D., McIntire, C.D., Nehlsen, W., Sherwood, C., and Small, L., 1984b, The Dynamics of the Columbia River Estuarine Ecosystem, Volume II. Columbia River Estuary Data Development Program. Pages 341-694.

Stead, J.E., Welsh, Jr., H.H., and Pope, K.L., 2005, Census of amphibians and fishes in lentic habitats of Lassen Volcanic National Park: A report to the National Park Service. LVNP Study Number: LAVO-00717. 77 p.

Stribling, J.B., Jessup, B.K., White, J.S., Boward, D., and Hurd, M., 1998, Development of a Benthic Index of Biotic Integrity for Maryland Streams: CBWD-MANTA - EA-98-3, Maryland Department of Natural Resources, Chesapeake Bay and Watershed Programs, Monitoring and Non-Tidal Assessment Division, Annapolis, MD.

Thompson, J.M., 1983, Chemical analyses of thermal and nonthermal springs in Lassen Volcanic National Park and Vicinity, California: U.S. Geological Survey Open-File Report 83-311, 26 p.

Thompson, J.M., White, L.D., and Nathenson, M., 1987, Chemical analysis of waters from Crater Lake, Oregon, and nearby springs: U.S. Geological Survey Open-File Report 87-587, 26 p.

USFWS. 2001. Final restoration plan for the anadromous fish restoration program: a plan to increase natural production of anadromous fish in the Central Valley of California. United States Fish and Wildlife Service. 146 p.

Wallis, O.L., 1948, Trout studies and a stream survey of Crater Lake National Park, Oregon: Corvallis, Oregon State University, MS Thesis, 124 p.

Wallis, O.L., 1959, Interpretation, Research, and Management of the Fishery Resources, Lassen Volcanic National Park, California: Report, National Park Service, Mineral, CA, 38 p.

Waring, G.A., 1915, Springs of California: U.S. Geological Survey Water Supply Paper No. 338, 410 p.

Webster, I.T., and Harris, G.P., 2004, Anthropogenic impacts on the ecosystems of coastal lagoons: modeling fundamental biogeochemical processes and management implications. Marine and Freshwater Research 55:67-78.

Weitkamp, L.A., 1994, A review of the effects of dams on the Columbia River estuarine environment, with special reference to salmonids: Report funded by Bonneville Power Administration, Portland, and National Marine Fisheries service, Seattle. 148 p.

West, J.R., 1976, The Lentic Resources of Lassen Volcanic National Park: Report, National Park Service, Mineral, CA.

Wetzel, R.G. 1983. Limnology, 2nd ed.: Saunders College Publishing, Philadelphia. 858 p.

Williamson, R.L., O'Keefe, J. Simonsen, R., Spoto, D., Eggleston, B., and Hendrickson, J., 1997, Lassen Volcanic National Park Sanitary Survey: Department of Civil Engineering and Applied Mechanics, San Jose State University, San Jose, CA.

ATTACHMENT I

BIBLIOGRAPHY OF KLAMATH NETWORK PARK UNIT AQUATIC RESOURCES INVENTORY, MONITORING AND RESEARCH STUDY REPORTS AND PUBLICATIONS

CRATER LAKE NATIONAL PARK WATER QUALITY AND LIMNOLOGY

Allen, JE. 1935. Crater Lake Nature Notes 8(1).

Anonymous,1963, USGS, Surface Water Records of Oregon, 27 p.

Anonymous, 1964, USGS, Water Resources Report, 15 p.

Anonymous, 1965 - 1981, USGS, Water resource data for Oregon, Annual Reports.

Baird, DS, 1956, Crater Lake Nature Notes 22.

Benton, R. E. A report on Crater Lake water quality, Crater Lake National Park, Oregon, 1986-1987. Crater Lake National Park, 1988.

Benton, R.E. A report on Crater Lake water quality Crater Lake National Park, Oregon 1982-1983. 1983.

Benton, R.E. A report on Crater Lake water quality Crater Lake National Park, Oregon 1984-1985. Unpublished 1985.

Benton, R.E. A report on Crater Lake water quality, Crater Lake National Park, Oregon, 1988-1989. 1989.

Bergmann. 1997. Report. National Park Service, Crater Lake, OR.

Bisbee, L, F Laramie, R Strand & J Kezer. 1951. Crater Lake Nature Notes 17.

Brandt, R. 1992. Report. National Park Service, Crater Lake, OR.

Brandt, R. 1993. Crater Lake Nature Notes 24.

Branson, B. A., and R. M. Branson. "Distributional records for terrestrial and freshwater Mollusca of the Cascade and Coast Ranges, Oregon." The Veliger 26, no. 4 (1984): 248-257.

Brode, JS, 1933, Crater Lake Nature Notes 6(4).

Brode, JS, 1934, Crater Lake Nature Notes 7(3).

Brode, JS, 1935, Crater Lake Nature Notes 8(2).

Brode, JS, 1938, Northwest Science 12: 50-57.

Brown, Faith, Sue Fleming, Beth Williams, Cynthia Persichetty-O'Hara, Rich Nauman, George Liebercajt, and Terry Simpson. "Mazama watershed analysis (Draft)." 1996.

Burnham, EA. 1956. Crater Lake Nature Notes 22.

Byrne, JV, 1965, Limnology and Oceanography 10: 462-465.

Campbell, B, 1929, Crater Lake Nature Notes 2(2).

Clark, Shirley M., and Donald C. Barrett. Environmental assessment for the proposed new water source for Rim Village and Munson Valley, Crater Lake National Park, Oregon. Crater Lake National Park, 1975.

Collier, R., J. Dymond, J. Mcmanus, and J. Lupton. "Chemical and physical properties of the water column at Crater Lake, Oregon." In Crater Lake: an ecosystem study, by Gary Larson, et al, 69-79. San Francisco, CA: Pacific Division of the American Association for the Advancement of Science, 1990.

Collier, R., J. Dymond, J. Mcmanus, and J. Lupton. Chemical and physical properties of the water column at Crater Lake, OR [Draft]. Corvallis, OR: Oregon State University, no date.

Crater Lake National Park. A report on Crater Lake water quality, Crater Lake National Park, Oregon, 1984-1985. National Park Service, 1986.

Crater Lake National Park. A report on Crater Lake water quality, Crater Lake National Park, Oregon, 1988-1989. National Park Service, 1991.

Crater Lake National Park. Assessment of the environmental impact of the construction of a domestic water well for the proposed south entrance facilities at Crater Lake National Park. Unpublished report: Crater Lake National Park, 1973.

Crater Lake National Park. Environmental review: proposed new water source for Rim Village and Munson Valley, Crater Lake National Park, Oregon. Unpublished. nd.

Crater Lake National Park. Peer review meeting, Crater Lake water quality monitoring program, November 22, 1983. Unpublished report: Crater Lake National Park, 1983.

Crater Lake National Park. Role statements - Crater Lake water quality study. Unpublished report: Crater Lake National Park, 1984.

Crater Lake National Park. Water Crisis 1975. no date.

Crater Lake National Park. Water supply and waste disposal facilities, Crater Lake National Park, February 1986. Unpublished report: Crater Lake National Park, 1986.

Debacon, M. K., and C. D. McIntire. "Taxonomic structure of phytoplankton assemblages in Crater Lake, Oregon, U.S.A." Freshwater Biology 25 (1991): 95-104.

Denver Service Center, National Park Service. Environmental assessment: Crater Lake National Park, package 171, Lost Creek disinfection for public non-community water system. Unpublished1980.

Detterline, J. L. Untitled letter re: 1987 Nagleria fowleri survey of federal recreation waters. Unpublished: Memphis State University, Memphis, TN, 1988.

Diller, JS, 1897, National Geographic Magazine 8: 369-379.

Diller, JS & HB Patton, 1902, USGS Professional Paper 3.

Drake, ET, GL Larson, J Dymond & R Collier (eds), 1990, Crater Lake: An Ecosystem: Sixty-ninth Annual Meeting of the Pacific Division/ American Association for the Advancement of Science.

Dymond, J & R Collier, 1983, Investigator's Annual Report, National Park Service, Crater Lake, OR.

Eilers, J.M., J.A. Bernert, S.S. Dixit, C.P. Gubala, and P.R. Sweets. "Processes influencing water quality in a subalpine Cascade mountain lake." Northwest Science 70, no. 2 (1996): 59-70.

Eley, C. L., and C. L. Eley. "Use of Crater Lake by waterfowl." The Murrelet 53, no. 2 (1972): 27.

Fairbanks, CW, 1953, Crater Lake Nature Notes 19.

Fairbanks, CW, 1954, Crater Lake Nature Notes 20.

Farner, DS, 1946, Crater Lake Nature Notes 12.

Farner, DS, 1947, Copeia 1947(4): 259-261.

Forbes, M. E. Development/study package proposal: study water quality of Munson and Dutton Creeks. Unpublished: Crater Lake National Park, 1983.

Forbes, M. E., J. B. Jarvis, and G. D. Mccrea. A report on Crater Lake water quality, Crater Lake National Park, Oregon, 1982-1983. Unpublished: Crater Lake National Park, 1984.

Frank, F. J., and A. B. Harris. Water-resources appraisal of Crater Lake National Park, Oregon. Portland, OR: U.S. Geological Survey, Water Resources Division, 1969. U.S. Geological Survey Open-File Report 69-95.

Frost, WT & JE Doerr, 1937, Crater Lake Nature Notes 10(1).

Funkhouser, JW, 1949, Crater Lake Nature Notes 15.

Girdner, S, 2001/2002, Crater Lake Nature Notes 32/33.

Gregory, Stanley V., Gary L. Larson, C.David McIntire, and Mark Buktenica. "Water chemistry of caldera springs." In Crater Lake limnological studies final report, by Gary L. Larson, C.David McIntire, and Ruth W. Jacobs, 131-173. Seattle, WA: National Park Service Pacific Northwest Region, 1993.

Hampton, E. R. Evaluation of potential sources of water in Crater Lake National Park, Oregon. Portland, OR: USGS, 1967. Administrative Report.

Harding, S. T. Water supply of Crater Lake, Oregon. Unpublished: US Geological Survey, Medford, OR, 1953.

Hasler, AD, 1937, Crater Lake Nature Notes 10(2).

Hasler, AD, 1937, Crater Lake Nature Notes 10(3).

Heath, JP. 1938. Report. National Park Service, Crater Lake, OR.

Hoffman, FO, 1969, MS Thesis, Oregon State University, Corvallis, OR.

Hoffman, OW, 1999, Crater Lake Nature Notes 30.

Homuth, EU. 1929. Crater Lake Nature Notes 2(3).

Hubbard, L.E., C.G. Kroll, T.A. Herrett, R.L. Kraus, and G.P. Ruppert. Water resources data-- Oregon-- water year 1991. Portland, OR: US Geological Survey, 1992. USGS water-data report OR-91-1.

Hubbard, L.E., T.A. Herrett, R.L. Kraus, G.P. Ruppert, and M.L. Courts. Water resources data-- Oregon-- water year 1992. Portland, OR: US Geological Survey, 1993. USGS water-data report OR-92-1.

Hunt, JC & CW Fairbanks, 1955, Crater Lake Nature Notes 21.

Jarvis, J. B. Development/study package proposal: study water quality of Munson and Dutton Creeks. Unpublished: Crater Lake National Park, 1984.

Jarvis, J. B. The first Crater Lake winter water quality operation. Unpublished: Crater Lake National Park, no date.

Jarvis, J.B. "Crater Lake accomplishes first winter water quality sampling." Park Science 7, no. 2 (1987): 3-4.

Kelley, P. 2001/2002. Crater Lake Nature Notes 32/33.

Kemmerer G, JF Bovard & WR Boorman, 1924, US Bureau of Fisheries 39: 51-140.

Kezer, J. 1951. Crater Lake Nature Notes 17.

Kezer, J. 1952. Crater Lake Nature Notes 18.

Kezer, J & DS Farner, 1952, Crater Lake Nature Notes 18.

Kezer, J & DS Farner. 1955. Copeia 1955(2): 127-131.

Kibby, HV, JR Donaldson & GE Bond, 1968, Limnology and Oceanography 13: 363-366.

La Pierre, Yvette. "Taking stock: NPS reviews the effect of recreational fishing on native fish and park waters." National parks (1993).

Larson, DW, 1972, Limnology and Oceanography 17:410-417.

Larson, D. W.. Annual report on the limnology and water quality monitoring program at Crater Lake National Park 1982. 1983.

Larson, D. W. Limnological/water quality monitoring program, Crater Lake National Park1983. Unpublished: Crater Lake National Park, 1983.

Larson, D. W. Second annual report on the limnology and water quality monitoring program at Crater Lake National Park, Oregon Draft. Unpublished: Crater Lake National Park, 1983.

Larson, D. W. Untitled: field notes for water quality studies. Unpublished: Crater Lake National Park, no date.

Larson, D.W., 1984, Internationale Vereinigung fur Theoretische und Angewandt Limnologie 22: 513-517.

Larson, D. W., and M. E. Forbes. Annual report on the limnology and water quality monitoring program at Crater Lake National Park. Portland, OR: US Army Corps of Engineers, 1982.

Larson, D. W., M. E. Forbes, and J. B. Jarvis. First annual report on the limnology and water quality monitoring program at Crater Lake National Park, Oregon, final. Crater Lake Limnological Studies 1982, National Park Service/CRLA (Crater Lake National Park), 1983.

Larson, D. W., M. E. Forbes, and J. B. Jarvis. First annual report on the limnology and water quality monitoring program at Crater Lake National Park, Oregon. Portland, OR: US Army Corps of Engineers, 1983.

Larson, D. W., M. E. Forbes, and J. B. Jarvis. Second annual report on the limnology and water quality monitoring program at Crater Lake National Park, Oregon. Portland, OR: US Army Corps of Engineers, 1984.

Larson, DW & NS Geiger, 1980, Proceedings, 2nd Annual Conference on Scientific Research in National Parks, National Park Service, Washington, DC, Volume2: 96-104.

Larson, Gary L. A review of the geographical distribution, morphology and water quality of caldera lakes. Corvallis, Oregon: College of Forestry, Oregon State University, no date.

Larson, Gary L., 1984 - 2004, Annual Report: Limnological Studies of Crater Lake: National Park Service, Crater Lake, OR.

Larson, Gary L., 1987, In Boyle, TP (ed), New Approaches to Monitoring Aquatic Ecosystems, American Society for Testing and Materials, ASTM STP 940: 58-69.

Larson, Gary L., C.David McIntire, Michael Hurley, and Mark W. Buktenica. "Temperature, water chemistry, and optical properties of Crater Lake." Journal of Lake and Reservoir Management 12, no. 2 (1996): 230-247.

Larson, Gary L., CD McIntire & RW Jacobs (eds), 1993, Crater Lake Limnological Studies, Final Report, Technical Report NPS/PNROSU/NRTR-93/03.

Loeb, SL & FE Reuter, 1981, Internationale Vereinigung fur Theoretische und Angewandt Limnologie 21: 346-352.

Malick, JG, 1971, MS Thesis, Oregon State University, Corvallis, OR.

Marks, S. 2000. Crater Lake Nature Notes 31.

McIntire, C. David, Harry K. Phinney, Gary L. Larson, and Mark Buktenica. "Survey of deep-water benthic communities." In Crater Lake limnological studies final report, by Gary L. Larson, C. David McIntire, and Ruth W. Jacobs, 661-679. Seattle, WA: National Park Service Pacific Northwest Region, 1993.

McIntire, C. David, Harry K. Phinney, Gary L. Larson, and Mark Buktenica. "Vertical distribution of a deep-water moss and associated epiphytes in Crater Lake, Oregon." Northwest Science 68, no. 1 (1994): 11-21.

Mcintire, C. David, Harry K. Phinney, Gary L. Larson, and Mark Buktenica. The vertical distribution of a deep-water moss and its epiphytes in Crater Lake, Oregon. 1992.

Mohler, W. Water supply and waste disposal facilities, CRLA. Unpublished: National Park Service, 1986.

Morris, D. G., and D. G. Morris. An underwater visibility comparison of Lake Tahoe and Crater Lake. Unpublished: source unknown, 1982.

Myers, GS, 1942, Copeia 1942(2): 77-82.

Nathenson, M. "Chemical balance for major elements in water in Crater Lake, Oregon." In Crater Lake: an ecosystem study, by Gary Larson, et al, 103-114. San Francisco, CA: Pacific Division of the American Association for the Advancement of Science, 1990.

Nathenson, Manuel. Water balance for Crater Lake, Oregon. US Geological Survey, 1992. Open File Report 92-505.

National Park Service. Annual Report 1994 Water resources division. Fort Collins, CO: National Park Service, 1995.

National Park Service. Annual report 1996 Water resources division. Natural Resources Report NPS/NRWRD/NRR-97/06. Ft. Collins, Colorado: National Park Service, 1997. Natural Resources report NPS/NRWRD/NRR-97/06.

National Park Service. Water Resources Division. Water Rights Branch. Alternative sources of water supply, Crater Lake National Park, Ground water. Fort Collins, CO: U.S. National Park Service, 1995.

Neal, VT, SJ Neshyba & WW Denner, 1971, Limnology and Oceanography 16: 695-700.

Neal, VT, SJ Neshyba & WW Denner, 1972, Limnology and Oceanography 17: 451-453.

Nelson, CH, 1967, Bulletin of the Geological Society of America 78: 833-848.

Pacific Northwest Western Team. Environmental assessment: Crater Lake National Park, Package 171, Lost Creek disinfection for public non-community water system. Unpublished: National Park Service-Pacific Northwest Region, 1980.

Pettit, E. In examination of water from Crater Lake. Unpublished: Carnegie Institute of Washington, 1935.

Pettit, E, 1936, Proceedings of the National Academy of Sciences 22: 139-146.

Phillips, KN & AS Van Dendurgh, 1968, USGS Water Supply Paper 1859-E.

Redmond, Kelly. "Climate variability at Crater Lake National Park and its effect on water level." In Crater Lake limnological studies final report, by Gary L. Larson, C.David McIntire, and Ruth W. Jacobs, 39-61. Seattle, WA: National Park Service Pacific Northwest Region, 1993.

Ritchey, J. L. "Divergent magmas at Crater Lake, Oregon: products of fractional crystallization and vertical zoning in shallow water-saturated chamber." J Volcanol Geotherm Res 7 (1980): 373-386.

Robertson, Thomas E. "An ecological assessment of five springs in Crater Lake National Park. Part I: water chemistry and vegetation of saturated soils." no date.

Robinson, RS, 1950, Crater Lake Nature Notes 16.

Rowley, JR & CW Fairbanks, 1954, Crater Lake Nature Notes 20.

Ruhle, GC. 1951. Crater Lake Nature Notes 17.

Salinas, J. 1995. Crater Lake Nature Notes 26.

Salinas, J, 2001/2002, Crater Lake Nature Notes 32/33.

Salinas, J, R Truitt & DJ Hartesveldt. 1994. Final Report RCC-9404.

Shepard, PH, 1949, Crater Lake Nature Notes 15.

Smith, R. C. "The optical characterization of natural waters by means of an extinction coefficient." Limnol and Oceanog 13, no. 3 (1968): 423-429.

Smith, R. C., and J. E. Tyler. "Optical properties of clear natural water." Journal of Optical Soc Amer 57, no. 5 (1967): 589-595.

Smith, RC, JE Tyler & LR Goldman, 1973, Limnology and Oceanography 18: 189-199.

Sovereign, HE, 1958, Transactions of the American Microscopy Society 77: 96-124.

Sovereign, HE, 1963, Proceedings of the California Academy of Sciences 31: 349-368.

Special Issue, 1996, Lake and Reservoir Management 12: 221-310.

Stevens, J. C. Report on water supply and facilities for property of Crater Lake National Park Company Crater Lake, Oregon. Portland, Oregon: Stevens & Koons, Consulting Engineers, 1949.

Thompson, J. M., "Chemical and isotopic compositions of waters from Crater Lake, Oregon, and nearby vicinity." 1990.

Thompson, J. M., M. Nathenson, and L. D. White. "Chemical and isotopic compositions of waters from Crater Lake, Oregon, and nearby vicinity." In Crater Lake: an ecosystem study, by E.T. Drake, et al, 91-103. San Francisco, CA: Pacific Division of the American Association for the Advancement of Science, 1990.

Thompson, JM, LD White & M Nathenson, 1987, USGS Open-File Report 87-587.

Tyler, J. E. "In situ spectroscopy in ocean and lake waters." Journal of Optical Soc Amer 55, no. 7 (1965): 800-805.

Utterback, CL, LD Phifer & RJ Robinson, 1942, Ecology 23: 97-103.

Van Winkle, W & NM Finkbiner, 1913, Journal of Industrial Engineering Chemistry 5: 158-199.

Various Authors. Crater Lake water contamination hearings Sections 1, 2, 3, 4, and addendum to section 4. National Park Service, 1975.

Vincent, WS. 1947. Crater Lake Nature Notes 13.

Wheat, C.Geoffrey, James McManus, Jack Dymond, Robert Collier, and Michael Whiticar. "Hydrothermal fluid circulation through the sediment of Crater Lake, Oregon: pore water and heat flow constraints." Journal Of Geophysical Research 103, no. B5 (1998): 9931-9944.

Williams, DL & RP Von Herzen, 1983, Journal of Geophysical Research 88: 1094-1104.

CRATER LAKE NATIONAL PARK FISHERIES STUDIES

Aubry, Keith B., Catherine M. Raley, T. J. Catton, and Gregory W. Tomb. Ecological characteristics of fishers in southwestern Oregon. Olympia, WA: Pacific Northwest Research Station, USDA Forest Service, 2000.

Aubry, Keith B., Catherine M. Raley, T.J. Catton, and Gregory W. Tomb. Ecological characteristics of fishers in southwestern Oregon. Olympia, WA: Pacific Northwest Research Station, USDA Forest Service, 1999.

Aubry, Keith B., Catherine M. Raley, Timothy J. Catton, Gregory W. Tomb, and Fred E. Wahl. Rouge River Fisher study progress report: February 1997. 1997.

Aubry, Keith B., and Evan G. Olson. "The use of camera bait stations to detect fisher and wolverine in Crater Lake National Park." no date.

Aubry, Keith B., and Jeffrey C. Lewis. "Extirpation and reintroduction of fishers (Martes pennanti) in Oregon: Implications for their conservation in the Pacific states." Biological conservation 114, no. 1 (2003): 79-90.

Aubry, Keith, Catherine M. Raley, T.J. Catton, and Gregory W. Tomb. Ecological characteristics of fishers in southwestern Oregon. Olympia, WA: Pacific Northwest Research Station, USDA Forest Service, 1998.

Bahls, P. "The Status of Fish Populations and Management of High Mountain Lakes in the Western United States." Northwest Science 66, no. 3 (1992): 183-193.

Baird, Dick S. "Report on fish stomach contents analyzed during summer of 1956." 1956.

Brode, J. S. "Food habits of Crater Lake fish." Crater Lake Crater Lake Nature Notes 8, no. 2 (1935): 11-13.

Buktenica, M. 1992. Crater Lake Nature Notes 23.

Buktenica, M. 1993. Crater Lake Nature Notes 24.

Buktenica, M.W. Ecology of kokanee salmon and rainbow trout in Crater Lake, Oregon with comments on long-term implications of fish introductions. 1991.

Buktenica, Mark. "Bull trout restoration and brook trout eradication at Crater Lake National Park, Oregon: good fish- bad fish; old fish- new fish." 1996.

Buktenica, Mark, and Gary L. Larson. "Ecology of kokanee salmon and rainbow trout in Crater Lake with comments on long-term implications of fish introductions." In Crater Lake limnological studies final report, by Gary L. Larson, C. David McIntire, and Ruth W. Jacobs, 559-618. Seattle, WA: National Park Service Pacific Northwest Region, 1993.

California Cooperative Fish Research Unit. California Cooperative Fish Research Unit: 2001 annual report. 2001.

California Cooperative Fish Research Unit. California Cooperative Fish Research Unit: 2002 annual report. 2002.

California Cooperative Fish Research Unit. California cooperative fish research unit: 2003 annual report. 2003.

Crater Lake National Park. Crater Lake National Park summer back country regulation fishing regulations backcountry permit system. Crater Lake National Park, 1990.

Crater Lake National Park. Fish of Crater Lake National Park. Unpublished report: Crater Lake National Park, no date.

Crater Lake National Park. Fisher (Martes pennati) observations, Crater Lake National Park, Oregon, 1955-1972. Unpublished report: Crater Lake National Park, 1973.

Crater Lake National Park. Fishes - Stocking (to 1939). no date.

Crater Lake National Park. Fishing information, Crater Lake National Park. Unpublished report: Crater Lake National Park, 1970.

Dambacher, J. M., M.W. Buktenica, and G.L. Larson. Fishes and stream habitat in tributaries of the Klamath River in Crater Lake National Park, with special reference to the Sun Creek bull trout population. Seattle, WA: National Park Service, 1993.

Evermann, B. W. "US Fish Commission investigations at Crater Lake." In Mazama: A Record of Mountaineering in Pacific Northwest, 331-238. 1897.

Fairbanks, CW. 1952. Crater Lake Nature Notes 18.

Fairbanks, CW. 1953. Crater Lake Nature Notes 19.

Fairbanks, G. Warren. "Memorandum on fishing for the season of 1952." 1952.

Fairbanks, G. Warren. "Fishing report - 1954 season." 1954.

Farner, D.S. "Memorandum on fish stocking policy for Crater Lake." 1940.

Farner, D.S. "Natural reproduction of Crater Lake fish." 1940.

Farner, D.S. "Memorandum on fishing." 1941.

Farner, Donald S. "Memorandum on fishing." 1946.

Farner, D.S. "Memorandum on fishing for the season of 1948." 1948.

Farner, DS & J Kezer. 1953. American Midland Naturalist 50: 448-462.

Fishery Management Biologist. "Fishery management reconnaissance report - Crater Lake, Oregon." 1957.

Fortune, J. Untitled letter re: fish sampling data. Unpublished: Department of Fish and Wildlife, Klamath Falls, OR, 1982.

Hakel, L., and G. Kaye. Long range fishery management plan, Crater Lake National Park, 1967-1976. Unpublished: National Park Service-Crater Lake National Park, no date.

Hasler, AD, 1938, Crater Lake Nature Notes 11(2).

Hasler, A. D. "Fish biology and limnology of Crater Lake, Oregon." Journal of Wildlife Management 2 (1938): 94-103.

Hasler, A. D., and D. S. Farner. "Fisheries investigations in Crater Lake, Oregon, 1937-1940." Journal of Wildlife Management 6 (1942): 319-327.

Hasler, Arthur D. "Fish biology and limnology of Crater Lake, Oregon (preliminary report)." no date.

Hasler, Arthur D. "The productivity of Crater Lake in terms of fish food." 1937.

Hubbard, C. A. Fact and fancy about Crater Lake fish. Unpublished: Crater Lake National Park, 1933.

Hubbard, C. Andresen. "Fact and fancy about Crater Lake fish." 1933.

Huestis, R.R. "Progress report on saprolegnia in Crater Lake fish." no date.

Kartchner, Wayne E. "Fish planting in the small lakes of Wizard Island." no date.

Kemmerer, G., J. F. Bovard, and W. R. Boorman. Northwestern lakes of the United States: biological and chemical studies with reference to possibilities in production of fish. Bull Bur Fish 39, Document No 944. 1923.

Kibby, H. V. A study in fish ecology of Crater Lake, Oregon. Unpublished: Oregon State University, Corvallis, OR, 1966.

La Pierre, Yvette. "Taking stock: NPS reviews the effect of recreational fishing on native fish and park waters." National parks (1993).

Mahoney, Brian D. "Evaluation of electrofishing-induced injury to introduced brook trout (Salvelinus fontinalis) in Crater Lake National Park. 1995 research proposal (DRAFT)." 1995.

National Park Service, , and Oregon Department Of Fish And Wildlife. Memorandum of understanding between National Park Service, Pacific Northwest Region and State of Oregon, Department of Fish and Wildlife. Unpublished: National Park Service-Pacific Northwest Region/Oregon Department of Fish & Wildlife, 1986.

Raley, Catherine. Ecological characteristics of fishers in the southern Oregon Cascade Range: Final progress report. Olympia, WA: Pacific Northwest Research Station, USDA Forest Service, 2002.

Robinson, R. S. "How fish came to Crater Lake." Crater Lake Crater Lake Nature Notes 16 (1950): 15-17.

Shepard, P.H. "Memorandum on fishing for the season of 1949." 1949.

Thorne, Richard E., and David Marino. Hydroacoustic survey of fish in Crater Lake, Oregon. 1985.

U.S. Fish and Wildlife Service. "Endangered and threatened wildlife and plants; 12-month finding for a petition to list the west coast distinct population segment of the fisher (Martes pennanti)." Federal register 69, no. 68 (no date.): 18770-18792.

Various Authors. Fishes - General (1941 to 1960). Crater Lake National Park, no date.

Walker, M. V. "Fish and fishing problems of Crater Lake." 1940.

Walker, M.V. "Fish and fishing problems of Crater Lake." 1940.

Wallis, OL. 1947. Crater Lake Nature Notes 13.

Wallis, OL. 1948. MS Thesis, Oregon State College, Corvallis, OR.

Wallis, O. L. Review of the fishery situations in Crater Lake National Park. Unpublished: Crater Lake National Park, 1958.

Wallis, Orthello L. "Memorandum on fishing." 1947.

Wallis, Orthello L. "Plans and aims of stream fish survey of the streams of Crater Lake National Park during the 1947 season." no date.

Wild, Norman D. "Fish study - 1957." 1957.

Wild, Norman. "Fishing report 1958 season." 1958.

Wisely, Samantha M., Steven W. Buskirk, Gregory A. Russell, Keith B. Aubry, and William J. Zielinski. "Genetic diversity and structure of the fisher (Martes pennanti) in a peninsular and peripheral metapopulation." Journal of Mammalogy 85, no. 4 (2004): 640-648.

Yocom, Charles F., and Michael T. Mccollum. "Status of the fisher in northern California, Oregon and Washington." Calif Fish and Game 59, no. 4 (1973): 305-309.

CRATER LAKE NATIONAL PARK STREAM STUDIES

Dambacher, J. M., M.W. Buktenica, and G.L. Larson. Fishes and stream habitat in tributaries of the Klamath River in Crater Lake National Park, with special reference to the Sun Creek bull trout population. Seattle, WA: National Park Service, 1993.

Gregory, S., G. Lamberti, R. Wildman, and L. Ashkenas. Ecology of streams of Crater Lake National Park. 1987. Final Report CA 9000-3-0003.

Nelson, P., D. Myrold, D. Mcintire, and D. Perry. Program review: ecology of streams of Crater Lake National Park, February 26, 1987, panel recommendations. Unpublished: Crater Lake National Park, 1987.

Wallis, Orthello L. "Plans and aims of stream fish survey of the streams of Crater Lake National Park during the 1947 season." no date.

LASSEN VOLCANIC NATIONAL PARK WATER QUALITY

Author Unknown. 1955 Lake Survey Report

Author Unknown. 1965. Lake Survey Project Summary of Findings…NPS, LAVO.

Author Unknown. 1979. Lassen Park Summer 1979 Lake Surveys. (data in NPS-WRD, 1999a).

Author Unknown. 2000 Cluster and Twin Lakes Loop Report, August 12, 1999.

Ch2m Hill. Mill Creek Watershed Management Strategy Report. Redding, CA: CH2M Hill, 1996.

Clow, D. W. *et al*. 2002. Water, Air, & Soil Pollution: Focus 2: 139-164.

Clynne, MA, *et al*. 2002. US Geological Survey Fact Sheet 101-02.

Day, Arthur Loui, , and Allen, E. T. "The sources of the heat and the source of water in the hot springs of the Lassen National Park." Jour Geology 32, no. 3, April-May, 1924 (1924): 178-190.

Day, Arthur Louis, and E. T. Allen. "The source of the heat and the source of water in the hot springs of the Lassen National Park." Jour Geology 32, no. 3 (1924): 178-190.

Day, AL & ET Allen. 1925. Carnegie Institute of Washington Publication 360.

DeMartini, JD.1992, 1994, 1996. Field Notes. NPS, LAVO.

DeMartini, JD. 1994. Report, NPS, LAVO.

DeMartini, JD. 1997. Report, NPS, LAVO.

DeMartini, JD, *et al*. 2000. Surveys of Sifford Lakes. NPS, LAVO.

Dewitt. 1965. Lake Survey Project. Report. NPS, LAVO.

Dileanis, Peter D., Stephen K. Sorenson, and Thomas J. Suk. "The relation between human presence and occurrence of Giardia cysts in streams in the Sierra Nevada, California." Journal of Freshwater Ecology 4, no. 1 (1987): 71-75.

Dobson, Graham A. "Lost Creek water analysis 8-97, high turbidity event (unknown cause)." 1997.

Eilers, JM, *et al*. 1987. EPA-600/3-86/054b.

Everest, FH. 1964. Survey of Horseshoe and Snag Lakes…Report. NPS, LAVO. (data in NPS-WRD, 1999a).

Everest, FH. 1964. Survey of Juniper Lake…NPS, LAVO. (data in NPS-WRD, 1999a).

Fellers, G, *et al*. 2003. Apex Site Monitoring, Amphibian Research and Monitoring Initiative.

Fogelman, R. P. "Ground-water quality in the Sacramento Valley, California; water types and potential nitrate and boron problem areas." Hydrologic Investigations Atlas, no. HA-0651 (1983): 1 sheet.

Ghiorso, MS. 1972. Preliminary summary of the chemical nature of the thermal springs of LAVO.

Ghiorso, MS. 1976. Geochemistry of acid-sulfate hot springs. NPS, LAVO.

Ghiorso, MS. 1977. Rock alteration and aqueous chemistry of the hot springs in LAVO. NPS, LAVO.

Ghiorso, MS. 1979. Geochemistry of the hot springs in LAVO. NPS, LAVO.

Ghiorso, MS. 1980. Geochemical studies of the volcanic domes and hot springs of LAVO. NPS, LAVO.

Ghiorso, MS. 1980. Mineral-solution equilibria in volcanic hot springs. NPS, LAVO.

Ghiorso, MS. 1980. PhD Dissertation. UC Berkeley

Gunter, Bobby Dean. "Geochemical and isotopic studies of hydrothermal gases and waters." 125 p Diss Abstr 29, no. 1 (1968): 135B-136B.

Gunter, Bobby Dean. "Geochemical and isotopic studies of hydrothermal gases and waters." Diss., University of Arkansas, 1968.

Handman, E. H., C. J. Londquist, and D. K. Maurer. Ground-water resources of Honey Lake Valley, Lassen County, California, and Washoe County, Nevada. U. S. Geological Survey, 1990. Water-Resources Investigations Report 90-4050.

Hubbell, PM. 1960. A survey of general ecological conditions in a group of lakes in Lassen National Park, 1960. prepared for NPS by Humboldt State University. (data in NPS-WRD, 1999a).

Hubbell, PM. 1961. A survey of Manzanita and Reflection Lakes…Report. NPS, LAVO (data in NPS-WRD, 1999a).

Ingebritsen, S. E, , and Sorey, M. L. "A quantitative analysis of the Lassen hydrothermal system, north central California." Water Resources Research 21, no. 6 (1985): 853-868.

Ingebritsen, Steven E., and Michael L. Sorey. "A quantitative analysis of the Lassen hydrothermal system, north central California." Water Resources Research 21, no. 6 (1985): 853-868.

Keunster, Gail. "Mill Creek watershed monitoring." 1999.

Landers, DH. 1986. EPA-600/3-86/054a.

Lenn, Robin. U S G S Chemical analysis: Drakesbad, Devils Kitchen, Little Hot Springs water samples (Lassen Volcanic National Park). 1965.

Majors, HM. 1961. Progress Reports No. 2 and No. 3. Seattle University, Seattle, WA. NPS, LAVO.

Mariner, RH. 1985. In Guffanti, M & LJP Muffler (eds), Us Geological Survey Open-File Report 85-521.

Mariner, Robert H, Evans, William C., and White, Lloyd D. "Chemical and isotopic characteristics of the sodium-chloride and sodium-calcium-chloride type thermal waters of the Cascade Range." No Title 26, no. 7 (1994): 363.

Mariner, Robert H., William C. Evans, and Lloyd D. White. "Chemical and isotopic characteristics of the sodium-chloride and sodium-calcium-chloride type thermal waters of the Cascade Range." Geological Society of America, 1994 annual meeting Abstracts with Programs Geological Society of America 26, no. 7 (1994): 363.

Marron, Donna C., and Julie A. Laudon. "Susceptibility to mudflows in the vicinity of Lassen Peak, California." In Selected papers in the hydrologic sciences 1986, by Seymour Subitzky, 97-106. U S Geological Survey Water Supply Paper W 2310. Reston, VA: U. S. Geological Survey, 1987.

Maurer, Douglas K. Hydrogeologic setting and hydrologic data of the Smoke Creek Desert Basin, Washoe County, Nevada, and Lassen County, California, water years 1988-90. US Geological Survey water-resources investigations report. Carson City, Nevada: U.S. Geological Survey, 1993.

McClelland, EJ. 1973. A brief field survey…USGS, WRD. (data in NPS-WRD. 1999a).

Meadows, G. R, Dudka, S., Jackson, L. L., Gough, L. P., and Briggs, P. H. Analytical results and sample locality map of whiteleaf manzanita, digger pine, soil, and water samples, Redding CUSMAP sheet biogeochemical study, Tehama County, California. (United States Geological Survey) Open file report. 1988.

Moffett, J. W. A fishery survey of some waters in Lassen Volcanic National Park. Lassen Volcanic National Park, 1942.

Muffler, LJP, *et al*. 1982. The Lassen Geothermal System. USGS Proceedings, 1982 Geothermal Conf. (data in NPS-WRD, 1999a).

Muffler, LJP, *et al*. 1983. US Geological Survey Miscellaneous Field Studies Map MF-1484.

National Park Service Spreadsheet (RL_1986.xls). LAVO.

National Park Service-Water Resources Division, Baseline water quality data inventory and analysis, Lassen Volcanic National Park, Volume I of II. Denver, CO: Water Resources Division, National Park Service, Department of the Interior, 1999. Technical Report NPS/NRWRD/NRTR-99/244.

National Park Service-Water Resources Division, Baseline water quality data inventory and analysis, Lassen Volcanic National Park, Volume II of II. Denver, CO: Water Resources Division, National Park Service, U.S. Department of the Interior, 1999. Technical Report NPS/NRWRD/NRTR-99/244.

Olmsted, F.H, , and Davis, G.H. "Geologic features and ground-water storage capacity of the Sacramento Valley, California." US Geological Survey Water-supply Paper, no. 1497 (1961): plate 2.

Olmsted, F.H., and G.H. Davis. Geologic features and ground-water storage capacity of the Sacramento Valley, California. U. S. Geological Survey, 1961. Water supply paper 1497.

Patterson and Cooper. In prep. Research on the Drakesbad fen, 2002-2004.

Paulson, K. M, and Ingebritsen, S. E. Sodium and chloride data from selected streams in the Lassen area, north-central California, and their relation to thermal-fluid discharge from the Lassen hydrothermal system. Water Resources Investigations. 1991.

Paulson, K. M., and Steven E. Ingebritsen. "Sodium and chloride data from selected streams in the Lassen area, north-central California, and their relation to thermal-fluid discharge from the Lassen hydrothermal system." Water Resources Investigations, no. WRI 90-4201 (1991).

Purvis JM. 1976. Summary of Aquatic Resources Inventory, Unit 10…Report. NPS, LAVO.

Purvis JM. 1976. Summary of Aquatic Resources Inventory, Unit 14…Report. NPS, LAVO.

Purvis, JM. 1976. Snag Lake Management Report. NPS, LAVO.

Serr, Gene. Water for the giant: history of the Dutch Hill Ditch. 1992.

Shaw, Daniel W. H. "Changes in population size and colony location of breeding waterbirds at eagle lake, California between 1970 and 1997." Diss., California State University, Chico, 1998.

Smith, C. L, Ficklin, W. H., and Thompson, J. M. "Enrichment of arsenic, antimony, and tungsten in the waters of some modern high-temperature geothermal systems." The Geological Society of America, 97th annual meeting Abstracts with Programs Geological Society of America 16, no. 6 (1984): 660.

Smith, C. L., W. H. Ficklin, and J. Michael Thompson. "Enrichment of arsenic, antimony, and tungsten in the waters of some modern high-temperature geothermal systems." The Geological Society of America, 97th annual meeting Abstracts with Programs Geological Society of America 16, no. 6 (1984): 660.

Sorey, ML. 1983. Report on a field trip to Lassen Region on August 1-5, 1983. (data in NPS-WRD, 1999a).

Sorey, Michael L., and Steven E. Ingebritsen. Quantitative analysis of the hydrothermal system in Lassen Volcanic National Park and Lassen known geothermal resource area. U S Geological Survey Water-Resources Investigations Report 84-4278. Menlo Park, California: U.S. Geological Survey, 1984.

Sorey, Michael L., and Steven E. Ingebritsen. "Comparison of stream and hot-water discharge rates from the hydrothermal system in and adjacent to Lassen Volcanic National Park, California." AGU 1990 fall meeting Eos, Transactions, American Geophysical Union 71, no. 43 (1990): 1674.

Sorey, Michael L., Elizabeth M. Colvard, and Steven E. Ingebritsen. Measurements of thermal-water discharge outside Lassen Volcanic National Park, California, 1983-1994. Menlo Park, CA: U. S. Geological Survey, 1994. Water Resources Investigations 94-4180-B.

Taylor, Dean William, and David C. Randall. Ecological Survey of the Vegetation of the Cub Creek Watershed, Lassen National Forest, CA. 1977.

Taylor, Wm., and David C. Randall. "Ecological survey of the vegetation of the Cub Creek watershed, Lassen National Forest, California." no date.

Thompson, JM., 1982, "Preliminary chemical studies of thermal waters in Lassen Volcanic National Park and vicinity." Geothermal energy; turn on the power United States Transactions Geothermal Resources Council, San Diego, CA, Oct. 11-14, 1982, R. G. Lacy, 115-118. San Diego, CA: San Diego Gas and Electr. Co.

Thompson, JM. 1983. US Geological Survey Open-File Report 83-311.

Thompson, JM. 1985. Journal of Volcanology and Geothermal Research 25: 81-104.

Thompson, J. M, Keith, T. E. C., and Consul, J. J. "Water chemistry and mineralogy of Morgan and Growler hot springs, Lassen KGRA, California." 1985 International symposium on geothermal energy Geothermal Resources Council, Davis, CA, United States Transactions Geothermal Resources Council 9, no. Part 1 (1985): 357-362.

Thompson, J. Michael, T. E. C Keith, and J. J. Consul. "Water chemistry and mineralogy of Morgan and Growler hot springs, Lassen KGRA, California." 1985 International symposium on geothermal energy Transactions Geothermal Resources Council, Kailua-Kona, HI, August 26-30, 1985, 357-362. Davis, CA: Geothermal Resources Council, 1985.

U.S. Geological Survey. Measurements of thermal-water discharge outside Lassen Volcanic National Park, CA 1983-94. Menlo Park, CA1994. Water Resources Investigations Report 94-4180-B.

Waring, GA. 1915. US Geological Survey Water Supply Paper No. 338.

West, JR. 1976. The Lentic Resources of Lassen Volcanic National Park. Report. NPS, LAVO.

White, D. E. "Summary of studies of thermal waters and volcanic emanations of the Pacific region, 1920-1960." Geology and Solid Earth Geophysics of the Pacific Basin: Pacific Science Congress 10th, Honolulu, Hawai`i, 1961, G. A. Macdonald, pgs. 161-169. Rep Ser. 1961.

Williamson, R. L., J. O'Keefe, R. Simonsen, D. Spoto, B. Eggleston & J. Hendrickson. 1997. Lassen Volcanic National Park Sanitary Survey. Department of Civil Engineering and Applied Mechanics, San Jose State University, San Jose, CA. (data in NPS-WRD, 1999a).

LASSEN VOLCANIC NATIONAL PARK AMPHIBIAN AND FISHERIES STUDIES

Bodine, Lester D. Long range fishery management plan, Lassen Volcanic National Park, 1966-1975. 1966.

California Academy Of Sciences, Golden Gate Park. Specimen lists for reptiles and amphibians, and fish. San Francisco, CA: California Academy of Sciences, Golden Gate Park, 1998.

California Department of Fish and Game and National Park Service - Western Region. "Joint study on fishery management in National Parks in California." no date.

Deinstadt, John M., Glenn F. Sibbald, and Al Denniston. Manzanita Lake (Lassen Volcanic National Park) Fisheries Management Plan (Draft). State of California The Resources Agency Department of Fish and Game, 1995.

Deinstadt, John M., Terry Healey, and Al Denniston. "Elecrofishing survey of rainbow and brown trout in Manzanita Lake (Lassen Volcanic National Park) during November 1994 (Draft)." 1994.

Deinstadt, John M., and Alan E. Denniston. Status of the trophy rainbow trout fishery at Manzanita Lake (Lassen Volcanic National Park) based on reports from angler survey boxes in 1994. Rancho Cordova, California: California Department of Fish and Game, 1995. File Report 95-1.

Deinstadt, John M., and Russell P. Lesko. Status of the rainbow trout fishery in manzanita lake (Lassen Volcanic National Park) based on reports from angler survey boxes in 1996. Rancho Cordova, CA: Wild Trout Project, California Department of Fish and Game, 1997. File Report 97-1.

Denniston, Alan E. "News release: U.S. Department of the Interior, National Park Service, Fishing regulations change at Manzanita Lake." no date.

Denniston, Alan E. Status of the Manzanita Lake trout fishery, Lassen Volcanic National Park. 1978.

Denniston, Alan E. Summary of 1976 lake survey data relating to the status of trout fisheries in Lassen Volcanic National Park. 1977.

Dettman, D. H. "Distribution, abundance, and microhabitat segregation of rainbow trout and Sacramento squawfish in Deer Creek, California." Diss., University of California, Davis, 1973.

Jacot, Francis. Management of fishing and fish stocking in National Parks in California. San Francisco, CA: U.S. Department of The Interior, National Park Service, 1975.

Kimsey, J. B. "The life history of the Tui Chub, Siphateles bicolor (Girard), from Eagle Lake, California." Calif Fish and Game 40, no. 4 (1954): 395-411.

King, Vernon. First Progress Report of the Eagle Lake Rainbow Trout Fishery. California Department of Fish and Game, 1963.

Lassen Volcanic National Park. Fish. 1930.

Lassen Volcanic National Park. Fish. 1941.

Lassen Volcanic National Park. Fish planting. 1932.

Lassen Volcanic National Park. "Fishing regulations." 1991.

Maciolek, John A. "Aquatic resources of Lassen Volcanic, Sequoia-Kings Canyon, and Yosemite National Parks with special reference to trout stocking and the recreational fishery." 1978.

Moffett, J. W. A fishery survey of some waters in Lassen Volcanic National Park. Lassen Volcanic National Park, 1942.

Perrine, John D. "Annual Report to California Department of Fish and Game: Sierra Nevada red fox (Vulpes vulpes necator) research Program." 2000.

Perrine, John D., and Reginald H. Barrett. "Annual report to California Department of Fish and Game: Sierra Nevada Red Fox (Vulpes vulpes necator) Research Program, June 21, 2000 - June 20, 2001." 2001.

Potts, Merlin K., and Paul E. Schulz. Fish and fishing in Lassen Volcanic National Park. Mineral, CA: Loomis Museum Association, 1953.

Stead, J.E., Welsh, Jr., H.H., Pope, K.L. 2005. Census of amphibians and fishes in lentic habitats of Lassen Volcanic National Park: A report to the National Park Service. LVNP Study Number: LAVO-00717. 77 p.

Unknown, "Fishes of Lassen Volcanic National Park." 1970.

Unknown, Management of high country lakes in the National Parks of California, 1976.

Unknown, Snag Lake Management Report, 1976.

Unknown, Food Habits Analysis of Fish from Mountain Lakes in Lassen Volcanic National Park, California. 1977.

Unknown, Aquatic resources of Lassen Volcanic, Sequoia-Kings Canyon, and Yosemite National Parks, with special reference to trout stocking and the recreational fishery, 1978.

Unknown, FY04 Joint inventory of fishes, native amphibians, and invertebrates in all lakes and ponds of the park. Status of the trophy rainbow trout fishery at Manzanita Lake (Lassen Volcanic National Park) based on reports from angler survey boxes in 1994.

Unknown, Surveys of the Sifford Lakes, Lassen Volcanic National Park, 2000.

Wallis, OL. 1959. Fishery Resources Report. NPS, LAVO.

Wallis, O. L. Interpretation, research, and management of the fishery resources in Lassen Volcanic National Park. 1959.

Wallis, Orthello L. Review of trout fishery situation, Lassen Volcanic National Park, California. National Park Service, 1955.

Wallis, Orthello L. An analysis: Impacts of trout stocking upon recreational fishing and aquatic resources in Lassen Volcanic, Sequoia and Kings Canyon, and Yosemite National Parks, California. 1977.

Wauer, Ro. "Briefing Statement: Fish stocking in Yosemite, Lassen, and Sequoia-Kings Canyon National Parks." 1982.

LASSEN VOLCANIC NATIONAL PARK LAKE MONITORING

Blick, D. J., *et al.* Western Lake Survey, Phase I, Characteristics of lakes in the Western United States. Data compendium for selected physical and chemical variables. Washington, D. C: U. S. Environmental Protection Agency, Office of acid deposition, environmental monitoring and quality assurance, 1987. EPA-600/3-86/054b.

Christenson, D. P. "History of trout introductions in California high mountain lakes." Symposium on the management of high mountain lakes in Californias National Parks, Fresno, CA, January 29.1976, California Trout, Inc, 9-16. San Francisco, CA: California Trout, Inc, 1977.

Davis, G. E. Preliminary inventory survey of Cliff, Hat, Ink and Terrace Lakes. Lassen Volcanic National Park, 1967.

DeMartini, John D., Phillip Buttolph, and Stephen Newmann. "Pilot Surveys of the Sifford Lakes and of the Cluster Lakes of Lassen Volcanic National Park, July 11, 2000." 2000.

Demartini, John D., Phillip Buttolph, Stephen Newman, and Steven Zachary. "Surveys of the Sifford Lakes, Lassen Volcanic National Park." 2000.

Everest, Fred H. A Survey of Horseshoe and Snag Lakes and their Tributaries, Lassen Volcanic National Park, June-September, 1963. 1964.

Hubbell, Paul M. "A survey of Manzanita and Reflection Lakes, Lassen Volcanic National Park, June - September, 1961." Diss., Humboldt State College, 1961.

Hubbell, Paul M. "A survey of general ecological conditions in a group of lakes in Lassen Volcanic National Park, 1960." 1960.

Purvis, Jesse M. Summary of aquatic resources inventory for Management Unit 14 (Twin Lakes) Lassen Volcanic National Park. 1976.

Richards, Robert C., and Charles R. Goldman. "Limnology of Californias high mountain lakes." Symposium on the mangement of high mountain lakes in Californias National Parks, Fresno, California, January 29, 1976, Al Hall, and Richard May, 1-7. San Francisco, CA: California Trout, Inc, 1977.

Till, A. B, McHugh, E. L., and Ramsey, C. M. Mineral resource potential of the Thousand Lakes Wilderness, Shasta County, California. U S Geological Survey Open file report. 1983.

Till, A. B., and E. L. Mchugh. "Thousand Lakes Wilderness, California." In Wilderness Mineral Potential--Assessment of Mineral-Resource Potential in U S Forest Service Lands Studies 1964-1984, by R. G. Dickinson, S. J. Kropschot, and S. P. Marsh, gs. 199-201. 1984.

Till, Alison B., Edward L. Mchugh, and C. M. Ramsey. Mineral resource potential of the Thousand Lakes Wilderness, Shasta County, California. Reston, VA: U. S. Geological Survey, 1983. Open file report OF 83-0408.

Wallis, Orthello L. Management of high country lakes in the National Parks of California. San Francisco, CA: U.S. Department of the Interior, National Park Service, Western Regional Office, 1976.

Wallis, Orthello. "Management of high-country lakes in the National Parks of California." Symposium on the management of high mountain lakes in Californias National Parks, Fresno, CA, January 29, 1976, California Trout, Inc, 53. San Francisco: California Trout, Inc, 1977.

Watson, Sarah. "Camper impact on the Twin Lakes, Lassen Volcanic National Park." Diss., Humboldt State University, 1977.

West, JR. "Cluster Lakes Regional Report." 1976.

West, JR. 1976. Manzanita Lake. Report. NPS, LAVO.

West, JR. 1976. Report on Butte, Snag, and Horseshoe Lakes. NPS, LAVO.

West, JR. 1976. Report on Terrace, Shadow, and Cliff Lakes. NPS, LAVO.

West, JR. 1976. Twin Lakes Regional Report. NPS, LAVO.

West, John R. "Food Habits Analysis of Fish from Mountain Lakes in Lassen Volcanic National Park, California." 1977.

LAVA BEDS NATIONAL MONUMENT WATER QUALITY

California Department of Water Resources. "Northeastern counties ground-water investigations." California Dept Water Resources Bulletin, no. 98 (1963): Plates.

California Regional Water Quality Control Board. North Coast Region Water Quality Control Board 303(d) list update recommendations. 2001.

California Water Resources Planning Division. "Klamath River Basin Investigation." California Dept Water Resources Bulletin, no. 83 (1963): plate 6.

Cannon, Amanda. "1999 baseline water quality analysis of Lava Beds National Monument caves, headqarters building, and Tule Lake." 1999.

Cleghorn, John C. Historic water levels of Tulelake, California-Oregon and their relation to the petroglyphs. Klamath County Museum research papers. Klamath Falls, Oregon: Guide Printing Co, 1959.

National Park Service-Water Resources Division, Baseline water quality data: inventory and analysis: Lava Beds National Monument. Fort Collins, CO: U.S. National Park Service, 1999. NPS/NRWRD/NRTR-99/214.

Ochial, T., and H. Kawasaki. "Behavior of groundwater flowing in Lava Beds." Hiratsuka Agr Eng Res Sta Bull 8 (1970): 67-83.

Reece, Matthew. "Effects on water chemistry and flowpaths due to the removal of development above Mushpot Cave, Lava Beds National Monument. Investigators Annual Report." 2002.

Sisson, T. W, , and Grove, T. L. "Water-saturated melting of calc-alkaline high alumina basalt and basaltic andesite." No Title 71, no. 17 (1990): 648.

Wood, P.R. "Geology and ground-water features of the Butte Valley region Siskiyou County, California." US Geological Survey Water-Supply Paper, no. 1491 (1960): plate 1.

Wood, Perry. Geology and ground-water features of the Butte Valley Region, Siskiyou County, California. Geologic Survey Water-Supply Paper. Washington, D.C: GPO, 1960.

OREGON CAVES NATIONAL MONUMENT WATER QUALITY

Iwatsubo, R. T, and Washabaugh, D. S. Water-quality assessment of the Smith River drainage basin, California and Oregon. Report Available Only through NTIS. 1982.

Mark, S. 1994. Crater Lake Nature Notes, Volume 25.

National Park Service-Water Resources Division. 1998. Baseline Water Quality Data Inventory and Analysis: Oregon Caves National Monument. Technical Report NPS/NRWRD/NRTR-98/186. Water Resources Division and Servicewide Inventory and Monitoring Program, Fort Collins, CO. 361 p.

Roth, J. 1994. Crater Lake Nature Notes, Volume 25.

Salinas, John. "Cave Infiltration and Water Quality, Investigators Annual Report." 2001.

Salinas, John. "Cave Infiltration and Water Quality, Investigators Annual Report." 2002.

Wittenberg, L. A, , and McKenzie, S. W. Water quality of Bear Creek basin, Jackson County, Oregon. U S Geological Survey Open file report. 1980.

REDWOOD NATIONAL AND STATE PARKS WATERSHED MONITORING

Anderson, David G. Invertebrate drift and juvenile salmonid habitat of Redwood Creek watershed. 1981.

Anderson, David G., and Randy A. Brown. "Anadromous salmonid nursery habitat in the Redwood Creek watershed." Proceedings of the first biennial conference of research in Californias national parks, University of California, Davis, September 9-10, 1982, Lynn D. Whittig, Marsha L. Murphy, and Charles III Van Riper, 225-229. Davis, CA: Cooperative Parks Studies Unit, University of California, 1983.

Axelrod, David. "Vegetative propagation of blue blossom." Proceedings of a symposium on watershed rehabilitation in Redwood National Park and other Pacific coastal areas,August 24-28, 1981, R. N. Coats, 96-102. Center for Natural Resource Studies of JMI, inc./National Park Service, 1981.

Best, David W. Monitoring and evaluation of watershed rehabilitation of logged lands in Redwood National Park 1977-1991: 1991 progress report. 1992.

Best, David W., Mary Ann Madej, and John Pitlick. Construction of a sediment budget for Redwood Creek watershed, northern California. no date.

Best, David W., and Mark J. Alpert. Construction of a sediment budget for the Garrett Creek watershed, northwestern California. 1982.

Bloom, Anna. Evaluation of 1997 storm response and erosion control treatments on abandoned logging roads in Bridge Creek and adjacent tributary watersheds to Redwood Creek, California: preliminary analysis plan. 1997.

Bundros, Gregory J. "Erosion control treatments in watershed rehabilitation at Redwood National Park [abstract]." Conference on Science in the National Parks: The Fourth Triennial Conference on Research in the National Parks and Equivalent Reserves, program and abstracts, Fort Collins, CO, National Park Service, and George Wright Society, page 65. 1986.

Bundros, Gregory J. Summary report, C-Line, Fortyfour Creek watershed rehabilitation project, unit 87-9. 1989.

Bundros, Gregory J., Terry A. Spreiter, Kenneth W. Utley, and Edward P. Wosika. "Erosion control in Redwood National Park, northern California, 1980." Watershed rehabilitation in Redwood National Park and other Pacific coastal areas, Arcata, CA, August 24-28, 1981, Robert N. Coats, 273-282. Berkeley, CA: Center for Natural Resource Studies of the John Muir Institute, Inc. and National Park Service, 1981.

Bundros, Gregory J., and Barry R. Hill. Road conditions and erosion potential in the upper Redwood Creek watershed. 1997.

Burns, David M., and Perry Y. Amimoto. Corrective work needed for the rehabilitation of the headwaters of the Redwood Creek watershed [preliminary draft of interim report]. 1976.

Coats, Robert N., and Taylor O. Miller. "Cumulative silvicultural impacts on watersheds: a hydrologic and regulatory dilemma." Environmental Management 5, no. 2 (1981): 147-160.

Coey, Robert M. (Bob), Randy D. Klein, Mary Ann Madej, Carolyn B. Meyer, David W. Best, and Vicki L. Ozaki. Monitoring the impacts and persistence of fine sediment in the Prairie Creek watershed, 1990-1991: progress report. 1991.

Dame, James K. Summary report, watershed rehabilitation unit 93-2: K&K Road and spurs. 1994.

Denton, Douglas N. "Water management for fishery enhancement on north coastal streams." Symposium on watershed rehabilitation in Redwood National Park and other coastal areas, Arcata, CA, August 25-28, 1981, Robert N. Coats, 230-262. The Center for Natural Resources Studies; National Park Service, 1981.

Division Of Resource Management And Science, Redwood National And State Parks. Redwood Creek watershed analysis. 1997.

Durgin, Phillip B., and Jeffrey E. Tackett. "Erodibility of forest soils--a factor in erosion hazard assessment." Watershed rehabilitation in Redwood National Park and other Pacific coastal areas, Arcata, CA, August 24-28, 1981, Robert N. Coats, pages 118-127. Berkeley, CA: Center for Natural Resource Studies of the John Muir Institute, Inc. and National Park Service, 1981.

Gray, Donald H. "Biotechnical slope protection and earth support." Watershed rehabilitation in Redwood National Park and other Pacific coastal areas, Arcata, CA, August 24-28, 1981, Robert N. Coats, pages 128-142. Berkeley, CA: Center for Natural Resource Studies of the John Muir Institute, Inc. and National Park Service, 1981.

Griffin, Karen. "Watershed rehabilitation at Redwood National Park." Whole Earth Review (1990).

Griffith, Bonnie C. Watershed rehabilitation unit 83-2 (M-3-1 road and slope): vegetation summary report. 1984.

Griffith, Bonnie C. Watershed rehabilitation unit 83-5 (W-Line/K&K slope): vegetation summary report. 1984.

Griffith, Bonnie C. Watershed rehabilitation unit 85-4 (C-40, C-50, C-70, lower C-Line): vegetation summary report. 1986.

Heede, Burchard H. "Analysis and guidelines for watershed rehabilitation." Watershed rehabilitation in Redwood National Park and other Pacific coastal areas, Arcata, CA, August 24-28, 1981, Robert N. Coats, pages 103-117. Berkeley, CA: Center for Natural Resource Studies of the John Muir Institute, Inc. and National Park Service, 1981.

Hektner, Mary M. "Revegetation and watershed rehabilitation in Redwood National Park [abstract]." Conference on Science in the National Parks: The Fourth Triennial Conference on Research in the National Parks and Equivalent Reserves, program and abstracts, Fort Collins, CO, George Wright Society, and National Park Service, 27. 1986.

Hektner, Mary M., Lois J. Reed, James H. Popenoe, Ronald J. Mastrogiuseppe, D. J. Vezie, Neil G. Sugihara, and Stephen D. , Veirs. "A review of the revegetation treatments used in Redwood National Park: 1977 to present." Proceedings of a symposium on watershed rehabilitation in Redwood National Park and other Pacific coastal areas, Arcata, CA, August 24-28, 1981, Robert N. Coats, 70-77. Berkeley, CA: Center for Natural Resource Studies of the John Muir Institute, Inc. and National Park Service, 1981.

Hektner, Mary M., and Lois J. Reed. "Revegetation and watershed rehabilitation in Redwood National Park [draft]." Society for Ecological Restoration and Management Annual Meeting, Oakland, CA, January 16-20, 1989, author unknown. 1989.

Hofstra, Terrence D. "Aquatic resources rehabilitation program, Redwood National Park." Proceedings of a symposium on watershed rehabilitation in Redwood National Park and other Pacific coastal areas, Arcata, CA, August 24-28, 1981, Robert N. Coats, pages 230-235. Berkeley, CA: Center for Natural Resource Studies of the John Muir Institute, Inc. and National Park Service, 1981.

Hofstra, Terry. "Park Project Clearance: In-stream debris removal, May Creek watershed." 1981.

Holden, Baker, Terry Spreiter, and Mike Sanders. "A biological assessment of impacts to aquatic threatened and endangered species from the Watershed Restoration Program in the northern portion of Lost Man Creek Watershed, Redwood National and State Parks." 2002.

Janda, Richard J. Summary of watershed conditions in the vicinity of Redwood National Park, California. US Geological Survey Open-file Report. Menlo Park, CA: U.S Geological Survey, 1977.

Janda, Richard J., K. Michael Nolan, Deborah R. Harden, and Steven M. Colman. Watershed conditions in the drainage basin of Redwood Creek, Humboldt County, California, as of 1973. US Geological Survey Open-file Report 75-568. Menlo Park, CA: U.S Geological Survey, 1975.

Johnson, Louise E. M-3 and M-4 roads and slope, watershed rehabilitation project: unit 87-5. 1988.

Johnson, Louise E. The M-3-1-2 road and slope watershed rehabilitation project: unit 86-5. 1987.

Johnson, Louise E. The M-4-1/2 and M-5 roads and slope watershed rehabilitation project: unit 86-3. 1988.

Keller, Edward A., Anne Macdonald, and Taz Tally. "Streams in the coastal redwood environment: the role of large organic debris." Watershed rehabilitation in Redwood National Park and other Pacific coastal areas, Arcata, CA, August 24-28, 1981, Robert N. Coats, 161-176. Berkeley, CA: Center for Natural Resource Studies of the John Muir Institute, Inc. and National Park Service, 1981.

Keller, Edward A., Robert Curry, and Paul Seidelman. Watershed rehabilitation in Redwood National Park: a critical evaluation. 1981.

Kelsey, Harvey M. "Limits to the effectiveness of erosion control techniques in the highly erosive watersheds of north coastal California." Geological Society of America, Abstracts with Programs 12, no. 3 (1980): 114.

Kelsey, Harvey M., Mary Ann Madej, John Pitlick, Peter Stroud, and Michael C. Coghlan. "Major sediment sources and limits to the effectiveness of erosion control techniques in the highly erosive watersheds of north coastal California." Proceedings, 1981 Symposium of Erosion and Sediment Transport in Pacific Rim steeplands, Christchurch, New Zealand, January 25-31, 1981, Andrew J. Pearce, and Timothy R. H. Davies, pages 493-509. Washington, D.C: International Association of Hydrological Sciences, 1981.

Kelsey, Harvey M., William E. Weaver, and Mary Ann Madej. "Geology, geomorphic processes, land use and watershed rehabilitation in Redwood National Park, and vicinity lower Redwood Creek basin." In Guidebook for a field trip to observe natural and resource management-related erosion in Franciscan terrane of northwestern California, by Geological Society Of America, XIII-1- XIII-18. Menlo Park, CA: Geological Society of America, 1979.

Kelsey, Harvey M., and Peter Stroud. Watershed rehabilitation in the Airstrip Creek basin, Redwood National Park. Redwood National Park Watershed Rehabilitation. Arcata, CA: National Park Service, 1981.

Kelsey, Harvey M., and William E. Weaver. "Watershed rehabilitation for erosion control on logged lands in Redwood National Park." In Guidebook for a field trip to observe natural and resource management-related erosion in Franciscan terrane of northwestern California, by Geological Society Of America, XII-1 through XII-14. Menlo Park, CA: Geological Society of America, 1979.

Kelsey, Harvey M., and William E. Weaver. Watershed rehabilitation for erosion control on logged lands in Redwood National Park. 1979.

Kenning, Michael, and Darcia A. Short. M-7 Road and Chilula Creek culvert replacement, watershed rehabilitation project summary report [unit 88-9]. 1988.

Kenning, Michael. B-5-1 Road watershed rehabilitation project summary report [unit 88-5]. 1989.

Kenning, Michael. G-6 Road watershed rehabilitation project summary report [unit 87-2]. 1989.

Klein, Randy D. Stream channel adjustments following logging road removal in Redwood National Park. Redwood National Park Watershed Rehabilitation. Arcata, CA: National Park Service, 1987. Technical Report 23.

Klein, Randy D., and Thomas Marquette. Data release on rainfall, streamflow, and suspended sediment transport in the Redwood Creek watershed, Humboldt County, California, 1990 through 1997 [preliminary]. 1998.

Klein, Randy, and Tom Marquette. Data release on rainfall, streamflow, and suspended sediment transport in the Redwood Creek watershed, Humboldt County, California 1990 through 1998. Redwood National and State Parks, 1999.

Kramer, Sharon, and Randy Klein. "The distribution and role of large woody debris in upper Prairie Creek, a pristine northern California redwood watershed." Proceedings of the eighteenth annual salmonid restoration federation conference, Fortuna, CA, March 2-5, 2000, Johanna Schussler, 6. 2000.

Larson, James P., Cynthia L. Ricks, and Timothy J. Salamunovich. "Alternatives for restoration of estuarine habitat at the mouth of Redwood Creek, Humboldt County, California." Proceedings of a symposium on watershed rehabilitation in Redwood National Park and other Pacific coastal areas, Arcata, CA, August 24-28, 1981, Robert N. Coats, pages 236-245. Berkeley, CA: Center for Natural Resource Studies of the John Muir Institute, Inc. and National Park Service, 1981.

Lennox, William S., Esteban H. Muldavin, James M. Lenihan, and Stephen D. , Veirs. "A practical application of discriminant functions for classifying successional vegetation communities in the first ten years following logging of coast redwood forests, in Redwood National Park." Proceedings of a symposium on watershed rehabilitation in Redwood National Park and other Pacific coastal areas, Arcata, CA, August 24-28, 1981, Robert N. Coats, pages 56-69. Berkeley, CA: Center for Natural Resource Studies of the John Muir Institute, Inc. and National Park Service, 1981.

Lewis, Jack. Soil survey of Y-Line Road for watershed rehabilitation, Redwood National Park [rehabilitation site 82-3]. 1982.

Madej, Mary Ann. "Deterring aggradation by large-scale gravel extraction." Proceedings of a workshop on techniques of rehabilitation and erosion control in recently roaded and logged watersheds, with emphasis to north coastal California,March 13-14, 1978, Mary Ann Madej, and Harvey M. Kelsey, pages 80-82. Arcata, CA: Resources Management Division, Redwood National Park, National Park Service, 1978.

Madej, Mary Ann. "Development, implementation and evaluation of watershed rehabilitation in Redwood National Park, north coastal California." Watershed and stream restoration workshop: shared responsibilities for shared watershed resources (Symposium proceedings of the American Fisheries Society, Portland, OR, August 1993, pages 75-82. American Fisheries Society, 1993.

Madej, Mary Ann. "Hillslope-river interactions." Watersheds 94: Respect, Rethink, Restore (Proceedings of the fifth biennial Watershed Management Conference), Ashland, OR, November 16-18, 1994, Richard R. Harris, et al, pages 15-18. University of California Water Resources Center Report. Davis, CA: Centers for Water and Wildland Resources, Water Resources Center, University of California, 1995.

Madej, Mary Ann. Recovery of streams after watershed restoration [proposal]. USGS, 1995.

Madej, Mary Ann. "Measures of stream recovery after watershed restoration." Proceedings on watershed restoration management: physical, chemical, and biological considerations,, J. B. Stribling, *et al.* Syracuse, NY: American Water Resources Association, 1996.

Madej, Mary Ann, and Harvey M. Kelsey. "Sediment routing in stream channels: its implications for watershed rehabilitation." Watershed rehabilitation in Redwood National Park and other Pacific coastal areas, Arcata, CA, August 24-28, 1981, Robert N. Coats, 17-25. Berkeley, CA: Center for Natural Resource Studies of the John Muir Institute, Inc. and National Park Service, 1981.

Madej, Mary Ann, Harvey M. Kelsey, and William E. Weaver. Evaluation of 1978 rehabilitation sites and erosion control techniques, Redwood National Park. Redwood National Park Watershed Rehabilitation. Arcata, CA: National Park Service, 1980.

Madej, Mary Ann, and Vicki L. Ozaki. Risk assessment in watershed rehabilitation. 1996.

Madej, Mary Ann, Colleen O'Sullivan, and Nick Varnum. An evaluation of land use, hydrology, and sediment yield in the Mill Creek watershed, northern California. Redwood National Park Research and Development. Arcata, CA: Redwood National Park, 1986. Technical Report 17.

Madej, Mary Ann, William E. Weaver, and Harvey M. Kelsey. Watershed rehabilitation summary report 78-1 thru 78-5 (all 1978 rehab projects). 1980.

Martinez, Manuel, Chris McAuliffe, Bill Michaels, Dan Miles, and Mary Anne Pella. A survey of Streelow Creek watershed. no date.

Mattison, Jeffrey, Terry Spreiter, and Judy Wartella. "A biological assessment of impacts to terrestrial threatened and endangered species from the Watershed Restoration Program in portions of Lost Man Creek Watershed in Redwood National and State Parks (RNSP)." no date.

Mayer, Kenneth E., and Lawrence Fox. Final report: Watershed condition inventory of the Hoopa Valley Indian Reservation utilizing landsat digital data. Arcata, CA: U.S. Fish and Wildlife Service, Remote Sensing and Technology Transfer Project, no date.

McCain. M., Devlin-Craig, B., Black, C., 1995, Smith River ecosystem analysis: basin and sub-basin analyses and late-successional reserve assessment: Six Rivers National Recreation Area, Six Rivers National Forest, 192 p.

Mccullah, John A. Recent watershed conditions of Streelow Creek basin in the vicinity of Redwood National Park, California. 1983.

Mckay, Forrest, and Tim Mckay. Aquatic macroinvertebrates and land use in three watersheds. 1997.

Meyer, Carolyn B. Monitoring the impacts and persistence of fine sediment in the Prairie Creek watershed: final fisheries summary report, Water Years 1990-1994. 1994.

Meyer, Carolyn B. Monitoring the impacts and persistence of fine sediment in the Prairie Creek watershed: results for Water Year 1993 and a summary of study years 1989-1993, with recommendations based on data from 1981-1994 [DRAFT]. 1994.

Meyer, Carolyn B., Randy D. Klein, and Cara Smith. Monitoring the impacts and persistence of fine sediment in the Prairie Creek watershed: results for 1992-1993 and a summary of study years 1989-1993. 1994.

Meyer, Carolyn B., Robert M. (Bob) Coey, Randy D. Klein, Mary Ann Madej, David W. Best, and Vicki L. Ozaki. Monitoring the impacts and persistence of fine sediment in the Prairie Creek watershed, Water Years 1991-1992. 1994.

Meyer, Carolyn B., Robert M. Coey, Randy D. Klein, Mary Ann Madej, David W. Best, and Vicki L. Ozaki. Monitoring the impacts and persistence of fine sediment in the Prairie Creek watershed, WY1990 - WY1991. 1994.

National Marine Fisheries Service, Southwest Region. "Endangered species act, section 7 consultation, biological opinion [Lost Man Creek Watershed Restoration Program]." 2003.

National Marine Fisheries Service. Biological opinion and conference opinion watershed restoration program: Routine and non-routine road maintenance in Redwood National and State Parks. no date.

National Park Service. Land use requirements for protection of Redwood National Park, Redwood Creek watershed. San Francisco, CA: National Park Service, Department of the Interior, 1975.

Nolan, K.M., 1979, Graphic and tabular summaries of changes in stream-channel cross sections between 1976 and 1978 for Redwood Creek and selected tributaries, Humboldt County, and Mill Creek, Del Norte County, California: U.S. Geological Survey Open-File Report 79-1637, 38 p.

Nolan, K.M., Harden, D.R., 1976, Graphic and tabular summaries of water and suspended-sediment discharges during two periods of synoptic storm sampling during 1975 in the Mill Creek drainage basin, Del Norte county, California, U.S. Geological Survey Open-File Report 76-473, 13 p.

Nolan, K. Michael, and Richard J. Janda. "Recent history of the main channel of Redwood Creek, California." Symposium on watershed rehabilitation in Redwood National Park and other Pacific coastal areas: symposium program and readings in watershed management & rehabilitation, Arcata, CA, August 25-28, 1981, Robert N. Coats. Berkeley, CA: Center for Natural Resource Studies of the John Muir Institute, Inc. and National Park Service, 1981.

Parker, Gary. Formation and propagation of large-scale sediment waves in periodically disturbed mountain watersheds [study plan]. 1995.

Pitlick, John. "Organic debris in tributary stream channels of the Redwood Creek basin." Watershed rehabilitation in Redwood National Park and other Pacific coastal areas, Arcata, CA, August 24-28, 1981, Robert N. Coats, pages 177-190. Berkeley, CA: Center for Natural Resource Studies of the John Muir Institute, Inc. and National Park Service, 1981.

Popenoe, James H. "Effects of grass-seeding, fertilizer and mulches on seedling patterns at the Copper Creek Watershed Rehabilitation Unit." Proceedings of a symposium on watershed rehabilitation in Redwood National Park and other Pacific coastal areas, Arcata, CA, August 24-28, 1981, Robert N. Coats, pages 87-95. Berkeley, CA: Center for Natural Resource Studies of the John Muir Institute, Inc. and National Park Service, 1981.

Popenoe, James H. C-20 and C-30 roads: soils concepts for watershed rehabilitation (soil review). 1982.

Popenoe, James H. Soils in the Little Bald Hills watershed rehabilitation unit (87-7). 1987.

Popenoe, James H. Soils inventory of the D-Line watershed rehabilitation unit (83-4). 1983.

Popenoe, James H. Soils meeting, watershed rehabilitation staff, Redwood National Park. 1981.

Popenoe, James H. Soils of the G-Line road system, Tom McDonald Creek watershed [rehabilitation unit 87-2]. 1984.

Popenoe, James H. Soils of the Lyons Ranch Road watershed rehabilitation unit. 1988.

Popenoe, James H. Soils of the M-2-1-1, M-3-1-2, M-4-1 and beginning of M-3 and M-4 roads, Bridge Ridge and Bridge Creek headwaters [watershed rehabilitation units]. 1985.

Popenoe, James H. Soils of the M-7-5 and 1800 roads, east slope of Bridge Ridge [watershed rehabilitation unit]. 1985.

Popenoe, James H. Watershed rehabilitation and revegetation in Redwood National Park. 1991.

Popenoe, James H., Jack Lewis, and Donna C. Marron. Soil survey of L-1 and L-1-5 roads for watershed rehabilitation, Redwood National Park [rehabilitation unit 82-4]. no date.

Popenoe, James H., Mark J. Alpert, and Nancy K. Sturhan. Soils of the 1840 and 1850 roads, east slope of Bridge Ridge [watershed rehabilitation unit 84-4: unit pre-review draft]. 1984.

Popenoe, James H., and Ken A. Bevis. Soils of the upper Elam Creek tributary watershed. 1990.

Popenoe, James H., and Mark J. Alpert. Soils of the 1800, 1820, and 1821 roads, east slope of Bridge Ridge [watershed rehabilitation unit 84-3: unit pre-review draft]. 1984.

Popenoe, James H., and Nancy K. Sturhan. Soils of the lower K&K Road watershed rehabilitation unit. 1988.

Popenoe, James H., and Roy W. Martin. Soils of the Fortyfour Creek tributary watershed rehabilitation unit [84-5]. 1984.

Popenoe, James H., and Roy W. Martin. Soils of the M-6 Road, Bridge Creek watershed rehabilitation unit. 1985.

Popenoe, James H., and Roy W. Martin. Soils of the M-7 Road at the Bridge Creek crossing [watershed rehabilitation unit 86-1]. 1985.

Popenoe, James P. "Watershed rehabilitation and revegetation in Redwood National Park." Proceedings of the USDI-National Park Service Reclamation and Vegetation Workshop,, none. National Park Service, United States Department of the Interior, 1991.

Popenoe, James P. Soils of the Highway 101 Bypass watershed rehabilitation unit (88-1). 1988.

Popenoe, James P., Jack Lewis, Nancy K. Sturhan, and Roy W. Martin. Site-specific soil inventories from watershed rehabilitation sites in the lower Redwood Creek basin, Redwood National Park. 1980.

Popenoe, James P., and Nancy K. Sturhan. Soils of the May Creek headwaters watershed rehabilitation unit (87-1). 1987.

Potter, Robert G. Rehabilitating the Redwood Creek watershed: a preliminary plan prepared for the California Resources Agency by a multidisciplinary study team. 1975.

Proceedings of a symposium on watershed rehabilitation in Redwood National Park and other Pacific Coastal areas, Humboldt State University, Arcata, California, August 24-28, 1981, Robert N. Coats. John Muir Institute, Center for Natural Resource Studies/U.S. National Park Service, 1981.

Proceedings of a workshop on techniques of rehabilitation and erosion control in recently roaded and logged watersheds, with emphasis to north coastal California,March 13-14, 1978, Harvey M. Kelsey, and Mary Ann Madej. Arcata, CA: Resources Management Division, Redwood National Park, National Park Service, 1978.

Redwood National Park, and Denver Service Center. Watershed rehabilitation plan, Redwood National Park. Denver, CO: National Park Service, Denver Service Center, 1981. NPS 1746.

Redwood National Park. Field trip guide to observe watershed rehabilitation and geomorphic studies in Redwood National Park. 1985.

Redwood National Park. Monitoring the impacts and persistence of fine sediment in the Prairie Creek watershed, 1989-1990. Arcata, CA: United States Department of the Interior, National Park Service, 1991.

Redwood National Park. Nominating Redwood Creek as a sensitive watershed. 1993.

Redwood National Park. Persistence and impacts of fine sediment in the Prairie Creek watershed: A progress report to the California Department of Transportation. 1992.

Redwood National Park. Technical specifications for erosion control measures and watershed rehabilitation. 1980.

Redwood National Park. Technical specifications for watershed rehabilitation. 1978.

Redwood National Park. The Redwood National Park watershed rehabilitation program: a progress report and plan for the decade 1990-2000. 1990.

Redwood National Park. The Redwood National Park watershed rehabilitation program: a progress report and plan for the future. 1984.

Redwood National Park. The watershed rehabilitation program: accomplishments (1984-1990), [1990 progress report]. 1991.

Redwood National Park. Watershed rehabilitation plan, Environmental Assessment, Redwood National Park, Del Norte and Humboldt counties, California. Denver, CO: National Park Service, Denver Service Center, 1980.

Redwood National Park. Watershed restoration at Redwood National Park: sediment sources and the evolution of watershed restoration (1978-1997). 1997.

Redwood National Park. Wildlife species in the vicinity of the Redwood Creek watershed. no date.

Redwood National Park. untitled: Redwood Creek watershed: maps (untitled collection). 1993.

Redwood National and State Parks. Redwood Creek watershed analysis [Draft]. Redwood National and State Parks, 1995.

Reed, Lois J. Evaluation of revegetation at Copper Creek [watershed rehabilitation unit 79-5]. 1983.

Reed, Lois J. Watershed rehabilitation unit revegetation (RM-1): 1992 progress report (for the period from May 1991 to April 1992). 1992.

Reed, Lois J., and Mary M. Hektner. Watershed rehabilitation unit revegetation (RM-1): 1990 progress report. 1991.

Reeves, Gordon, Terry D. Roelofs, and John West. Aquatic ecosystem analysis of two logged and two unlogged watersheds in Redwood National Park and Prairie Creek Redwoods State Park. 1976.

Reid, Leslie M., Robert R. Ziemer, and Michael J. Furniss. "What do we need to know about roads? [draft]." In Issues in watershed analysis, by Leslie M. ReidAlbany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, 1996.

Robinson, Gordon P. A critique of An analysis of the buffers and the watershed management required to preserve the redwood forest and associated streams in the Redwood Natl Park by Edward C Stone, Rudolf F Grah, and Paul J Zinke, for the US NPS April 30, 1969. 1969.

Roelofs, Terry D., and William T. Trush. Carrying capacity and limiting factor analysis for coho salmon (*Oncorhynchus kisutch*) habitat on forested watersheds of northern California [proposal]. 1994.

Sacklin, John A. Restoring parklands: watershed rehabilitation in Redwood National Park. Redwood National Park, 1983.

Sanders, Michael B. Summary report, watershed rehabilitation unit 95-3, partial removal of the K&K Road, Phase VI: South Fork and Middle Fork Slide Creek. 1997.

Sanders, Michael B. Summary report, watershed rehabilitation unit 96-2, partial removal of the K&K Road, Phase VII: North Fork Slide Creek. 1997.

Short, Darcia A. A section of the C-20 road & rock quarry, watershed rehabilitation project summary report: unit 88-10. 1989.

Short, Darcia A. B-5-1-1 road and slope, watershed rehabilitation project summary report: unit 88-8. 1989.

Short, Darcia A. Summary report, watershed rehabilitation unit 90-3: M-7, M-5, G-4. 1992.

Short, Darcia A. Summary report, watershed rehabilitation unit 91-1: C-Line. no date.

Sinclair, J. D. Report of watershed conditions observed on lands of the Arcata Redwood Company, Humboldt County, California. 1966.

Smith, Becca. Summary report, rolling dip project 96-3, Coyote Creek watershed. 1997.

Smith, Becca. Summary report, watershed rehabilitation units 95-1 and 95-2: Ah Pah Road complex. 1997.

Sonnevil, Ronald A., and William E. Weaver. "The evolution of approaches and techniques to control erosion on logged lands in Redwood National Park, 1977-1981." Watershed rehabilitation in Redwood National Park and other Pacific coastal areas, Arcata, CA, August 24-28, 1981, Robert N. Coats, pages 258-272. Berkeley, CA: Center for Natural Resource Studies of the John Muir Institute, Inc. and National Park Service, 1981.

Sonnevil, Ronald A., and William E. Weaver. The evolution of conceptual approaches and specific techniques for watershed rehabilitation, Redwood National Park, 1977-1981. 1982.

Spreiter, Terry A. Watershed restoration in Redwood National Park: summer field seminar handbook. Arcata, CA: Humboldt State University, 1990.

Spreiter, Terry A. Watershed restoration manual, Redwood National Park. Orick, CA: Redwood National Park, 1992.

Spreiter, Terry A., and Louise E. Johnson. M-3-1 road and slope work and cost summary report, watershed rehabilitation unit 83-2. 1983.

Spreiter, Terry A., and Louise E. Johnson. Summary Report, 1840/1850 roads and slope: watershed rehabilitation unit 84-4. 1985.

Spreiter, Terry A., and Louise E. Johnson. Summary Report, Old County Road watershed rehabilitation unit: 84-7. 1984.

Spreiter, Terry A., and Louise E. Johnson. Watershed rehabilitation cost analysis Summary Report, unit 85-2: the 1800 and M-7-5 roads and slope. 1986.

Steensen, David L. Summary Report, watershed rehabilitation unit 88-1: lower May Creek. 1989.

Steensen, David L. Summary Report, watershed rehabilitation unit 88-2: Lower K&K road and slope. 1989.

Steensen, David L. Summary Report, watershed rehabilitation unit 89-2: lower K&K and 1800 Road. 1992.

Steensen, David L. Summary Report, watershed rehabilitation unit 90-1: C-20 Road. no date.

Steensen, David L. Summary Report: watershed rehabilitation unit 90-2: Lower K&K, Camp, and spur roads. 1992.

Steensen, David L., and Terry A. Spreiter. "Watershed rehabilitation at Redwood National Park." Proceedings of the 1992 National Meeting of the American Society of Surface Mining and Reclamation, Duluth, MN, June 14-18, 1992, author unknown, 280-286. National Park Service, United States Department of the Interior, no date.

Stone, Edward C., Rudolf F. Grah, and Paul J. Zinke. An analysis of the buffers and the watershed management required to preserve the redwood forest and associated streams in the Redwood National Park. Stone & Associates, 1969.

Stone, L., 1976, Graphic and tabular summaries of water and suspended-sediment discharge for two periods of synoptic storm sampling during 1975 in the Mill Creek drainage basin, Del Norte County, California: U.S. Geological Survey Open-File Report 76-473, 13 p.

Stone, L., 1976, Redwood National Park studies preliminary data release for Mill Creek, Del Norte County, California, January, 1974 - March, 1975: U.S. Geological Survey Open File Report 76-474, 10 p.

Stone, L., 1998, Multi-species habitat conservation plan for timberlands managed by Stimson Lumber, Del Norte County, California: Beak Consultants Incorporated, Sacramento, CA, 473 p.

Stone, L., 2002, Mill Creek Interim Management Plan: Stillwater Sciences, Arcata, CA, 160 p.

Sugihara, Neil G. Revegetation Report - Site 83-4, D-Line [watershed rehabilitation unit]. no date.

Sugihara, Neil G., and Kermit Cromack. "The role of symbiotic microorganisms in revegetation of disturbed areas - Redwood National Park." Proceedings of a symposium on watershed rehabilitation in Redwood National Park and other Pacific coastal areas, Arcata, CA, August 24-28, 1981, Robert N. Coats, 78-86. Berkeley, CA: Center for Natural Resource Studies of the John Muir Institute, Inc. and National Park Service, 1981.

Swanson, F. J., and Stephen D. Veirs. "Management of watershed rehabilitation--Reflections from Mt St Helens and Redwood Creek." Watershed rehabilitation in Redwood National Park and other Pacific coastal areas, Arcata, CA, August 24-28, 1981, Robert N. Coats, pages 11-16. Berkeley, CA: Center for Natural Resource Studies of the John Muir Institute, Inc. and National Park Service, 1981.

Symposium on watershed rehabilitation in Redwood National Park and other Pacific Coastal areas / symposium program and readings in watershed management and rehabilitation, Arcata, CA, August 25-28, 1981, Robert N. Coats. John Muir Institute, Center for Natural Resource Studies/U.S. National Park Service, 1981.

Taylor, Ross N. "The spawning ecology of coastal cutthroat trout and steelhead in the Stone Lagoon watershed and the potential for hybridization." Diss., Humboldt State University, 1997.

Teti, Patrick. "Rehabilitation of a 290 hectare site in Redwood National Park." Watershed rehabilitation in Redwood National Park and other Pacific coastal areas, Arcata, CA, August 24-28, 1981, Robert N. Coats, 283-297. Berkeley, CA: Center for Natural Resource Studies of the John Muir Institute, Inc. and National Park Service, 1981.

Turello, David, Bruce Black, and Nelson Murdock. Concept paper for proposed Buffer & Watershed Management sec 3(e) Public Law 90-545, Redwood National Park. 1969.

U. S. Department of the Interior. Monitoring the impacts and persistence of fines in the Prairie Creek watershed [final draft report]. 1990.

U.S. Department of the Interior, National Park Service. Report to the State of California concerning sedimentation problems in the Redwood Creek watershed, and their impact on park resources. San Francisco, CA1975.

U.S. Department of the Interior, National Park Service. Watershed rehabilitation prog. 1978.

Utley, Kenneth W. Procedures of erosion control watershed rehabilitation in Redwood National Park, northern California, USA [abstract]. no date.

Utley, Kenneth W. Watershed rehabilitation report for South of Copper Creek (Big Tree), site 80-1 [draft]. 1981.

Utley, Kenneth W., and *et al.* Field trip guide of watershed rehabilitation project, Redwood National Park. no date.

Veirs, Stephen D., and William S. Lennox. "Rehabilitation and long-term park management of cutover redwood forests: Problems of natural succession." Proceedings of a symposium on watershed rehabilitation in Redwood National Park and other Pacific coastal areas, Arcata, CA, August 24-28, 1981, Robert N. Coats, 50-55. Berkeley, CA: Center for Natural Resource Studies of the John Muir Institute, Inc. and National Park Service, 1981.

Wallen, Rick, Bill Falvey, and Terry A. Spreiter. A biological assessment of the impacts to threatened and endangered species from watershed restoration program actions in Redwood National and State Parks [DRAFT]. 1997.

Wallen, Rick, Terry Spreiter, Dick Mayle, and Bill Falvey. A biological assessment of impacts to aquatic threatened and proposed species from the watershed restoration program in Redwood National and State Parks (RNSP). Redwood National and State Parks, 1998.

Watershed rehabilitation in Redwood National Park and other Pacific coastal areas, Arcata, CA, August 24-28, 1981, Robert N. Coats. Berkeley, CA: Center for Natural Resource Studies of the John Muir Institute, Inc. and National Park Service, 1981.

Wawona, Meca, and Dahinda Meda. A labor-intensive approach to watershed repair: earthwork in the redwood region. 1977.

Weaver, William E. Sediment control and watershed rehabilitation at Redwood National Park: a common sense status report of the first three years (1978-1980). no date.

Weaver, William E., Anne V. Choquette, Danny K. Hagans, and John P. Schlosser. "The effects of intensive forest land-use and subsequent landscape rehabilitation on erosion rates and sediment yield in the Copper Creek drainage basin, Redwood National Park." Watershed rehabilitation in Redwood National Park and other Pacific coastal areas, Arcata, CA, August 24-28, 1981, Robert N. Coats, pages 298-312. Berkeley, CA: Center for Natural Resource Studies of the John Muir Institute, Inc. and National Park Service, 1981.

Weaver, William E., Danny K. Hagans, and Mary Ann Madej. "Managing forest roads to control cumulative erosion and sedimentation effects." Proceedings of the California watershed management conference, West Sacramento, CA, November 18-20, 1986, Robert Z. Callaham, and Johannes J. Devries, 119-124. Berkeley, CA: Wildland Resources Center, University of California, Berkeley, 1987.

Weaver, William E., Mark S. Seltenrich, Ronald A. Sonnevil, and Elizabeth M. Babcock. "The use of cost-effectiveness as a technique to evaluate and improve watershed rehabilitation for erosion control, Redwood National Park." Watershed rehabilitation in Redwood National Park and other Pacific coastal areas, Arcata, CA, August 24-28, 1981, Robert N. Coats, 341-360. Berkeley, CA: Center for Natural Resource Studies of the John Muir Institute, Inc. and National Park Service, 1981.

Weaver, William E., Mary M. Hektner, Danny K. Hagans, Lois J. Reed, Ronald A. Sonnevil, and Gregory J. Bundros. An evaluation of experimental rehabilitation work, Redwood National Park. Redwood National Park Watershed Rehabilitation. Arcata, CA: National Park Service, 1987. Technical Report 19.

Weaver, William E., and James H. Popenoe. Geomorphology, soils, landuse and watershed rehabilitation: California Forest Soils Council field trip (road log - day 2). no date.

Winston, Matthew, and James D. Goodridge. Precipitation and runoff in the Smith River watershed. 1980.

Wosika, Edward P. Watershed rehabilitation report for the Maneze Creek unit (site 80-2). no date.

Wosika, Edward P., and Michael Kenning. G-Line IFB contract, watershed rehabilitation unit 84-1. 1984.

Wunner, Robert C. McDonald Creek watershed restoration project, 1984-1985 [final report]. 1987.

Youngblood, Neal. Summary Report, watershed rehabilitation unit 95-4: 210 and 220 roads and spurs. 1996.

Youngblood, Neal. Summary Report, watershed rehabilitation unit 96-1: 230 Road [draft]. no date.

Ziemer, Robert R., and Leslie M. Reid. "What have we learned, and what is new in watershed science?." What is watershed stability? A review of the foundation concept of Dynamic Equilibrium in watershed management: proceedings of the sixth biennial watershed management conference, Ca./Neva Resort Hotel, Lake Tahoe, CAlifornia/Nevada, October 23-25, 1996, Sari Sommarstrom, 43-56. Davis, CA: Center for Water and Wildland Resources, Water Resources Center, University of California, 1997.

Zinke, Paul J. "Floods, sedimentation, and alluvial soil formation as dynamic processes maintaining superlative redwood groves." Proceedings of symposium: Watershed rehabilitation in Redwood National Park and other Pacific coastal areas, Arcata, CA, August 24-28, 1981, Robert N. Coats, pages 26-49. California: Center for Natural Resource Studies, JMI, Inc, 1981.

REDWOOD NATIONAL AND STATE PARKS WATER QUALITY

Anderson, Henry W. "Sources of sediment-induced reductions in water quality appraised from catchment attributes and land use." Journal of Hydrology 51, no. Water for Survival (1981): 347-358.

Austin, David A., Edward C. O'Rourke, and Mary Lund. Water quality samples: Marshall Pond. Redwood National Park, 1988.

Bradford, W.L., Iwatsubo, R.T., 1978, Water chemistry of the Redwood Creek and Mill Creek basins, Redwood National Park, Humboldt and Del Norte Counties, California: U.S. Geological Survey Water-Resources Investigations 78-115, 112 p.

California Regional Water Quality Control Board. North Coast Region Water Quality Control Board 303(d) list update recommendations. 2001.

California State Water Resources Control Board. California marine waters, areas of special biological significance, reconnaissance survey report: Redwood National Park, Del Norte and Humboldt Counties. Water Quality Monitoring Report. 1981.

Hatzimanolis, Theologue F. A water quality surveillance network for Redwood National Park. Crescent City, CA: National Park Service, Department of the Interior, 1972.

Iwatsubo, R.T., Averett, R.C., 1981, Aquatic biology of the redwood Creek and Mill Creek drainage basins, Redwood National Park, Humboldt and Del Norte counties, California: U.S. Geological Survey Open-File Report 81-143, 115 p.

Iwatsubo, R.T., Washabaugh, D.S., 1982, Water-quality assessment of the Smith River drainage basin, California and Oregon: U.S. Geological Survey Water-Resources Investigations 81-22, 118 p.

Klein, Randy. "The side-effects of road decommissioning: A bitter pill or no big deal?." A conference on water quality monitoring: Spatial and temporal variability in forest water quality monitoring; water quality research and regulations, Redding, CA, December 1-2, 2003, Unknown author, 4-5. 2003.

Larson, James P., Joseph F. Mckeon, Timothy J. Salamunovich, and Terrence D. Hofstra. "Water quality and productivity of the Redwood Creek estuary." Proceedings of the first biennial conference of research in Californias national parks, University of California, Davis, September 9-10, 1982, Charles III Van Riper, Marsha L. Murphy, and Lynn D. Whittig, 190-199. Davis, CA: Cooperative Parks Studies Unit, University of California, 1983.

Markman, Steve G. "Longitudinal variation in suspended sediment and turbidity of two undisturbed streams in northwestern California in relation to the monitoring of water quality above and below a land disturbance." Diss., Humboldt State University, 1990.

Mcdonald, Ann. Untitled: Field data on water quality of Larry Damm Creek. 1980.

Redwood National Park. Redwood Creek estuary water quality data [computer printouts]. 1983.

Redwood National Park. Redwood Creek estuary water quality data [folder collection]. 1983.

Ricks, Cynthia L. (?). Summary of seasonal sediment transport, habitat and water quality at the mouth of Redwood Creek, August 1979 - present. 1982.

Southern California Coastal Water Research Project. Final Report: Discharges into state water quality protection areas. 2003.

Stone, L., 1975, Basic data on the quality of water in Redwood Creek and selected tributaries, Humboldt County and Mill Creek, Del Norte County, California, water years 1974 and 1975: U.S. Geological Survey Water Resources Divisions.

U. S. Geological Survey, Water Resources Division. A summary of selected water-quality data for Redwood Creek at south park boundary near Orick, Del Norte County, California. Menlo Park, CA: United States Geological Survey, 1973.

U. S. Geological Survey, Park studies, data release number 2, Redwood Creek, Humboldt County, and Mill Creek, Del Norte County, California, April 11, 1974-September 30, 1975: U.S. Geological Survey Open-File Report 76-678, 247 p.

Wallace, Michael. Seasonal water quality monitoring in the Klamath River Estuary, 1991-1994. 1998. Inland Fisheries Administrative Report No. 98-9.

Wheat, Gordon J. Water quality of Freshwater Lagoon. 1982.

REDWOOD NATIONAL AND STATE PARKS FISHERIES STUDIES

Anderson, David G. "Importance of estuaries to survival and growth of salmonids." Proceedings of the Estuary and Ocean Productivity Workshop, Humboldt State University, Arcata CA, September 22, 1990, Craig A. Tuss, pages 19-24. Klamath River Basin Fisheries Task Force, 1990.

Anderson, David G. "Juvenile salmonid habitat of the Redwood Creek basin, Humboldt County, California [abstract]." Program and abstracts of presented posters and papers, Third Biennial Conference of Research in Californias National Parks, University of California, Davis CA, September 13-15, 1988, page 29. Davis, California: Cooperative National Parks Resources Studies Unit/Institute of Ecology, University of California, Davis, 1988.

Anderson, David G. "Juvenile salmonid habitat of the Redwood Creek basin, Humboldt County, California." Diss., Humboldt State University, 1988.

Anderson, David G. Biological supplement to Redwood National and State Parks U.S. Army Corps of Engineers application: Coho salmon utilization of the Redwood Creek estuary. 1995.

Anderson, David G. Invertebrate drift and juvenile salmonid habitat of Redwood Creek watershed. 1981.

Anderson, David G. Summary of reports relating to coho salmon (*Oncorhynchus kisutch*) in the Redwood Creek basin. 1994.

Anderson, David G., and Randy A. Brown. "Anadromous salmonid nursery habitat in the Redwood Creek watershed." Proceedings of the first biennial conference of research in Californias national parks, University of California, Davis, September 9-10, 1982, Lynn D. Whittig, Marsha L. Murphy, and Charles III Van Riper, 225-229. Davis, CA: Cooperative Parks Studies Unit, University of California, 1983.

Anderson, David. Juvenile salmonid scale mounting protocol. Redwood National Park, 1992.

Anderson, David. Redwood Creek embayment- salmonid monitoring project: Data summary sheet. Redwood National Park, 1988.

Anderson, David. Redwood Creek embayment- salmonid monitoring project: Data summary sheet. Redwood National Park, 1988.

Anderson, David. Redwood Creek embayment- salmonid monitoring project: Data summary sheet. Redwood National Park, 1988.

Anderson, David. Redwood Creek embayment- salmonid monitoring project: Data summary sheet. Redwood National Park, 1988.

Anderson, David. Redwood Creek embayment- salmonid monitoring project: Data summary sheet. Redwood National Park, 1988.

Bartley, Devin M., Boyd Bentley, Paul G. Olin, and Graham A. E. Gall. "Population genetic structure of coho salmon (*Oncorhynchus kisutch*) in California." California Fish and Game 78, no. 3 (1992): 88-104.

Bell, Ethan. "Survival, growth and movement of juvenile coho salmon (*Oncorhynchus kisutch*) over-wintering in alcoves, backwaters, and main channel pools in Prairie Creek, California." 2001.

Bensen, Keith. "A biological assessment of impacts to threatened and endangered anadromous salmonid species from the 2002 prescribed burns in Redwood National and State Parks (RNSP)." 2002.

Bensen, Keith. "A biological assessment of impacts to threatened and endangered anadromous salmonids from the 2004 Fire Management Plan in Redwood National and State Parks (RNSP)." 2004.

Brakensiek, Kyle E. "Abundance and survival rates of juvenile coho salmon (*Oncorhynchus kisutch*) in Prairie Creek, Redwood National Park." 2002.

Briggs, John C. "The behavior and reproduction of salmonid fishes in a small coastal stream." Fish Bulletin 94 (1953): 1-62.

Briggs, John C. The salmonid fishes of Prairie Creek, Humboldt County, California: progress report, season of 1948-1949. California Dept. of Fish and Game, Inland Fisheries Branch, 1949. Administrative Report 49-34.

Brown, Larry R., Peter B. Moyle, and Ronald M. Yoshiyama. "Historical decline and current status of Coho salmon in California." North American Journal of Fisheries Management 14, no. 2 (1994): 237-261.

Brown, Randy A. "Physical rearing habitat for anadromous salmonids in Redwood Creek basin, Humboldt County, California." Diss., Humboldt State University, 1988.

Brownell, Nels F., William M. Kier, and Michael L. Reber. Historical and current presence and absence of coho salmon, *Oncorhynchus kisutch*, in the northern California portion of the Southern Oregon - Northern California evolutionary significant unit. Sausalito, CA: Kier Associates, 1999. National Marine Fisheries Service 40-ABNF-7-01479.

Burns, James W. "The carrying capacity for juvenile salmonids in some northern California streams." California Fish and Game 57, no. 1 (1971): 44-57.

California Cooperative Fisheries Research Unit. Survival of coho salmon in northern California streams of varying habitat quality. 2000.

California Department of Fish and Game. Length of residency of juvenile chinook salmon in the Klamath River estuary: annual performance report. 1994.

California Department of Fish and Game. California fish and wildlife plan: Volume III-supporting data: Part B- inventory, salmon-steelhead and marine resources. 1965.

Campbell, Elizabeth A., and Peter B. Moyle. "Historical and recent population sizes of spring-run chinook salmon in California." Proceedings of the 1990 northeast Pacific chinook and coho salmon workshop, Arcata, CA, September 18-22, 1990, Thomas J. Hassler, 155-216. Arcata, CA: California Cooperative Fishery Research Unit, 1990.

Coey, Robert M. "Effects of sedimentation on incubating coho salmon, (*Oncorhynchus kisutch*) in Prairie Creek, California." Diss., Humboldt State University, 1998.

Coey, Robert M. (Bob). "Effects of sedimentation on incubating coho salmon (*Oncorhynchus kisutch*) in Prairie Creek, California [abstract]." Program and abstracts of presented posters and papers, Fourth Biennial Conference of Research in California's National Parks, University of California, Davis, September 10-12, 1991, Author Unknown, #58. Davis, CA: Cooperative National Parks Resources Studies Unit/Institute of Ecology, University of California, 1991.

Coey, Robert M. (Bob). "Effects of sedimentation on incubating coho salmon, *Oncorhynchus kisutch*, in Prairie Creek, California [DRAFT]." Diss., Humboldt State University, 1994.

Coey, Robert M. (Bob). "Factors affecting incubating chinook salmon due to sedimentation of spawning gravel [proposal]." Diss., Humboldt State University, 1990.

Decker, L. Habitat utilization by salmonids in Prairie Creek, California. 1970.

Denega, Michael M. "Age composition and growth rates of chinook salmon from northern Californias salmon troll fishery." Diss., Humboldt State University, 1973.

Dixon, Richard L. "Development and implementation of the Klamath Ocean harvest model." Proceedings of the 1990 northeast Pacific chinook and coho salmon workshop, Arcata, CA, September 18-22, 1990, Thomas J. Hassler, 35-44. Arcata, CA: California Cooperative Fishery Research Unit, 1990.

Duffy, Walter, David Hankin, Terry Roelofs, Sarah Beesley, Ethan Bell, Kyle Brakensiek, and Michael Sparkman. Interim report: Coho salmon survival in northern California streams of varying habitat quality. 1999.

Farro, Mitch. Prairie Creek salmon restoration, 1992/'93 season. Pacific Coast Fish, Wildlife & Wetlands Restoration Association, 1993.

Farro, Mitch. Prairie Creek salmon restoration, preliminary report [1991-1992 season]. Pacific Coast Fish, Wildlife & Wetlands Restoration Association, 1992.

Farro, Mitch. Trinidad Fishermens salmon enhancement, Prairie Creek project 1989-1990 [final report]. Pacific Coast Federation of Fisherman's Associations Inc, 1990.

Farro, Mitch. Trinidad Fishermens salmon enhancement, Prairie Creek project 1990-1991 [preliminary draft of final report]. Pacific Coast Federation of Fisherman's Association Inc, 1991.

Forest Science Project. Regional juvenile coho salmon abundance survey. Arcata, CA: Forest Science Project, 2000.

Gangmark, H. A., and R. G. Bakkala. "A comparative study of unstable and stable (artificial channel) spawning for incubating king salmon at Mill Creek, California." Fish and Game 46, no. 2 (1960): 151-164.

Geniella, Mike. "Salmon study shows a pleasant surprise." Press democrat (2000).

Hadden, Samantha, M. Wilzbach, and K. Cummins. "Relative effects of organic and inorganic constituents of the suspended sediment load on salmonid foraging and prey availability." Understanding, protecting, and enjoying California's fishes from the Sierra to the sea, Redding, California, April 22-24, 2004, M. Madej, and American Fisheries Society. Symposium & annual meeting of the California-Nevada and Humboldt Chapters conference program. American Fisheries Society, 2004.

Hallock, Richard J., George H. Warner, and Donald H. Fry. "Californias part in a three-state salmon fingerling marking program." California Fish and Game 38, no. 3 (1952): 301-332.

Harvey, Bret C., and Thomas E. Lisle. "Scour of chinook salmon redds on suction dredge tailings." North American journal of fisheries management 19 (1999): 613-617.

Hayes, John M. "A study of the salmonids and some other fishes of Big Lagoon, Humboldt County, California." Diss., Humboldt State University, 1960.

Heifetz, Jonathan. "Use of radio telemetry to study upriver migration of adult Klamath River chinook salmon." Diss., Humboldt State University, 1982.

Hofstra, Terrence D., and Vicki L. Ozaki. "Cold pools: a potential management tool for improving salmonid rearing habitat [abstract]." Wetland and riparian ecosystems of the American west [final program], Seattle, WA, May 26-29, 1987, page 61. Society of Wetland Scientists, 1987.

Holden, Baker. Study plan FY 2002: Distribution and status survey of federally listed and non-listed salmonid species. 2001.

Howard, C., Albro, P., 1995, Mill Creek report: habitat and fisheries analysis: Rellim Redwood Company, Crescent City, CA, 127 p.

Humboldt Chapter of the American Fisheries Society. "Humboldt AFS: Pacific Salmonids at the Crossroads." 1991.

Humboldt Chapter of the American Fisheries Society. "Notes on stocks of Pacific Salmon at risk in Humboldt AFS area." 1991.

Jong, Bill. "Coho salmon presence/absence survey results; Richardson Creek trib [sic] to Klamath River (Del Norte County) (field note)." 2003.

Keller, Edward A., and Terrence D. Hofstra. "Summer cold pools in Redwood Creek near Orick, California and their importance as habitat for anadromous salmonids." Proceedings of the first biennial conference of research in Californias national parks, University of California, Davis, September 9-10, 1982, Marsha L. Murphy, Lynn D. Whittig, and Charles III Van Riper, 221-224. Davis, CA: Cooperative Parks Studies Unit, University of California, 1983.

Klatte, Bernard, and Terry Roelofs. 1997 final report, draft: Salmon redd composition, escapement and migration studies in Prairie Creek, Humboldt County, California, 1996-1997. 1997.

Klein, Randy D., and Mary Ann Madej. Evaluating effects of fine sediment on salmonid egg survival, Prairie Creek, northwestern California: a proposal to the US Man and the Biosphere Program. 1990.

Klein, Randy. "Rigid, immobile structures: Frozen assets in a liquid economy." Proceedings of the eighteenth annual salmonid restoration federation conference, Fortuna, CA, March 2-5, 2000, Johanna Schussler, 21-22. 2000.

Klein, Randy. Duration of turbidity and suspended sediment transport in salmonid-bearing streams, north coastal California. Redwood National and State Parks, 2003.

Krakker, Joseph J. "Utilization of the Klamath River estuary by juvenile chinook salmon (*Oncorhynchus tshawytscha*), 1986." Diss., Humboldt State University, 1991.

Kramer, Sharon H. Scientific Investigations Permit: Density of juvenile coho salmon occupying large wood refuge habitat. Arcata, CA: Stillwater Sciences, Private Consulting Firm, 2000.

Kramer, Sharon, and Randy Klein. "The distribution and role of large woody debris in upper Prairie Creek, a pristine northern California redwood watershed." Proceedings of the eighteenth annual salmonid restoration federation conference, Fortuna, CA, March 2-5, 2000, Johanna Schussler, 6. 2000.

Larson, James P. "Utilization of the Redwood Creek estuary, Humboldt County, California, by juvenile salmonids." Diss., Humboldt State University, 1987.

Lechuga, Gilbert. Comparison of condition factors, length and weights of 3 yr-old adult hatchery and wild coho salmon (*Oncorhynchus kisutch*) during upstream migration. 1983.

Lewis, Tim. Scientific Investigations Permit: Regional population estimates of coho salmon. 1999.

Madej, Mary Ann. "Determining replenishment rates for aggregate mining." Proceedings of the 8th Annual California Salmon, Steelhead and Trout Restoration Conference, Eureka, CA, February 23-25, 1990, Jim Waldvogel, pages 71-76. California Salmon, Steelhead and Trout Restoration Federation, 1990.

Manning, David J., Terry D. Roelofs, and William T. Trush. Carrying capacity and limiting habitat analysis for coho salmon in streams of northwestern California. Arcata, California: Department of Fisheries and Institue for River Ecosystems; Humboldt State University, 1996.

McCain, Michael Eugene. "Habitat utilization by the 1987 and 1988 cohorts of chinook salmon from emergence to outmigration in Hurdygurdy Creek, California." Diss., Humboldt State University, 1994.

McGie, Alan M. "Life-history studies of the salmonids inhabiting Maple and Tom Creeks, tributaries to Big Lagoon, California." Diss., Humboldt State University, 1960.

McKeon, Joseph F. A summary of data compiled from sampling efforts of downstream migrant salmonids in Redwood Creek, Orick, CA. 1981.

McCanne, Dana. Investigator's annual report- 2002: Coho salmon and steelhead trout regional abundance survey for the Mad River/Redwood Creek hydrologic unit. Redwood National and State Parks, 2002.

Mckeon, Joseph F. "Downstream migration, growth and condition of juvenile fall chinook salmon in Redwood Creek, Humboldt County, California." Diss., Humboldt State University, 1985.

Mckeon, Joseph F., Richard L. Ridenhour, and Terrence D. Hofstra. "Downstream migration, growth, and condition of juvenile fall chinook salmon in Redwood Creek, Humboldt County, California [abstract]." Program and abstracts of presented posters and papers, Third Biennial Conference of Research in Californias National Parks, University of California, Davis CA, September 13-15, 1988, page 30. Davis, California: Cooperative National Parks Resources Studies Unit/Institute of Ecology, University of California, Davis, 1988.

Meffe, Gary K. "Techno-arrogance and halfway technologies: Salmon hatcheries on the Pacific Coast of North America." Conservation biology 6, no. 3 (1992): 350-354.

Meyer, C. B. "The importance of measuring biotic and abiotic factors in the lower egg pocket to predict coho salmon egg survival." Journal of fish biology 62 (2003): 534-548.

Meyer, Carolyn B., Mary Ann Madej, and Randy D. Klein. "Effects of fine sediment on salmonid redds in Prairie Creek, a tributary of Redwood Creek, Humboldt County, California." Proceedings of the fourth conference on research in California's National Parks, University of California, Davis, September 10-12, 1991, Thomas J. Stohlgren, Stephen D. , Veirs, and Christine Schonewald-Cox, 47-55. Denver, CO: National Park Service, 1993.

Meyer, Carolyn B., and Robert M. Coey. Effects of highway-construction sediment on salmonid redds in an old-growth forest stream in California. Redwood National Park, 1997.

Meyer, Carolyn, Michael Sparkman, and Bernard A. Klatte. "Sand seals in coho salmon redds: Do they improve egg survival?." North American journal of fisheries management 25 (2005): 105-121.

Moyer, C.D., 1999, Implementation of a modified small stream juvenile salmonid survey design: M.S. Thesis, Humboldt State University, Arcata, CA, 127 p.

National Park Service. "Salmon conservation and restoration efforts in the Pacific Northwest." 1995.

Nehlsen, Willa, Jack E. Williams, and James A. Lichatowich. "Pacific salmon at the crossroads: Stocks at risk from California, Oregon, Idaho, and Washington." Fisheries 16, no. 2 (1991): 4-21.

Neillands, George. Redwood Creek embayment salmonid monitoring project. 1986.

Pacific Coast Fish, Wildlife and Wetlands Restoration Association. "Redwood Creek salmon spawner survey 2000/01 season." 2002.

Pacific Coast Fish, Wildlife and Wetlands Restoration Association. Prairie Creek salmon project progress report. 1995.

Quinones, Rebecca M. "Habitat utilization and foraging habits of juvenile salmonids in the Smith River estuary, California." Diss., Humboldt State University, 2003.

Rathjen, Mark. "Where have all the Salmon gone." Eureka Times Standard 140, no. 136 (1992): 2.

Redwood Creek Landowners Association. A study in change: Redwood Creek and salmon. Portland, OR: CH2M Hill, Inc, 2000.

Redwood National Park. Redwood Creek embayment - salmonid monitoring project: 1989 summer data summary sheets [collection]. 1989.

Redwood National Park. Salmonid and estuary data, 1987 - 1990 [field notebooks: collection]. 1987.

Redwood National Park. Salmonid data, 1995 - 1998 [collection]. 1995.

Regnart, Jeff R. "Physical parameters associated with coho salmon redds in northwest California." Diss., Humboldt State University, 1991.

Rellim Redwood Company. Mill Creek monitoring program: juvenile salmonid monitoring on the east and west branches of Mill Creek. 1994.

Ridenhour, Richard L. Survey of the salmonid nursery areas of Redwood Creek [project title]. 1980.

Roelofs, Terry D., Michael J. Furniss, and Carlton S. Yee. Forest roads: design, construction, and maintenance to protect anadromous salmonid habitats [DRAFT]. no date.

Roelofs, Terry D., and Bernard Klatte. Anadromous salmonid escapement and downstream migration studies in Prairie Creek, California, 1995-1996: 1996 progress report. 1996.

Roelofs, Terry D., and Michael D. Sparkman. Effects of sediments from the Redwood National Park bypass project (CALTRANS) on anadromous salmonids in Prairie Creek State Park 1995-1998: Review draft. 1999.

Roelofs, Terry D., and William T. Trush. Carrying capacity and limiting factor analysis for coho salmon (*Oncorhynchus kisutch*) habitat on forested watersheds of northern California [proposal]. 1994.

Sakai, Howard. "Redwood National Park project clearance: May Creek salmon & steelhead habitat restoration project." 1996.

Sakai, Howard. May Creek salmon and steelhead habitat restoration project. Redwood National Park, 1996. Project Clearance 96-7.

Self, S. "Some questions to be addressed regarding the current instream production of anadromous salmonids from the mainstem of Redwood Creek: Draft." 2001.

Sloat, Todd. Salmonid spawning estimates and habitat surveys on Miller Timber Company land during winter, 1993-1994: Draft Report. 1994.

Smedley, S.C. "Pink Salmon in Prairie Creek, California." California Fish and Game 38, no. 2 (1952): 275.

Sparkman, Michael D. "Fry emergence and gravel permeability of chinook (*Oncorhynchus tshawytscha*) and coho salmon (*Oncorhynchus kisutch*) spawning redds in Prairie Creek, Humboldt County, California." Diss., Humboldt State University, 1997.

Sparkman, Michael D. "Negative influences of predacious egg-eating worms, Haplotaxis ichthyophagous, and fine sediments on coho salmon, *Oncorhynchus kisutch*, in natural and artificial redds." Diss., Humboldt State University, 2003.

Sparkman, Michael D. 2002 Annual Report: Upper Redwood Creek juvenile salmonid downstream migration study, 2000-2002 seasons. Northern California: California Department of Fish and Game, 2003. Project 2a5.

Sparkman, Michael D. 2003 Annual Report: Upper Redwood Creek juvenile salmonid downstream migration study, 2000-2003 seasons. California Department of Fish and Game, 2004. Project 2a5.

Sparkman, Michael D. Annual Report: Upper Redwood Creek juvenile salmonid downstream migration study, 2000-01, project 2a5. California Department of Fish and Game, 2002.

Sparkman, Michael. "Phase II of the Timing and period of fry emergence from chinook and coho salmon redds in Prairie Creek, Humboldt County, California." no date.

Sparkman, Michael. Summary report on salmon & steelhead outmigration, upper Redwood Creek, Humboldt County, California, April 5-August 5, 2000. 2000.

Stone, L., 1994, Mill Creek monitoring program: juvenile salmonid monitoring program on the east and west branches of Mill Creek: Rellim Redwood Company, Crescent City, California, 25 p.

The Forest Foundation. Forests & Salmon: Forest-fisheries management relationships in northern California during the 19th & 20th centuries. 1998.

Various Authors. untitled: Pacific salmon archives at Humboldt State University, Arcata CA. no date.

Waldvogel, Jim. Fall chinook salmon spawning escapement estimate for a tributary of the Smith River, California Second Interim Report. California: University of California Cooperative Extension, 1988. UCSGEP 88-5.

Waldvogel, Jim. Fall chinook salmon spawning escapement estimate for a tributary of the Smith River, California: Interim Report. University of California Cooperative Extension, 1985.

Waldvogel, Jim. Mill Creek chinook salmon spawning results (1980-1993). 1993.

Wallace, M. "The emigration timing of juvenile salmonids through the Klamath River estuary." Proceedings Klamath Basin Fisheries Symposium, Eureka, CA, March 23-24, 1994, Thomas J. Hassler, pages 54-72. 1995.

Wallace, M. Distribution, abundance, size, and coded-wire tag recovery of juvenile chinook salmon in the Klamath River estuary, 1986-1989: final performance report. Arcata, CA: California Department of Fish and Game, 1993.

Warren, Charles D. "Salmon carcass decomposition and its effect on stream productivity." Diss., Humboldt State University, 1988.

Warren, Charles D., and Richard L. Ridenhour. "Effects of salmon carcass decomposition on stream productivity [abstract]." Program and abstracts of presented posters and papers, Third Biennial Conference of Research in Californias National Parks, University of California, Davis CA, September 13-15, 1988, page 31. Davis, California: Cooperative National Parks Resources Studies Unit/Institute of Ecology, University of California, Davis, 1988.

Warren, Charles D., and Richard L. Ridenhour. Contribution of salmon carcasses to stream fertility [DRAFT]. 1988.

Weseloh, Thomas J. "Prairie Creek/Redwood Creek: Fish habitat from the good to the bad and the ugly." Proceedings of the eighteenth annual salmonid restoration federation conference, Fortuna, CA, March 2-5, 2000, Johanna Schussler, 1. 2000.

Young, Douglas A. "Juvenile chinook salmon abundance, growth, production and food habits in the Mattole River lagoon, California." Diss., Humboldt State University, 1987.

Young, Jeffrey S. "Identification of larval smelt (Osteichthyes: Salmoniformes: Osmeridae) from Northern California." Diss., Humboldt State University, 1984.

Zajanc, David. "Residence of juvenile chinook salmon in the Smith River estuary, California, 1998-2000." Diss., Humboldt State University, 2003.

WHISKEYTOWN NATIONAL RECREATION AREA WATER QUALITY

Alpers, C N, Nordstrom, Darrell Kirk and J M Burchard 1992. Compilation and interpretation of water-quality and discharge data for acidic mine waters at Iron Mountain, Shasta County, California, 1940-91. Map

Analytical Report N3617: Water Tests for Mines.1990. NPS-WRD, 2000

Archive File Memorandum CWRCB. 1976-1977. NPS-WRD, 2000

Bureau of Reclamation. Water Quality Baseline Data. 1972-1991, 1996-1998. NPS-WRD, 2000

CDHS Database. 1984-1996. NPS-WRD, 2000

CDWR Database. 1970-1994. NPS-WRD, 2000

CDWR Clear Creek Basin Study. 1997-1998. NPS-WRD, 2000

CWRCB Database. 1963-1987. NPS-WRD, 1999b.

CWRCB Bacteriological Surveys. 1986-1991. NPS-WRD, 2000

Data collected by park personnel. 1973-1980. NPS-WRD, 2000

Hothem, *et al*. 2002-2004. USGS Project CA598

May, J & L Brown. 2004-2006. USGS Project 9VL22

National Park Service-Water Resources Division. 2000. Baseline Water Quality Data Inventory and Analysis: Whiskeytown National Recreation Area. Technical Report NPS/NRWRD/NRTR-2000/257. Water Resources Division and Servicewide Inventory and Monitoring Program, Fort Collins, CO. 799 p.

NPS, Shasta College, Salix Applied Earthcare: Watershed Restoration and Logging Road Removal Project, 1996

NPS-WHIS Bi-monthly water quality analysis report N-2615. 1979. NPS-WRD, 2000

Petrovich, Alexander. A water quality study of Whiskeytown, Black Butte, Stony Gorge and East Park reservoirs. California Department of Fish and Game Administrative Report No. 66-2, 1966.

UC Davis report to Bureau of Reclamation. 1994. NPS-WRD, 2000

USGS Water Resources Reconnaissance Report. 1969. NPS-WRD, 2000

Water Quality Folder, Miscellaneous Papers. 1975, 1980-1981, 1984. NPS-WRD, 2000

Whiskeytown National Recreation Area. Whiskeytown Unit - Whiskeytown-Shasta-Trinity Recreation Area Swimming beach water quality monitoring record. 1988.

WHISKEYTOWN NATIONAL RECREATION AREA FISHERIES STUDIES

Fish & Game Committee. Proposed Anadromous fisheries program on Clear Creek Shasta County, California. Redding, CA: Fish & Game Committee, Greater Redding Chamber of Commerce, 1971.

Healey, Terrance P. "A review of Whiskeytown Lake fishery management from 1963-1975." 1977.

Healey, Terrance P. A Review of Whiskeytown Lake fishery management from 1963-1975. Inland Fisheries, California Department of Fish and Game, 1977. Administrative Report No. 77-2.

Huber, D. F, Nelson, S. C., Cather, E. E., and Ritchey, J. L. Mineral resource potential of the Fisher Gulch Roadless Area, Trinity County, California. U S Geological Survey Open file report. 1983.

Rasmussen, B. 2004. Monitor Paige and restore Paige-Boulder Creek.

US Bureau of Reclamation. Sacramento basin fish habitat improvement study draft environmental assessment. US Department of the Interior Bureau of Reclamation Mid-Pacific Region, 1994.

US Bureau of Reclamation. Sacramento basin fish habitat improvement study special report. US Department of the Interior Bureau of Reclamation Mid-Pacific Region, 1993.

Whiskeytown National Recreation Area. Summary of Whiskeytown lake fish plants. no date.

Whiskeytown National Recreation Area. Untitled: Fish planting data, Whiskeytown Lake. no date.

ATTACHMENT II
AQUATIC RESOURCES AND WATER QUALITY QUESTIONNAIRE

1. Name of national park unit covered by this questionnaire:

2. Contact information for the principal person completing this questionnaire:

A. Name:

B. Position:

C. Telephone number:

D. Email address:

3. What aquatic resources are present within the park boundary (see next page for list of definitions); have any of these systems/subsystems been inventoried (I), monitored (M) or has research (R) been conducted within any of these systems/subsystems (respond in column 4 with an I, M, and/or R); provide the actual total count for each system/subsystem inventoried, or if not inventoried provide an estimated count, if possible, for each system/subsystem (column 5); in column 6, identify the source of the count in column 5 (I for Inventory, E for estimate).

System	Subsystem	Present in park (Y/N)	I/M/R	Count	Inventory/Estimate
Marine	subtidal				
	intertidal				
Estuarine	subtidal				
	intertidal				
Lotic	tidal				
(streams and springs)	perennial				
	intermittent				

3. continued

System	Subsystem	Present in park (Y/N)	I/M/R	Count	Inventory/Estimate
Lentic	permanent > 8 ha				
(lake, pond, reservoirs)	permanent < 8 ha, > 2m max depth				
	permanent < 8 ha, < 2m max depth				
	intermittent ponds				
Palustrine (wetlands)	marsh				
	prairie				
Ice Caves					
Geothermal					

Definitions of terms associated with 3 above:

1. Marine System: open ocean
2. Subtidal Subsystem: substrate continuously submerged
3. Intertidal Subsystem: substrate is exposed and flooded by tides and includes associated splash zone
4. Lotic System: flowing water
5. Tidal Subsystem: channel gradient is low and water velocity fluctuates under tidal influence
6. Perennial Subsystem: water flows throughout the year
7. Intermittent Subsystem: channel contains flowing water for only part of the year. When water is not flowing, it may remain in isolated pools or surface water may be absent
8. Lentic System: ponds, lakes, and reservoirs
9. Palustrine System: all nontidal wetlands dominated by trees, shrubs, persistent emergent vegetation, emergent mosses or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean-derived salts is below 0.5 $^{0}/_{00}$

4. List water bodies of particular importance or interest to the park and park management (for Column 2 see 3 above).

Water Body	Type	Reason for Importance or Interest

5. List past and current water quality monitoring (physical, chemical, biological) efforts within your park. Attach additional page, if necessary.

Brief description of the monitoring effort	Duration of this effort	Who conducted or is conducting this monitoring?			
		a	b	c	d (explain)

Who conducted or is conducting this monitoring?
a = park staff; b = another federal, or a state agency; c = university; d = other

6. List the water resource management issues or land use issues that now impact water resources from either within or outside your park. *Examples* of issues to list include: atmospheric deposition, introduced species, resource degradation due to visitor impact, logging/deforestation, agriculture, grazing, mining, road construction, off-road vehicles, sewage from second homes, boats & personal water craft, urbanization on a park boundary, etc (you may have other issues). Issues also may include "point discharges" into park aquatic systems or their upstream tributaries (note, a "point discharge" is something coming from a pipe or a distinct point of leakage, as opposed to a "non point discharge" from diffuse sources, such as contaminated runoff coming from farm fields. Point discharges also can include public or privately owned treatment works (POTW's) --i.e., sewage plants. Point discharges also can include EPA designated Superfund Sites. Think in terms of both current impacts to water bodies and future impacts related to growth (industrial, commercial, or residential) or expansion of various types of development. Attach additional page, if necessary.

Issues Within the Park Boundary		**Issues Outside the Park (upstream, adjacent to, nearby)**	
The Issue (describe the issue and its general location)	Near-term or long-term?	The Issue (describe the issue and its general location)	Near term or long-term?

"Near term" refers to impacts that are current or < 3 years away; "**Long-term**" refers to potential impacts > 3 years away

7. List the Staff level of experience or interest in water quality monitoring at the park. Identify individuals with a particular interest in water resources or water quality monitoring. If your park has particular outside contacts or sources for water quality and water resource issues, please include them.

Name	Phone	Email	Experience	Expertise

Thank you for your time and effort in completing this questionnaire.
If you have any questions or need clarification, please contact:
Robert Hoffman: (541) 750-1013 or robert_hoffman@usgs.gov

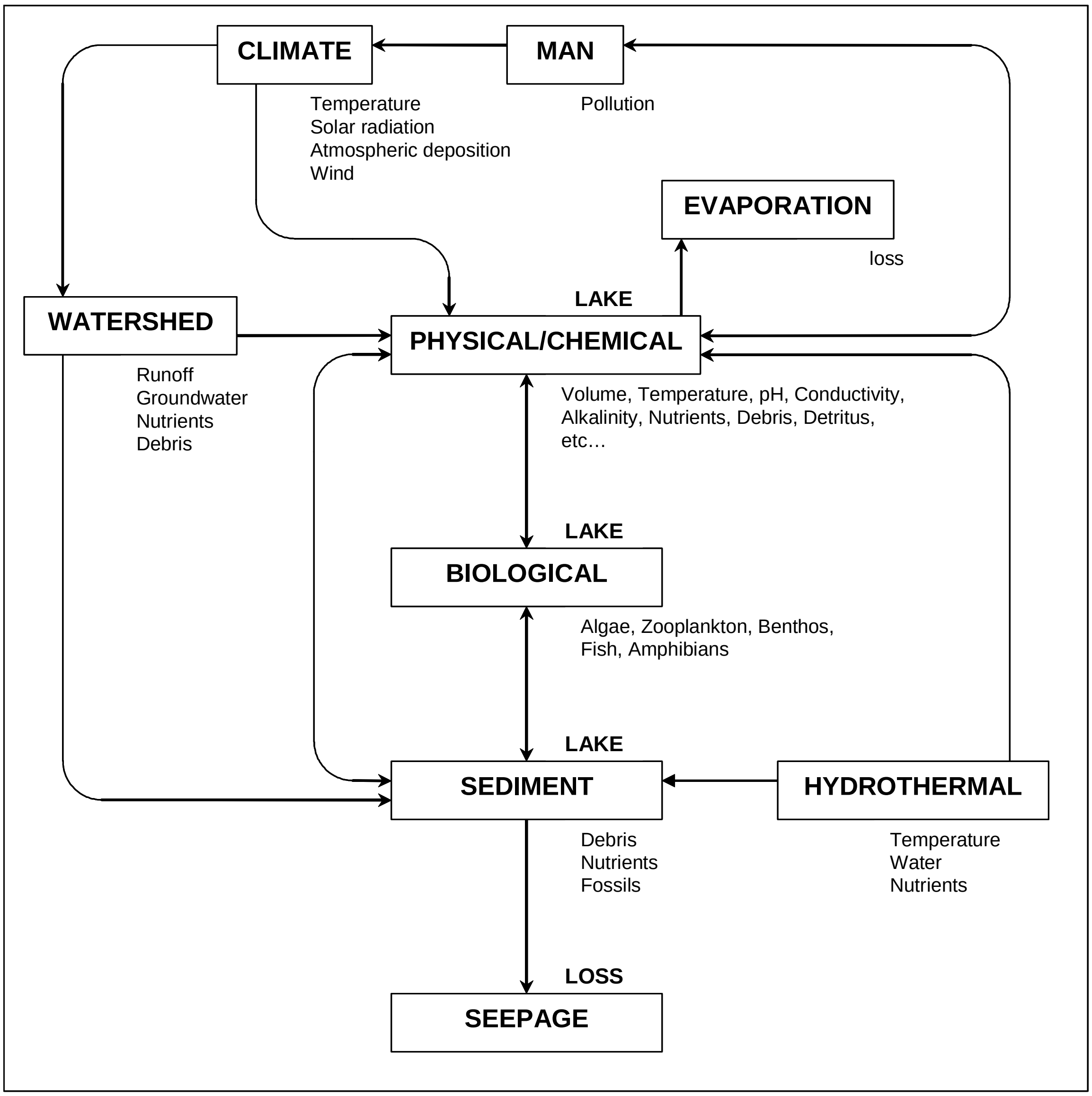
The questionnaire can be returned to Robert Hoffman via email or snailmail:

Robert Hoffman
USGS FRESC
3200 SW Jefferson Way
Corvallis, OR 97331

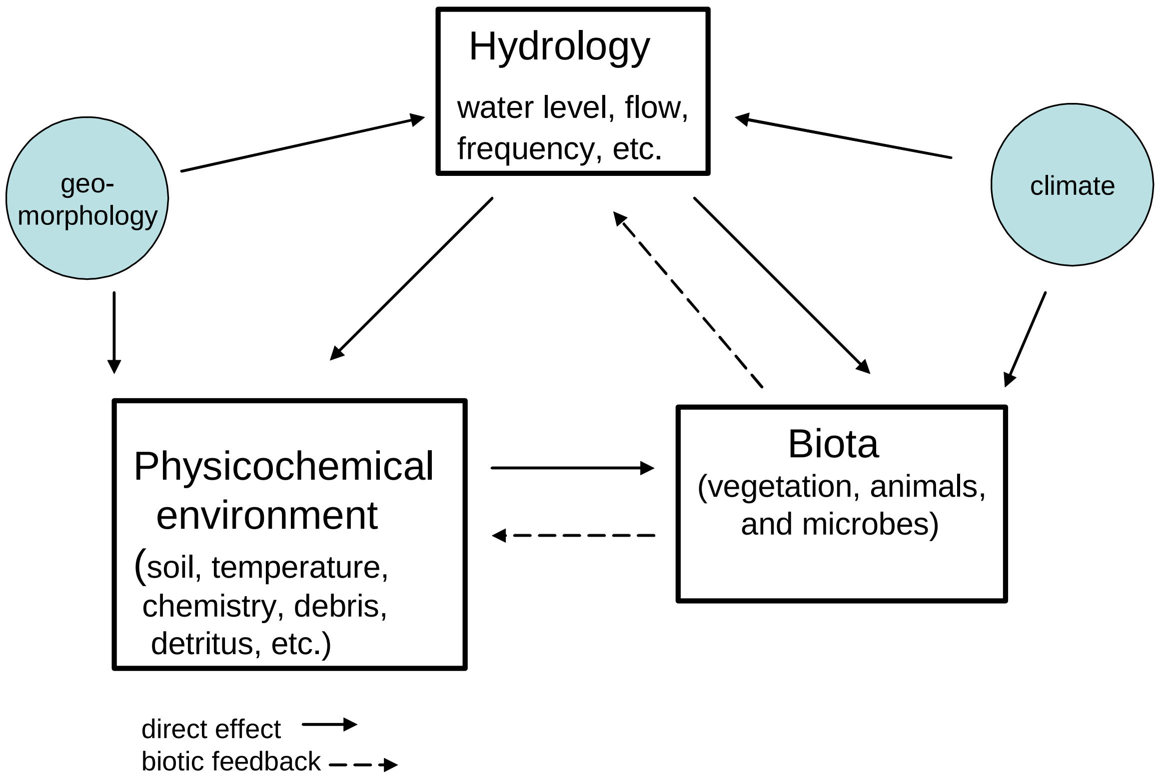
ATTACHMENT III

General Conceptual Models of Freshwater and Marine Ecosystems

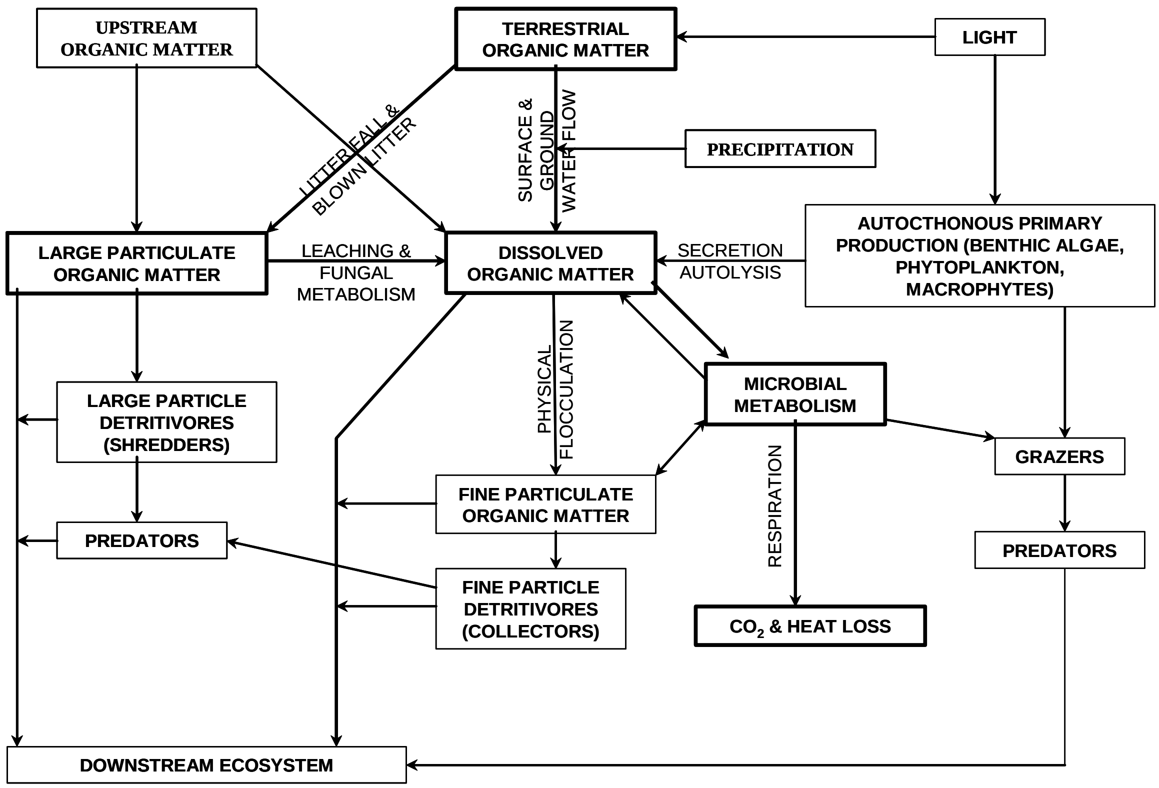
Freshwater lentic (lakes and ponds): after Larson 1990



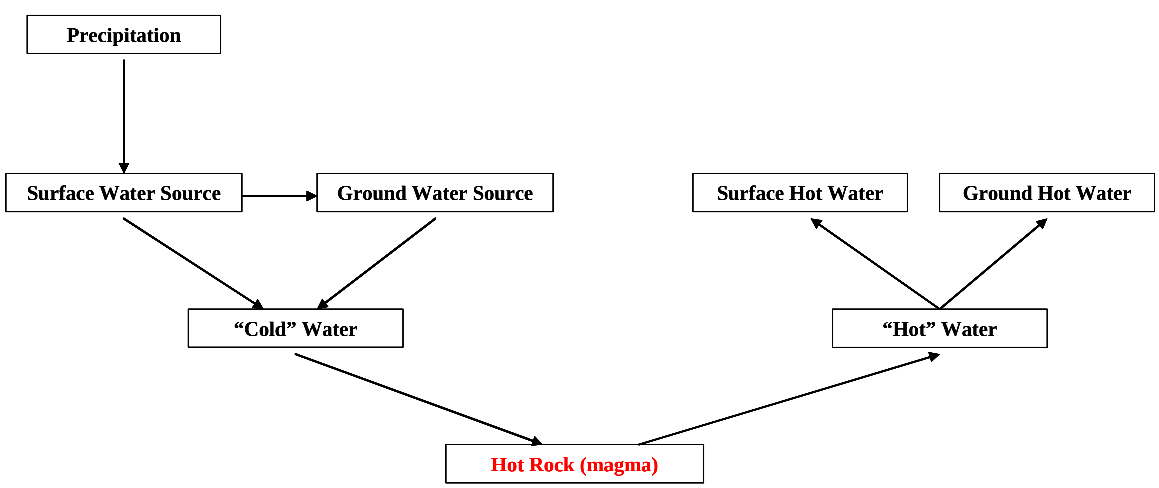
Freshwater lentic (wetlands): after Mitsch and Gosselink 2000



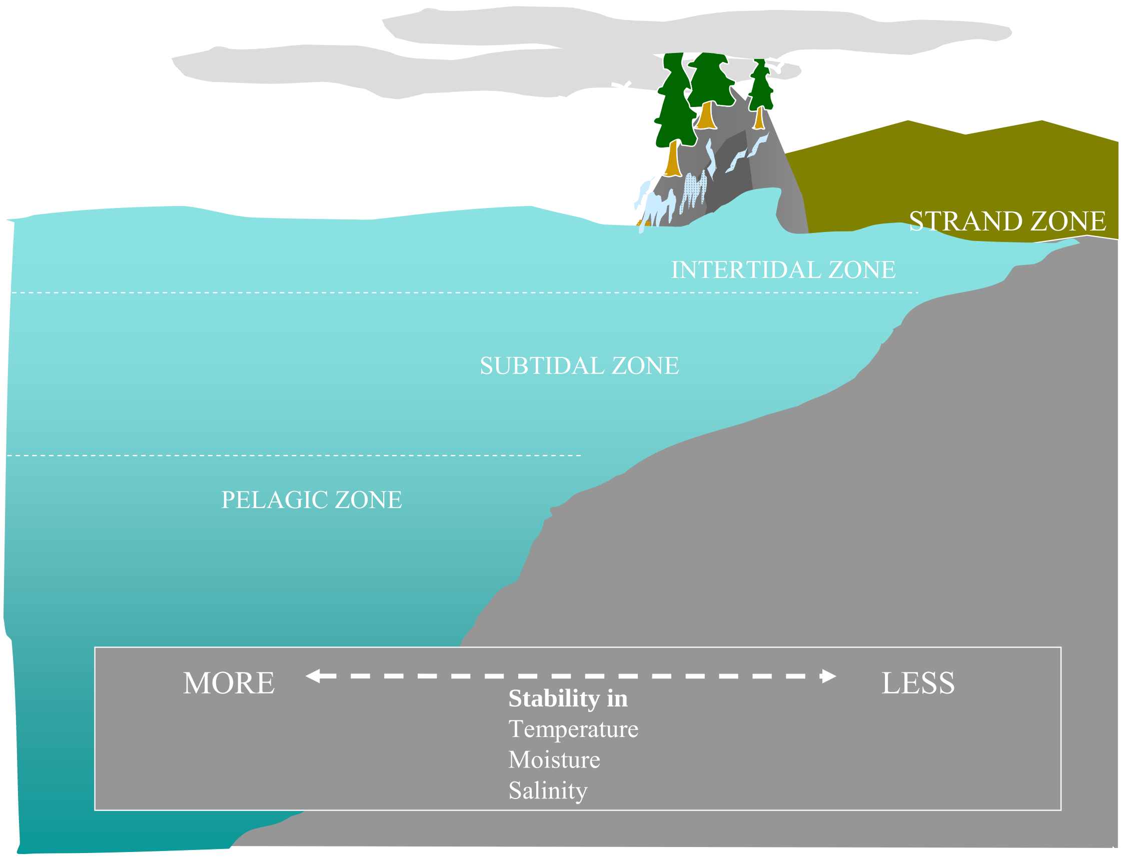
Freshwater lotic (streams and rivers): after Wetzel 1983

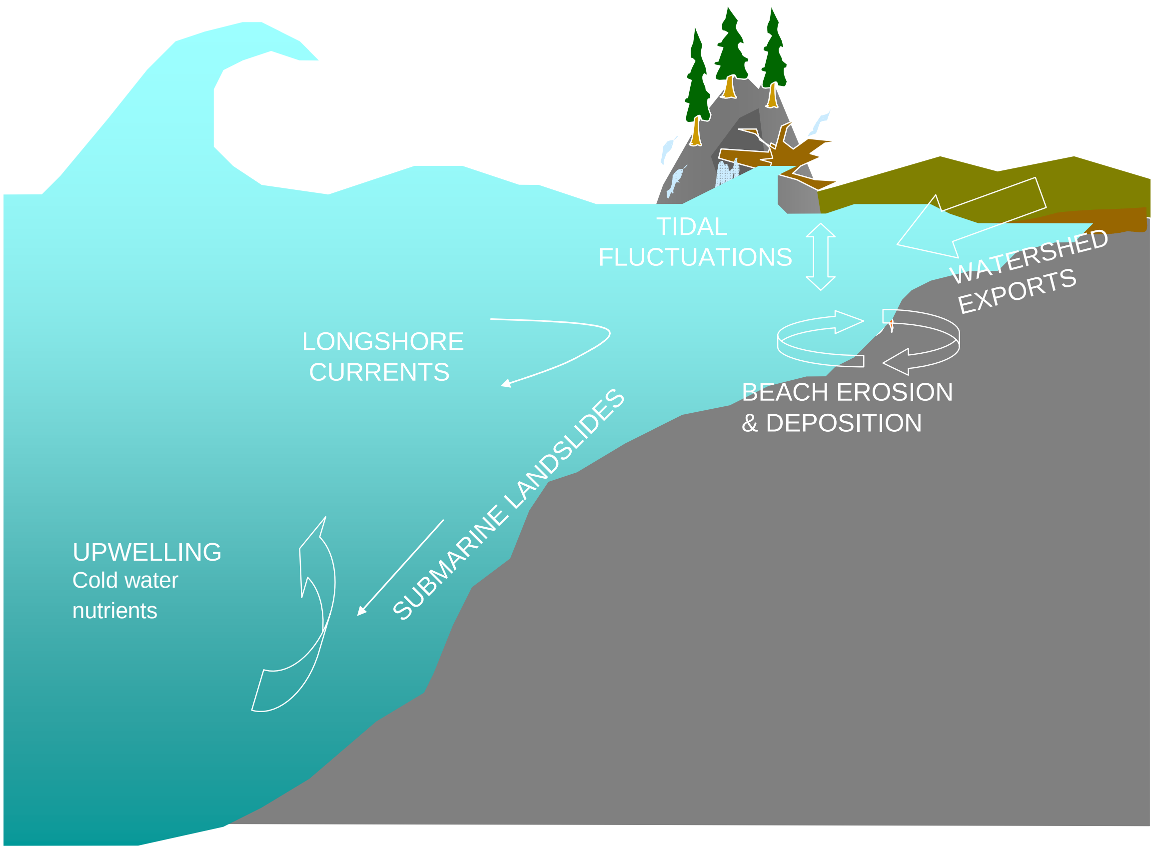


General Geothermal/hydrothermal water model:

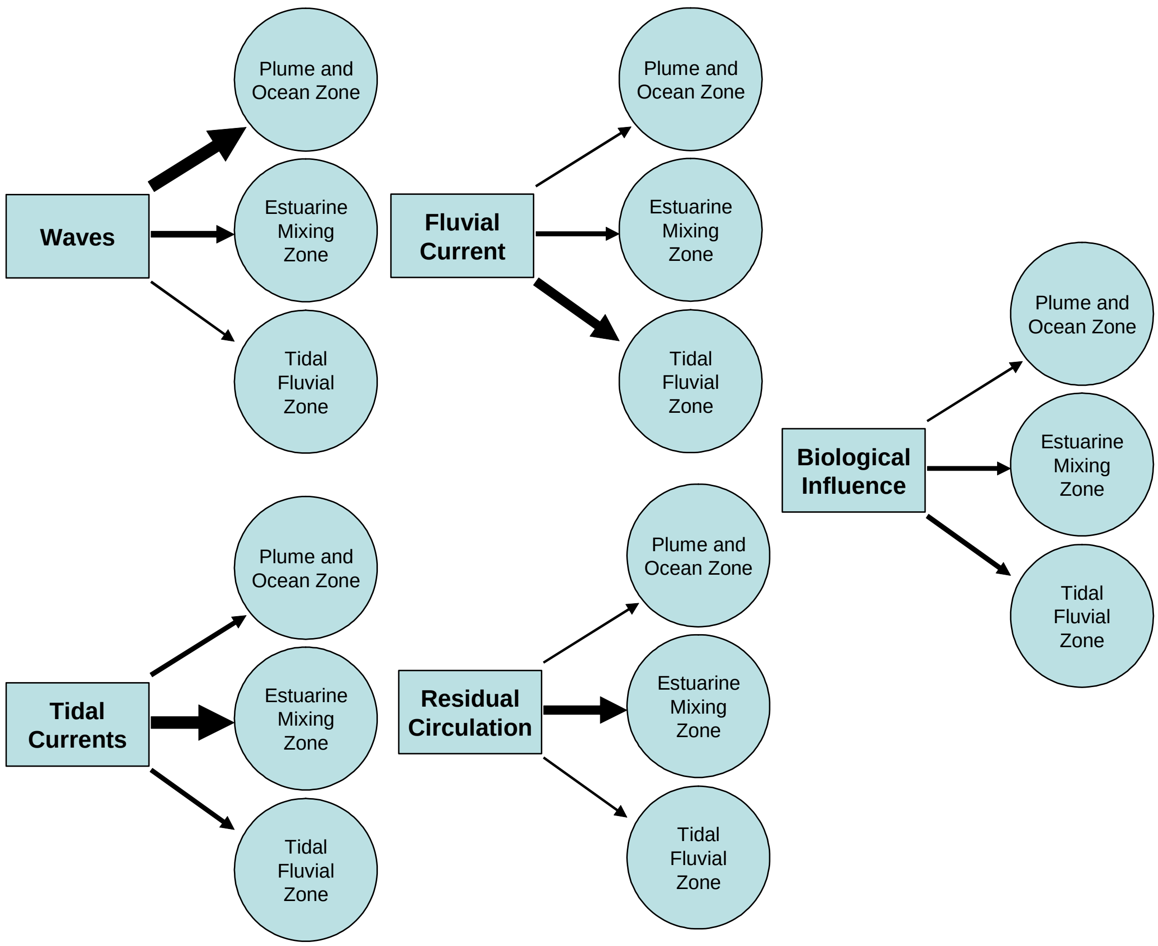


Marine Ecosystem Zonation: Sarr *et al.* 2004

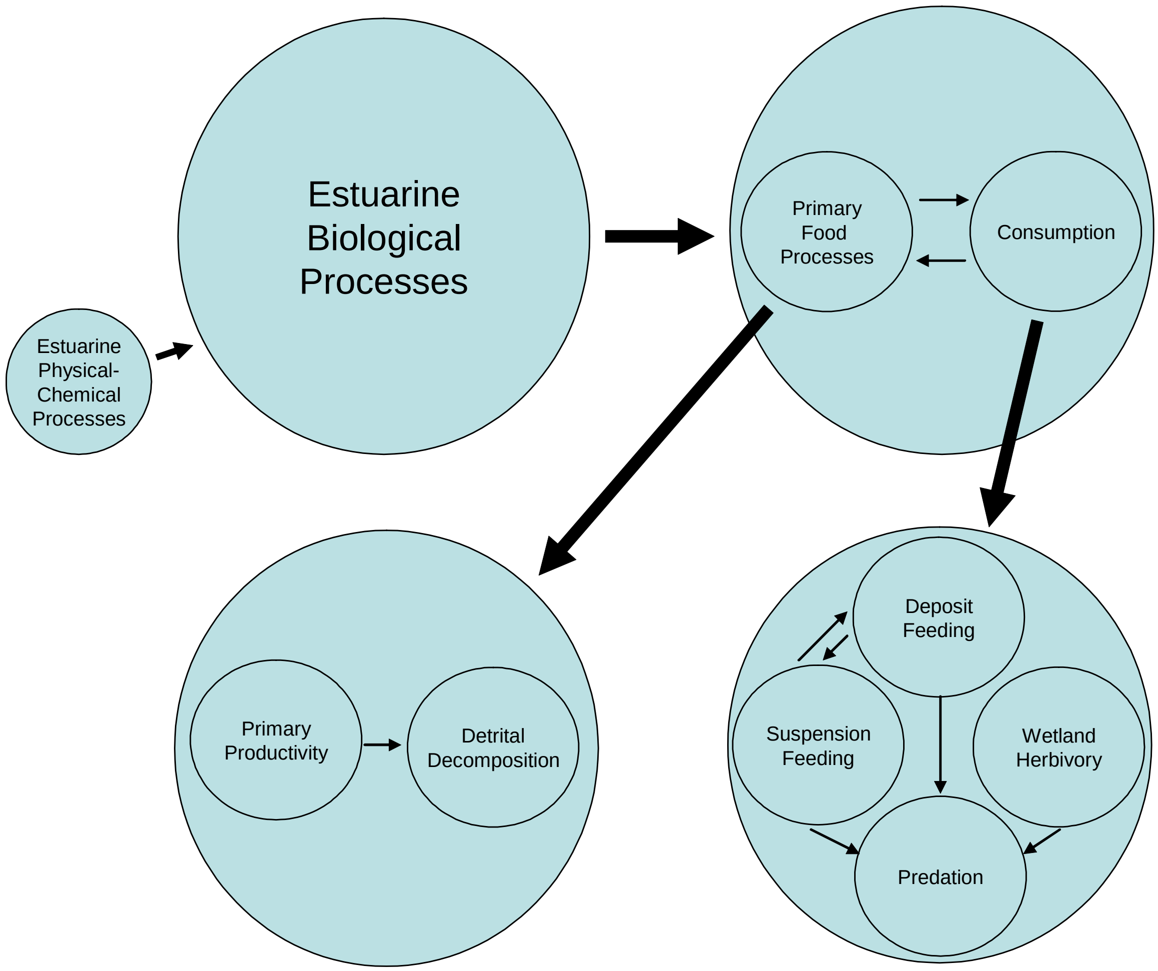



TIDAL
FLUCTUATIONS
WATERSHED
EXPORTS
LONGSHORE
CURRENTS
BEACH EROSION
& DEPOSITION
SUBMARINE LANDSLIDES
UPWELLING
Cold water
nutrients

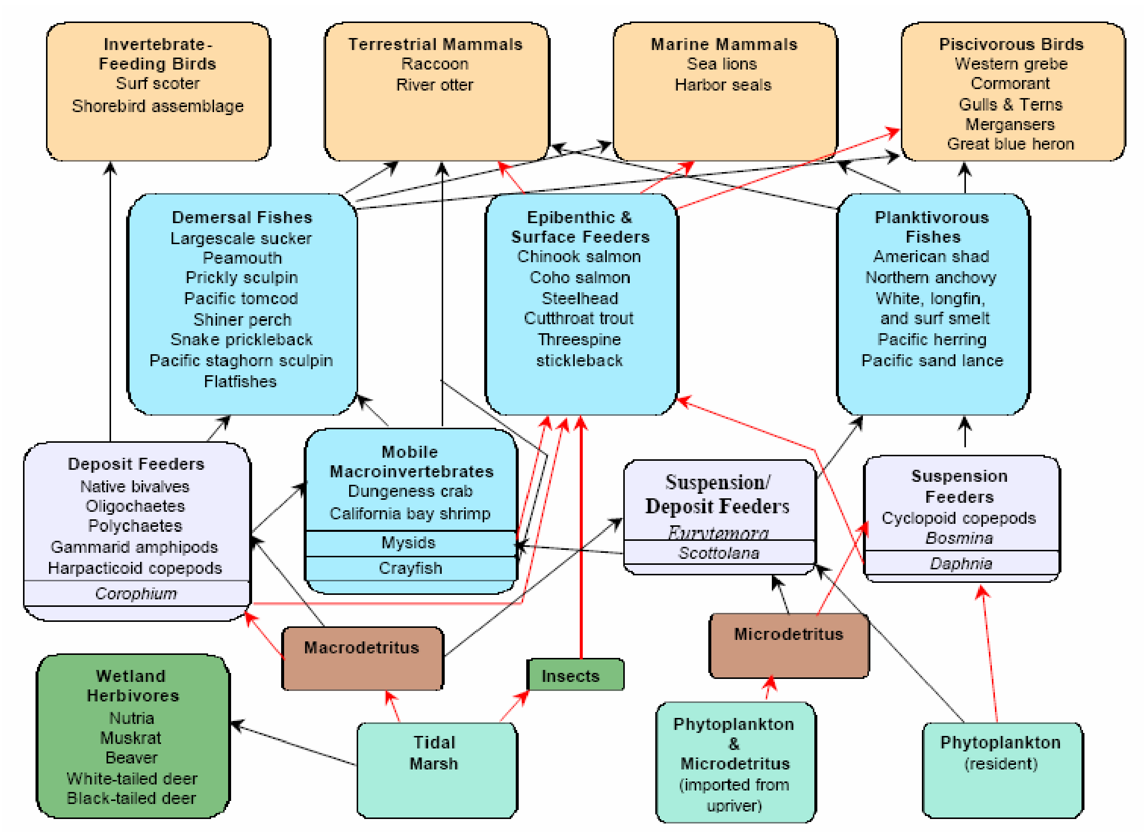
River Estuary: dominant influences on sedimentation and erosion (after Simenstad *et al*. 1984a). Width of arrow indicates level of impact of influence-type in each of three zones of the Columbia River Estuary.



River Estuary Biological Processes: hierarchical model of the biological processes for the Columbia River Estuary (after Simenstad *et al.* 1984b).



River Estuary Trophic Groups: simplified representation of major linkages between Columbia River Estuary trophic groups (from Weitkamp 1994)



Lagoon Estuary: model structure for nitrogen cycling (after Webster & Harris 2004). DIN = dissolved inorganic nitrogen; DON = dissolved organic nitrogen.