COVER SHEET

FEDERAL ENERGY REGULATORY COMMISSION

DRAFT ENVIRONMENTAL IMPACT STATEMENT
FOR THE KLAMATH HYDROELECTRIC PROJECT
Docket No. P-2082-027

Section 3
Environmental Consequences
Pages 3-1 to 3-192
DEIS

3.0 ENVIRONMENTAL CONSEQUENCES

In this section, we first describe the general environmental setting in the project vicinity and any environmental resources that could be cumulatively affected by relicensing the Klamath Hydroelectric Project facilities. Then we address each affected environmental resource. For each resource, we first describe the affected environment—the existing condition, and the baseline against which to measure the effects of the proposed project and any alternative actions—and then the environmental effects of the proposed project, including proposed enhancement measures. Unless otherwise stated, the source of our information is the license application for the project (PacifiCorp, 2004a).

3.1 GENERAL DESCRIPTION OF THE KLAMATH RIVER BASIN

The Klamath River watershed begins in the northwestern-most extent of the Basin and Range physiographic province and is one of only three drainages originating in Oregon that cut across both the Cascade and Coastal ranges. It is also unique because of its large, north-south-striking headwater lake and wetland complex—the Klamath River Basin—located in south-central Oregon and northwestern California. The Klamath River Basin lies in the transition zone between the Modoc Plateau and Cascade Range physiographic provinces, with the Klamath River cutting west through the Klamath Mountain province and then the Coast Range province where it reaches the Pacific Ocean near Requa, California. The Klamath River passes through four distinct geologic provinces, each of which changes the character of the river's channel morphology and that of its tributary watersheds, varying the supply of inputs such as water, sediment, nutrients, and wood.

The upper Klamath Basin, within the Modoc Plateau province, is bounded on its west side by the eastern edge of the Cascades Range, with tributaries of Wood River draining the flanks of the Crater Lake area (see figure 1-1). To the east, the northwesterly trending fault-block mountains with intervening valleys are commonly interspersed with lakebed deposits, shield volcanoes, cinder cones, or lava flows. Shallow lakes (Upper Klamath, Lower Klamath, and Tule lakes) and marshes (Klamath Marsh) are prominent features of the Modoc Plateau, as are areas drained by Anglo-American immigrants. The land surrounding the lakes and the drained lake areas now serves as productive agricultural land. The high-elevation, semi-arid desert environment of the Modoc Plateau receives an average of about 15 inches of precipitation annually. With its porous volcanic geology and relatively moderate topography, runoff is slow, and there are relatively few streams compared to downstream provinces. Sediment yield also is low relative to provinces downstream.

The transition from the Modoc Plateau to the Cascade Range province is subtle; the Klamath River enters the Cascade Range province roughly in the area below Keno dam. The Shasta River is the major tributary to the Klamath River within the Cascade Range province (see figure 1-1). The headwaters of the Shasta River originate on the flanks of Mt. Shasta and the majority of its watershed is comprised of the expansive Shasta Valley (Crandell, 1989). The western side of the Shasta River and Cottonwood Creek watersheds marks the western boundary of this province. The portion of the Cascade Range province included in the Klamath River watershed is largely in the rain shadow of Mt. Shasta and the Klamath Mountains; precipitation is highly variable by elevation and location. Mass wasting and fluvial erosion are the main erosional processes within this province (Forest Service, 2005).

The Klamath Mountains province includes a complex of mountain ranges in southwest Oregon and northwest California, collectively called the Klamath Mountains; they include the Trinity Alps, Salmon Mountains, Marble Mountains, and Siskiyou Mountains. Large tributary watersheds to the Klamath River in this province include the Scott, Salmon, and Trinity rivers. Compared to all other areas of the Klamath River watershed, this province includes some of the steepest topography and tallest mountains; summits in the Trinity Alps exceed 9,000 feet in elevation. Gold-bearing deposits occur within this province, and the legacy effects of gold mining and dredging persist in some areas. Precipitation generally increases in proximity to the coast, so here soils are generally deeper than in upstream provinces. Deep soils, steep slopes, and high precipitation make mass wasting and fluvial erosion the main geomorphic processes in this province, particularly in the middle to lower portions of the mid-Klamath River (i.e., the Salmon River watershed) (Forest Service, 2005; de La Fuente and Haessig, 1993). Because of this, sediment yields are relatively high compared to upstream areas of the Klamath River watershed.

The lowermost 40 miles of the Klamath River (from the town of Weitchpec to the Pacific Ocean) traverse the Coast Range province. The Coast Range province comprises three linear belts of rock separated by faults (most notably the San Andreas and also including thrust faults that are presently increasing the height of the range). The Klamath River watershed portion of the Coast Range province comprises Franciscan Complex rocks. These rocks are generally sandstones with smaller amounts of shale, chert, limestone, conglomerate, as well as serpentine and blueschist. Because of Coast Range faulting, the relatively young Franciscan rocks are still uplifting, encouraging steep hillslopes and relatively high erosion rates resulting in high sediment yields.

The Klamath River begins at the outlet of Upper Klamath Lake in Oregon at elevation 4,139 feet and flows southwest approximately 260 miles to the Pacific Ocean at Requa, California. Most of the inflow to the upper Klamath River Basin enters Upper Klamath Lake via the Sprague, Williamson, and Wood rivers. Upper Klamath Lake is a shallow, regulated natural lake, which serves as a storage reservoir for extensive, irrigated lands (approximately 250,000 acres) in the basin.

Temperatures in the project area range from below freezing during the winter to 38 degrees Celsius (°C) during the summer. The higher elevation, upstream part of the project area is generally cooler than the downstream Iron Gate and Copco areas. Average annual precipitation is 18.2 inches at Copco reservoir, although higher elevation areas in the surrounding mountains can receive more than 50 inches on average. Annual precipitation in Klamath Falls is 13.3 inches, and precipitation in the project area occurs primarily as rain, mostly during the fall and winter, with occasional afternoon thunderstorms occurring in the summer. During the winter, snow is common, particularly in the higher elevations (i.e., above the canyon rim and east to Klamath Falls).

Historically, annual precipitation patterns define distinct dry and wet cycles that are closely related to runoff on the river. The most recent climatic trends include wet periods from 1885 to 1915 and 1940 to 1975, and dry periods from 1915 to 1940 and 1975 to 1994. Gaged runoff and flow patterns on the river closely reflect these climatic cycles. General decreases in runoff and discharge during the last 20 years also coincide with a generally decreasing trend in precipitation amounts. The peak of the natural annual hydrograph in the area is dominated by spring snowmelt.

3.2 SCOPE OF THE CUMULATIVE EFFECTS ANALYSIS

According to the Council on Environmental Quality's regulations for implementing NEPA (50 CFR §1508.7), an action may cause cumulative effects on the environment if its effects overlap in space and/or time with the effects of other past, present, and reasonably foreseeable future actions, regardless of what agency or person undertakes such other actions. Cumulative effects can result from individually minor but collectively significant actions taking place over a period of time, including hydropower and other land and water development activities.

Based on information in the license application, agency comments, other filings related to the project, and preliminary staff analysis, we preliminarily identified the following resources that have the potential to be cumulatively affected by the continued operation of the Klamath Hydroelectric Project in combination with other activities in the Klamath River Basin: geomorphology, water quantity, water quality, anadromous fish**,** ESA-listed suckers, redband trout, and socioeconomic values.

The Klamath Hydroelectric Project is located on the Klamath River. Most of the project water comes from Upper Klamath Lake, part of Reclamation's Klamath Irrigation Project. The Klamath

Irrigation Project, which has been in existence since 1905, uses water from the Klamath and Lost rivers to supply agricultural water users in southern Oregon and northern California. A portion of the water diverted from Upper Klamath Lake and the Klamath River for irrigation purposes returns to the Klamath River, along with certain return flows from the Lost River, at Keno reservoir.

Since about 1992, Reclamation has modified Link River dam operations to benefit the shortnose sucker and the Lost River sucker, two Klamath River Basin fish listed in 1988 as endangered under the ESA. To protect these fish, FWS required that water levels in Upper Klamath Lake be managed within specific elevation limits. In 1999, in response to ESA listing of Southern Oregon/Northern California Coasts coho salmon Evolutionarily Significant Unit (ESU), NMFS provided a BiOp and an associated Incidental Take Statement to Reclamation containing terms and conditions that require Reclamation to provide for specific instream flows at Iron Gate dam and PacifiCorp to operate the dam to release those specified instream flows and implement identified ramping rates. Reclamation now defines Klamath Irrigation Project operations through annual operations plans in consultation with NMFS and FWS. The plan specifies how Upper Klamath Lake elevation and discharge at Iron Gate dam are to be regulated based on hydrological conditions.

Reclamation has been engaged in a planning process since the mid-1990s to develop a long-term operating strategy for the Klamath Irrigation Project. It began preparation of its EIS in 1997, and this preparation is ongoing. Alternatives identified in the Reclamation EIS could affect the Klamath Hydroelectric Project. Pursuant to a requirement of the May 2002 NMFS BiOp for Klamath Irrigation Project operations, Reclamation is currently developing the Klamath River Conservation Implementation Plan (CIP). The CIP is a basinwide multi-interest initiative to address issues associated with endangered fish in the Klamath River Basin, and it will address protection, restoration, and enhancement of fisheries and other aquatic resources. This program could be relevant to our cumulative effects analysis for the Klamath Hydroelectric Project.

3.2.1 Geographic Scope

The geographic scope of the analysis defines the physical limits or boundaries of the proposed action's effects on the resources. Because the proposed action would affect the resources differently, the geographic scope for each resource may vary.

For geomorphology, water quantity, and water quality, we include Upper Klamath Lake, the area encompassed by the Lower Klamath Lake Wildlife Refuge (which includes Lower Klamath Lake); the Lost River diversion channel; the Lost River from the confluence of the Lost River diversion channel to Tule Lake; Tule Lake; the mainstem Klamath River to its confluence with the Pacific Ocean; and the Shasta, Trinity, Scott, and Salmon rivers (the four major tributaries to the Klamath River downstream of Iron Gate dam). We chose this geographic scope because project developments, major irrigation diversions (which occur at Upper Klamath Lake, Keno reservoir, and the Shasta and Trinity rivers) and returns (which occur at Keno reservoir), and land use practices have cumulatively affected geomorphology, water quantity, and water quality within and downstream of the project area, and these effects have been linked by some parties to aquatic habitat effects in the mainstem Klamath River.

For ESA-listed sucker species (the Lost River and shortnose suckers), our geographic scope of analysis includes Upper Klamath Lake, the area encompassed by the Lower Klamath Lake Wildlife Refuge, the Lost River diversion channel, the Lost River from the confluence of the Lost River diversion channel to Tule Lake, Tule Lake, and the mainstem of the Klamath River to Iron Gate dam. This area includes the lake and reservoir habitat that is suitable for these species as well as riverine migratory corridors between the lakes and reservoirs.

For redband trout, we include all habitat that was historically accessible to redband trout upstream of Iron Gate dam. This includes spawning, rearing, and adult habitat that is currently directly influenced by project operations; fish passage facilities operated by PacifiCorp and Reclamation; and potentially accessible habitat upstream of Upper Klamath Lake.

For anadromous fish, we include the mainstem Klamath River and all habitat that was historically accessible upstream of the mouth of the river. We chose this geographic scope because project developments, irrigation diversions, and land use practices have cumulatively affected the condition of upstream historic habitats as well as the downstream mainstem river corridor that is currently used by anadromous fish. Anadromous fish that use mainstem tributaries downstream of Iron Gate dam for spawning and rearing habitat could be cumulatively affected by water quality and quantity in the mainstem of the river (which could block upstream adult movement or downstream juvenile movement), as well as the timing of fish released from or returning to the Iron Gate Hatchery (which could create crowding conditions and conflict with key habitat space limitations, such as thermal refugia). We also consider appropriate management plans for salmon fisheries including those relating to the Klamath Management Zone, which extends 200 miles offshore from Humbug Mountain, Oregon, to Horse Mountain (near Shelter Cove), California. We consider these plans because harvest (including commercial, tribal, and recreational) and escapement for Klamath stocks can affect the numbers of adult salmonids returning to the Klamath River Basin to spawn. We acknowledge that management measures for Klamath River fall Chinook currently constrain fishing on other salmon stock, from central Oregon to central California. As mentioned above, Klamath Hydroelectric Project structures and operation can affect adult spawning and subsequent downstream migration of juvenile salmonids which, in turn, serve as the basis for future harvests.

For socioeconomic values, we include the same geographic area defined for anadromous fish in the previous paragraph. We also include the geographic area encompassed by the Klamath Irrigation Project, which includes about 240,000 acres of irrigable lands in southern Oregon and northern California, adjacent National Wildlife Refuges, and some other non-Klamath Irrigation Project lands that consumptively use upper Klamath River Basin water. We include the same geographic area defined for anadromous fish because numerous actions that can influence the abundance of anadromous fish stocks, including relicensing the Klamath Hydroelectric Project, influences the incomes of people who depend on that resource for both commercial (including tribal) and recreational purposes. We include the area encompassed by the Klamath Irrigation Project, as well as the additional water users, including the refuges, because they historically received reduced electrical rates and other benefits pursuant to a 1956 contract between the licensee of the Klamath Hydroelectric Project and Reclamation. This contract expired in April 2006, and the loss of financial benefits associated with this contract would influence the economic viability of those entities historically receiving them. This overlapping action represents a potential cumulative socioeconomic effect that we consider in this EIS.

3.2.2 Temporal Scope

The temporal scope of our cumulative effects analysis in this EIS includes past, present, and future actions and their possible cumulative effects on each resource. Based on the license term, the temporal scope looks 30 to 50 years into the future, concentrating on the effect on the resources from reasonably foreseeable future actions. The historical discussion, by necessity, is limited to the amount of available information for each resource.

3.3 PROPOSED ACTION AND ACTION ALTERNATIVES

3.3.1 Geology and Soils

3.3.1.1 Affected Environment

3.3.1.1.1 Soils

Soils within the Klamath River watershed span multiple geologies, terrains, and climates. Soil types in the project area can be grouped generally into those on steeper slopes, floodplain or terrace surfaces, or directly along the river itself. Soils on steeper slopes are shallow to moderately deep (typically 17 to 40 inches) and comprise a 7- to 8-inch surface horizon of gravelly loam; an underlying horizon of gravelly, clayey loam; and locally a very gravelly clay (FERC, 1990).

Floodplain or terrace surface soils comprise a deep, well-drained combination of alluvium[1] (and in some places colluvium).[2] These soils as found in the project area within the canyon of the J.C. Boyle peaking reach can be divided typically into a 15-inch very gravelly loam upper horizon, a transitional 6-inch gravelly clay loam layer, and a 39-inch horizon of heavy clay loam underlain by weathered bedrock to 60 inches or more below the surface (FERC, 1990).

The third soil type, located directly along the river, comprises unconsolidated alluvium, colluvium, and fluvial deposits. These geologically recent alluvial, low terrace and landslide deposits consist of unconsolidated sand, silt, and gravels deposited by water or erosion.

3.3.1.1.2 Slope Stability/Landslides

Mass failures and other gravity-driven erosion processes require relatively steep slopes. Such conditions within the project area exist only within the Klamath River Canyon area from J.C. Boyle dam to just downstream of Iron Gate dam. Landsliding outside the project area is prevalent in the Franciscan geology of the lower Klamath River watershed (see section 3.1) and in certain Klamath Mountain province watersheds, such as the Salmon River (de la Fuente and Haessig, 1993).

Surface and subsurface geologic mapping in the area of the J.C. Boyle bypassed and peaking reaches shows a long history of landsliding from the steep valley walls (FERC, 1990). This area contains numerous mass failures including deep-seated rotational landslides, shallow secondary landslides, and rockfalls and slumps on talus-covered slopes. Evidence of rockfalls is apparent above and below the J.C. Boyle canal. On December 2, 2005, a large rockfall collided with the canal wall, blocking an access road and creating a hole in the canal flume (letter from R.A. Landolt, Managing Director, Hydro Resources, to J. Raby, Field Manager, Bureau of Land Management, Klamath Falls, dated December 5, 2005). The resulting canal leak eroded the adjacent road and slope downhill from the canal, forming a debris fan at the river's edge. The canal was repaired by December 13, 2005, and the road opened (letter from R.A. Landolt, Managing Director, Hydro Resources, to J. Raby, Field Manager, Bureau of Land Management, Klamath Falls, dated December 23, 2005).

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[1]Alluvium is material deposited by streams or rivers on a channel's bed, banks, and/or floodplain and on alluvial fans.

[2]Colluvium is loose and incoherent deposits, usually at the toe of a cliff or hillslope, transported primarily via the direct force of gravity.

Occurrence of large landslides is associated with exposure of Western Cascade tuff[3] in roughly the area in the 4 miles of the peaking reach upstream of the California-Oregon state line (RMs 210 to 214) where basalt movement is caused by slip surfaces initiated within the weaker tuff. Individual slide blocks of tuff and basalt involve up to 3,000 feet of canyon wall and may be several hundred feet thick. Some areas have experienced repeated events, and secondary landslides have occurred in the toe wall (leading edge) of some of these slide masses. A large slide dammed the river at RM 214.3 in recent geological time,[4] resulting in accumulation of silty lake deposits up to 200 feet thick above the blockage. These deposits form the terrace areas now referred to as the Frain Ranch area (FERC, 1990).

Other potential landslide/rockfall areas include all steep slopes underlain by tuff, as well as areas of deep colluvium/talus slopes that could produce slumps and debris flows. Talus slopes are found throughout the Klamath River Canyon portion of the project area, and are particularly visible in the J.C. Boyle bypassed reach. Continuous creep of talus and rapid rockfalls are likely on and near the talus slopes, and the potential exists for slow to moderate migration of some of the large slides.

3.3.1.1.3 Klamath River Geomorphology

Channel and Floodplain Morphology

The Klamath River, from its origin at Upper Klamath Lake to its mouth, is a predominantly non-alluvial, sediment supply-limited river flowing through mountainous terrain (figure 3-1). For most of its length, it maintains a relatively steep, high-energy, coarse-grained channel that is frequently confined by bedrock (Ayres Associates, 1999). Much of the river in the project area is geologically controlled, interspersed with relatively short alluvial reaches. PacifiCorp's pebble count sampling shows broad variation and generally suggests strong local control on sediment particle size distributions (figure 3-2). Floodplain development is minimal, and wider valleys allowing more alluvial channel migration processes are rare. A variable local climate and geology are reflected in the geomorphic and vegetative characteristics of the river valley, and generally, the channel changes character as it passes from one geologic province to the next (see section 3.1 for province details). The following sections describe the morphological characteristics of the project-related lake, river, and floodplain environments.

Most information for our description of the project-area geomorphology of the area from Upper Klamath Lake through and including Lower Klamath Lake comes from Reclamation (2005a). Where we use another source, including the project's license application, we indicate it. We also supplement information from available sources with our observations during the publicly noticed site visit (May 18 and 19, 2004) and from a supplemental visit to the project area on August 29, through September 1, 2005.

<u>Upper Klamath Lake (RMs 254.3–282.3)</u>. Management of the water surface elevation of Upper Klamath Lake by regulating the outflow did not occur until 1919 by which time 29,000 acres of marshland had been diked off from the natural lake. These dikes separate the lake from pasture land and established a new perimeter for the open water surface of the lake. Groundwater elevations are managed for these reclaimed areas by a series of drains and pumps that discharge the drainwater into the lake. Overall, the combined diking and conversion of marshland, and the regulation of the outflow, has fundamentally changed the lake's hydraulic performance. This likely also includes changes in sediment and nutrient yields to the Link River as well as the area served by the Klamath Irrigation Project via withdrawals from the lake through the A canal (see figure 2-4).

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[3]A general term that can be applied for all consolidated pyroclastic rocks (those explosively or aerially ejected from a volcanic vent).

[4]The American Geological Institute (1984) defines "recent" to be synonymous with the Holocene, a geologic epoch of the Quaternary period, stretching from the end of the Pleistocene, approximately 8,000 years ago, to the present time.

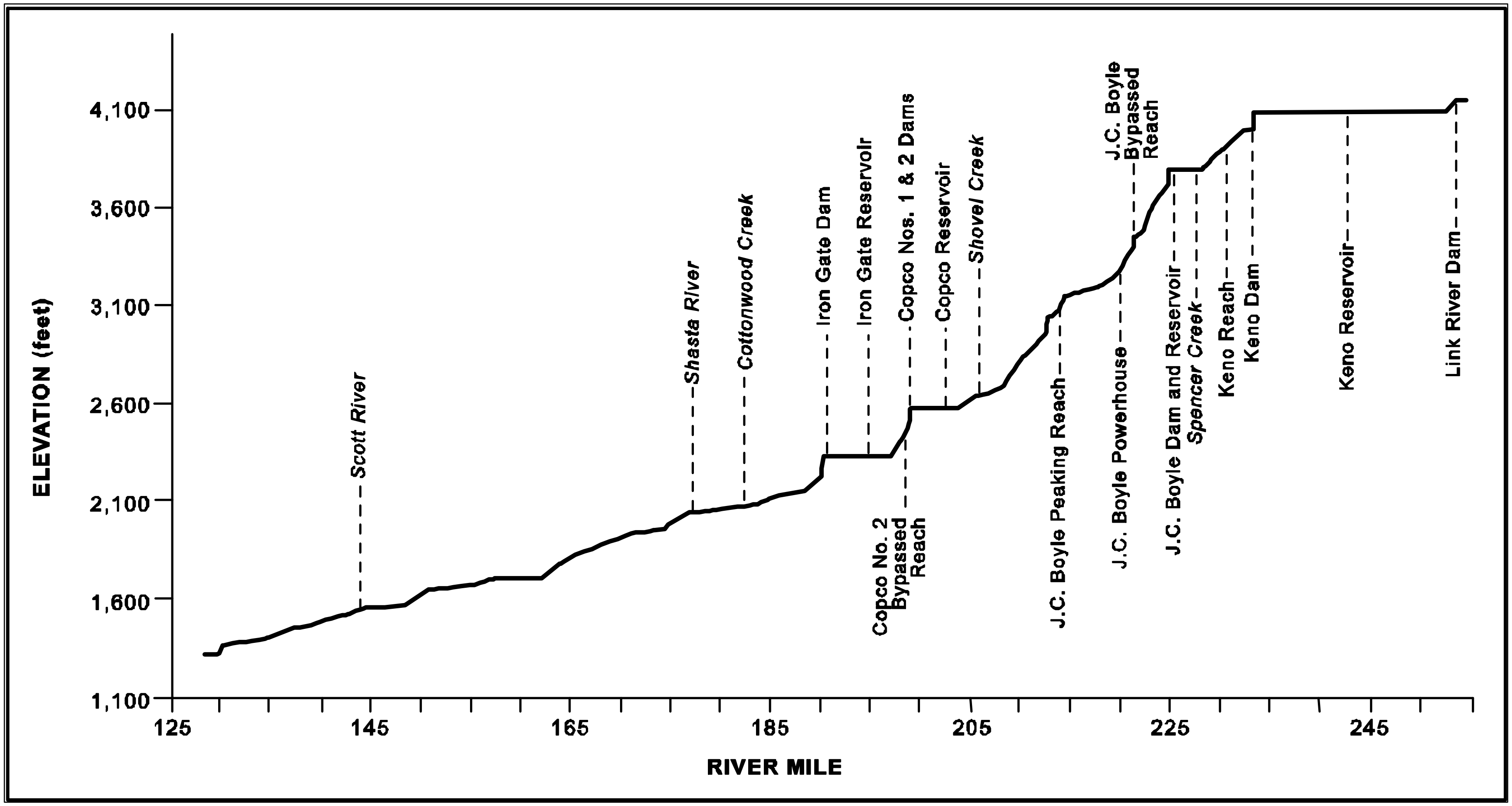

Figure 3-1. Klamath River profile. (Source: PacifiCorp, 2004a)

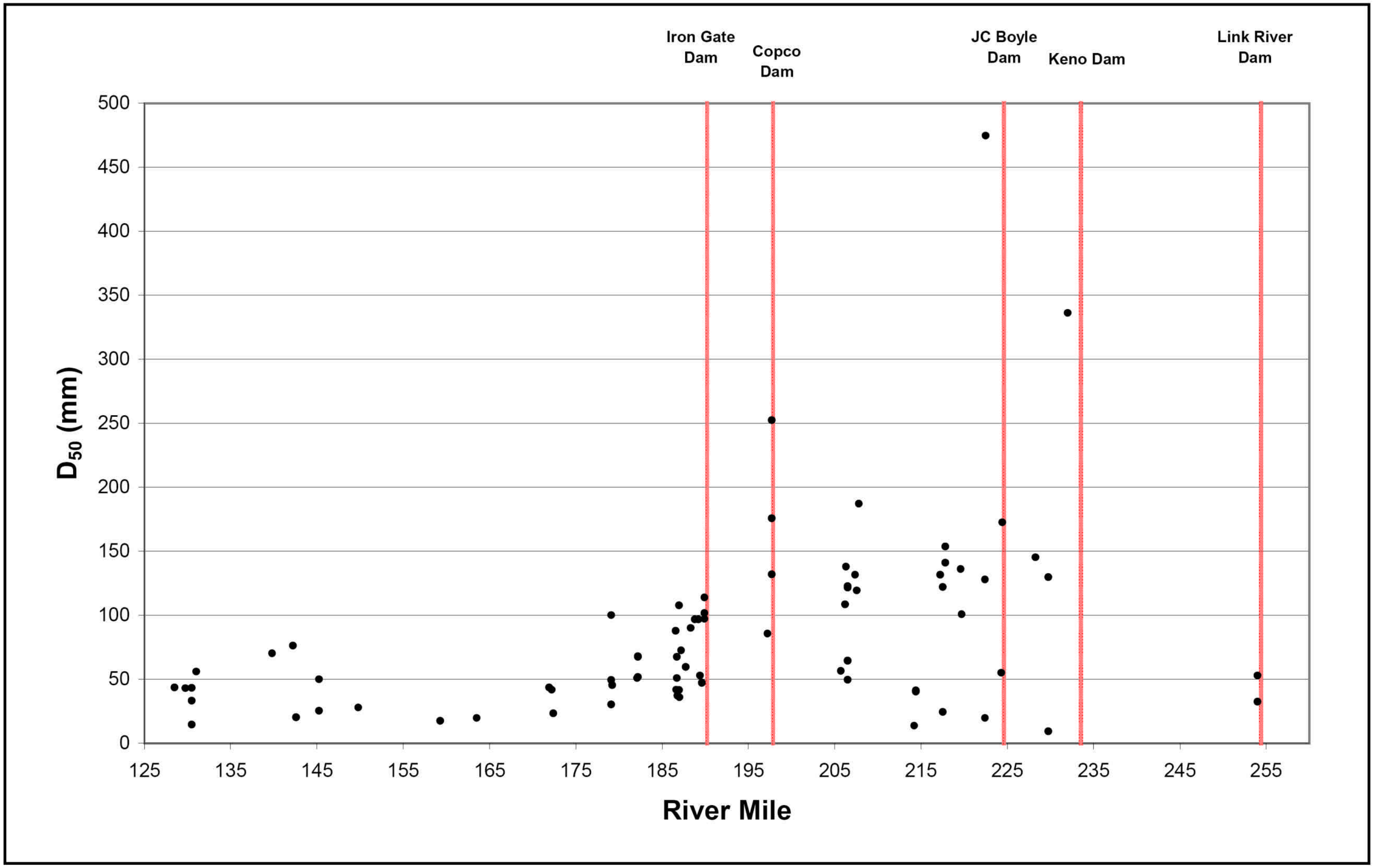

Figure 3-2. Klamath River pebble counts, median (D50) particle size longitudinal distribution. (Source: PacifiCorp, 2004a)

Link River (RMs 254.3–253.1). There is substantial bedrock control throughout most of the Link River reach. Prior to the placement of Link River dam, the river contained a bedrock sill that prevented Upper Klamath Lake from dropping below elevation 4,140 feet (Oregon Water Resources Department, 1999). To gain additional active storage, construction of Link River dam included notching the natural bedrock reef upstream of the dam in the narrows of the lake's outlet. This notching lowered the hydraulic control point 3 feet so the lake could be drawn down to an elevation of 4,137 feet, thus increasing the operational control of the dam.

Downstream of the dam, the Link River channel is composed of bedrock with occasional ledges and some boulders and cobble—a portion of which appear to be related to the construction of the canals. PacifiCorp measured the slope[5] of the channel at about 1.1 percent, and identified a conspicuous bedrock-cored mid-channel island located just downstream of the dam, with low, narrow terraces on either bank. Our observations found the channel to have very limited sediment storage, and we consider it to be historically starved of (at least coarse) sediment by Upper Klamath Lake (Reclamation, 2005a). Very few patches of apparently mobile fine or coarse sediment were present at the time of PacifiCorp's bed material sampling, and the lack of suitable substrate for surface pebble counts confirms that this is a sediment transport reach. We observed that the backwater effects from Keno dam appear to begin to influence the Link River near the Highway 97 overpass (Reclamation, 2005a).

Keno Reservoir (RMs 253.1–233.0). Keno reservoir is a narrow impoundment with a distinct riverine character. PacifiCorp indicates that it attempts to operate Keno dam to maintain the elevation of Keno reservoir at a relatively steady elevation. We observed that, along with dredging, diking, and channelization, these operations have resulted in a relatively stable channel configuration with a grass-lined, moderately sinuous channel with little visible current. The reservoir area is characterized by low topographic relief and was formerly the area where, depending on water levels and discharges, water from Upper Klamath Lake (having flowed through the Link River) could flow down the Klamath River, overflow from Lake Ewauna into the Lost River (via the Lost River Slough), or flow from the Klamath River into Lower Klamath Lake (via the Klamath Straits).

The historical outlet of Lake Ewauna to the downstream Klamath River (about 2 miles downstream of the mouth of Link River) was created by a bedrock reef, which created a drop of about 1 foot during periods of relatively low flow. Adjacent to the reef, a natural overflow channel, the Lost River Slough, carried water out of Lake Ewauna into the Lost River and the closed basin of Tule Lake when the water surface of Lake Ewauna exceeded elevation 4,085 feet.

Prior to human modification, the Klamath Straits (see figures 2-3 and 2-4) were the main natural channel for water exchange between the Klamath River and Lower Klamath Lake. In times of high river flow, the Klamath River would overflow through the straits, flowing to Lower Klamath Lake; during low river flow (and comparatively high Lower Klamath Lake levels) water in the lake would drain back into the Klamath River. That action cut a large channel about 225 feet wide and 20 feet deep. The construction of a railroad grade formed a dike across the northern end of the Lower Klamath Lake, and Reclamation made an agreement with the railroad to place a concrete structure in the straits to control the flow of water from the Klamath River. The straits were excavated and channelized and now function as a drain, conveying drainage water from irrigated land reclaimed from Lower Klamath Lake and from the Lower Klamath National Wildlife Refuge.

Before the construction of Klamath Irrigation Project in the early 1900s, water surface elevations in Lower Klamath Lake and upstream along the Klamath River to the basalt reef-outlet of Lake Ewauna were controlled by a second natural basalt reef located in the river channel at Keno. This reef held water

[5]Slopes are based on PacifiCorp's study reach averages which are shorter, sub-segments of the larger reaches defined in this document. Because survey of the study reaches was targeted in representative locations, these values should approximate the average slope throughout the reach.

levels in Lower Klamath Lake and upstream along the channel to a minimum elevation of about 4,084 feet. At higher flows, water in the river backed up as the water surface of Lower Klamath Lake rose; above water surface elevation 4,085.1 feet Lake Ewauna was inundated and became a continuous part of Lower Klamath Lake. If Lower Klamath Lake/Lake Ewauna water levels were high enough (at and above elevation 4,085.1 feet), lake water from the south merged with Lost River Slough and were carried to the Tule Lake Basin. This connection was closed with a dike in 1890. The current Lost River diversion channel (see figure 2-4) was constructed primarily at the former location of the Lost River Slough.

In 1908, the height of the reef at Keno was lowered with dynamite, which lowered the level of Lower Klamath Lake making it suitable for agricultural land and a wildlife refuge (Carlson et al., 2001). However, according to the Klamath Drainage District, the remaining portion of the reef provided sufficient head to meet its water delivery needs and those of the Lower Klamath Lake Wildlife Refuge (letter from S. Henzel, President, Klamath Irrigation District, to the Commission, dated June 16, 2004). When Reclamation constructed the original Keno regulating dam in the vicinity of Keno (a needle-type dam), the remaining portion of the rock reef at Keno was removed, according to the Klamath Drainage District, making it dependent on the regulating dam to provide appropriate head to maintain flow to the district. The original Keno regulating dam, which also supported hydroelectric generation, was damaged during the floods of 1964–1965, and the existing Keno dam now serves to regulate upstream water levels. In addition, the channel upstream of Keno dam between RMs 235 and 249 was dredged between 1966 and 1971 to provide a channel capacity of 13,300 cfs to accommodate inflow from Klamath Irrigation Project canals and reduce the risk of flooding (letter from C. Scott, Licensing Project Manager, PacifiCorp, to the Commission, dated May 16, 2005, responding to an additional information request dated February 17, 2005).

<u>Lower Klamath Lake</u>. Generally, the predevelopment Lower Klamath Lake was a very shallow water body that averaged less than about 5 or 6 feet deep. Inflow to the lake was from backwater overflow of the Klamath River, through the bulrush wetland marsh adjacent to the river, and through the naturally deep channel of the Klamath Straits. Backwater control of this inflow was by the natural bedrock reef at Keno. The broad, wetland marsh surrounding the central, open water area of the lake, grew in very shallow water near the lakeshore.

The greatest expanse of open water was resident in the deeper, southern portion of the lake where evaporation made the lake moderately alkaline. During the most typical years, the stable water surface for the lake was probably about elevation 4,084 to 4,085 feet, although the flood of 1888 was so great that the water surface of Lower Klamath Lake may have exceeded elevation 4,088 feet for a considerable time. Such a flood event would have created a broad, expansive lake that would have included the Klamath River upstream of Keno and Lake Ewauna.

During drought, water drained from Lower Klamath Lake into the Klamath River, and the associated marsh would dry up. Large islands of emergent growth would initially appear and, as dry conditions continued, these islands would become fragmented. Alkalinity in the lake would have increased and caused accelerated deterioration of the bulrush wetlands. Open water areas were somewhat shallower and, during such dry conditions, would have been warmer and more brackish. The water surface of the lake during such dry years may have been about elevation 4,083 feet or lower during much of the summer.

Beginning in 1908, work began to reclaim Lower Klamath Lake for agricultural land uses. The railroad dike was constructed east of the Klamath River, cutting off all flow into Lower Klamath Lake, except flow through the Klamath Straits. By 1917, with closure of the Klamath Straits, the last phase of draining the vast area of open water and marshland of Lower Klamath Lake began. Within a decade, the natural character of Lower Klamath Lake was gone. From 1917 to the mid-1950s, the dry lakebed of Lower Klamath Lake was extensively converted to irrigated agriculture; however, a part of the former lake was re-flooded and is managed as a wetland complex within the Lower Klamath National Wildlife Refuge. Factors that historically and currently influence geomorphological processes in the Klamath River upstream of Keno dam are predominantly associated with processes at Keno reservoir (Lake Ewauna) and Lower Klamath Lake, and the direct effect of flows from Clear and Tule lakes on the Klamath River would be minimal.

Keno Reach (RMs 233–228.3). This bedrock-controlled section of river is somewhat steeper (average slope is approximately 1.3 percent) than the Link River, and the channel consists of sequences of boulder/bedrock cascades and deep bedrock runs. Steep banks and alternating bedrock terraces confine the channel. Marginal islands occur sporadically, usually associated with bedrock protrusions or accumulations of coarse cobble and boulders. The Keno reach exhibits substantial bedrock control with little riparian vegetation influence. Pebble counts confirm this is primarily a sediment transport reach; however, local geologic controls provide sheltered depositional areas where relatively fine sediment is deposited and temporarily stored in the channel. The downstream end of this reach is characterized by the transition from the Keno Gorge to the lower gradient and more open topography that holds J.C. Boyle reservoir.

J.C. Boyle Reservoir and Spencer Creek (RMs 228.3–224.7). J.C. Boyle reservoir is located at a topographic transition on the Klamath River, whereby the wider, shallower upstream-end of the reservoir is sitting atop a formerly lower-gradient reach of river, with wide, grassy floodplain on the left bank and low hills on the right bank near the Spencer Creek confluence. Downstream of the Highway 66 Bridge, the reservoir narrows and deepens, and at about the location of J.C. Boyle dam, the Klamath River begins to enter the basalt cliff-lined canyon that contains the Klamath River all the way into California. We discuss reservoir bathymetry and substrate conditions later in *Reservoir Sedimentation and Dredging*.

Spencer Creek is the only tributary of significance to the J.C. Boyle reservoir, entering on the right bank with little delta deposition found during PacifiCorp's delta topographic surveys. The pre-dam channel of the creek was braided near the confluence area (except at the very final approach to the river), and it appears that a topographic control existed that created a braided, depositional reach upstream. PacifiCorp's review of historical aerial photographs indicates that much of the braided nature of the creek channel in this area has diminished over time, and only limited vegetation encroachment into the channel has occurred.

J.C. Boyle Bypassed Reach (RMs 224.7–220.4). The J.C. Boyle bypassed reach begins just downstream of J.C. Boyle dam, and is also the beginning of the Klamath Gorge and an associated increase in channel slope (averaging from 1.4 to 2.3 percent through the bypassed reach). Generally, the slopes of the gorge are stable except for numerous talus slopes (accumulations of rock colluvium at the base of cliffs or on steep slopes) and loose pieces of basalt that occasionally fall from the cliffs. Sloughing talus and basalt fragments commonly extend down the valley walls to the river (FERC, 1990).

In the upper portion of this reach (from RMs 224.5 to 222.5) much of the river is flanked on the right bank by a maintenance road and the J.C. Boyle canal until the canal transitions to a tunnel through Big Bend[6] to the J.C. Boyle powerhouse penstock. Construction of the road and canal on the steep canyon wall in this reach resulted in deposition of sidecast rock and soil material on the hillslope directly adjacent to the river, in some cases eliminating the river's already-small floodplain and spilling into the channel and locally affecting the river's substrate composition. Natural colluvial material forms an apron on the lower slopes of the canyon along much of the left bank of the river in the bypassed reach, generally in the area from RMs 224.3 to 221.6.

[6]Big Bend is a prominent, elongated ridge around which the river flows in a relatively tight bend controlled by the narrow canyon topography.

The channel through this reach is often V-shaped and consists primarily of boulder and bedrock. Other sections consist of a coarse plane-bed[7] with large boulders (and sidecast material in some areas), with gravel and cobble on small bars and in pockets created by coarser material. The channel morphology of the river upstream of the canal emergency spillway (located at the upstream end of Big Bend, just upstream of the entrance to the tunnel leading to the penstocks for the J.C. Boyle powerhouse) consists of alternating pools and boulder cascades. The channel slope of the J.C. Boyle bypassed reach downstream of the emergency spillway is one of the highest in the project area at 2.3 percent and may be related to substantial input of coarse sediment from the large eroded area at the base of the emergency overflow spillway. Although the transport capacity is high for the reach (due to the high local slope), PacifiCorp states that sediment is added frequently to the channel from operation of the canal spillway. We discuss the erosion at the toe of the spillway in greater detail later in *Other Sediment Inputs*.

The downstream portion of the bypassed reach is substantially different from the channel upstream of the emergency spillway. Boulder runs contain substantial pockets of fine sediment, and boulder and coarse cobble riffles exist. Downstream of the emergency spillway, the channel appears to be adjusting to the sediment input from operation of the overflow spillway. The road and its fill slope are far above the river and do not influence the channel or its floodplain. The reach ends at the downstream end of Big Bend (RM 220.4), where the J.C. Boyle powerhouse reintroduces river flows diverted at the dam.

J.C. Boyle Peaking Reach (RMs 220.4–203.1). The J.C. Boyle peaking reach begins as a broad, plane-bed channel, just downstream from the powerhouse. The channel remains steep and full of scattered boulders until downstream of the Spring Island boater access at the USGS gage (RM 219.7). Downstream of this location, while still steep, the channel is characterized by alternating cobble riffles and runs, with cobble bar and pool morphology. The gradient of the river remains high (about 1.7 percent) in the first mile or so; however, local areas of sediment deposition (e.g., bars, terraces) also begin to become present. In this area, the channel is flanked by relatively wide terraces at multiple levels. These terraces are related to the thick prehistoric lacustrine[8] deposits found in the river canyon from a short distance downstream of the J.C. Boyle powerhouse downstream to RM 214.3.

By RM 217 the river is much less steep (slope of about 0.3 percent), and the lacustrine terraces are relatively wide and conspicuous. The decreased channel gradient allows for an increased frequency of depositional areas through this area, and the pebble counts in this area highlight the storage of relatively fine sediments (gravel and fine cobble). The terraces of the Frain Ranch area (upstream of RM 214.3) are open, grassy, and very noticeable.

At RM 214.3, the river drops into Caldera Rapid. From this point downstream for about 5 miles the river becomes extremely confined, and the channel gradient increases to 2 percent through this steepest section of the peaking reach. The river is characterized by steep bedrock and boulder cascades and the channel bed, channel margins, and steep banks consist of large boulders and bedrock outcrops, which hinder development of laterally extensive riparian vegetation. PacifiCorp identified small patches of fine gravel behind boulders at the margin of the gorge. Frequently, oak woodland species overhanging the steep, bedrock banks take the place of riparian vegetation. We identified one noteworthy mid-channel bar that stretches from RMs 210.4 to 210.25. It is a very mature feature that includes cobble- and boulder-sized sediment, and is vegetated with a mature forest of both riparian and oak woodland species.

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[7]Plane-bed channels lack well-defined bed forms and are characterized by long stretches of relatively planar channel bed that may be punctuated by occasional channel-spanning rapids (Montgomery and Buffington, 1997).

[8]Lacustrine is pertaining to, produced by, or inhabiting a lake or lakes.

Gradient begins to decrease a bit by RM 210.2, and unscreened gravity-fed water diversions[9] at RM 209.7 (leading to a canal on the left bank) and at RM 209.4 (leading to a canal on the right bank) remove water from the river via localized alterations to the channel. These diversions do not contain any concrete or other formally constructed features; instead, they are formed from natural bed material—mostly cobble-sized sediment—that appears to us to be bermed up via heavy equipment to connect the ditch inlet to the river elevation.

Near the California-Oregon state line (RM 209.3) the river canyon begins to open, and there is a decrease in channel slope. Alternating pools, bars, runs, and riffles characterize this section of the reach, which has a relatively low gradient (about 0.8 percent). A comparatively wide terrace that supports a riparian corridor of varying width borders the channel, beyond which there is a floodplain that supports mostly irrigated pastureland. This general channel and floodplain configuration continues, with pasture on one or both banks, for the next 5 miles. In this reach of river, several side channels exist in conjunction with lateral bars and islands. At RM 206.5, Shovel Creek, the largest tributary in this reach, enters the Klamath River on its left bank. The reach ends at Copco reservoir (RM 203.1).

Copco Reservoir and Tributaries (RMs 203.1–198.6). Copco reservoir is located at a topographic transition on the Klamath River, whereby roughly the upper 80 percent of the reservoir is sitting atop a formerly lower gradient reach of river, with a steeper reach of river (still visible in the Copco No. 2 bypassed reach, described later) located downstream. This break in stream gradient is largely the result of Pleistocene-aged cinder cones and associated lava flows at the downstream end of Copco reservoir. The lower gradient upstream portion of the reservoir is likely the result of extensive valley-fill alluvium upstream of that lava flow (which likely dammed the river for some period of time). We discuss reservoir bathymetry and substrate conditions later in *Reservoir Sedimentation and Dredging*.

Several streams enter Copco reservoir, including Long Prairie Creek (the largest), Beaver Creek, Deer Creek, and Raymond Gulch, and multiple springs emerge from the hillside above the reservoir northeast of Copco Cove. Sediment deposition and/or delta formations are present at the mouths of the larger tributaries. We also observed sediment deposition via shoreline erosion in the vicinity of Beaver Creek Cove, adjacent to Copco Road and along the opposite (southern) shoreline of Copco reservoir during an August 30, 2005, visit to this area.

Copco No. 2 Reservoir (RMs 198.6–198.3). Copco No. 2 reservoir is a relatively short (just over 0.25 mile) impoundment, formed by the 33-foot tall Copco No. 2 dam. The reservoir is narrow, confined by a narrow bedrock canyon formed by the previously mentioned lava flow. No reservoir bathymetry or substrate information is available for this reservoir.

Copco No. 2 Bypassed Reach (RMs 198.3–196.9). Downstream of Copco No. 2 dam, the Copco No. 2 bypassed reach is characterized by a confined, boulder- and bedrock-dominated channel. The average gradient of the reach is about 1.9 percent. Fossilized[10] boulder-cobble bars have become dominated by very mature alders, but also include individual sycamore and maple trees, and these bar features dominate the channel cross section. PacifiCorp measured the surface median grain size on a fossilized bar as about 10 inches, compared to about 3 inches for the surface of an active bar. Bedrock ledges also exist within the reach. Because of the steep canyon topography—the river in this reach is strongly influenced by the lava flow on the north (right bank) side of the river—there are minimal

[9]These diversions lead to PacifiCorp's Copco Ranch (a non-hydro related property).

[10]Fossilized refers to a condition whereby the bar deposit has been totally stripped of finer sediment, leaving only the coarsened fraction of the point bar that is unable to be moved by the river. Under an altered flow regime such as the Copco No. 2 bypassed reach, river flows are never sufficient to mobilize the bar, leaving it essentially frozen in place or fossilized. Vegetation growth can further fossilize the bar surface.

floodplains in this reach. At RM 196.9, the Copco No. 2 powerhouse discharges water back into the Klamath River, and, roughly coincident with this location, the reach ends at Iron Gate reservoir.

Iron Gate Reservoir and Tributaries (RMs 196.9–190.1). Iron Gate reservoir overlies a topographic transition on the Klamath River, where a steeper reach of river upstream (that of the Copco No. 2 bypassed reach and a portion of the river inundated by Copco reservoir and Copco No. 2 reservoir) transitions into the lower gradient reach downstream of Iron Gate reservoir. In this area, the topography opens up, and the restrictions on the channel placed by the localized basalt flow (north of the Copco No. 2 bypassed reach) are relieved. We discuss reservoir bathymetry and substrate conditions later in *Reservoir Sedimentation and Dredging*.

Several sizeable tributaries enter Iron Gate reservoir on its right (north) bank, many with delta formations at their mouths. Fall Creek enters at RM 196.3 in a disturbed area,[11] and there are no signs of deposition via PacifiCorp's survey and review of historical aerial photograph analysis. We also observed that the confluence with the reservoir is within the upper end of the reservoir, and depending on reservoir stage the river may flow at this location (versus being constantly impounded), potentially transporting sediment and precluding delta formation. Jenny, Camp, Dutch, and Scotch creeks all display signs of substantial deposition at their confluences with the reservoir. We discuss details of these depositional features and the sediment supply later in *Reservoir Tributary Sediment Yield Data*.

Iron Gate Dam to Seiad Valley (RMs 190.1–130). Below Iron Gate dam, the river flows through a narrow valley cut into Cascade volcanic rocks; it has alluvial features, but with frequent bedrock outcrops in the bed. The reach is characterized by alternating coarse cobble-boulder bars and cobble runs. The average gradient ranges from about 0.16 to 0.4 percent in the first 5 miles below Iron Gate dam. A narrow, discontinuous floodplain and extensive high terraces border the channel. Small deltas have formed at the tributary confluences with the Klamath River that are composed of finer grained material than the mainstem. At RM 184 (near the Klamathon Bridge), the valley begins to widen, and by the confluence with Cottonwood Creek (RM 182.1) the river is flowing through a broad valley, formed by the intersection of the Klamath and Cottonwood drainages.

The Cottonwood Creek watershed is not a major source of sediment to the Klamath River; however, along with Bogus and Little Bogus creeks, these tributaries are the first potential sources of sediment downstream of Iron Gate dam and may contribute sediment at higher flows (Ayres Associates, 1999; Buer, 1981). Extensive placer and hard rock mining have occurred in Cottonwood Creek and its watershed, especially near the towns of Hornbrook and Henley (Ayres Associates, 1999). Buer (1981) indicates that the creek has been mined for its gravel for the construction of Interstate-5 and other purposes, and that only minor deposits remain. Similarly, Ayres Associates (1999) observed the Cottonwood Creek channel about a mile upstream of its confluence with the Klamath as "floored by bedrock and scoured clean of any significant alluvium."

Less than a mile downstream of Cottonwood Creek the valley again constricts, with a V-shaped valley formed by bedrock and colluvial material. Downstream of Interstate-5 (at RM 179.2), the river begins to cut through the Klamath province, and the channel is steeper and bedrock-controlled, with limited accumulations of alluvium. In this section of river, the channel is confined between canyon walls with a cobble-gravel bed and well-developed pool-riffle morphology flanked by discontinuous floodplain and minimal terraces. Bars from the confluence of Cottonwood Creek to Scott River appear to consist of finer material with increasing distance downstream; the median grain size on a bar at the upstream extent of the reach is about 2 inches, compared to about 1 inch at the downstream extent of the reach. Unlike the bars, the median grain size in riffles at the upstream and downstream extent of this geomorphic reach

[11]PacifiCorp notes that hydroproject development and other grading in the vicinity of the delta deposits affect the deposits directly, or compromises its ability to interpret the deposits (GM&A, 2003).

remained consistent at about 2 inches. High terraces are no longer extensive and discrete delta deposits and downstream bars occur at tributary confluences.

The Shasta River (at RM 176.6) may be a source of suspended sediment and possibly some sand and finer gravel (Ayres Associate, 1999). This is consistent with the morphology of the watershed where the broad Shasta Valley and low-gradient meandering channel within it likely intercept and store most of the coarser sediment from the upper watershed (Ayres Associates, 1999; USGS, 2006b; Buer, 1981). Downstream of the Highway 263 crossing, the Shasta River leaves its relatively flat, Shasta Valley alluvial section and drops into a steep, narrow bedrock canyon surrounded by high, steeply sloping mountainsides. The highway cuts into these steep hillsides, with fillslopes spilling down to the river. These fillslopes may be a minor source of fine sediment (Ayres Associates, 1999), in addition to the agriculture sources upstream. The lower gorge of the river contains little evidence of a major sediment supply, and the lack of any substantial sedimentation in the Klamath River at the confluence, or downstream, suggests that the Shasta River does not supply much coarse sediment to the Klamath River (Ayres Associates, 1999).

From RMs 172 to 169 there are signs of floodplain and near-channel mining[12] activities, with tailings piles still observable in some floodplain areas. Here and in the miles downstream, the steep, mountainous terrain in part dictates valley width, which in turn controls channel form. Valley width ranges from as narrow as 300 feet (with the river occupying most of the valley bottom) to almost 1,200 feet; the average is about 650 feet. Channel slope is roughly correlated with valley width, whereby steeper sections of channel occur in the more-constricted narrow valley sections. Wider valley sections typically promote lower gradient channel sections and more frequent alluvial features and floodplains; however, the size of alluvial features is largest in the miles downstream of major confluences (i.e., the Shasta and Scott rivers), and does not increase markedly to amounts greater than about 17 acres/mile until after the confluence with the Scott River (RM 143).

The Scott River is considered a major source of fine sediment (Ayres Associates, 1999). Extensive erosion of hydraulic mine sites and extensive in-channel placer and dredge mining sites upstream—along with timber harvest and fires in the upper watershed—are sources of this sediment (Ayres Associates, 1999). Scott Valley lies 35 miles upstream of the confluence with the Klamath River, and the conspicuous northeast-southwest trending Scott Bar Mountain forces the river in a large bend to the west before it can again flow east and then north to meet the Klamath River. This reach of river from Scott Valley to the confluence is steep and geologically controlled.

There are noteworthy gravel/cobble bars located at the Scott River confluence with the Klamath River, and PacifiCorp noted increased amounts of sand and fine gravel in pebble counts with distance downstream. Downstream of the confluence of the Scott River, the channel is made up of finer grained materials compared with the upper reaches. The median grain size for the five pebble counts conducted on bars ranged from 1.3 to about 3 inches; for the three riffles where pebble counts were conducted in this reach, the range was from 0.6 inch to 1.7 inches. Near Seiad Valley (RM 130) the river is still characterized by gravel/cobble bars, riffles, and runs. Locally, channel slope is less than at upstream locations and there has been extensive gold and gravel mining in the floodplain area of Seiad Valley.

<u>Seiad Valley to Confluence with the Pacific Ocean (RMs 130–0)</u>. The Klamath River from Seiad Valley to the Pacific Ocean maintains similar channel conditions to those described for the reach from the Scott River to Seiad Valley, albeit with a progressively larger channel and lower gradient. Major tributaries entering the Klamath River include the Salmon River at RM 66.0 and the Trinity River at RM 40.0. Numerous smaller creeks enter on both banks. Steep tributaries entering the river occasionally contribute sediment via debris torrents, with resultant alluvial fans forming at their mouths. Bedrock

[12]Such mining would be for gold, using dredges, and later for gravel to be used as aggregate for construction.

outcrops constrict the river at some locations, and larger rapids are formed by boulder bars/cascades (for example, landslide debris, debris fan deposits, bedrock and a major constriction of the valley at Sugarloaf Mountain produce Ishi Pishi Falls [RM 66.5], upstream of the mouth of the Salmon River).

The Salmon River is a substantial source of sediment and a major contributor of sand and gravel (Ayres Associates, 1999). The watershed drains several large areas of plutonic (granitic or dioritic) rocks which produce large volumes of fine sediment. The local channel morphology of the Klamath River (narrow bedrock constriction) downstream of the confluence precludes local storage of sediment from the Salmon River, and there is no fan or delta at the confluence (Ayres Associates, 1999).

The Trinity River (RM 40.0) is a major source of sediment, albeit somewhat finer than other large tributaries (Ayres Associates, 1999). The channel of the Trinity upstream of the confluence with the Klamath River is confined by a narrow bedrock valley with little sediment storage and terrace development. Upstream, the South Fork Trinity maintains a largely natural hydrograph (it is free of large dams), but the larger mainstem Trinity is controlled by Lewiston and Trinity dams. These two dams are an integral part of the Central Valley Project's Trinity River Division (TRD) since they were constructed in the 1960s and allow for the transfer of Trinity River water into the Sacramento River Basin. Out-of-basin diversions by the TRD averaged nearly 90 percent of the upper Trinity Basin inflow for the first 10 years of full TRD operations (Interior, 2000). These dam operations eliminate nearly all high flows responsible for forming and maintaining dynamic channel processes. No longer scoured, riparian vegetation encroached on the channel, creating lateral riparian berms. Combined with a loss of coarse sediment, this caused the mainstem Trinity River to change from a series of alternating riffles and deep pools (which provided good salmonid habitat) to a largely monotypic run habitat confined by the berms (FWS/HVT, 1999).

Since December 2000, when the Trinity River Mainstem Fishery Restoration Record of Decision (ROD) was signed, the Trinity River Restoration Program[13] has implemented variable flow releases (based on water type year) to meet various restoration objectives and management targets. To recreate inter-annual, or "between-year" flow variability, the ROD defined five water year types with a minimum volume of water to be released into the Trinity River for each type. Each year, the water not allocated to the river is available for export to the Central Valley Project for water supply and power generation. Other components of the restoration program include implementing fine-sediment reduction and coarse-sediment augmentation projects to restore the river's altered sediment budget because of operation of Lewiston and Trinity dams, and mechanical channel rehabilitation to remove fossilized riparian berms along the banks of the river that prevent access by the river to the historic floodplain.

Sediment Supply

Sediment is supplied to stream channels through mass wasting (landslides, debris flows, earthflows), sheetwash, gullying, bank collapse, fluvial erosion (bank erosion, channel avulsion), dry ravel (loss of cohesion in surface materials), tree throw, wind erosion, animal action (e.g., burrowing), and soil creep. Sediment supply via these sources often is affected (and typically increased[14]) by land use-related activities such as grazing, agriculture, timber harvest, road building, mining, and urbanization.

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[13]The Trinity River Restoration Program has four main organizational elements: The Trinity Management Council, the Trinity Adaptive Management Working Group, the Adaptive Environmental Assessment and Management Staff, and the Scientific Advisory Board. These elements work together to develop and implement a management program to restore the fish and wildlife populations in the Trinity River Basin to levels that existed prior to construction of Trinity and Lewiston dams.

[14]Important exceptions to this include dredging, gravel mining, and dams which remove sediment from channels and/or floodplains.

PacifiCorp assessed sediment contribution from bank erosion, bank collapse, and tree throw through review of aerial photographs. Most channel banks in the study area are composed of bedrock, boulders, and cobble, and thus only subject to minor erosion. Bank collapse in a few locations in the steeper canyons did not appear to be a substantial source of sediment. Tree throw, which was limited along the mainstem Klamath River, also is not a substantial source of sediment.

Information on sediment supply to the river in areas downstream of the project area is somewhat limited. Sommarstrom et al. (1990) investigated sediment supply in the Scott River watershed (entering the Klamath River at RM 143, about 47 miles downstream of Iron Gate dam) coming from sub-watersheds dominated by granitic geology. Differing markedly from the Salmon River Basin (described below), the dominant sources of sediment in the surveyed part of the Scott River watershed were found to be roads and skid trails (75 percent) and streambanks (23 percent). The study estimates that, on average, upland erosion in the granitic sub-watersheds[15] of the Scott River produce 1,011 tons/mile^2/year; however, the amount of sediment delivered to the Scott River (using the preferred sediment delivery factor of 0.21 as specified in the study) is 212 tons/mile^2/year.

In 2005, The California State North Coast Regional Water Quality Control Board (NCRWQCB) produced a staff report delineating total maximum daily load (TMDL) allocations of sediment for the Scott River watershed (NCRWQCB, 2005). Analysis in that report reviewed, and to some extent integrated, data from Sommarstrom et al. (1990), as well as new data from the study's own field work. The report estimated that the current sediment load (yield) in the Scott River watershed is 747 tons/mile^2/year. Of that total, 299 tons/mile^2/year were estimated to be from sources associated with human activity.

A Forest Service study (de la Fuente and Haessig, 1993) systematically measured landslides and estimated sediment yields for the Salmon River, which joins the Klamath River at RM 66, about 124 miles downstream of Iron Gate dam. Differing markedly from the Scott River Basin, this study found that, for the Salmon River watershed, mining and landsliding are the major sources of sediment, contributing 57 and 38 percent of the total sediment volume from 1904 through 1989, respectively. Surface erosion contributed another 5 percent; channel erosion was not quantified, but a large portion was observed to be "directly related to landsliding." De la Fuente and Haessig estimated the sediment yield from the Salmon River under current, disturbed conditions at between[16] 460 and 570 tons per square mile per year (tons/mi^2/yr). This sediment yield estimate is for total load—the sum of bed load and suspended load. According to PacifiCorp, the Salmon River sediment yield estimates of de la Fuente and Haessig were later calibrated to 450 tons/mi^2/yr by observations during the 1997 water year; however, the 1993 Forest Service study contains no information on this calibration. It is noteworthy that the 1997 water year contained a particularly high flow event (70,800 cfs[17] on January 1, 1997; flows from December 30, 1996, through January 3, 1997, averaged over 35,000 cfs; USGS, 2006c), which was one of the highest flows on

[15]Sommarstrom et al. (1990) reported that sub-watersheds dominated by granitics comprise approximately 41 percent of the Scott River watershed, leaving 59 percent of sub-watershed lands as without granitics. NCRWQCB (2005) used more-refined GIS techniques to account for the actual watershed area underlain by granitics (rather than lump entire watersheds as "granitic" or "not granitic"), and found the 11 percent of the Scott River watershed area was underlain by granitics, and 10 percent of the stream miles passed through granitic geology.

[16]Sediment yields reported in the study were originally in units of yards^3/mile^2. We converted these units using the two conversion factors noted in PacifiCorp's license application: 1.2 tons/yard^3 and 1.485 tons/yard^3, yielding values of 460 and 570 tons/mi^2/yr, respectively.

[17]As gaged on the Salmon River at Somes Bar, California, 1 mile upstream of the confluence with the Klamath River.

record. Because of this, we conclude that the 1997 water year may be anomalous and perhaps not appropriate for calibrating sediment yields.

Reservoir Tributary Sediment Yield Data

Streams that flow into the Klamath River deliver both bed load and suspended load to the mainstem. PacifiCorp conducted a survey of representative delta deposits (formed where tributaries flow directly into project reservoirs) to quantify sediment supply (particles larger than 0.8 inch) from tributaries. Surveys of tributary deltas included a combination of detailed bathymetric and terrestrial surveys. Detailed field surveys of the entire delta deposit were completed and compared to the pre-dam topography obtained by PacifiCorp. The process included field surveys, preparation of digital terrain models for both sets of survey data, and computation of net change in volume between the two surfaces.

Table 3-1 presents the results of PacifiCorp's sediment yield estimates based on the field surveys and analyses. Average unit yield (tons/mile^2/year) is computed based on the drainage area and the number of years since closure of the dam. An estimate of 20 percent washload also is added to the yield to reflect the very fine-grained sediments that would not likely be deposited in the delta. This percentage is simply an estimate based on limited suspended sediment size distribution data from the Shasta River (the nearest watershed with such data that drains mostly volcanic terrain) where approximately 20 to 30 percent of the suspended sediment load was in the clay and silt size classes.

Using two different bulk density factors, the computed yields range from 1.3 tons/mile^2/year for Spencer Creek (which flows into J.C. Boyle reservoir) to 220 tons/mile^2/year for Scotch Creek, an obviously large range spanning two orders of magnitude. We concur with PacifiCorp that the values for Spencer and Jenny creeks (18 tons/mile^2/year to 22 tons/mile^2/year) seem unreasonably low. Potential reasons for unexpectedly low yields in these tributaries include upstream water supply reservoirs, channel alterations, or other disturbances that could trap some sediment, or perhaps sediment is being deposited in a location upstream of the surveyed deltas. Scotch and Camp/Dutch creeks have generally similar yields ranging from 134 tons/mile^2/year to 220 tons/mile^2/year, depending on bulk density values. Because the deltas of Scotch and Camp/Dutch creeks have merged together within Iron Gate reservoir, we agree with PacifiCorp that combining the two sites and computing a combined sediment yield is the most appropriate method. Given this, a reasonable long-term sediment yield from Iron Gate tributaries is in the range of 150 to 190 tons/mile^2/year.

Other Sediment Inputs

PacifiCorp undertook a reconnaissance-level analysis of aerial photographs and limited field observations to identify project-related sediment sources. This analysis reported relatively few obviously active, measurable sources of sediment. The principal sources were generally associated with the J.C. Boyle canal emergency spillway, its sidecast boulders, and gullies eroded into the slope below the canal road. Another source was a large earthflow on the left bank immediately downstream of the USGS gage near Bogus Creek. However, without a basis to infer movement rates, PacifiCorp was unable to turn these observations into a rate of sediment yield.

Spills from the emergency spillway have eroded the side of the hill. PacifiCorp conducted a survey of the eroded hillside between 2003 and 2004 and found the volume of eroded material to be about 68,740 cubic yards.

Table 3-1. Computation of tributary sediment yields from reservoir delta deposits. (Source: GM&A, 2003; as modified by staff).

	Scotch	**Camp/Dutch**	**Scotch/Camp/ Dutch Combined**	**Jenny**	**All Iron Gate Tributaries Combined**	**Spencer**
Deposit volume (yd^3)	88,500	73,500	162,000	107,200	269,200	2,812
Drainage basin area (mi^2)	17.94	19.72	37.65	209.89	247.54	84.62
Period (years)	40	40	40	40	40	36
	Yield Using Bulk Density Value Of 1.485 tons/yd^3 (110 pounds/ft^3) or 1.2 tons/yd^3 (88 pounds/ft^3)					
Yield (tons/mi^2/year)	183.2 / 148.0	138.4 / 111.8	159.7 / 129.1	19.0 / 15.3	40.4 / 32.6	1.4 / 1.1
Add 20% for washload (tons/mi^2/year)	219.8 / 177.6	166.1 / 134.2	191.7 / 154.9	22.8 / 18.4	48.4 / 39.1	1.6 / 1.3

Construction of the canal and canal road involved considerable sidecasting of material excavated from the hillslope, and much of this sidecast material is still present as unweathered boulder-sized blocks on the north slope of the canyon. PacifiCorp reports that historical photographs document encroachment of sidecast material into the channel at only one location (about 4,800 feet upstream of the emergency spillway), a highly visible site where the sidecast material crossed the channel, creating a dam. The dam has partially washed out but still creates a pool upstream, and the mass of material from the right bank deflects flow into the left bank. PacifiCorp states that the left bank is undercut for nearly 400 feet, which has produced an estimated 10,200 cubic yards of sediment. Elsewhere, the sidecast material has narrowed the channel by causing the right bank to extend into the channel.

Another visible source of sediment in the J.C. Boyle bypassed reach is rill and gully erosion on the slope below the canal road. PacifiCorp estimates that this rill and gully erosion yielded a total minimum sediment volume of about 1,500 cubic yards based on measurements of the dimensions of four of the larger gullies.

PacifiCorp also identified three small landslides in the J.C. Boyle bypassed reach. All three slides were located at the downstream end of the J.C. Boyle bypassed reach at Big Bend (table 3-2). The slides were relatively small, and two were related to the presence of road cuts. Slides of similar volume could have been obscured by vegetation along the channel in other locations. Additionally, numerous debris chutes were observed in the reaches that are confined by steep canyons, but PacifiCorp considered these chutes too narrow to be accurately mapped. Thus, PacifiCorp felt this analysis underestimates the contribution of sediment from narrow chutes along the channel.

Table 3-2. Measured landslide sediment volumes in the J.C. Boyle bypassed reach. (Source: PacifiCorp, 2004g, table 6.7-10)

Slide ID	Volume of Slide Accessible by Channel (yd^3)	Mass of Slide Accessible by Channel (tons)	Slide Age (years)	Slide Yield to Channel (tons/year)
Big Bend 1	376	558	51	11
Big Bend 2	1,510	2,242	46	49
Big Bend 3	590	876	46	19

Contribution of sediment to the mainstem Klamath River from hillslope landslides appears limited compared to the contribution from tributaries. PacifiCorp estimates that 79 tons per year of sediment were delivered to the J.C. Boyle bypassed reach channel from measured landslides compared to more than 5,000 tons per year of sediment contributed by tributaries.

Reservoir Sedimentation and Dredging

Bathymetric surveys were conducted on Keno, J.C. Boyle, Copco, and Iron Gate reservoirs in fall 2001, with additional survey work on Keno reservoir in August 2003. Beyond producing data and imagery of existing bathymetry, these surveys also provided the data for estimates of reservoir sediment accumulation and reservoir surface substrate composition. Keno reservoir is the only project reservoir where dredging has occurred. Dredging at Keno occurred shortly after dam construction (1966 through 1971), and, in 2002, about 17,000 cubic yards of material was removed from above the dam to enhance flow to the fish ladder exit to the reservoir.

Comparison of Bathymetry with Historical Topography

Accumulated sediment in the impoundments was assessed by comparing the current bathymetry of the impoundments with pre-impoundment topography. Preconstruction topography was used to generate a surface to compare with the current bathymetry. Because no historical topographic map was available for Lake Ewauna, this area was not included in the historical comparison. Furthermore, bathymetry within the historic river channels of the impoundments was unavailable except for the part of Keno reservoir in the reach between Highway 66 and the dam. This is important because in some reservoirs (e.g., J.C. Boyle reservoir downstream of the Highway 66 Bridge) this is where most of the reservoir depth occurs.

Pre-impoundment mapping often is at lower resolution or contains data alignment irregularities, compared to recent bathymetry. Because the comparison of any two data sets is only as precise as lowest quality data set, interpretation of results can be problematic. This is the same difficulty encountered in the reservoir tributary delta sediment yield study discussed previously. Because of such errors and alignment issues, PacifiCorp points out the reservoir sediment accumulation assessments may be unreliable (letter from C. Scott, Licensing Project Manager, PacifiCorp, to the Commission, dated May 16, 2005, in response to AIR WQ-2 [e]). For example, alignment issues are particularly egregious for the upstream end of Copco reservoir, an area we would suspect to have perhaps the most sediment accumulation of all project impoundments because of its age and location at the upstream end of the reservoir. Table 3-3 presents the results (rounded to the nearest acre-foot) of PacifiCorp's assessment of reservoir sediment accumulation. Note that only current bathymetry is available for the full reach between Lake Ewauna and Keno dam.

Table 3-3. Estimated loss in reservoir volume based on comparison of current bathymetry with historic topography for four of the five study sites. (Source: Eilers and Gubala, 2003, as modified by staff)

Reservoir	Historic Reservoir Volume (acre-feet)	2001 Surveyed Volume[a] (acre-feet)	Loss in Volume (percent)
Keno[b]	926	837	9.6
J.C. Boyle	2,281	2,267	0.6
Copco reservoir	39,601	33,724	14.8
Iron Gate	53,926	50,941	5.5

[a] Additional survey work was conducted in Keno reservoir in August 2003.

[b] Historical topographic mapping was not available for Lake Ewauna, the upstream-most 2 miles of what is now Keno reservoir. Therefore, this estimated loss in volume only includes Keno reservoir below the historic downstream limit of Lake Ewauna.

Reservoir Substrate Composition

During fall 2001, PacifiCorp sampled reservoir surface sediment for subsequent particle size and chemical analyses at 41 locations within project reservoirs, with 20 successfully sampled cores. These samples obtained a shallow sample (generally less than or equal to about 4 inches) using either a mini-Glew gravity corer or an anchor of undefined type. PacifiCorp also undertook detailed hydroacoustic imaging of sediment regularity and reflectivity (Eilers and Gubala, 2003). The data on particle size and other observations were integrated with the unsupervised hydroacoustic imaging of the sediments by combining hydroacoustic images of similar type to yield a "supervised" map of sediment composition.[18] The resulting data show the differences in sediment composition of the project impoundments.

These data describe only surface sediment, however, and do not necessarily provide an indication of the dominant sediment accumulation (which may exist as a different size class at depth) at any particular location. The sediment samples used to classify the acoustically sensed substrate types are shallow (4 inches or less), and the hydroacoustic beams do not penetrate deeply into the sediment. As such, accumulated sediment mapped as silt could actually be a silt or soil layer covering coarser substrate, such as gravel; conversely, areas mapped as gravel could be sitting atop buried layers of finer sediment.

Another important consideration is related to the coarser fraction of sediment that is generally referred to as rock or gravel in the core results. Neither term necessarily differentiates between the various rock types (such as bedrock, cobble, or gravel) to be expected in the reservoir bed, because all of these rocky substrate types will not enter the mini-Glew gravity corer. When assigned by PacifiCorp, it appears that this sediment type was typically inferred qualitatively, either through underwater video or based on refusal of the sampler or anchor.

Keno Reservoir Dredging and Spoil Disposal Sites

The original Keno needle-type regulating dam was damaged during the floods of 1964 to 1965, and a new dam was constructed to replace it. In addition, channel improvements between RMs 234.6 and 236 were completed during the construction of the new dam in 1966, and channel improvements from the Highway 66 Bridge (RM 235) to the Highway 97 Bridge (RM 249) were completed by 1971. The channel dredging was done to fulfill the agreement with Reclamation to provide a channel capacity of 13,300 cfs to accommodate inflow from Reclamation canals. Up to 3.75 million cubic yards of material were removed and deposited on adjacent lands. Spoil material was spread across dispersed parcels bordering the river, and at least one portion of the river alignment was slightly smoothed. Sampling of the material prior to dredging indicated that most of the dredge spoil consisted of diatomite and sand (internal memorandum from J.L. Blackburn, Pacific Power & Light Company, to H.A. Hurbut, Jr., Klamath Falls, Oregon, dated August 15, 1966; attachment A-2 of PacifiCorp's response to AIR WQ-2 [c] dated May 16, 2005).

In March 2002, dredging was conducted in the Keno reservoir in front of the fish ladder exit to remove debris and sediment that were partially blocking the exit/water intake. About 17,000 cubic yards of material were removed via suction dredge, and the spoils were pumped across the Keno Park (the Keno Recreation Area) to a vacant lot about 600 feet to the southeast of Keno Park boat dock (letter from C. Scott, Licensing Project Manager, PacifiCorp, to the Commission, dated May 16, 2005, in response to AIR WQ-2 [c]). Material consisted of fine sediment and large wood debris. Permitting requirements did not require sediment testing, and no analyses of these sediments are available.

Sediment Transport

The transport of sediment within a river is a primary physical process, setting the stage for numerous ecological processes, including but not limited to, the recruitment of riparian vegetation, the scour and sorting of spawning gravels, and the creation and maintenance of complex instream habitat. Further, sediment transport (as modeled with numerical equations using selected parameters from field

[18] In this context, we conclude that PacifiCorp means that they used computer algorithms to filter the regularity and reflectivity, resulting in an unsupervised (meaning without human intervention) classification of bottom types. We conclude that they then used the coring data to establish which of the unsupervised classes correspond to specific bottom, resulting in a "supervised" interpretation of the hydroacoustic survey data.

work, explained below) is the backbone of PacifiCorp's sediment budget, upon which many geomorphological results and conclusions are based.

Data for bedload and suspended sediment sampling and observations on movement of tracer gravels are very limited for the project-affected reaches of the Klamath River. Bedload and suspended sediment transport sampling for project relicensing studies only occurred during 2003 at a site at the J.C. Boyle peaking reach upstream of the confluence of Shovel Creek. Peak flow during bedload sampling was 3,000 cfs, which is the flow release when both J.C. Boyle generators are operating. At 3,000 cfs, PacifiCorp measured a bedload transport rate of 1.04 tons per day, and at 2,800 cfs it was 0.6 ton per day; the suspended load transport rate was measured at 3,000 cfs as 256 tons per day. PacifiCorp concluded, based on these results, that the existing bed is not fully mobilized at 3,000 cfs.

In addition, tracer gravels (and surveyed cross sections and gravel location) were initially placed in the Klamath River in the following locations to document bed mobility during the 2002 snowmelt flow season: (1) upstream of the Shovel Creek confluence, (2) near R-Ranch downstream of Iron Gate dam, (3) above the Cottonwood Creek confluence, (4) at the I-5 rest area, and (5) in two tributaries (Shovel and Humbug creeks). Because flows were inadequate to produce movement of the tracer gravels in 2002, winter 2003, and spring 2003, new tracer gravel study sites were added to the J.C. Boyle bypassed reach near the emergency overflow spillway, in the J.C. Boyle peaking reach at the USGS gage, and in the Frain Ranch area of the J.C. Boyle reach. The Frain Ranch site included only unsurveyed tracer pockets, which were ostensibly sites where gravels were placed without a formal cross section to aid in recovery.

Tracer gravel transects were resurveyed in late June 2003 (table 3-4). Because of high flows at the time of survey, which made wading unsafe, only partial surveys were completed (data are available for three of nine sites). In several instances, tracer gravels were not recovered. During deployment, flows at the study sites were not large or long enough to completely mobilize the channel bed at the tracer transect locations. However, at the three resurveyed sites, some tracer gravels were mobilized. The bed elevation did not increase or decrease during the tracer studies, which is consistent with the tracer gravel results showing a lack of full bed mobility and the flow record illustrating that flows were below the discharge required for active channel bed conditions.

3.3.1.1.4 Fluvial Geomorphic Conditions for Riparian Vegetation

Fluvial processes can play a major role in generating floodplains of different heights suitable for establishing woody riparian species (Stromberg et al., 1991; Johnson, 1992; Scott et al., 1993; Rood and Mahoney, 2000). Flow regimes also are a potentially more important aspect governing the recruitment of riparian vegetation, regardless of geomorphic setting (Mahoney and Rood, 1998; Friedman and Auble, 1999). The following section presents the geomorphological foundation for our detailed discussion of riparian vegetation later in this EIS in section 3.3.4, *Terrestrial Resources*.

Fluvial geomorphic conditions affecting riparian vegetation recruitment and sustained growth include proper substrate and flow regime requirements, including (a) the timing, shape, and duration of descending limb of hydrograph, and (b) the timing, magnitude, and duration of peak flows.

Riparian trees, as pioneer species, are poor competitors that require bare, open sites with moist, fine-grained mineral soil with no organic duff for establishment. Recently scoured point bars or isolated patches of alluvial soil deposition along a river provide such conditions. Riparian seed viability is generally short, lasting about 2 to 4 weeks. Hence, these substrate conditions must coincide with both seed dispersal and a favorable rate of decline in soil moisture (water table elevation), discussed further in this section.

Table 3-4. Tracer gravel sites, deployment, and recovery. (Source: PacifiCorp, 2004f, as modified by staff)

Site	RM	Reach	Cross-section Tracer Location	Pocket Tracer Location	Deployment Date	Size of Tracers Deployed (mm); Number per Size Class Deployed (bold), if available	Size of Particles that Moved (bold); Were Unrecovered (*italics*), if available (mm)	High Flow During Tracer Deployment (cfs)
J.C. Boyle bypassed reach downstream of emergency overflow spillway	222.6	J.C. Boyle bypassed reach	Approx. 30 meters upstream of mid-channel bar	--	04/01/2003	Range = 41-115 mm 32-64 mm (**3**) 64-128 mm (**13**)	-- 32-64 mm (**2**) (*0*) 64-128 mm (**2**) (*4*)	1,700
			--	Upstream of island near the right bank of the main channel	04/01/2003	Range = 41-92 mm	N/A	1,700
			--	Midway along island near the right bank of the main channel	04/01/2003	Range = 47-91 mm	N/A	1,700
			--	Downstream end of island near the right bank of the main channel	04/01/2003	Range = 49-86 mm	N/A	1,700
J.C. Boyle peaking reach downstream of USGS gage	219.7	J.C. Boyle Peaking Reach	10 ft upstream of double snag and fallen trunk on right bank to	--	11/03/2002	Range = 45-96 mm 32-64 mm (**2**)	-- 32-64 mm (**0**) (*1*)	3,850

Site	RM	Reach	Cross-section Tracer Location	Pocket Tracer Location	Deployment Date	Size of Tracers Deployed (mm); Number per Size Class Deployed (bold), if available	Size of Particles that Moved (bold); Were Unrecovered (*italics*), if available (mm)	High Flow During Tracer Deployment (cfs)
			pine on left bank			64-128 mm (**12**)	64-128 mm (**0**) (*3*)	
J.C. Boyle peaking reach upstream of Shovel Creek confluence	206.5	J.C. Boyle Peaking Reach	Upstream of Shovel Creek confluence	--	2/14/02, additional traces placed on 04/26/2002	Range = 32-150 mm[a] 16-32 mm (**1**) 32-64 mm (**6**) 64-128 mm (**15**) 128-256 mm (**2**)	 16-32 mm (**0**) (*1*) 32-64 mm (**0**) (4) 64-128 mm (**1**) (*2*) 128-256 mm (**0**) (*0*)	3,988[b]

Notes: N/A = Not Available.

All resurvey of tracer gravels occurred on June 25, 2003. We assume that particles that were not recovered were either washed farther away than the zone re-surveyed (i.e., they were moved), or, alternatively they were not found at the time of resurvey because of survey error or the appearance of the tracer gravels was altered (via algae growth) such that they were no longer discernible as tracer gravels.

a While tables in the report results indicate the range as stated here, figure 3.7-57 in the report indicates that one smaller particle, in the medium gravel (8 to 16 mm) size class, was also deployed but did not move.

b Flow was estimated by adjusting flows measured at the J.C. Boyle USGS gage for accretion based on drainage area.

In terms of recruitment, spring peak flows and the descending limb of the annual hydrograph relative to seed dispersal are the most important aspects of riparian establishment. Riparian seedlings are intolerant of drought. The timing and rate of drop of the descending limb with respect to the elevation of the seed is important. If river water levels decline too rapidly, tree seedlings will not be able to grow roots fast enough to follow the coincident decline in soil moisture (caused by the drop in the water table[19]), and the seedling will die of desiccation. PacifiCorp assumed that coyote willow seed disperses in May and June and collected data accordingly. However, because only incidental observations of coyote willow seed dispersal were made in late May or early June 2002, these observations may not reflect the time period where the majority of willow seed dispersal occurs.

Although riparian seedlings are drought intolerant, they do tolerate flooding. This adaptation allows seedlings to handle short-duration flooding during the year of their establishment, or in the spring of subsequent years. However, despite this adaptation to inundation, seedlings can still be eliminated by physical scour or sediment deposition. Hence, establishment must occur at an elevation range high enough to escape peak flows that could scour or bury seedlings, but still low enough to maintain contact with a declining water table.

Link River

Because it is primarily a bedrock reach, channel morphology does not appear to be substantially controlled by riparian vegetation conditions. Likewise, the lack of substantial alluvial deposits also limits the recruitment of substantial amounts of riparian vegetation.

Keno Reach

The Keno reach also exhibits substantial bedrock control, and the influence of riparian vegetation on channel form is only slightly more substantial than in the Link River reach. The active channel in the Keno reach comprises a relatively large proportion of the valley bottom with relatively steep canyon walls extending up from the narrow floodplain. Therefore, surfaces for colonization by riparian vegetation (e.g., bars, terraces, islands) are relatively small and limited. There is generally a sharp demarcation between coarse substrates within the active channel and finer substrates on narrow terraces at the base of the canyon slopes.

J.C. Boyle Bypassed and Peaking Reaches

Geomorphic characteristics vary considerably throughout the J.C. Boyle bypassed and peaking reaches. Nonetheless, the relatively narrow band of riparian vegetation does not appear to substantially affect the formation and persistence of bedforms in the active channel or riparian zones. Even in alluvial portions of the reach downstream of the gorge, channel-forming processes do not currently appear to be strongly linked to riparian vegetation.

However, riparian vegetation on bars and channel margins of this reach appears to be affected by peaking operations. For instance, the sediment composition of most alluvial bars appears amenable to riparian vegetation recruitment and growth, but the bars are unvegetated to the margin of inundation during peaking. Similarly, vegetation is generally absent from channel margins within the same area of peaking inundation.

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[19] Although the elevation of the water table and soil moisture decline more slowly than do river levels, the stage (elevation) of the river is frequently gaged and provides readily accessible data. Further, although lagging behind the river to some degree, studies show that the decline of water table and soil moisture closely mirrors that of river stage.

Copco No. 2 Bypassed Reach

Because the base flow in this reach has been reduced to about 10 cfs (with occasional uncontrolled spill flows of thousands of cfs) for a long period of time, the river channel in the Copco No. 2 bypassed reach is characterized by very coarse cobble and boulder bars and substantial encroachment of riparian vegetation. The encroaching trees and their roots are holding cobbles and boulders in place, creating fossilized bars whereby the vegetation, channel position, and cobbles/boulders essentially do not move or substantively change, even with larger flows.

Iron Gate Dam Downstream to Seiad Valley

Throughout most of this reach, channel morphology and areas of riparian vegetation are influenced by local geologic control and, in some cases, by the presence of mine tailings. In addition, fluctuations in the annual hydrograph and decreased sediment supply also influence the recruitment and maintenance of riparian vegetation. As the lowest dam in the project, discharge from Iron Gate dam may influence recruitment for some distance downstream. In addition, the reach downstream of Iron Gate would theoretically face the largest sediment deficit of any reach related to the project.

PacifiCorp conducted studies of the reach downstream of Iron Gate dam to analyze the relationship between project flows and recruitment conditions. Studies included analysis of tree ages/recruitment date relative to flow records (from 1964 to 2001). PacifiCorp sampled the age of riparian trees using an increment borer at five vegetation transects where stage-discharge was modeled in the reach downstream of Iron Gate (the Iron Gate reach). The flow regime was evaluated with respect to tree age samples from water years 1964 to 2001.

3.3.1.2 Environmental Effects

3.3.1.2.1 Shoreline Erosion

There is little detailed information in the record regarding reservoir shoreline erosion. Information that is available is related to the role of shoreline erosion (compared to other factors such as livestock grazing and recreation) in the establishment of shoreline vegetation, and as related to cultural sites. PacifiCorp states that shoreline erosion is particularly apparent in the drawdown zones of J.C. Boyle, Copco, and Iron Gate reservoirs, and all three reservoir drawdown zones have extensive eroded areas. Several mechanisms contribute to the erosional loss of sediments in reservoir drawdown zones. Wave energy is undoubtedly the single largest factor moving sediments, with wave formation produced by wind and boat wakes. Wave erosion occurs mostly near the water's edge and, as the pool level fluctuates, this effect moves back and forth across the drawdown zone. This mechanism is most effective at removing fine sediments (that is, sands, silts, and clays), although larger waves associated with storms probably move gravel-sized particles as well. Erosion tends to have a winnowing effect, removing the finer sediments while leaving coarser gravel and cobbles. Ultimately, this coarser material can develop into an armored surface that is much less susceptible to erosion.

Shoreline erosion can be quantified by pedestalled trees and stumps along the reservoir margins, suggesting that at least 0.7 to 3.3 feet of sediment has eroded away in many places, with erosion most evident and pronounced on the shoreline of Copco reservoir. Wave-eroded cut banks between 10 and 15 feet in height exist on the shoreline of Copco reservoir. On J.C. Boyle and Iron Gate reservoirs, shoreline erosion is considerably less, but increases within about 1 mile upstream of the dams.

Issues related to erosion of riverine shorelines and cultural sites are documented in the license application based on observations during site visits made by PacifiCorp and tribal representatives. Tribal representatives expressed concern about the exposure and subsequent vandalism of sensitive cultural sites along the lower portion of Keno reservoir during drawdowns (the sites are inundated during normal project operations). Before Keno dam was constructed, this area was likely a patchwork of marsh and upland. Keno dam inundated this area and eliminated a substantial portion of the emergent vegetation. Therefore, when drawdowns occur, flow over unvegetated fine sediments could disturb and expose sensitive cultural resources sites.

Tribal representatives also expressed concern about project-related erosion of a sensitive cultural site in the J.C. Boyle peaking reach near Frain Ranch. PacifiCorp staff observed erosion downstream of Iron Gate dam at the "Osburger" site during a site visit, where two historic houses were relocated from the town of Klamathon. Though PacifiCorp provided no reason for the site visit in the license application, we conclude the site was reviewed to assess erosion and whether it could be related to project operations. The houses currently sit on a terrace approximately 30 feet above the water surface.[20]

PacifiCorp's proposed measures to address shoreline erosion are related to cultural sites, and are included in its HPMP discussed in section 3.3.9.2.2, *Management of Cultural Resources*. No other entities have made specific recommendations that pertain to controlling shoreline erosion.

Our Analysis

We observed steep, tall, eroded shorelines along the south shore of Copco reservoir during our site visits to the project area. It is unclear from the information available to us if erosion in this area has any detrimental effects on other resources. In the absence of such information, the need for remedial measures beyond those necessary to protect cultural sites has not been established.

The effects of erosion of riverine shoreline at cultural sites are site specific. The Keno reservoir reach of the Klamath River had a very low gradient before the project was established because of the flatness of the valley and the hydraulic control by the bedrock reef at Keno, so sediment transport dynamics were not changed substantially with the completion of Keno dam. However, because of the inundation associated with Keno dam, emergent wetland and riparian vegetation characteristics have changed, making cultural sites more visible when the reservoir level is low. Nonetheless, we conclude that exposure and vandalism of cultural sites at Keno reservoir is related to relatively infrequent reservoir drawdowns (every 2 years or so), not erosion. We discuss proposed measures to address these cultural sites during drawdown in section 3.3.9.2, *Cultural Resources*.

Erosion of the site in the J.C. Boyle peaking reach occurred during a flow that was well beyond the control of project facilities, within a back eddy at high river stage, and would probably have occurred even without the project. Although the project has altered sediment transport dynamics in this reach (see section 3.3.1.2.2, *Project Effects on Sediment Supply*), we conclude that erosion of this cultural site was driven mostly by the extreme flow event that occurred in 1997, and is not likely the direct result of project effects on geomorphology or sediment transport.

Erosion adjacent to the Osburger site downstream of Iron Gate dam does not appear to be directly linked to project effects on geomorphology and sediment transport. Evidence of erosion (and associated bank protection) was observed at the base of a steep slope below the houses and about 38 feet away from and 9.8 feet above the active channel edge and water surface elevation, respectively. The flow during the 1997 event that caused the erosion (20,500 cfs) was well above the range of project control. Although there has been an alteration to the river's capacity to supply and transport sediment in the reach downstream of Iron Gate dam, it appears to us that, similar to the site in the J.C. Boyle peaking reach, erosion at this site occurred in an area that could be a back eddy during high flows. Largely influenced by natural topographic controls during high magnitude floods, existing local site conditions appear to be the primary factor in the erosion that threatened cultural resources in this area, not project operations.

[20]The flow at the time of PacifiCorp's site visit was 1,350 cfs, which it indicates did not appear to be actively eroding banks or mobilizing the bed.

3.3.1.2.2 Project Effects on Sediment Supply

Natural river reaches export fine and coarse sediment at rates approximately equal to sediment inputs. Although the amount of and mechanism for sediment storage within any particular river reach fluctuates from one year to the next, it sustains channel morphology and habitat attributes in a dynamic quasi-equilibrium[21] when averaged over the course of longer time periods such as a series of wet and dry years (on the order of 5 to 10 years or more).

The sediment that makes up the bed and banks of the Klamath River ranges in size from silt and sand to gravel, cobbles, and boulders with outcrops of bedrock. Since their construction, project dams have trapped most sediment that was previously delivered to downstream reaches and altered the flows necessary to transport sediment in reaches of the river. Together, these changes have altered natural sediment transport processes, reduced gravel bar and pocket gravel deposits, and reduced salmonid and lamprey spawning and rearing habitat. Additionally, project operations have increased sediment supply from point sources of erosion and fill encroachment on the river channel.

To evaluate sediment-related project effects, we used PacifiCorp's sediment budget[22] and hydraulic calculations as tools to assist in our evaluation of project effects. We also reviewed the record for information on point sources of sediment, canal failures, landslides, and other types of erosion, and made use of our site visit observations. We discuss sediment supply as it pertains to accumulation in project reservoirs in section 3.3.1.2.6, *Dam Removal and Decommissioning*.

Point-Sources of Erosion and Sediment Input in the J.C. Boyle Bypassed Reach

Maintaining the canal and roadway on the steep right bank[23] of the river canyon through the J.C. Boyle bypassed reach has resulted in the introduction of sidecast material to the river. This has narrowed the river channel in places, filled across the channel in one location, and caused erosion of the opposite bank. Rill and gully erosion of fill slopes below the road would likely continue if left unchecked. Landslides originating near the roadway in the downstream part of this reach (near Big Bend, downstream of the emergency spillway) are old and have largely stabilized.

With nearly 70,000 cubic yards of sediment eroded below it, the J.C. Boyle canal emergency spillway is the single largest point source of sediment in the project area. Currently, if the J.C. Boyle powerhouse trips offline, there is no bypass through the powerhouse to accommodate the water in the canal. Instead, it is spilled through the relatively low gradient concrete emergency spillway. Once water reaches the end of the concrete, it freefalls onto the canyon slope below, and flows to the river, eroding the hillslope in the process. The headward erosion of this hillslope may ultimately threaten the adjacent roadway, or even the canal itself. Given the nature of bypassed flows in the reach, sediment input from the spillway to the channel far outpaces the river's ability to transport it.

PacifiCorp proposes to install a synchronized bypass valve on each of the two Boyle powerhouse units to ensure ramping rates and minimum flows could be met if a unit trips offline. This would minimize or eliminate spill events at the emergency spillway.

Oregon Fish & Wildlife recommends that, within 1 year of license issuance, PacifiCorp implement a flow continuation measure at the J.C. Boyle canal and powerhouse to provide a minimum of

[21]Dynamic quasi-equilibrium refers to the fact that sediment is dynamically transported through, or stored within, the channel, but channel morphology fluctuates only narrowly over time.

[22]Information on equations, actual spreadsheets, and other details of the sediment budget and associated hydraulic calculations are provided PacifiCorp (2004a) and PacifiCorp's AIR responses dated May 16, 2005, and December 16, 2005.

[23]Viewed from the perspective of looking downstream.

48 hours of continuous flow under powerhouse shutdown conditions. The Hoopa Valley Tribe makes a similar recommendation, except the tribe recommends that the flow continuation device should provide "several hours of continuous flow" compared to the 48 hours recommended by Oregon Fish & Wildlife. Oregon Fish & Wildlife also recommends that PacifiCorp develop, in consultation with the agencies, a monitoring and maintenance plan that would eliminate or reduce failure of the water conveyance system and excess use of the emergency spillway. The monitoring component of the plan would include technology for early detection of waterway failure and protocols for stopping flows in the canal at the same time as restoring flows in the bypassed reach to maintain flows downstream of the powerhouse.

Oregon Fish & Wildlife recommends that, within 1 year of license issuance, PacifiCorp develop a plan, in consultation with the agencies, that addresses procedures, environmental permits, and subsequent mitigation measures for any emergency spill, canal failure, or slope failure along the J.C. Boyle bypassed reach. The plan would include (1) implementation strategies for agency coordination, restoration actions, monitoring and evaluation, and potential mitigation measures; (2) provisions to ensure that the J.C. Boyle powerhouse has the capacity to maintain flow continuously for a minimum of 48 hours after an emergency shutdown; when powerhouse failure occurs, flow shall be released at the powerhouse for the duration of the failure; (3) provisions for implementing mitigation measures including revegetation of affected hillslope and riparian areas, monitoring surveys and photopoints for revegetation work, and evaluation and monitoring of affected reaches with channel transects and flow augmentation measures to eliminate channel impingements and to remove fine sediments in the spawning area downstream of the [spillway] failure; (4) provisions to prevent further erosion in the area below the emergency spillway; stabilization plans shall consider structural, vegetative, and flow strategy methods to halt erosion and restore the damaged hillslope, riparian, and channel areas to stop resource degradation and repair visual impacts; and a detailed monitoring strategy based on development of channel cross sections that is implemented annually for 10 years; and (5) site-specific restoration plans for the emergency spillway, and other canal and slope failures that include a map depicting the location of the proposed activity, designs for site stabilization, channel restoration, location of disposal sites, an erosion control plan, implementation and effectiveness monitoring designed to meet restoration criteria such as fish passage, channel bed and bank stability, and appropriate riparian vegetation, data collection, biological evaluation, or consultation in accordance with applicable Bureau of Land Management regulations. Oregon Fish & Wildlife also recommends that, within 3 years of license issuance, PacifiCorp restore the J.C. Boyle bypassed reach channel from damage due to the emergency spillway.

Oregon Fish & Wildlife recommends that, within 24 hours of an accidental spill or discharge from the waterway system or other event, PacifiCorp notify the Oregon Emergency Response System and provide a verbal report on location, duration, and effect on water quality and aquatic life. If PacifiCorp observes or suspects fish or wildlife or their habitat have been harmed, PacifiCorp would immediately (no later than next business day) notify and consult with the Oregon Fish & Wildlife's Klamath Falls office and the hydropower coordinator at the Prineville office. Additionally, PacifiCorp would file a written report with Oregon Fish & Wildlife, Oregon Environmental Quality, the Bureau of Land Management, FWS, and the Commission within 2 weeks of the event describing location, duration, and effect on water quality and aquatic life. Additionally, Oregon Fish & Wildlife recommends that PacifiCorp coordinate emergency response to spillway or water failure "or other events." Subsequent remediation planning and implementation would be initiated within 24 hours of the event. PacifiCorp would develop site-specific plans for remediation in consultation with Oregon Environmental Quality, FWS, the Bureau of Land Management, Oregon Division of State Lands, and Oregon Fish & Wildlife that would include immediate steps to remedy the failure and bring the waterway back into operation, and timing and performance criteria to be met for completion of needed remediation. PacifiCorp would provide to the agencies by March 1 for the preceding calendar year, an annual report that describes each event and action taken to remediate effects, and the operation changes taken or proposed to reduce reoccurrence of the spill, discharge, or other event.

Oregon Fish & Wildlife recommends that, within 1 year of license issuance, PacifiCorp develop in consultation with the agencies, an action plan that details protocols for assessing environmental damage caused by flume failure, spillway overflow at the forebay, and other events. The measure would include assessing and documenting immediate and long-term effects on water quality, fish and wildlife, riparian and aquatic organisms, and habitat. PacifiCorp would consult with fish agencies to develop a fish and wildlife habitat restoration plan that ensures compensation for short- and long-term loss of individuals and habitat caused by unanticipated project-related events that cause environmental damage. The plan would identify measures to meet Oregon Fish & Wildlife's objectives and standards for fish and wildlife, a schedule to accomplish these objectives and standards, and needs for additional studies.

Oregon Fish & Wildlife recommends that PacifiCorp consult with them, Oregon Parks & Rec, and other agencies 90 days before commencing any project-related land-clearing, land-disturbing, or spoil-producing activities, and use agency input to develop a comprehensive plan to control erosion, dust, and slope stability to minimize the quantity of sediment or other potential water pollutants resulting from project construction, spoil disposal, and project operation and maintenance. The plan would include detailed descriptions and functional design drawings of control measures, topographic map locations of all control measures, an implementation schedule, and details of monitoring and maintenance programs, and a schedule for periodically updating the plan. Similarly, the Bureau of Land Management's Condition 1-H specifies that PacifiCorp prepare a spoils disposal plan in consultation with the Bureau, prior to initiating any ground-disturbing activity on Bureau-managed lands. The plan would address disposal and storage of waste soil or rock material generated by road maintenance, slope failures, and construction projects and include provisions for (1) identifying and characterizing the nature of the spoils in accordance with applicable Bureau of Land Management regulations; (2) identifying sites for disposal and storage of spoils to prevent contamination of water by leachate and surface water runoff; and (3) developing and implementing stabilization, slope reconfiguration, erosion control, reclamation, and rehabilitation programs. PacifiCorp would modify the Bureau of Land Management's Condition 1-H to limit the scope of that condition to Bureau lands within the project boundary. PacifiCorp also adds the phrase "in its reasonable discretion" to the Bureau approval of the spoil disposal plan prior to submittal to the Commission.

The Bureau of Land Management's Condition 1-O specifies that PacifiCorp, within 1 year of license issuance, develop a standard operating procedures plan, in consultation with the Bureau, for emergencies to address procedures, environmental permits, and subsequent remediation for any project-related effects on Bureau-managed lands, including but not limited to, the emergency spillway and canal and slope failures. The plan would include implementation of strategies for agency coordination, restoration actions, monitoring and evaluation, and potential remediation measures. PacifiCorp would modify the Bureau's Condition 1-O by limiting the scope of that condition to Bureau-managed lands within the project boundary, and eliminating the required development of standard operating procedures that would specifically address emergency spillway and canal and slope failures.

Interior recommends that, within 1 year of license issuance, PacifiCorp (1) develop, in consultation with the Bureau of Land Management, standard operating procedures for emergency situations that address emergency spillway and canal and slope failures and include implementation strategies for agency coordination, restoration actions, monitoring and evaluation, and potential mitigation measures; (2) ensure the J.C. Boyle powerhouse can maintain flow continuously for 48 hours during a powerhouse failure; (3) develop stabilization plans that consider structural, vegetative, and flow strategies to minimize erosion and restore damaged hillslopes, riparian areas, and stream channels to minimize resource and visual impacts that could occur in the event of an emergency; (4) develop a plan, in consultation with the Bureau of Land Management, to restore the Klamath River from J.C. Boyle dam to Copco reservoir to compensate for effects from use of the J.C. Boyle emergency spillway; and (5) develop monitoring protocols based on channel cross sections to determine effectiveness of restoration activities.

Interior recommends that PacifiCorp prepare site-specific remediation plans for the J.C. Boyle spillway and other canal and slope failures including (1) a map depicting the location of the proposed activity; (2) designs for site stabilization, channel restoration, location of disposal sites, and erosion control plan; (3) implementation and effectiveness monitoring of whether restoration objectives were met; (4) survey data, biological evaluations, or results from consultation for ground or habitat disturbing activities on Bureau of Land Management-managed land; and (5) an environmental analysis of the proposed action that meets NEPA requirements.

NMFS recommends that as part of a gravel augmentation plan (described in detail later in *Sediment Deficit in River Reaches Downstream of Project Dams*) PacifiCorp identify areas for removal of deposits of large debris. We presume that this is referring to the sediment deposition in the channel from the J.C. Boyle canal emergency spillway and road fill.

Our Analysis

Based on site conditions and past events, it is reasonable to expect rill and gully erosion, canal failures from rockfalls (such as the one in December 2005), and erosion at the emergency spillway to occur in the future. Because of the steep natural slope angles in the canyon, any remedial action to address road fill and sidecast material on the right bank of the canyon (which are inherently steeper than the natural slope angles, in order to fit in the space available) would require well-planned remediation and stabilization measures to maintain the road and canal without infringing on, or contributing sediment to, the channel.

The steepness and extent of the eroded slope at the emergency spillway would prove challenging to stabilize such that the slope would not erode further and would not contribute sediment to the river below. These difficulties, as well as the proximity of this erosion to the adjacent road and other infrastructure, and the effects of erosion on the river below are all strong reasons to address this site with a solution that eliminates the need to discharge water onto the slope.

The bypass system proposed by PacifiCorp and recommended by the agencies and tribes would alleviate the need to spill water through the J.C. Boyle canal emergency spillway. This would reduce the potential for greater erosion or mass failures of the slope that could jeopardize the road or other infrastructure. It would eliminate discharges of sediment from the eroded spillway slope into the bypassed reach, improving habitat and reducing turbidity, and would also reduce flow fluctuations in the bypassed and peaking reaches.

Oregon Fish & Wildlife and the Bureau of Land Management's measures would have PacifiCorp restore the J.C. Boyle bypassed reach channel from damage due to erosion of materials from the canal road cut and the emergency spillway and develop site-specific restoration plans to rehabilitate the site and prevent further erosion. Restoration would use structural, vegetative, and flow strategies to halt erosion and restore the damaged hillslope, riparian, and channel areas to stop resource degradation and repair visual effects. Monitoring would be undertaken so that actions would meet restoration criteria such as fish passage, channel bed and bank stability, and establishing appropriate riparian vegetation. The Bureau of Land Management specifies the development of standard operating procedures (including implementation strategies) for emergencies to address procedures, environmental permits, and subsequent measures for any project-related effects on Bureau-managed lands, including but not limited to, the emergency spillway and canal and slope failures. This is similar to Oregon Fish & Wildlife's recommendation that PacifiCorp develop an action plan that details protocols for assessing environmental damage caused by flume failure, spillway overflow, and other events and would provide a consistent set of metrics from which to determine environmental effects. Both measures would assist in planning and prioritizing response actions.

Oregon Fish & Wildlife's recommendation that PacifiCorp consult with the appropriate agencies 90 days before commencing any project-related land-clearing, land-disturbing, or spoil-producing activities constitutes a practical planning and coordination mechanism to protect resources. We expect appropriate site-specific erosion and sedimentation control measures to be incorporated into the plans for such actions that would be submitted to the Commission for approval. Consultation with the agencies regarding protective measures that would be included in the final plans would enable any contractors who would implement the plans to understand agency concerns and plan their activities accordingly.

Similarly, Oregon Fish & Wildlife's recommendation to have PacifiCorp notify the Oregon Emergency Response System within 24 hours of an accidental spill or discharge and provide a written report to the appropriate agencies and the Commission within 2 weeks of the event would provide additional coordination and timely disclosure of events that could be potentially detrimental to natural resources. PacifiCorp's development of an appropriate emergency response and remediation plan (in consultation with the appropriate agencies) and implementation within 24 hours of the event would ensure timely and appropriate response to immediately remedy any spill or failure and bring the waterway back into operation. However, Oregon Fish & Wildlife's language requiring notification following accidental spills, discharges, or other events is so broadly worded that it is unclear what "other events" would require such notification of agencies and development of emergency response plans. Defining the specific types of events that would trigger agency notification would eliminate ambiguity regarding whether this emergency notification measure should be implemented. Annual reporting by PacifiCorp describing each event and action taken to address effects, and any operational changes taken or proposed to reduce reoccurrence of the spill, discharge, or other event would provide annual documentation of events and responses. Review of this annual report could support adaptive management whereby the standard operating procedures for emergency situations could be modified based on the experiences of past actions. Notification of the Commission concurrently with the agencies, and providing the Commission with the annual reports that document actions taken in response to accidental spills and discharges, would enable the Commission to determine if appropriate actions were taken and whether follow-up proactive actions may be necessary to prevent future inadvertent releases.

NMFS's recommendation for a plan that would include identification of areas for removal of deposits of large debris would be a useful mechanism to identify and prioritize for removal those areas of debris encroaching on the channel. As currently worded, such large debris could include naturally deposited debris that has no definable linkage to project operations. Defining the types of large debris that should be removed from the channel, and establishing a linkage of the debris removal to project operations, prior to developing detailed removal plans, would ensure debris is removed by the appropriate party.

3.3.1.2.3 Project Effects on Sediment Transport

Project dams interrupt the natural movement of sediment on the Klamath River, resulting in the potential for adverse effects on aquatic habitat (decreased spawning substrate and increased algal growth) and riparian vegetation. In response, PacifiCorp proposes and several agencies recommend supplementing the supply of sediment (especially gravel-sized material to enhance spawning habitat) in various river reaches. Also, because project effects on sediment transport likely extend downstream of the project boundary, determining the extent of these effects is important for developing the area of potential effects (APE) for cultural resources (see section 3.3.9, *Cultural Resources*) because it influences the distribution of riparian vegetation that is important for traditional tribal purposes.

Quantifying the rate of sediment transport, either at a single location for a specific discharge, or for part of an entire river system for an extended period of time, is inherently difficult. If at all possible, as suggested by Wilcock et al. (1996), estimates of bed mobility and bedload transport should be based on actual observations of bed movement. Although input data based on actual observations is low, we used hydraulic computations within microcomputer-based spreadsheet software (Microsoft Excel) to analyze project effects on sediment transport using data collected and assumptions made by PacifiCorp in its project license application. The spreadsheets were submitted by PacifiCorp (2005h; 2005j) in response to our AIR dated February 17, 2005, and in response to our correspondence with PacifiCorp dated November 10, 2005, and are the same base calculations that drive the sediment budget.[24] To supplement PacifiCorp's sediment budget, we also reviewed available aerial photographs and PacifiCorp's analysis on attributes of alluvial features downstream of Iron Gate dam.

Although the peer-reviewed mathematical equations that have been developed to quantify sediment transport are exacting in their execution, the outputs are also highly susceptible to variations in input parameters—several of which must be estimated or back-calculated in the absence of substantial empirical data collected in the field. Further, as noted by the American Society of Civil Engineers (Vanoni, 1975), different bedload transport formulas using the same hydraulic input data can yield results differing by several orders of magnitude. Thus, although useful, the analyses and results in this section should be understood to be approximations of complex physical processes. The results of our analyses are most useful in determining the relative (as opposed to absolute) level of change caused by the project, evaluating proposed environmental measures, and developing potential staff alternatives.

Threshold of Bed Mobility

In determining how much sediment is moved through a river, one of the first steps is determining the flow level at which certain sediment sizes are mobilized within the channel, or the threshold of mobility. Such analysis is also important in determining the adequacy of various flow levels to flush fine sediment and transport spawning gravels. Once threshold mobility analysis is completed, hydraulic parameters can be back-calculated and entered into sediment transport formulae, and ultimately those formulae can be used to drive a sediment budget, which is a conceptual model of how sediment is supplied to and transported through a river. Thus, the determination of mobility thresholds for certain particle sizes is an important first step in accurately portraying sediment movement in a river system.

The effects of the project on channel form, riparian vegetation, and aquatic habitats (notably salmonid spawning beds) are a function largely of the flows needed to mobilize the bed, the effects that project operations have on these flows, and the frequency and duration of bed mobility and sediment transport given the lack of sediment recruitment from above the dams. Of specific interest is the threshold above which a given particle size[25] of sediment becomes mobile. In estimating this threshold,[26] both the bed material composition and the hydrology must be considered. Accordingly, and as explained in detail in the license application, PacifiCorp used tracer gravel and bedload sampling data, along with cross-sectional and long profile data for the representative reaches and hydrologic records, to evaluate flows needed to mobilize the bed and determine the frequency and duration of mobilization. Additionally, we evaluate effects on particle mobilization under proposed flow conditions. We adopted PacifiCorp's assumptions that the D_{50} for the without-project condition (34.16 mm) is equal to the

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[24]A sediment budget is a conceptual model that accounts for sediment production and routing from sources (hillslopes, streambanks, etc.) through reservoirs and river reaches in the project area. It provides a framework to describe the relative importance of various sediment sources within which the relative magnitude of project effects can be evaluated. We describe the sediment budget for the project area in greater detail in *Sediment Deficit in River Reaches Downstream of Project Dams*.

[25]Frequently the D_{50} (the median grain size in a given size distribution) particle size is used; we do so in our analyses.

[26]While the baseline for our analysis is the existing project, PacifiCorp conducted many of its analyses in terms of with- and without-project conditions, and we draw on its work to support our evaluations.

average D_{50} from the tributary delta surveys, and the D_{50} for the with-project condition is variable and is based on pebble counts and tracer gravel observations at PacifiCorp's study cross sections.[27]

The agencies have made a number of recommendations to address project effects on sediment transport and fine sediment flushing. NMFS recommends that, within 1 year of license issuance, PacifiCorp, in consultation with the agencies, assess flows needed to transport gravels and maintain holding habitat. Oregon Fish & Wildlife recommends that, at least once a year between February 1 and April 15, no water be diverted to the J.C. Boyle and Copco No. 2 powerhouses when inflow to J.C. Boyle reservoir (including Spencer Creek) exceeds 3,300 cfs, and that this diversion cessation be maintained for at least 7 full days. The Bureau of Land Management specifies the above flushing flow regime for the J.C. Boyle bypassed reach, and FWS recommends that at least once yearly between February 1 and April 15, PacifiCorp not divert water to the Copco No. 2 powerhouse when inflow to Copco reservoir first exceeds 3,300 cfs; cessation of diversion would be maintained for at least 7 full days.

All other flow-related recommendations in this proceeding are for lower, base-flow discharges intended to enhance aquatic habitat (discussed in section 3.3.3.2, *Aquatic Resources*); those flows would not be capable of mobilizing substantial sizes or quantities of sediment.

Our Analysis

Even though a given flow reaches the threshold of mobility for the D_{50} particle, or even fully mobilizes that particle size, the coarser component of the bed may not have initiated motion. Despite this, we assume that mobilization of the D_{50} particle approximates the flow that mobilizes the bed at a particular location, allowing us to analyze flushing flows relative to their potential efficacy. Table 3-5 summarizes PacifiCorp's calculated flows at the threshold of bed mobility for each study cross section. PacifiCorp calculated the frequency of bed mobility for each study reach using with- and without-project hydrology (mean daily flow data from 1968 to 2001); table 3-6 shows these results. Those results indicate that, except for the Link River and Keno reaches, the project consistently increases the estimated discharge required to mobilize the bed. Project operations reduce the frequency of bed-mobilizing events from roughly an annual or semi-annual basis to about two times less frequent. This indicates that, without project operations, spawning gravels would be more-frequently mobilized, flushed, and replenished from upstream. In the river reaches immediately downstream of Iron Gate dam, results indicate that the bed is only mobilized on average every 4 to 9 years. More-frequent flushing flows would refresh spawning gravels and disperse sediment across the channel (and potentially onto the floodplain, depending on the magnitude of the flow), benefiting aquatic and riparian habitats.

Table 3-5. Flow at threshold of mobility for with- and without-project conditions. (Source: PacifiCorp, 2004a)

Study Reach	Cross Section	With-Project Flow at Threshold of Mobility (cfs)	Approximate Return Interval (years)	Without-Project Flow at Threshold of Mobility (cfs)	Approximate Return Interval (years)
Link River Geomorphic Reach					
Link River	RM 254	1,346	0.7	Same	0.7
	RM 253.9	1,191	0.7	Same	0.7
	Study Reach Average	1,268	0.7	Same	0.7
Keno Geomorphic Reach					
Keno	RM 232.4	3,310	1.7	Same	1.7
	RM 232.1	4,706	2.7	Same	2.7

[27]The median grain sizes used for the with-project condition are contained in table 6.7-13 of PacifiCorp (2004a).

Study Reach	Cross Section	With-Project Flow at Threshold of Mobility (cfs)	Approximate Return Interval (years)	Without-Project Flow at Threshold of Mobility (cfs)	Approximate Return Interval (years)
	RM 231.9	3,225	1.6	Same	1.6
	Study Reach Average	3,747	2.0	Same	2.0
J.C. Boyle Bypassed Geomorphic Reach					
J.C. Boyle	RM 223.5	2,251	1.0	1,968	0.9
Bypass	RM 223.3	1,921	0.9	1,604	0.9
Upstream of	RM 223.25	181	0.6	112	0.6
Blowout	Study Reach Average	1,451	0.8	1,228	0.8
J.C. Boyle	RM 222.55	4,188	1.7	2,323	1.0
Bypass	RM 222.4	3,828	1.5	1,432	0.8
Downstream	RM 222.3	3,548	1.4	1,577	0.9
of Blowout	Study Reach Average	3,855	1.5	1,778	0.9
J.C. Boyle Peaking USGS Gage/Frain Ranch Geomorphic Reach					
J.C. Boyle	RM 219.9	4,489	1.8	2,232	1.0
Peaking at	RM 219.7	4,293	1.7	2,449	1.1
USGS Gage	Study Reach Average	4,391	1.8	2,340	1.1
J.C. Boyle	RM 217.8	46,497	n/a	2,922	1.2
Peaking at	RM 217.5	40,946	n/a	5,935	2.6
Bureau of	RM 217.2	47,164	n/a	5,502	2.4
Land Management Campground	Study Reach Average	44,869	n/a	4,786	2.1
J.C. Boyle Peaking at Gorge Geomorphic Reach					
J.C. Boyle	RM 214.4	3,410	1.4	3,186	1.3
Peaking at Gorge	Study Reach Average	3,410	1.4	3,186	1.3
J.C. Boyle Peaking Near Shovel Creek Geomorphic Reach					
J.C. Boyle	RM 206.5	4,849	2.0	1,931	0.9
Peaking near	RM 206.4	4,320	1.7	1,753	0.9
Shovel Creek	RM 206.2	4,887	2.0	164	0.6
Confluence	Study Reach Average	4,685	1.9	1,283	0.8
Copco No. 2 Geomorphic Reach					
Copco No. 2	RM 197.7	1,801	<1	167	<1
	RM 197.66	2,505	<1	255	<1
	Study Reach Average	2,153	<1	211	<1
Downstream of Iron Gate Dam to Cottonwood Creek Geomorphic Reach					
Downstream	RM189.7	27,655	24.4	3,429	1.5
of Iron Gate	RM 189.6	8,558	2.6	4,542	1.7
dam to USGS	RM 189.5	11,050	3.5	4,365	1.6
Fish Hatchery	RM 189.45	12,504	4.2	5,224	1.8
Gage	Study Reach Average	14,942	8.7	4,390	1.7
Downstream	RM 187	9,731	3.0	6,639	2.1
of Iron Gate	RM 186.7	12,403	4.1	6,201	2.0
dam at R-	RM 186.6	14,408	5.2	11,450	3.7
Ranch	Study Reach Average	12,181	4.1	8,096	2.6
Cottonwood Creek to Scott River Geomorphic Reach					
Downstream	RM 179.1	6,348	2.0	3,769	1.5
of Iron Gate dam at I-5 Rest Area	Study Reach Average	6,348	2.0	3,769	1.5
Downstream	RM 172.4	11,819	3.9	5,891	1.9
of Iron Gate	RM 172.2	14,172	5.1	6,627	2.1
dam at Tree of	RM 171.9	25,994	20.1	13,654	4.8

Study Reach	Cross Section	With-Project Flow at Threshold of Mobility (cfs)	Approximate Return Interval (years)	Without-Project Flow at Threshold of Mobility (cfs)	Approximate Return Interval (years)
Heaven Campground	Study Reach Average	17,329	9.7	8,724	2.9
Downstream of Scott River Geomorphic Reach					
Downstream of Iron Gate dam at Seiad Valley-Hardy Site	RM 131.55	389,623	n/a	210,470	n/a
	Study Reach Average	389,623	n/a	210,470	n/a
Downstream of Iron Gate dam at Seiad Valley USGS Gage	RM 128.5	67,913	10	26,658	2.9
	Study Reach Average	67,913	10	26,658	2.9

Table 3-6. Frequency when flows exceeded the threshold of mobility. (Source: PacifiCorp, 2004a)

		Percent of Period of Record Flows Exceeded Threshold of Mobility		
Study Reach	**Cross Section**	**With Project**	**Without Project**	**Ratio (With Project to Without Project)**
Link River Geomorphic Reach				
Link River	RM 254	32	32	1
	RM 253.9	36	36	1
	Study Reach Average	33	33	1
Keno Geomorphic Reach				
Keno Reach	RM 232.4	11	11	1
	RM 232.1	6	6	1
	RM 231.9	11	11	1
	Study Reach Average	9	9	1
J.C. Boyle Bypass Geomorphic Reach				
J.C. Boyle Bypass Upstream of Blowout	RM 223.5	6	30	0.19
	RM 223.5	7	34	0.20
	RM 223.25	16	100	0.16
	Study Reach Average	9	46	0.19
J.C. Boyle Bypass Downstream of Blowout	RM 222.55	2	28	0.07
	RM 222.4	3	46	0.06
	RM 222.3	3	40	0.08
	Study Reach Average	3	35	0.07
J.C. Boyle Peaking Geomorphic Reach				
J.C. Boyle Peaking at USGS Gage	RM 219.9	7	29	0.23
	RM 219.7	7	26	0.28
	Study Reach Average	7	27	0.26
J.C. Boyle Peaking at the Bureau of Land Management Campground	RM 21738	0	16	0.00
	RM 217.5	0	3	0.00
	RM 217.2	0	4	0.00
	Study Reach Average	0	6	0.00
J.C. Boyle Peaking at Gorge Geomorphic Reach				
J.C. Boyle Peaking at Gorge	RM 214.4	12	13	0.91
	Study Reach Average	12	13	0.91
J.C. Boyle Peaking Near Shovel Creek Geomorphic Reach				
J.C. Boyle Peaking near Shovel Creek Confluence	RM 206.5	7	33	0.20
	RM 206.4	9	37	0.23
	RM 206.2	6	100	0.06
	Study Reach Average	7	54	0.13

Study Reach	Cross Section	Percent of Period of Record Flows Exceeded Threshold of Mobility		Ratio (With Project to Without Project)
		With Project	Without Project	
Copco No. 2 Geomorphic Reach				
Copco No. 2	RM 197.7	7	100	0.07
	RM 197.66	5	100	0.05
	Study Reach Average	6	100	0.06
Downstream of Iron Gate dam to Cottonwood Creek Geomorphic Reach				
Downstream of Iron Gate dam at USGS Fish Hatchery Gage	RM 189.7	0	16	0.00
	RM 189.6	1	10	0.13
	RM 189.5	0.2	10	0.02
	RM 189.45	0.1	7	0.01
	Study Reach Average	0.3	11	0.04
Downstream of Iron Gate dam at R-Ranch	RM 187	1	4	0.18
	RM 186.7	0.1	5	0.02
	RM 186.6	0.03	0.2	0.16
	Study Reach Average	0.4	3	0.12
Cottonwood Creek to Scott River Geomorphic Reach				
Downstream of Iron Gate dam at I-5 Rest Area	RM 179.1	6	17	0.33
	Study Reach Average	6	17	0.33
Downstream of Iron Gate dam at Tree of Heaven Campground	RM 172.4	1	9	0.08
	RM172.2	0.3	6	0.04
	RM 171.9	0.02	0.3	0.08
	Study Reach Average	0.4	5	0.07
Downstream of Scott River Geomorphic Reach				
Downstream of Iron Gate dam at Seiad Valley-Hardy Site	RM 131.55	0	0	0
	Study Reach Average	0	0	0
Downstream of Iron Gate dam at Seiad Valley USGS Gage	RM 128.5	0.02	0.2	0.1
	Study Reach Average	0.02	0.2	0.1

The ratio of with-project to without-project frequencies illustrates the degree of alteration caused by the project. A high ratio (approaching 1.0) indicates that the frequency of mobilization under current conditions closely matches that of without-project conditions. Low (or zero) ratio values indicate that rarely (or never) do existing conditions match the frequency of without-project conditions. This can be the result of two things: either the flows are not high enough to exceed the threshold of mobility for sediment that is essentially similar to without-project size distribution, or the existing with-project bed condition (as characterized by the pebble counts data and D_{50} used in the analysis) has become too coarse to be mobilized by the current flow regime.

The deployment and monitoring of tracer gravels provides empirical data on which flows are capable of initiating particle movement, which assists in determining the effects of proposed flushing flows. All of PacifiCorp's tracer gravel work was completed within the J.C. Boyle bypassed reach (one site) or the J.C. Boyle peaking reach (two sites). During the study, the site in the bypassed reach downstream of the emergency spillway experienced a peak flow of 1,700 cfs and had 4 tracers out of 16 total tracers undergo some movement. All tracers at the site ranged from 32 to 128 mm, and 2 tracers each from both the 32 to 64 mm class and the 64 to 128 mm class moved. Because 2 tracers in the 64 to 128 mm class moved at flows below 3,800 cfs, the calculated threshold estimate of roughly 3,800 cfs needed to move a 128 mm particle is probably an overestimate, and lower flows are likely capable of mobilizing spawning-sized sediment in this reach. Overall, these tracer gravel results and the results from the other sites, suggest that the reliability of PacifiCorp's hydraulic threshold of mobility calculations is variable when compared to empirical data.

The estimates of discharge at the threshold of bed mobility have substantial uncertainty. Sources of uncertainty include the Shield's numbers (a dimensionless value of critical shear stress) used in the calculations for each study reach cross section, which PacifiCorp based on a limited set of tracer gravel movement observations. PacifiCorp calibrated the Shield's number with the tracer observations at just one study reach (J.C. Boyle peaking reach at the USGS gage). PacifiCorp applied this value to all study sites for the with-project condition analysis. For the without-project estimates, PacifiCorp used an experimentally derived Shield's number obtained from studies on gravel-bed systems. Aside from arbitrary judgment, we have no further basis or available information upon which to quantitatively modify these parameters. Further, the Manning's roughness coefficient that PacifiCorp used to estimate the discharge associated with the depth of flow at the threshold of bed mobility was also calibrated at a limited number of study reach cross sections and then applied to the remaining study sites. Again, we have no data upon which to propose an alteration.

The NMFS recommendation to assess flows needed to transport gravels and maintain holding habitat would provide the information necessary to implement any sediment augmentation measures. The agency recommendation to suspend diversion of water to the J.C. Boyle and Copco No. 2 powerhouses for 7 full days once a year between February 1 and April 15 when inflow to the J.C. Boyle reservoir exceeds 3,300 cfs would ostensibly provide flows through the J.C. Boyle and Copco No. 2 bypassed reaches of the Klamath River at levels that could mobilize sediment of existing particle sizes. The magnitude and duration of flows that actually exceed the threshold of mobility would essentially be controlled by upstream outflow from Upper Klamath Lake. Because there is variation in natural flows leaving the lake, it is difficult to precisely quantify future flows and effects on sediment mobilization; however, some comparison to past flow records is possible. Between 1990 and 2005, J.C. Boyle dam spills exceeding about 3,300 cfs occurred five times. This yields an existing spill frequency of about once every 3 years for flows greater than 3,300 cfs under existing conditions. Such flows are likely to mobilize spawning gravel, based on available information. The NMFS, Bureau of Land Management, and Oregon Fish & Wildlife flushing flow measure would result in annual spills of at least 3,300 cfs, provided that inflow to J.C. Boyle reservoir exceeds 3,300 cfs. This would provide a threefold increase in the frequency of flows 3,300 cfs or greater through the bypassed reach, all of which would be capable of mobilizing the D_{50} particle size at the majority of the study cross section sites in the reach and would increase the frequency of flows capable of cleansing existing or augmented spawning gravels (should they be introduced under a new license). Although the benefits in the confined J.C. Boyle bypassed reach might be small, these flows could encourage desirable riparian vegetation (such as willows, alders, and cottonwoods) and potentially scour and discourage more invasive vegetation types such as reed canarygrass.

Sediment Deficit in River Reaches Downstream of Project Dams

Project dams prevent the downstream transport of sediment, which may result in a diminished supply of spawning gravel and other altered geomorphological processes (including sand and silt starvation) that may influence aquatic habitat and adversely influence the establishment of riparian vegetation. Measures designed to address these effects focus on assessing the extent of project effects and supplementing the sediment supply downstream of project dams. Also, The California Coastal Commission (in a letter dated July 22, 2004), requested that we evaluate how project dams may be affecting the movement of sediment to the coastal littoral zone. Similarly, the Humboldt County Board of Supervisors (in a letter dated June 22, 2004) asked that we consider sediment supply beyond the Klamath River (i.e., down the coast), and Interior (in a letter dated July 22, 2004) asked that we consider the effects of project operations on coastal resources at Redwood National and State Parks.

PacifiCorp proposes to place about 100 to 200 cubic yards of spawning gravel in the upper end of the J.C. Boyle bypassed reach and 1,800 to 3,500 cubic yards downstream of Iron Gate dam and upstream of the Shasta River confluence, and to monitor the gravel augmentation efforts. In its July 21, 2004, response to our request that PacifiCorp provide specific costs for its proposed environmental measures, PacifiCorp indicated that gravel augmentation would occur over a 30-year period; however, from the description in the license application we interpret this measure to be a one time deposition.

The Bureau of Land Management specifies in 4(e) measure 4D1(a)(b) that PacifiCorp, within 1 year of license issuance, develop a river gravel management plan for J.C. Boyle bypassed and peaking reaches in consultation with the Bureau, designed to increase channel complexity and availability of spawning habitat for resident and anadromous fish. The plan would include the following components: (1) a description of how channel complexity would be provided such that variation in channel depth, velocity, substrate, cover, and temperature at all flows is restored; (2) quantity of gravel to be added, such that the minimum amount added would be 1,226 tons/year (20 percent of the maximum) and the maximum amount added is equal to the estimated average annual deficit of 6,134 tons/year; (3) timing of gravel added, based on estimates of ongoing reductions in sediment supply because of J.C. Boyle dam; (4) methods of gravel augmentation, including passive augmentation at a logistically convenient location, allowing high flows to distribute over time; placement of discrete quantities of gravel in locations, usually riffles, where they are expected to provide the most benefit, based on hydrologic and biologic considerations; and modeling of reach characteristics to determine gravel augmentation; (5) objectives describing how the plan satisfies the Bureau's Management Plan direction; and (6) evaluation procedures. The program would be implemented over the term of the license, with implementation during years 1 through 3, monitoring and evaluation during years 1 through 7, and adaptation during years 7 through 9 (which would be used to modify the plan for the next 10 year gravel management cycle).

The Bureau of Land Management specifies in 4(e) measure 4D1(c) that PacifiCorp submit to the Bureau and the Commission, within 6 months of the end of each implementation and monitoring year, an annual report on the activities of the gravel management program during the previous year, including the quantities of gravel added, methods used, and monitoring data. PacifiCorp would consult with the Bureau regarding any proposed changes to implementation and monitoring, and implement the changes after Commission approval. PacifiCorp would submit to the Bureau and the Commission in the 7^{th} year, a comprehensive monitoring report of the monitoring data from the previous 6 years, consult with the Bureau regarding any necessary changes to the gravel management plan, and implement any proposed changes after Commission approval. In response, PacifiCorp's alternative condition would delete all of the Bureau of Land Management's aforementioned 4(e) specifications related to gravel augmentation and monitoring because PacifiCorp claims the Bureau lacks jurisdiction over the Klamath River channel. PacifiCorp's position is driven by legal rather than environmental arguments. Consequently we do not analyze this alternative 4(e) condition.

Oregon Fish & Wildlife recommends that, within 1 year of license issuance, PacifiCorp develop and submit to the Commission for approval a sediment and gravel resource management plan in consultation with Oregon Fish & Wildlife (allowing 60 days for review and comment)and other state, federal, and tribal agencies. PacifiCorp would update the plan every 5 years in consultation with the agencies. PacifiCorp would submit annual reports to the Commission and the agencies that include the annual work plan for the upcoming year and a report with narrative and graphs summarizing an annual compilation of activities associated with protection and restoration measures and associated monitoring that would be implemented to mitigate for the lack of sediment transport through project reaches to riverine habitat. Oregon Fish & Wildlife also recommends that, within 2 years of license issuance and after consultation with agencies, PacifiCorp file with the Commission a gravel and sediment plan that identifies measures that would be implemented to provide for the restoration of spawning habitat below each project dam. The plan would include provisions to map and characterize the character and distribution of gravels within project reaches, the approximate area of suitable spawning habitat, and the depths and velocities of flows required for each mapped gravel deposit to assess suitability of gravels as spawning habitat. Oregon Fish & Wildlife recommends that within 3 years of license issuance and in consultation with resource agencies PacifiCorp develop and implement recommendations for gravel management for each project-affected reach including the approximate size and volume of gravels needed to compensate for project effects and locations and timing for gravel introduction. Oregon Fish & Wildlife recommends that, upon placement of gravel in project reaches, PacifiCorp develop and implement a monitoring program to assess how introduced gravels are distributed and used under project operations. If monitoring indicates that the plan does not achieve the plan objectives, PacifiCorp would revise the plan in consultation with the resource agencies. Cal Fish & Game and the Hoopa Valley Tribe recommend measures that are essentially identical to the aforementioned Oregon Fish & Wildlife measures.

NMFS recommends that, within 1 year of license issuance and in consultation with the agencies, PacifiCorp develop a gravel augmentation plan for project reaches and the Klamath River downstream of Iron Gate dam. The plan would include (1) identification of priority spawning and holding reaches; (2) assessment of flows needed to transport gravels and maintain holding habitat (pools); (3) identification of areas for removal of deposits of large debris; and (4) identification of priority areas for gravel augmentation, volumes of gravel, and flows to implement deposition of gravel in target areas and schedule for periodic replenishment of gravels. The plan would be implemented within 3 years of license issuance, results monitored in consultation with agencies, and reviewed at least every 5 years for the term of the license to facilitate adaptive management. FWS recommends a measure that is essentially identical to the aforementioned NMFS measure.

Siskiyou County recommends that PacifiCorp expend funds necessary to remove and manage sediment in refuge areas along the Klamath River below Iron Gate dam and to remove any existing sediment barriers to fish passage in the lower Klamath River.

Our Analysis

Our assessment of measures to augment sediment supply (particularly spawning gravel) downstream of project dams includes review and assessment of PacifiCorp's study results and information on the record, and also entails determining the downstream extent of project-induced sediment deficit, which influences colonization by riparian vegetation of importance to Native Americans, and is therefore a key factor in our determination of an appropriate APE for cultural resources. We assess the sediment deficit in river reaches downstream of project dams using the bedload sediment budget developed[28] by PacifiCorp. The focus of the sediment budget analysis was the coarser (i.e., bedload) components, because these would be more strongly influenced by project effects, and because they are especially important for channel form and salmonid habitat (e.g., spawning gravels). Using estimates of the flows at which various sizes of sediment are mobilized, PacifiCorp used the Meyer-Peter Muller equation in its sediment budget to calculate the bedload transport rate for each cross section in each study reach for both existing conditions and without-project hydrology and bed material composition. Annual transport capacities were generated using daily hydrology data for water years 1968 to 2001.

The sediment budget results are most useful in assessing relative effects in different project reaches. The average annual theoretical transport capacity is used in the calculation of outputs and changes in storage because PacifiCorp did not conduct any direct bedload sediment transport sampling at appropriate[29] flows. Actual data collection to calibrate the estimates of annual transport capacity would greatly improve the accuracy of the sediment budget. PacifiCorp notes that, because of this, and for other reasons, the uncertainty associated with this sediment budget is likely high. We concur, but nonetheless conclude that the sediment budget still provides a useful framework for assessing the relative extent of project effects on sediment supply, transport, and storage. One fact that supports this notion is that the

[28]PacifiCorp described the methods used to estimate inputs to the sediment budget in its response (dated December 16, 2005) to our AIR WQ-5.

[29]To create a bedload transport rating curve, sampling must be conducted over a range of flows that exceed the threshold of bed mobility, yielding multiple data points upon which a curve can be fit.

theoretical calculations show that in most reaches, transport capacity far exceeds supply on a long-term basis, so the river is supply-limited (yet frequently starved of sediment by project dams) through much of the project area. At some point downstream of Iron Gate dam, the river's sediment supply begins to exceed transport capacity; we examine this in greater detail later in this section.

We are unaware of any project related sediment barriers in the Klamath River. All the sediment trapped in project reservoirs is eliminated as a source of supply to downstream reaches, and sediment starvation (a sediment deficit) is a direct project effect on the geomorphology of the Klamath River. High spring flows diminish below Iron Gate dam as a result of Reclamation filling Upper Klamath Lake; this could cause sediment barriers to be established. As such, Siskiyou County's recommended measure seems misplaced.

PacifiCorp provided revised sediment budget results (PacifiCorp, 2005h) in response to our AIR dated February 17, 2005. Those results detail PacifiCorp's assessment of the sediment deficit in various project reaches (table 3-7). Their results indicate that the project-induced sediment deficit on the Klamath River would be eliminated by incoming sediment at the location of the Cottonwood Creek confluence.

In general, because of limited available data, we do not disagree with the approach of, or results generated by, PacifiCorp for reaches upstream of Iron Gate reservoir. However, from that point downstream we have concerns regarding the appropriateness of certain PacifiCorp assumptions in running the model (such as concerns about not consistently applying connectivity factors, and inappropriate sediment yield assumptions for tributaries). To address these concerns, we used PacifiCorp's sediment budget, unaltered from PacifiCorp's AIR submission, except we changed some of the sediment input parameters based on our assessment of site conditions and review of available evidence. Modifications are as follows:

- For the Iron Gate reservoir tributaries, as well as Bogus and Willow creeks downstream of the dam, we averaged our suggested range of 150 to 190 tons/mile^2/year (including the 20 percent washload factor), resulting in a yield of 170 tons/mile^2/year.
- For Bogus and Willow creeks downstream of Iron Gate dam, we reduced PacifiCorp's sediment yield by 20 percent to account for suspended load, as PacifiCorp did on upstream tributaries. We also gave these two tributaries connectivity factors (moderate for both creeks) as PacifiCorp did on upstream tributaries. We base this change on our site visit observations, and conclude that there is no basis to disregard suspended sediment, particularly given the relatively intensive land uses in watersheds such as those of the Shasta River and Cottonwood Creek.
- We reduced the yield of Cottonwood Creek from 450 tons/mi^2/yr to 170 tons/mi^2/yr. Although we agree with PacifiCorp that geology does change downstream of Iron Gate dam, based on our site observations and review of available information, we conclude that to use the same sediment yield as the far-downstream Salmon River for this drainage is inappropriate, particularly given the diminished supply of gravel in this stream from extraction for construction of Interstate 5. Also, consistent with PacifiCorp's methods used upstream, we included a low connectivity factor to account for the broad Hornbrook Valley. Our configuration of sediment yield for Cottonwood Creek acknowledges a geologic difference from upstream terrain, but allows for a more-gradual transition to the higher sediment yields we know to exist further downstream.

Table 3-7. Sediment budget modeling results. (Source: PacifiCorp, 2005h; staff)

Project Reach	**Geomorphic Reach (or Tributary Sediment Source)**	**Theoretical Average Annual Transport Capacity (tons/yr)**		**Average Annual Bedload Delivery (tons/ year)**		**Cumulative Average Annual Bedload Delivery (tons/ year)**		**Potential Average Annual Deficit or Surplus by Reach or Subreach (tons/yr)**		**Actual Average Annual Deficit or Surplus by Reach or Subreach (tons/yr)**		**Cumulative Deficit (or Surplus) to Downstream Reach (tons/year)**	
		FERC Analysis	**PacifiCorp Analysis**	**FERC Analysis**	**PacifiCorp Analysis**	**FERC Analysis**	**PacifiCorp Analysis**	**FERC Analysis**	**PacifiCorp Analysis**	**FERC Analysis**	**PacifiCorp Analysis**	**FERC Analysis**	**PacifiCorp Analysis**
Link	Link River/Keno reservoir	249,487	249,487	169	169			-249,318	-249,318	-169	-169		
Subreach Total		**249,487**	**249,487**	**169**	**169**			**-249,318**	**-249,318**	**-169**	**-169**	**0**	0
Keno	Keno reach	899,654	899,654	3,032	3,032	3,032	3,032	-896,622	-896,622	-3,032	-3,032		
	JC Boyle reservoir	0	0	3,102	3,102	6,134	6,134	-893,520	-893,520	-3,102	-3,102		
Subreach Total		**899,654**	**899,654**	**6,134**	**6,134**			**-893,520**	**-893,520**	**-6,134**	**-6,134**	**-6,134**	**-6,134**
J.C. Boyle													
	J.C. Boyle bypass	255,853	255,853	4,104	4,104	4,104	4,104	-251,748	-251,748	-4,104	-4,104		
	J.C. Boyle USGS Gage/Frain Ranch	142,080	142,080	1,798	1,798	5,903	5,903	-249,950	-249,950	-1,798	-1,798		
	J.C. Boyle Gorge	210,771	210,771	3,421	3,421	9,323	9,323	-246,529	-246,529	-3,421	-3,421		
	J.C. Boyle Shovel Creek	197,114	197,114	2,572	2,572	11,895	11,895	-243,957	-243,957	-2,572	-2,572		
	Copco Reservoir	0	0	3,522	3,522	15,417	15,417	-240,436	-240,436	-3,522	-3,522		
Reach Total		**805,818**	**805,818**	**15,417**	**15,417**			**-790,401**	**-790,401**	**-15,417**	**-15,417**	**-21,551**	**-21,551**
Copco													
	Copco Bypassed reach	475,785	475,785	15	15	15	15	-475,770	-475,770	-15	-15		
	Iron Gate reservoir	0	0	33,667	9,603	33,682	9,618	-442,103	-466,167	-33,667	-9,603		
Subreach Total		**475,785**	**475,785**	**33,682**	**9,618**			**-442,103**	**-466,167**	**-33,682**	**-9,618**	**-55,233**	**-31,169**
Iron Gate													
	Bogus Cr	2,450	2,703	3,668	8,272	3,668	8,272	1,218	5,570	1,218	5,570		
	Willow Creek	same	same	3,989	8,995	7,657	17,268	5,206	14,565	-3,989	-8,995		
Subreach Total		**2,450**	**2,703**	**7,657**	**17,268**			**5,206**	**14,565**	**5,206**	**14,565**	**-50,027**	**-16,604**
	Cottonwood Cr.	19,300	19,300	3,376	44,678	3,376	44,678	-15,924	25,379	-3,376	25,379	**-65,951**	**8,775**

Project Reach	Geomorphic Reach (or Tributary Sediment Source)	Theoretical Average Annual Transport Capacity (tons/yr)		Average Annual Bedload Delivery (tons/ year)		Cumulative Average Annual Bedload Delivery (tons/ year)		Potential Average Annual Deficit or Surplus by Reach or Subreach (tons/yr)		Actual Average Annual Deficit or Surplus by Reach or Subreach (tons/yr)		Cumulative Deficit (or Surplus) to Downstream Reach (tons/year)	
		FERC Analysis	**PacifiCorp Analysis**	**FERC Analysis**	**PacifiCorp Analysis**	**FERC Analysis**	**PacifiCorp Analysis**	**FERC Analysis**	**PacifiCorp Analysis**	**FERC Analysis**	**PacifiCorp Analysis**	**FERC Analysis**	**PacifiCorp Analysis**
	Shasta R.	same	same	9,514	356,783	12,890	401,461	-6,410	382,161	-6,410	-356,783	**-72,361**	**390,936**
	Lime Gulch	same	same	5,023	16,621	17,913	418,082	-1,387	398,783	-1,387	-16,621	**-73,747**	**789,719**
	Mainstream Tribs.	same	same	44,996	115,046	62,909	533,128	43,609	513,828	43,609	-115,046	**-30,138**	**1,303,547**
	Vesa Cr.	same	same	3,824	7,967	66,733	541,095	47,433	521,795	-3,824	-7,967	**17,295**	**1,825,342**
	Beaver Cr.	same	same	27,864	48,980	94,597	590,075	75,297	570,775	-27,864	-48,980	**92,592**	**2,396,117**
	Horse Cr.	same	same	18,015	27,388	112,612	617,463	93,312	598,163	-18,015	-27,388	**185,905**	**2,994,280**
Subreach Total		**19,300**	**19,300**	**112,612**	**617,463**			**93,312**	**598,163**	**93,312**	**598,163**	**43,286**	**581,559**
	Scott River	589	589	486,121	366,055	486,121	366,055	485,533	365,467	485,533	365,467		
	Upper Grinder Cr.	same	same	15,541	19,426	501,662	385,481	501,074	384,893	-15,541	-19,426		
	Seiad Cr.	same	same	10,401	13,002	512,064	398,483	511,475	397,894	-10,401	-13,002		
Subreach Total		**589**	**589**	**512,064**	**398,483**			**511,475**	**397,894**	**511,475**	**397,894**	**554,761**	**979,454**

- We reduced the yield of the Shasta River from 450 tons/mi^2/yr to 15 tons/mi^2/yr, based on information from Buer (1981). Although the confluence of this tributary is further downstream than Cottonwood Creek, the dominantly spring-fed Shasta River flows through a broad valley comprised of volcanic geology, before dropping steeply to meet the Klamath River. We conclude that this large valley (and Lake Shastina) has a substantial ability to store upland sediment, and as such, the watershed yields far less bedload sediment than Cottonwood Creek. Further, Buer (1981) estimated bedload transport from the Shasta River to the Klamath River at 5,000 yd^3/yr (~10 tons/mi^2/yr using a conversion factor of 1.485 tons/yd^3), so our estimate is probably an over-estimate, but still reasonable. Because this is based on Buer's actual estimates of bedload yield to the Klamath, we did not use a connectivity factor.

- For tributaries between the Shasta and Scott rivers—all of which drain similar terrain—we assumed a sediment yield of 170 tons/mi^2/yr, and then increased the yield by 50 tons/mi^2/yr for each tributary downstream. This progressive approach acknowledges that yields likely begin to increase in this part of the Klamath River Basin; however, it also acknowledges that the terrain and geology in this area are more stable than further west (where the 450 tons/mi^2/yr-Salmon River estimate was generated), and also accounts for the progressive increase in precipitation that occurs to the west.

- Based on information developed by NCRWQCB (2005), we have increased the sediment yield of the Scott River to 747 tons/mi^2/yr. We conclude that given the recent and highly focused nature of the work that went in to the generation of this yield estimate, it is perhaps the most-accurate of any of the sediment yields being used in the sediment budget.

Table 3-7 shows the results of our analysis. The theoretical sediment transport dynamics downstream of Iron Gate dam show two changes. These changes influence the transition from a supply-limited system to a potentially transport-limited system, and ultimately to the recovery of the sediment deficit from upstream project dams. First, the channel gradient decreases, generally by an order of magnitude compared to upstream reaches, which decreases the sediment transport capacity of the lower reaches. Second, the geologic terrain of tributary watersheds begins the transition from relatively low-yield Cascade volcanics to the higher-yield Klamath geology. Because of these changes, our results (using PacifiCorp's sediment budget with our input data) indicate that somewhere near Lime Gulch (RM 169.7) the river recovers from its cumulative bedload deficit. As discussed below, we have doubts that these results are definitive in estimating the location of recovery from the sediment deficit, and provide additional analysis to supplement our sediment budget results.

Downstream Extent of Sediment Deficit: Defining a Portion of the APE. We assessed the downstream extent of project effects (to assist in determining the APE for cultural resources) on sediment deficiency by reviewing PacifiCorp's "quantification of alluvial features with distance downstream of Iron Gate dam" in light of our sediment budget analysis and other available information. In the broadest sense, the sediment deficit caused by project dams can be viewed to continue all the way to the mouth of the Klamath River. Indeed, Willis and Griggs (2003) conclude that Klamath River sand and gravel supply to the Pacific Ocean is reduced by 37 percent because of project dams and other dams on the Klamath (Link River) and Trinity rivers. However, this appears to be based on an approach that does not account for the strong variation in sediment contribution by watershed area that exists between the project area (and the watershed upstream of Upper and Lower Klamath lakes) and the area of the watershed including, and downstream of, the Scott River. Further, because the Klamath River becomes transport-limited[30] in its lower reaches, the sediment deficit is only really important upstream in the local reaches where the river would have stored that sediment in the channel, in bars, or on the floodplain, creating and maintaining aquatic and riparian habitat. Once the river has a surplus of sediment, the deficit from upstream simply reduces that surplus. Given the very considerable sediment yields from tributaries such as the Scott, Salmon, and Trinity rivers, we conclude that project-related sediment deficits do not adversely affect conditions to the mouth of the Klamath River or down the coast.

The sediment budget results indicate that sediment supply exceeds transport capacity locally at several cross sections downstream of Iron Gate, and exceeds the river's cumulative deficit somewhere between RM 169.7 (Lime Gulch) and RM 164.3 (Vesa Creek), which would indicate substantial average annual storage at and downstream of this location. However, available data to create and drive the sediment budget are limited, and there is evidence[31] that the sediment budget—regardless of the configuration of sediment inputs—is probably not an entirely accurate or definitive means to ultimately determine the downstream extent of project effects on sediment. Therefore, we also reviewed other information such as PacifiCorp's alluvial features analysis and, to the extent possible, conditions using aerial photographs submitted by PacifiCorp (December 14, 2005) in response to our AIRs.

In its license application, PacifiCorp quantified the area and number of alluvial features downstream of Iron Gate dam to RM 133. It also examined valley width at the location of alluvial features in relation to channel slope. We further investigated alluvial features in available historic aerial photographs to determine if there were any detectable changes in the composition of alluvial features through time and to see if there were any discernable changes after large flow events, such as in the years 1955 and 1997.

We agree with PacifiCorp that the area of alluvial features (rather than number of features) is probably a better indication of the effects of project facilities downstream of Iron Gate dam. The area of alluvial features mapped by PacifiCorp downstream of Iron Gate dam is less than 0.2 acre for the first 9 miles downstream of Iron Gate dam. This is likely due in part to sediment trapping by project dams (especially immediately downstream of Iron Gate dam) and the relatively narrow width of the valley upstream of Cottonwood Creek. The area of alluvial features increases and peaks around RM 171 (an area extensively mined) and then decreases to the second trough at RM 151 (0.2 acre/mile). Downstream of RM 152 the area of alluvial features increases, and once downstream of the Scott River confluence this

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[30]Further, inputs of sediment from land management activities have increased sediment yields in the lower Klamath River Basin above natural levels. We are not able to determine if those increases exceed the sediment deficit caused by the project. However, as previously noted, the project-related deficit only applies where that sediment would normally be in use in the channel or floodplain. Any sediment in surplus of capacity (which is great in the lower Klamath River) would be in storage upstream.

[31](1) PacifiCorp notes that "It is likely that the theoretical transport capacities for the study reaches downstream of Iron Gate dam were significantly underestimated…Thus, the actual sediment transport capacity is almost certainly greater than is implied by these uncalibrated model results. Moreover, there is no geomorphic evidence of channel aggradation in this reach, as implied by the model results." Our own site visit observations and review of photographs concur with this. (2) Cross sections used in PacifiCorp's sediment budget are not equally spaced or necessarily frequent enough to accurately characterize reaches of river that span many miles. In short, the resolution of the model is such that accurately pinpointing where the sediment deficit ends is difficult using currently available tools and data. (3) Hydraulic calculations in PacifiCorp's sediment budget predict sediment movement in the reaches of river immediately downstream of Iron Gate dam on average only every 4 to 9 years. If the bed were only mobilized that rarely (and tributaries input the amounts of sediment assumed by PacifiCorp), we would expect to see aggradation and signs of sediment deposition—neither of which is supported by the license application or our site visit observations.

likely corresponds to the substantial sediment yields from that river. We also agree with PacifiCorp's conclusion that sediment yield (and in our opinion, transport capacity as driven by channel configuration) is more likely to control the number and extent of alluvial features than is valley width.

Changes in the composition and yearly extent of alluvial features in the available historic aerial photographs are difficult to discern. Because of the limited availability of photographs and the lower resolution of the images, for bars and deposits that persist from year to year, it is difficult to determine if those features are growing or shrinking, or if they appear coarser than in earlier photos. Further, differing flow levels complicate this sort of analysis. It is more conclusive to track the planform and nature of channel migration (or lack thereof) through time. For instance, in general, it appears that in more-recent photos (i.e., the 2001 USGS Digital Ortho Quarter Quadrangles) the channel margin is currently lined with a fairly consistent band of mature riparian vegetation (Ayres [2003] notes the occurrence of low cobble-boulder benches along the channel). This mature riparian margin does not appear to be as consistent in older (1944) photographs, and floodplain areas show signs of scour and inundation absent in later photos. So, while many of the alluvial features do not appear to have emerged or disappeared through time, there are some indications that through time they may not be inundated as frequently (potentially because of channel incision or because coarse sediment or riparian berms are holding it in place). We concur with Ayres (2003) that many of the coarse cobble and boulder features currently in the channel and floodplain are likely remnants of in-channel mining (at least in locations where that activity occurred). However, the effects of sediment starvation from upstream project dams certainly have not helped the river recover from the effects of in-channel mining and later floodplain grading.

We were also able to see that the channel's interaction with mine tailings in the area of RMs 169 to 172 (from photos in year 1955 through 2001) has been such that the channel has simplified and become locked in place by coarser cobble and boulder tailings (see below), but in isolated areas (such as at RM 170.2, as noted by Ayres, 1999) mine tailings are finer grained and contribute a substantial amount of sediment in such areas. This mining area, along with contributions from local creeks, probably mark a turning point where more alluvial features are present along the river, and sediment supply may begin to overcome the deficit caused by upstream project dams. However, as previously mentioned, because of the uncertainty in the sediment transport calculations in PacifiCorp's sediment budget, and in our attempt to conservatively estimate the downstream extent of project effects on sediment, we conclude a sediment deficit could easily exist to the confluence with the Scott River (RM 143). The deficit almost certainly does not persist downstream of the Scott River because this watershed inputs more sediment than the entire Klamath River upstream of that confluence.

Our conclusion is based on available information. As the channel evolves, it is likely to continue its trend of becoming straighter (at least in locations where it is currently working its way through alluvial deposits left from mining or other activities), more simplified, and more capable of sluicing finer sediments from and through the channel. Through time, the river may winnow all the in-channel mining material (and perhaps floodplain mining material, if it can be accessed by the river) for which it is competent to carry. This could eliminate this area as a supplemental source of finer material, and result in the location of the downstream extent of the sediment deficit gradually moving downstream.

<u>Proposed Measures to Augment Sediment Supply</u>. PacifiCorp's proposal to place up to 200 cubic yards of spawning gravel in the upper end of the J.C. Boyle bypassed reach and up to 3,500 cubic yards downstream of Iron Gate dam and upstream of the Shasta River confluence, and to monitor these efforts, would enhance spawning habitat that may have been adversely influenced by the sediment deficit and armoring of the channel in those two reaches created by project dams, and enable evaluations of whether gravel remains in place and available for salmonid spawning. However, compared to the actual sediment deficit in those reaches, and the competence and capacity of those reaches to transport sediment, there is no basis to conclude that such quantities would provide meaningful long-term enhancements to spawning habitat value if they were one-time placements. Further, this measure does not compensate for any of the fine-sediment deficit, which is important for riparian vegetation (as is discussed in section

3.3.1.2.5, *Fluvial Geomorphic Effects on Riparian Vegetation*, the role of finer sediment sizes [those particles not transported as bedload] is important for developing and maintaining conditions conducive for riparian vegetative communities).

The Bureau of Land Management's specification to develop a river gravel management plan for the J.C. Boyle bypassed and peaking reaches could provide for measures that would increase channel complexity and availability of spawning habitat for resident and any anadromous fish in those reaches. The minimum quantity of gravel to be added would be 1,226 tons/year (about 850 cubic yards/year) and the maximum amount is 6,134 tons/year (about 4,100 cubic yards). The adaptive aspects of the plan would be used to modify the plan for 10-year gravel management cycles, which would ensure that management (i.e., the size, amount, and frequency of augmentation) is appropriate to meet plan goals, including riparian resources. We are uncertain that the specified minimum and maximum volumes of sediment in the Bureau of Land Management's measure are appropriate bracketing points from which to begin augmentation. An adaptive approach to gravel augmentation, as recommended by Oregon Fish & Wildlife, Cal Fish & Game, and the Hoopa Valley Tribe, that begins by mapping existing spawning gravel deposits and alluvial surfaces suitable for riparian recruitment and, based on the results of that mapping, develops sediment augmentation volumes, locations, and sizes that meet plan goals, would provide habitat enhancements based on the flow regime that may be included in a new license. Monitoring initial gravel augmentation efforts would enable subsequent augmentation efforts to reflect replenishment needs based on the intervening flow regime. We expect that, during some years, it may not be necessary to provide any augmentation if previous gravel has remained at locations that would provide appropriate spawning habitat (e.g., during relatively dry years). During wet years, larger quantities of gravel may be needed to augment gravel washed downstream from suitable spawning areas. The reporting aspects specified by the resource and land management agencies and the Hoopa Valley Tribe for gravel augmentation would provide for coordination and review of the program by the Commission and stakeholders, and allow for consultation regarding any proposed changes to implementation and monitoring. This approach would facilitate any future augmentation necessary to meet habitat objectives in these reaches.

Oregon Fish & Wildlife, Cal Fish & Game, and the Hoopa Valley Tribe recommendations pertaining to gravel augmentation would all work together to address any lack of spawning substrate. The objectives would largely focus on providing suitable spawning habitat and do not appear to be intended to address the finer sediment components that influence riparian vegetation.

Oregon Fish & Wildlife, Cal Fish & Game, and the Hoopa Valley Tribe specify that PacifiCorp should develop multiple plans that address sediment augmentation (e.g. a gravel resource management plan, a gravel and sediment plan, and a gravel monitoring plan). The need to develop multiple plans to address sediment and gravel management is not clear to us (i.e., a sediment and gravel resource management plan that is distinct from a sediment and gravel plan). We consider it more practical and efficient to develop a single plan that addresses consultation, specific measures that would be implemented, reporting requirements, and how adaptive strategies would be implemented.

NMFS's and FWS's recommendations are similar to those of the other resource agencies and also would have PacifiCorp identify priority spawning and holding reaches in reaches within the project area and downstream of Iron Gate dam. Within an adaptive management context these measures would assess the flows needed to transport gravels and maintain holding habitat (pools). This would help identify and refine priority areas for gravel augmentation, appropriate volumes of gravel to be deposited, flows to distribute gravel after deposition, and an appropriate schedule for periodic replenishment of gravels. This measure would properly identify those locations where gravel augmentation would be most useful, and would examine the relationship between flows and habitat formation.

3.3.1.2.4 Effect of Project Operations on Erosion and Sediment Transport at Cultural Sites and Tributary Confluences

At the Shasta River confluence, the primary active channel of the Shasta River enters the Klamath River at the downstream end of its delta deposit. The Yurok Tribe suggests that the primary channels of the Shasta River and other tributaries (e.g., Omagar, Bear, and Pine creeks) have recently shifted downstream from the centers of those streams' deltas. The tribe also notes that Pine Creek is no longer directly connected to the mainstem Klamath because the bed of Pine Creek has aggraded and its base flow now infiltrates before reaching the Klamath River. They suggest this condition could be a substantial barrier to fish passage.

At the Ukonom Creek confluence, a large landslide just upstream of the confluence (in the Ukonom drainage) is the source of a large episodic delivery of sediment. Tribal representatives suggest that several long, deep pools downstream of this confluence have been filled by fine sediment and no longer provide cold-water habitat for migrating salmon. At the Rock Creek confluence with the Klamath River, flow through the delta formation at the confluence seems to have shifted recently to the downstream end of the delta.

At Ishi Pishi Falls, Karuk Tribe oral histories suggest that floods much larger than the 1964 flood have occurred on the Klamath River in recent centuries. Despite this perceived reduction in recent flood flows, tribal representatives note increases in the recent rate of erosion that they feel are correlated with the construction and operation of project facilities. They note specific locations in this area that, in their opinion, were adversely affected during the 1997 flood. Also, the erosion rate observed by tribal representatives at specific ceremony sites has apparently increased over the past 25 to 50 years.

Our Analysis

PacifiCorp's geomorphology study did not attempt to detect historical changes in the active channel paths through confluence delta deposits, as this would have entailed detailed aerial photograph analysis and field studies to determine if some systematic change has occurred and to assess whether such a change was linked to project effects. However, we conclude that project reservoirs have had little effect on high flows because they have relatively limited storage capacity. Reclamation restricts releases from Link River dam from about October through April to allow Upper Klamath Lake to refill after it is drawn down during the irrigation season, and thus exerts a strong influence on flows entering and leaving the project during this period. Large flood events still occur downstream of Iron Gate dam but are unrelated to project operations. Consequently, aggradation at tributary confluences is not likely caused by the project, but more likely attributable to variations in sediment delivery from tributaries to the mainstem. For instance, in the watersheds of the Shasta River and nearby creeks, sediment transport to the Klamath River during the 1997 flood event was perhaps the greatest in recorded history. As subsequent peak flows (smaller than that of 1997) have traveled down those stream channels, the relatively large sediment deltas at the mouths of those streams have likely been eroded, with channels becoming inset upon the deltas. Shifts of those inset channels are largely a function of the flows and sediment loads in the tributary streams, which are not influenced by project operations.

In the areas of Ukonom Creek and Rock Creek, it is likely that the filling of any deep pools in the Klamath River with fine sediment is caused by sources of fine sediment in tributary watersheds, such as timber harvest and road construction. Lying more than 100 miles downstream of Iron Gate dam, channel processes related to pool filling at these sites are likely overwhelmed by tributary flows and sediment loads with distance downstream of Iron Gate dam. Similarly, at Ishi Pishi Falls, direct project effects are likely overwhelmed by tributary flows and sediment loads because of the considerable (over 100 miles) distance downstream of Iron Gate dam. The degradation of various cultural sites occurred during large floods (e.g., 1997), whose magnitude would be unaffected by project operations, and during which a wide range of other processes (natural and human-induced) occur (e.g., the massive landslide on the mountain downstream of Ishi Pishi Falls on the left side of the river).

3.3.1.2.5 Fluvial Geomorphic Effects on Riparian Vegetation

In terms of riparian vegetation recruitment and geomorphology, the two key elements for successful recruitment are clean, bare mineral soil and adequate hydrologic conditions. Both variables are altered on the Klamath River through the project area.

The California Indian Basketweavers Association and Interior (in comments on our SD1) state that flow releases from project dams interfere with the renewal pattern of riparian willow shoots downstream of Iron Gate dam. They indicate that the existing flow regime seems to promote colonization of willow shoots by insect larvae, which makes them unsuitable for use for weaving baskets. The Karuk Tribe has indicated that fresh willow growth on gravel bars (the growth that produces the best basket materials) has become less common in the region near Ishi Pishi Falls. They also state that following naturally occurring spring freshet flows, the exposed willow roots are gathered for basket weaving, and the altered hydrograph no longer is sufficient to expose willow roots.

Our Analysis

For the hydrologic element of recruitment, spring peak flows (those able to scour soil surfaces) and the descending limb of the annual hydrograph relative to seed dispersal are the most important aspects for riparian establishment. Because riparian seedlings are intolerant of drought, the timing and rate of drop of the descending limb with respect to the elevation of the seed is important. In general, river water levels that decline too rapidly are a primary cause for failure of cottonwood and willow to regenerate because root growth cannot keep pace with the drop in river stage. Mahoney and Rood (1998) developed the box model for riparian recruitment, detailing the requirements of the hydrograph relative to the timing of seed dispersal (figure 3-3). If river water levels decline too rapidly, tree seedlings will not be able to grow roots fast enough to follow the coincident decline in soil moisture (caused by the drop in the water table), and the seedling will die of desiccation. Young trees can also be killed by inundation (from later-season flow increases), or scour in subsequent years because they recruited too low. Rood and Mahoney (2000) cite various studies that consistently determined that a drop of about 2.5 centimeters per day or less is required for seedling survival.

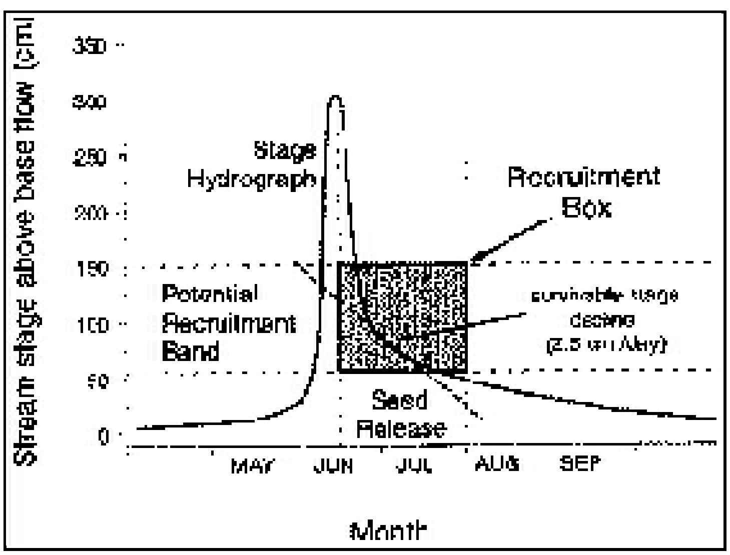


Figure 3-3. Conceptual diagram of the box model for riparian recruitment. (Source: Mahoney and Rood, 1998)

PacifiCorp provided analysis on the relationship of past flows and riparian vegetation recruitment and we review those results here. We also assess Reclamation's recently implemented (March 2006) 2002 BiOp phase III flows discharged from Iron Gate dam. PacifiCorp assumes that coyote willow seed disperses in May and June and collected data accordingly.[32] However, because only incidental observations of coyote willow seed dispersal were made in late May or early June 2002, these observations may not reflect the time period when the majority of willow seed (coyote or other species) dispersal occurs. If most seed dispersal occurs earlier or later than May or early June, willow recruitment could be different from that portrayed in PacifiCorp's results. Additionally, PacifiCorp did not excavate to the root crown of the trees that it cored and age-dated. The clonal habit of coyote willow growth makes it difficult to know if the tree-age samples are the result of vegetative expansion by suckers (after, for instance an event that flood trained and buried the original stem that grew from seed), or of sexual reproduction from seed. Excavating and finding the original root crown is the only way we know of to definitively determine the mode of reproduction, and this was not a part of the PacifiCorp's methods.

Relatively fine substrate is necessary for the recruitment of riparian vegetation (Mahoney and Rood, 1992). The bedload sediment deficit within the Klamath River was assessed in previous sections, with bedload assumed to be about 10 percent of the total sediment load. Therefore, the deficit of finer sediments is roughly nine times as great as the results presented for bedload. Although flows in many reaches may not be able to mobilize the D_{50} sediment size, flows have likely been more than sufficient to mobilize and winnow away the finer (sand, silt, and clay) particle sizes—the particle sizes that are important for colonization by many species of riparian vegetation.

J.C. Boyle Bypassed Reach. Conditions for riparian vegetation in the J.C. Boyle bypassed reach are naturally limited by the narrow width of the valley bottom and the amount of that bottom width occupied by the channel. Despite this fact, scattered areas of fine sediment deposition along the channel margin do support a relatively narrow fringe of riparian vegetation. Through the reach below the canal and emergency spillway, substantial portions of the right bank are comprised of coarse material from the road upslope. The material has constricted the channel and has altered the riparian vegetation along much of the reach. Riparian vegetation (such as willows, alder, cottonwood, sycamore) does not become established in the coarse (cobble, boulder, and larger) material coming from upslope; frequently it is displaced by reed canarygrass, an ecologically undesirable species that provides little habitat for native fauna. Further, sediment supply to the reach is largely eliminated by J.C. Boyle dam, and few sources of sediment (aside from the coarse fill encroachment) occur upstream of the emergency spillway blowout.

J.C. Boyle Peaking Reach. Geomorphic characteristics vary considerably throughout the J.C. Boyle peaking reach. For example, we would not expect there to be extensive cottonwood recruitment through the steep, bedrock-controlled gorge reach. We observed a distinctly-bare "bathtub ring" in the zone of fluctuating inundation from peaking operations, even in the gorge. Riparian vegetation on bars in the alluvial portions of the reach appeared to be affected by the hydroperiod from peaking operations. Although the sediment composition of most alluvial bars appeared amenable to riparian vegetation recruitment and growth, the bars were unvegetated to the margin of inundation during peaking, indicating that project effects are limiting recruitment and growth within that zone of fluctuation.

Coyote willow does persist along the river outside the zone of fluctuation. Tree age data were collected by PacifiCorp at vegetation transects 2015B (RM 204.6) and 177B (RM 206.5). The ages determined for some of the older coyote willow trees were somewhat unreliable because of rot; the estimated ages of the older willows ranged from 42 to 66 years old. Observations of younger trees by PacifiCorp surveys were evidently limited, and our site visit observations agree. One site analyzed by PacifiCorp indicated that the younger willows it investigated would not have been able to recruit via seed

[32] Coyote willow is the most abundant willow species along the Klamath River from Iron Gate dam to the Shasta River.

because of inundation (over 700 times in the 2 years bracketing the age date of the willow). PacifiCorp suggests, and we concur, that this type of inundation pattern is not conducive to reproduction of coyote willow from seed. Although recruitment via seed has likely been diminished (or in some areas, eliminated) in this reach, coyote willow in the J.C. Boyle peaking reach can clearly increase its distribution by suckering when the conditions are right and probably contributes to the ability of this species to persist on in-channel bars and islands between establishment events that are likely quite infrequent.

Copco Reach. Project-related effects on riparian vegetation and geomorphology in the Copco No. 2 bypassed reach are related to the absence of intermediate flows, diminished sediment supply, and occasional peak flows that scour the channel of finer sediment and young vegetation. This has created a reach where mature alders have rooted in and fossilized large cobbles and boulders in the active channel. Because these conditions have persisted for many years and high flows are obviously not sufficient to clear the channel, mechanical removal of vegetation may be the only way to re-establish the open canopy and bare-surface conditions necessary for seed-recruitment of riparian vegetation.

Downstream of Iron Gate. The river reaches immediately downstream of Iron Gate dam are constrained by geomorphology, with little meandering or aggradation evident. This changes downstream (near RM 171) where alluvial deposits increase, and some channel meandering within alluvium occurs. In our review of historic aerial photographs, the established riparian vegetation along the relatively narrow river banks and minor floodplains appear relatively unaffected by large flows, although the resolution of the images makes it difficult to discern what is happening with younger vegetation.

Downstream of Iron Gate dam, PacifiCorp conducted more extensive analysis on the geomorphologic factors influencing recruitment of riparian vegetation. It undertook analysis of some of the factors that influenced the recruitment of existing riparian vegetation, and focused in particular on stage, elevation, and timing relationships in an effort to document whether conditions for the successful recruitment of vegetation downstream of Iron Gate dam currently exist. A key component of that work involved determining the age of trees,[33] thereby yielding the likely year of recruitment. Subsequently, PacifiCorp examined the flows and recession rates during the respective recruitment years for a small set of sampled trees.

PacifiCorp makes no definitive conclusions regarding the role of project operations and geomorphology on existing conditions for riparian recruitment. However, we have reservations in using PacifiCorp's analysis results to draw our own conclusions because of several limitations in its study methods.

First, because riparian trees in alluvial environments are frequently flood trained or damaged, tree trunks at the ground surface cannot be assumed to necessarily represent the original stem coming up from the taproot, nor the elevation at which recruitment occurred. PacifiCorp conducted riparian tree age dating on 29 trees using coring or cutting techniques with no indication that excavation to the root crowns was completed for these cuttings or cores. Such excavation is necessary to (1) determine that the tree trunk being sampled is the product of sexual reproduction (i.e., riparian recruitment) and is not a clonal re-sprout off a branch, log, or flood-trained trunk; and (2) ensure that the core or cutting is taken in the most appropriate location to determine the true age of the individual because the main trunk of the tree can break off and re-sprout at unknown locations. This is particularly important because coyote willow is a clonal species that can spread by creeping rootstocks that generate new shoots forming multi-stemmed, dense thickets (Forest Service, 2004). Hence, dendrochronologic work undertaken by PacifiCorp does not address the basic question of whether these trees established via sexual reproduction (i.e., seed

[33]PacifiCorp's sample size was 29 trees for the reach from Iron Gate dam to Seiad Valley, a relatively low sample size of 0.48 samples per river mile.

recruitment) or if they are the result of stump sprouting. PacifiCorp notes in one instance that "it is also possible that the presence of this tree is the result of clonal growth by suckers."

Second, because the elevations of the trees were not measured at the root crown (the actual elevation at time of recruitment if the tree grew from seed), the elevations used by PacifiCorp to compute flows and recession rates are likely different from those that actually existed at the time of recruitment. In one instance, PacifiCorp notes that "Whether the island [the recruitment surface for a particular tree] was at the same elevation in 1967 as it is now is difficult to assess."

There is a probable connection between the recruitment and maintenance of young riparian vegetation and project effects on sediment supply and the river's altered hydrograph. Based on information available, we conclude that project effects on sediment supply may be combining with the Klamath River's altered flow regime downstream of Iron Gate dam (dictated primarily by the NMFS 2002 BiOp for Reclamation's Klamath Irrigation Project) and other factors to cumulatively affect riparian vegetation.

PacifiCorp concludes that "minimal willow reproduction [was] observed" in the reach below Iron Gate dam, and goes on to suggest that "it may be that there are no river bars at appropriate elevations to support cottonwood and species of willow other than coyote willow." We agree with this conclusion, but also conclude that, although bars may be too high for effective riparian recruitment, this could be a result of channel entrenchment caused by flow and sediment alterations from upstream project dams. Alternatively, these bars may be at an appropriate elevation but too coarse because of scour and a lack of replenishing sediment. This latter notion is supported by PacifiCorp when it concludes that "it may be that the general scarcity of finer sediment moving through the river is limiting the ability of large flows to deposit fresh sediment into the floodplain…"

Reclamation's recently implemented (March 2006) 2002 NMFS BiOp Phase III flow regimes for discharges from Iron Gate dam (figure 3-4) suggest that the flow regimes for wet, above average, and average water year types would result in large decreases in stage during the recruitment period of May through June, with stage reductions in below average and dry water year types being less than during wetter years. Determining precisely how these decreases in flow translate to stage-discharge relationships at unique recruitment sites downstream of Iron Gate dam would require additional analysis using data currently unavailable. However, our observation of recent down-ramping rates under Phase III during a 10-day period in mid-July (flow decreased from about 3,200 cfs to about 1,000 cfs in 10 days) indicates that stage can drop a little over 0.25 foot per day, as measured at the USGS gage downstream of Iron Gate dam. This rate of decline is too fast for tree roots to follow. For flows less than 1,750 cfs, the Phase III rate of decline would be about half as fast (about 0.125 foot/day), yet this lower ramp rate is also too steep to allow tree roots to chase the declining water table. As such, we expect that the Phase III flows would not provide the conditions needed for riparian recruitment at locations downstream of Iron Gate dam that are within the dam's range of hydrologic influence and have channel configurations similar to that of the USGS gage downstream of the dam.

Determining how our observations at the USGS gage downstream of Iron Gate dam translate to sites for the rest of the downstream reach would entail additional site reconnaissance and survey. However, because the river generally broadens with distance downstream, any decrease in discharge in a wider, broader channel would result in a smaller decrease in stage at that location. Therefore, although Phase III ramp rates might be too steep in the areas immediately downstream of Iron Gate dam, this effect may decrease with distance downstream, as channel morphology changes and as tributary discharges begin to mask the release pattern from Iron Gate dam.

No proposals or recommendations directly address geomorphologic effects on riparian resources. We discuss proposals and recommendations related to riparian vegetation in section 3.3.4.2, *Terrestrial Resources*. However, some proposed measures to address flows and sediment (discussed and analyzed in previous sections) also relate to how geomorphology relates to riparian vegetation.

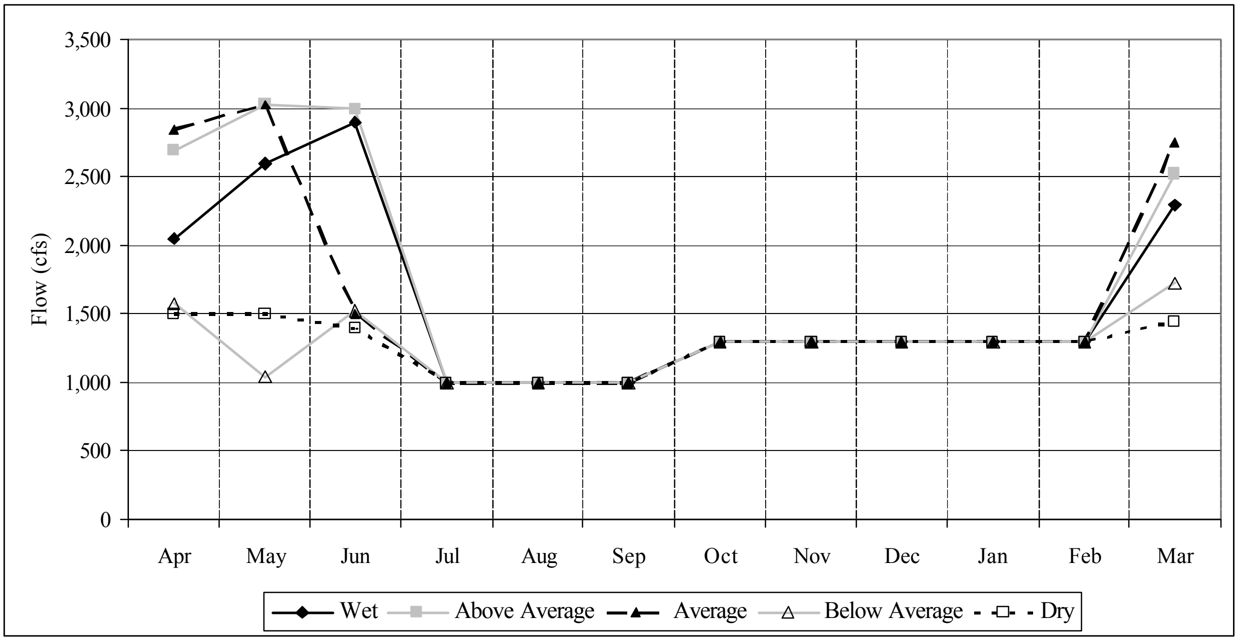


Figure 3-4. NMFS BiOp Phase III flow regimes for Iron Gate dam based on water year. (Source: Reclamation, 2006c)

Flow measures that increase base flows in project-affected reaches would increase the low-level stage within the channels, increasing the elevation above which successful riparian recruitment would be able to occur. Proposed measures that would augment sediment supply in project-affected reaches would likely be somewhat beneficial for riparian vegetation. Because almost all measures focus on spawning gravel-sized sediment, the benefits would be somewhat limited. Fine sediment is the more-important component for establishing riparian vegetation in areas where it is currently precluded by project operations.

3.3.1.2.6 Development Decommissioning and Dam Removal

Many parties recommend removal of some or all project dams to achieve water quality and anadromous fish passage objectives. Among the entities recommending removal of all project dams are the Institute for Fisheries Resources/Pacific Coast Federation of Fishermen's Associations and the Resighini Rancheria. Entities that recommend removal of the four lower mainstem dams include: Quartz Valley Indian Reservation; Klamath Tribes, Karuk Tribe, Yurok Tribe, Conservation Groups, NMFS, and the Pacific Fishery Management Council (PFMC). Additional entities recommend that if water quality or fish passage objectives cannot be achieved after feasible measures have been implemented, the specific development that does not achieve those objectives should be decommissioned and removed. Entities taking this approach include Oregon Fish & Wildlife, Cal Fish & Game, and the Hoopa Valley Tribe. Nearly all entities that recommend dam removal also recommend the development of a decommissioning plan prior to dam removal that would address measures to minimize environmental effects.

Our Analysis

Potential effects of project dam removal related to geology and soils pertain to handling and disposition of sediment in project reservoirs prior to, during, and after dam removal. Effects of removal of the Fall Creek diversion dams on sediment would likely be minimal, other than to restore sediment transport to downstream reaches that are currently influenced by the diversion dams. However, we focus our analysis of dam removal effects on the mainstem dams. We first discuss the quantity of sediments that may be in each mainstem project reservoir followed by potential effects if the sediment is found to be contaminated, thus requiring special treatment as a hazardous waste, or if it is uncontaminated, and can reasonably be expected to be allowed to pass downstream via natural processes.

Reservoir Sedimentation. Removal of any mainstem dam would require addressing the disposition of sediment that has accumulated in each project reservoir. There is a considerable disparity in the estimates for project reservoir volume loss (see table 3-33), ranging from 0.6 percent in J.C. Boyle reservoir to 17.4 percent in Copco reservoir. The greatest loss in volume—that calculated for Copco reservoir—appears to be realistic considering that this is the oldest impoundment in the system (constructed in 1918), is deep and has a high trapping efficiency, and is situated in a portion of the project area with greater topographic relief than upstream reservoirs. Iron Gate reservoir would be expected to have a considerably lower degree of infilling because it is relatively young (constructed in 1962) and is located immediately below Copco reservoir, which would trap most sediment input.

For three of the impoundments, J.C. Boyle, Copco, and Iron Gate, the historical topography does not include elevation data below the original river channel. This results in underestimating the total loss of volume from sedimentation. We know the volumes computed for Keno reservoir are based on the bathymetry of the impoundment before dredging in the forebay began in 2002. However, it appears that the undated, historic contour map used by PacifiCorp to compare with the current bathymetric map was compiled before the substantial (up to 3.75 million cubic yards) amount of dredging between 1966 and 1971. Hence, the estimates of sedimentation in Keno reservoir may be understated.

Our review of available information leads us to conclude that PacifiCorp's estimate of the change in volume attributed to sedimentation at J.C. Boyle reservoir is unreasonably low. The reason for the low infilling calculated by PacifiCorp for J.C. Boyle reservoir may be related to the nature of the historical topography, which does not show a deep channel in the northern portion of the reservoir. However, for J.C. Boyle reservoir, the volume of the original river channel is much greater, relative to the volume of the impoundment. The degree to which the loss of reservoir volume is likely underestimated at J.C. Boyle is difficult to assess, but is likely greater than for other project reservoirs.

Sediment Disposal Prior to or During Dam Removal. If sediments in any reservoir are found to be contaminated, and not suitable for downstream transport, it would likely be necessary to remove sediments that would be susceptible to scour following dam removal. The amount of sediment that would need to be removed would depend on site-specific conditions and the nature of contaminants; it could be feasible to allow sediments not subject to scour following dam removal to remain in place with or without capping or other protective measures. Mechanized removal would entail the removal of sediment from the reservoirs by hydraulic or mechanical dredging, or conventional excavation, for long-term storage at an appropriate disposal site. The disadvantages of mechanical removal are potential adverse effects from spoil piles, and construction effects on roads, air quality, and the reservoir site itself. It also can be difficult to remove all reservoir sediment. Stabilization in place is a method where project facilities are modified (typically this is a partially breached dam) and designed with appropriate protective measures against erosion, allowing storage of at least some sediments in the reservoir over the long-term. This approach minimizes disposal site considerations.

If contaminated sediments need to be removed from project reservoirs, disposal sites would need to be identified. Appropriate sites might exist nearby; however, they would need to accommodate hazardous wastes, and the design of the site would need to incorporate specific provisions to accommodate the specific contaminants that might be present. Disposal site preparation would likely require clearing and grading, a source for capping material, and erosion control. It also would be likely that a long-term monitoring program would be needed to ensure that surface or groundwater is not contaminated by leachate from the disposal site. Regardless of whether reservoir sediments are contaminated, disposal sites for demolition material would be necessary.

Downstream Transport of Sediment During and Following Dam Removal. If sediment in project reservoirs is allowed to be flushed downstream during and following dam removal; it would affect downstream habitat in the downstream portions of the Klamath River. If downstream dams remain in place, most sediment would be deposited in the next downstream reservoir. If more than one of the mainstem dams is removed, the most likely sequence would be to remove upstream dams first. This would allow releases when the downstream dam is removed to occur in a controlled manner. Based on work from Stillwater Sciences (2004), we assessed some of the effects of a natural release of reservoir sediment under several sets of hydrologic conditions. Stillwater used DREAM-1, a one-dimensional sediment transport model designed to assess sediment transport and deposition following dam removal for reservoir deposits primarily composed of sand. The model assumes that, following dam removal, the Klamath River would carve a channel with a trapezoidal cross section. The maximum amount of sediment that can be eroded and transported downstream is a function of the thickness of sediment deposit in the main channel (i.e., average thickness over the pre-dam channel bed). The channel is also assumed to occupy the historical Klamath River channel, and would not be expected to meander through the reservoir deposit and erode substantially more sediment than the volume necessary to create a single channel. Potential sediment release from erosion of lateral sediments outside the single channel was accounted for in the modeling using safety factors. Other detailed assumptions are described in Stillwater Sciences (2004). We did not conduct an independent assessment of downstream sediment transport, but the Stillwater modeling provides a reasonable tool to conservatively assess what may occur if Copco No. 1 and Iron Gate dams are removed.

Table 3-8 shows the predicted thickness of the sediment deposit in Iron Gate reservoir. This thickness would be greater if upstream dams (Copco No. 1, Copco No. 2, and J.C. Boyle) were also removed before removal of Iron Gate dam; however, because of the relatively small volume of sediment in J.C. Boyle and Copco No. 2 reservoirs, only the sediment deposited in Copco reservoir was considered in Stillwater's modeling, because it would contribute to the sediment volume in Iron Gate reservoir.

Table 3-8. Estimate of sediment thickness in Iron Gate reservoir, as modeled by DREAM-1. (Source: Stillwater Sciences, 2004).

	Copco	**Iron Gate only**	**Copco release plus Iron Gate sediment in Iron Gate reservoir**
Total volume (yd^3)	10,370,000	4,810,000	9,943,000 (=5,135,000 + 4,810,000)
Depositional area (ft^2)	32,000,000	75,000,000	75,000,000
Thickness (ft)	8.75	1.73	3.58 (=1.85 + 1.73)
Safety factor	5	5	5
Estimated width (ft)	150	150	150
Estimated length (mile)	4	6.5	6.5
Estimated sediment release (yd^3) if deposits are uniformly distributed	1,000,000	330,000	680,000
Estimated sediment release (yd^3) with safety factor to be used in the model	5,100,000	1,600,000	3,400,000

Following the removal of Copco dam, the model predicts that flows would carve a channel similar in size to the pre-dam channel, which has an average width of approximately 150 feet. The volume released downstream to Iron Gate reservoir is modeled as the width of the channel multiplied by the average sediment depth and the length of the reservoir (4 miles), amounting to about 1,027,000 cubic yards of sediment released. As a safety precaution, Stillwater assumed that 5 times this amount would be released, i.e., the average thickness of sediment deposit to be released is 43.75 feet, and the volume of sediment to be released to Iron Gate dam following the removal of Copco No. 1 dam is 5,135,000 cubic yards, which is about half of the sediment deposit in the Copco reservoir. This five times thickness increase is very conservative for use across the entire reservoir, but might represent extreme conditions in isolated locations. Adding the 5,135,000 cubic yards of potentially mobile Copco sediment to Iron Gate reservoir results in an additional average depositional thickness of 1.85 feet in Iron Gate reservoir. Again, a safety factor was used to make it highly unlikely that the sediment release from Iron Gate dam is underestimated.

The model was run with different combinations of wet, dry, and average water year hydrographs, and also examined the role of the low-level outlet at Iron Gate dam. The following assumptions were used to model removal of Iron Gate dam: (1) the low-level outlet would be used to allow for reservoir draw-down during the base-flow season; (2) removal of the dam would occur above the water surface; and (3) removal of the underwater portion of the dam would occur as quickly as possible to complete dam removal. These are similar to the assumptions that we made in our independent assessment of the process of dam removal, described in section 4.4, *Conceptual Costs of Project Dam Removal*.

In the worst case scenario (a dry water year following 3 months of low flow at the beginning of reservoir drawdown), the model assumed that the removal of the dam would take 6 months to complete (i.e., the flow and sediment would pass through the outlet for the first 6 months of simulation and then through the main channel once the dam was removed). Results of the simulation indicate that there would be a maximum of less than 4 feet of sediment deposition downstream of the dam and upstream of RM 183. After 2 weeks, the maximum sediment deposition would decrease to less than 2 feet. Almost all the sediment deposit is modeled to disappear in 6 months following the final stage of the dam removal, and no sediment deposition is predicted downstream of RM 183. Again, the prediction of this simulation represents a worst-case, dry-year scenario, with multiple safety factors; under actual conditions we expect that the sediment deposition downstream of Iron Gate dam would be substantially smaller following the removal of the dams.

The release of sediment from the reservoirs is not predicted to adversely affect flooding. Stillwater Sciences (2004) note that, if a high flow does occur, it might result in an increased stage height in the river, but the high flow would act to rapidly transport sediment, possibly during the rising stage of the flood, thereby minimizing the time period of elevated stage. There are several potential benefits of sediment discharged from the reservoirs, including a re-invigorated sediment supply that would benefit riparian vegetation, spawning gravel, and channel complexity. We conclude that the river is sediment starved downstream to about RM 170. The adverse effects of mining on the channel and floodplain in the reaches downstream of Iron Gate dam (such as constraint of the channel by bank and floodplain sediment too-coarse to be eroded and migrated through) would likely benefit from an influx of sediment, creating deposition of finer material on floodplains, diversifying monotonous plane-bed reaches, and potentially increasing sinuosity. Potential adverse effects include increased fine sediment in spawning gravels, pool filling, and increased levels of suspended sediment and turbidity. Most of these effects are predicted by Stillwater's DREAM-1 model efforts to be of relatively short duration. Based on the available information and modeling, we conclude that, although any dam removal option would need to be undertaken with substantial additional planning and studies, the downstream effects of sediment on resources is likely to be minimal, and relatively short term—particularly if dam removal occurs during a wet year.

3.3.1.3 Cumulative Effects

Our evaluation of cumulatively affected geomorphology resources includes sediment transport, substrate composition, and channel shape. Based on information available, we conclude that project effects on sediment supply may be combining with the Klamath River's altered flow regime downstream of Iron Gate dam (dictated primarily by the NMFS 2002 BiOp for Reclamation's Klamath River Project) and other factors to cumulatively affect riparian vegetation. Combined with any effects from Reclamation dams upstream, project effects on sediment supply may be decreasing the amount of sediment available for riparian recruitment in project reaches. In the Keno reach, the project-induced sediment deficit is combining with flow alterations from Reclamation's Klamath River Project (described in the terrestrial resources chapters of the license application) to adversely affect the conditions needed to recruit and maintain riparian vegetation.

Project dams contribute to a deficit of sediment supply from the upper watershed to the lower portions of the Klamath River Basin. However, as described previously, because sediment supply outpaces the ability of the river to transport it, this effect is local to the area upstream of about the Scott River. Therefore, it seems unreasonable to consider removing trapped sediment behind the dams to reduce any perceived effects on coastal shoreline erosion.

If any dams were removed, the cumulative effects on other resources from sediment dispersal (see section 4.4, *Conceptual Costs of Project Dam Removal*) might include increased fine sediments in spawning gravels; alteration of pools, riffles, and other important channel attributes of salmonid habitat; alterations to the flood capacity of the river in certain reaches; and increased difficulty of diversion for any domestic, municipal, or agricultural water diversions.

Environmental measures have been recommended by many entities that would reduce fine sediment input to the Klamath River (such as stabilization of eroding banks along the J.C. Boyle bypassed reach) and enhance spawning habitat downstream of Iron Gate dam through gravel augmentation. When considered over the life of a new license and in conjunction with similar enhancement efforts of TMDLs for the Scott River (fine sediment reduction) and the Trinity ROD (spawning habitat enhancement), implementation of such measures at the Klamath Hydroelectric Project would have cumulative beneficial effects on downstream water quality and salmon habitat.

3.3.1.4 Unavoidable Adverse Effects

Even with implementation of best management practices, project-related construction associated with recreation sites, major civil improvements (such as the flow continuation device at the J.C. Boyle powerhouse or decommissioning East Side and West Side developments), and major restoration activities that would be associated with the eroded slope at the J.C. Boyle emergency spillway may cause erosion and sedimentation. With appropriate erosion control measures in place, such effects, however, would be relatively minor and short-term.

3.3.2 Water Resources

3.3.2.1 Affected Environment

3.3.2.1.1 Water Quantity

The upper Klamath River Basin, above Iron Gate dam, is generally bordered by the Sacramento River Basin to the south, closed basins within the Great Basin to the east and north, and the Rogue River Basin to the northwest. Precipitation occurs mostly during the late fall, winter, and spring and is mostly in the form of snow above elevations of 5,000 feet. Average yearly precipitation varies greatly with elevation and location and ranges from about 10 to more than 50 inches. Streamflow normally peaks during the late spring and/or early summer from snowmelt runoff. Low flows within this watershed typically occur during the late summer or early fall, after the snowmelt and before the runoff from the fall storms moving in from the Pacific Ocean.

Upper Klamath Lake receives most of its water from the Williamson and Wood rivers (NAS, 2004). The Williamson River watershed consists of two subbasins drained by the Williamson and Sprague rivers (see figure 1-1), which together provide about 75 percent of the drainage area to Upper Klamath Lake (table 3-9). The Sycan River, a major tributary to the Sprague, drains much of the northeastern portion of the watershed. Both the Williamson and Sprague subbasins are primarily forested and are largely within the Winema and Fremont National Forests, with some areas of shrub and grassland, agriculture, and wetland. The Wood River drains an area northeast of Upper Klamath Lake extending from the southern base of the eastern slopes of the Cascade Mountains near Crater Lake to its confluence with the northern arm of Upper Klamath Lake, which is often referred to as Agency Lake. Although primarily forested, the Wood River watershed also contains extensive agricultural lands and wetlands. The balance of the water reaching Upper Klamath Lake is derived from direct precipitation and flows from springs, small streams, irrigation canals, and agricultural pumps.

Table 3-9. Average flows in the Upper Klamath Lake and Keno reservoir area. (Source: PacifiCorp, 2004a; PacifiCorp, 2005f, as modified by staff; Reclamation, 2006a, as modified by staff; and USGS, 2006, as modified by staff)

Location (gage number)	Drainage Area (square miles)	Mean Annual Flow (acre-feet x 1,000)	Mean Annual Flow (cfs)	River Mile
Williamson River gage (11502500)	3,000	780[a]	1,079[a]	270
Reclamation A canal	NA	236[b]	327[b]	255
Link River dam/Upper Klamath Lake	3,800	812[b]	1,123[b]	282.3 to 254.3
East Side powerhouse	NA	435[b]	601[b]	253.7
West Side powerhouse	NA	81[b]	112[b]	253.3
Link River gage (11507500)	3,810	812[b]	1,123[b]	253.2
Lost River diversion channel	NA	30[b] 115[b]	41[b] 159[b]	249.5
North canal	NA	36[c]	50[c]	246
Klamath Straits drain	NA	82[c]	114[c]	240.5
Ady canal	NA	120[b]	166[b]	240.3
Keno reservoir	3,920[d]	1,139[b]	1,575[b]	253.1 to 233

[a] USGS, 2006 (WY 1963-2004).
[b] PacifiCorp, 2005f (1/2/1990 - 12/5/2004).
[c] Reclamation, 2006a (1/2/1990 through 12/5/2004).
[d] Does not include Lost River.

Upper Klamath Lake and Link River Dam

Upper Klamath Lake is a large and relatively shallow natural lake with a mean depth of only 9 feet. Link River dam, operated by PacifiCorp, was constructed at the natural bedrock ledge-controlled outlet of Upper Klamath Lake in 1921. During construction, the bedrock ledge at the outlet area was removed to allow the lake to be drawn down about 3 feet lower than the natural elevation of 4,140.0 feet, resulting in a maximum range of water level variation of about 6 feet, between elevations 4,137 and 4,143 feet. Substantial drainage of the surrounding marshes for agricultural production has occurred in the last hundred years resulting in a present surface area of about 67,000 acres. The added available range in water levels increased the storage capacity to the present active storage of 486,830 acre-feet and a total storage of 629,780 acre-feet.

Reclamation manages water levels within Upper Klamath Lake to ensure that lake levels do not recede lower than the average end-of-month elevations that occurred between October 1990 and September 30, 1999, in accordance with the 2002 BiOps (FWS, 2002a; NMFS, 2002) for Reclamation's 10-year operating plan (Reclamation, 2002). This water level management regime and associated operational plan was developed to protect the federally listed Lost River and shortnose suckers and to enable seasonal minimum flows to be released downstream of Iron Gate dam that would be protective of federally listed coho salmon, discussed further in sections 3.3.3, *Aquatic Resources*, and 3.3.5, *Threatened and Endangered Species*. Lake levels are divided into water year-based rule curves defined by predicted inflow to Upper Klamath Lake 9 (table 3-10). Figure 3-5 shows historical (before construction of Link River dam) and recent water levels.

Table 3-10. Reclamation's Upper Klamath Lake operational plan per water year type. (Source: Reclamation, 2005b)

	Water year type, predicted inflow to Upper Klamath Lake, and end of month lake levels (USGS datum)			
	Above Average (more than 500,000 acre-feet)	**Below Average (between 500,000 and 312,000 acre-feet)**	**Dry (between 312,000 and 185,000 acre-feet)**	**Critical Dry (less than 185,000 acre-feet)**
October 31	4,139.7	4,138.8	4,138.2	4,137.3
November 30	4,140.3	4,139.0	4,139.0	4,138.1
December 31	4,141.0	4,138.8	4,139.7	4,138.9
January 31	4,141.5	4,139.5	4,140.3	4,140.1
February 28	4,141.9	4,141.7	4,140.4	4,141.1
March 31	4,142.5	4,142.7	4,141.7	4,142.0
April 30	4,142.9	4,142.8	4,142.2	4,141.9
May 31	4,143.1	4,142.7	4,142.4	4,141.4
June 30	4,142.6	4,142.1	4,141.5	4,140.1
July 31	4,141.5	4,140.7	4,140.3	4,138.9
August 31	4,140.5	4,139.6	4,139.0	4,137.6
September 30	4,139.8	4,138.9	4,138.2	4,137.1

Water flows from Upper Klamath Lake either through the Reclamation A canal (described in more detail below), PacifiCorp's East and West Side development canals, or through Link River dam. Flows from the East and West Side powerhouses are released back into the Link River 0.6 and 1.0 miles, respectively, downstream of Link River dam. Near this location, Link River enters the upper reaches of Keno reservoir. Table 3-11 shows monthly discharge statistics for the East and West Side powerhouses based on the available daily flow data for these powerhouses and the Link River immediately downstream of West Side powerhouse. USGS operates a real-time gage (no. 11507500, Link River at Klamath Falls, Oregon) slightly below the discharge of the West Side powerhouse. Table 3-12 provides the minimum flow and ramping rates for Link River dam as established in the 2002 BiOp (FWS, 2002a).

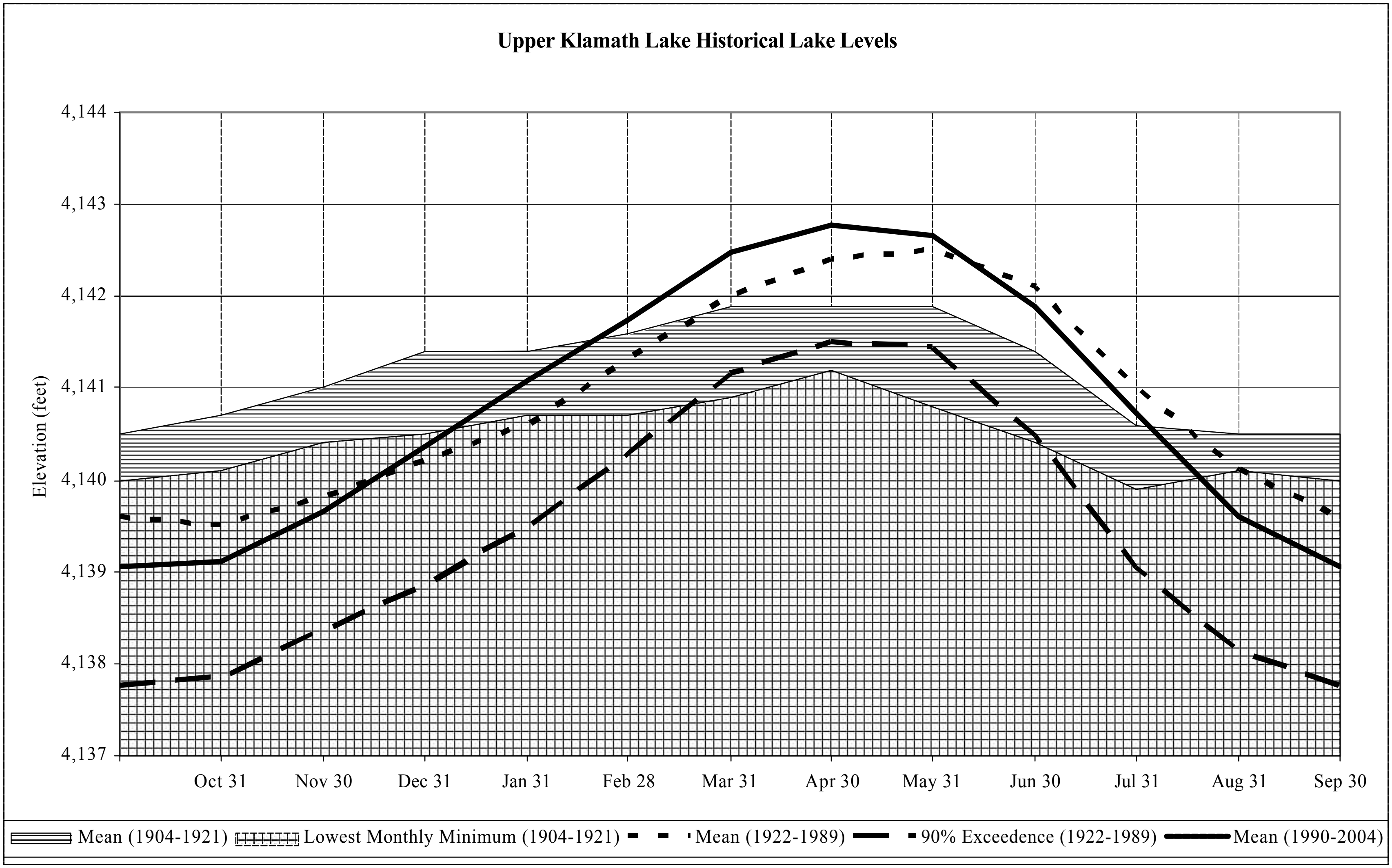


Figure 3-5. Upper Klamath Lake historical lake levels. (Source: Reclamation, 2005b; PacifiCorp, 2005f)

Table 3-11. Monthly discharge (cfs) statistics for East Side and West Side powerhouses and Link River downstream of the East Side powerhouse for January 2, 1990, through December 5, 2004. (Source: PacifiCorp, 2005f)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Yearly
East Side powerhouse													
Mean	590	552	602	639	522	531	693	585	729	635	608	523	601
Median	650	570	570	650	468	520	745	595	750	595	561	504	596
Max.	1179	1242	1357	1310	1155	1170	1310	1200	1500	1310	1420	1349	1500
Min.	0	0	0	0	0	0	0	0	0	0	0	0	0
10% Exceed.	964	930	1039	1060	1013	980	1040	1023	1048	991	1000	987	1015
90% Exceed.	120	150	150	150	120	0	204	120	312	289	250	120	150
West Side powerhouse													
Mean	78	122	140	121	101	95	129	130	152	138	81	65	113
Median	0	115	230	202	7	0	230	230	230	220	0	0	100
Max.	258	256	410	230	230	230	230	230	256	256	264	272	410
Min.	0	0	0	0	0	0	0	0	0	0	0	0	0
10% Exceed.	230	230	230	230	230	230	230	230	230	230	230	230	230
90% Exceed.	0	0	0	0	0	0	0	0	0	0	0	0	0
Link River, USGS gage no. 11507500													
Mean	769	746	945	1,420	1,397	1,572	1,612	1,443	1,157	863	832	732	1,124
Median	738	712	817	889	702	1,010	1,187	1,136	1,052	837	813	748	854
Max.	1,343	2,053	2,518	6,986	6,046	6,674	6,261	5,254	6,325	2,107	1,794	1,459	6,986
Min.	113	200	195	113	89	83	191	175	247	275	258	130	83
10% Exceed.	1,079	1,072	1,722	2,742	3,502	3,984	3,485	3,171	1,711	1,214	1,181	1,113	2,181
90% Exceed.	502	456	458	384	198	126	563	345	565	539	504	364	396

Table 3-12. Minimum flow and ramping rates for Link River dam. (Source: PacifiCorp, 2004a)

Location	Minimum Flow Information
Immediately below Link River dam	90 cfs but 250 cfs during the summer when water quality is adverse as per the FWS 2002 BiOp on suckers
Downstream of West Side powerhouse	450 cfs
Flow Rates (cfs)	**Link River Dam Ramping Rates**
0 to 300	20 cfs per 5 minutes
300 to 500	50 cfs per 30 minutes
500 to 1,500	100 cfs per 30 minutes

Klamath Irrigation Project

Reclamation's Klamath Irrigation Project (see figure 2-4) developed substantial water storage and distribution systems and drainage of lakes and wetlands, and it currently includes about 240,000 acres of irrigable lands. In an average year, the project provides water to about 200,000 acres of agricultural land. Reclamation states that, during a normal year, the net use of irrigation project water is 2.0 acre-feet per acre including water used by FWS in the Tule Lake and Lower Klamath National Wildlife Refuges. The main sources of water for this system are Upper Klamath Lake via the A canal, the Klamath River from Keno reservoir, and the naturally closed Lost River Basin.

Table 3-13 provides a general summary of the dams and canals in the Klamath Irrigation Project, and table 3-14 shows monthly flow statistics for many of the Reclamation canals. According to Reclamation, it obtained water rights for the Klamath Irrigation Project in accordance with California and Oregon State law, pursuant to the Reclamation Act of 1902. The priority date of the Klamath Irrigation Project water is generally 1905, with some rights dating back to 1878.

Table 3-13. General information on dams and canals within the Klamath Irrigation Project. (Source: Reclamation, 2006a)

Structure	Location	Storage (acre-feet)	Description
Link River dam	Outlet of Upper Klamath Lake	629,780	Regulates water surface levels in Upper Klamath Lake and flows in the Link River.
A canal	On Upper Klamath Lake above Link River dam	NA	Capacity of 1,150 cfs, conveys irrigation water from Upper Klamath Lake to irrigate about 63,000 acres.
Clear Lake dam and reservoir	Upper Lost River	527,000	Provides storage for irrigation and flow reduction.
Malone diversion dam	Lost River, 11 miles below Clear Lake dam	limited	Diverts water to agricultural lands along the Lost River in the Langell Valley.
Gerber dam and reservoir	Miller Creek a tributary to the Lost River below Malone dam	94,300	Provides storage for irrigation and reduces flow into the reclaimed portions of Tule Lake and the Tule Lake Sumps in the Tule Lake National Wildlife Refuge.

Structure	Location	Storage (acre-feet)	Description
Lost River diversion dam	Lost River	2,300	Diverts water to the Klamath River through the Lost River diversion channel to control water reaching the Tule Lake area.
Anderson Rose diversion dam	Lost River	limited	Diverts water to agricultural lands near Tule Lake.
Lost River diversion channel	Lost River diversion dam to the Klamath River	NA	Diverts water from the Klamath River to the Lost River diversion dam. The canal is about 8 miles long and has a capacity of 3,000 cfs. During the irrigation season, the flow is generally from the Klamath River to supply irrigation water to agricultural areas near Tule Lake. During the winter the flow is generally from the Lost River diversion dam to the Klamath River, limiting flooding of the Tule Lake agricultural lands.
North canal	Klamath River	NA	Conveys water from the Klamath River and provides water for the irrigation of about 10,000 acres. Maximum capacity is about 300 cfs
Klamath Straits drain	Klamath River	NA	Conveys drainage water from the Lower Klamath National Wildlife Refuge and irrigated agricultural lands reclaimed from Lower Klamath Lake to the Klamath River. The drain is about 20 miles long and has a capacity of 600 cfs.
Ady canal	Klamath River	NA	Diverts water from the Klamath River to provide irrigation for about 15,000 acres in the Lower Klamath Lake area. Ady canal has a maximum capacity of about 1,050 cfs.

Table 3-14. Monthly discharge (cfs) statistics for canals in the Klamath Irrigation Project area for January 2, 1990, through December 5, 2004. (Source: PacifiCorp, 2005f, as modified by staff; Reclamation, 2006a, as modified by staff)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Yearly
Reclamation A canal (PacifiCorp daily database)													
Mean	170	0	0	0	0	1	286	579	702	809	790	558	327
Median	0	0	0	0	0	0	238	610	755	880	818	610	70
Max.	635	5	0	0	0	80	830	955	1,025	1,055	1,005	965	1,055
Min.	0	0	0	0	0	0	0	0	0	0	0	0	0
10% Exceed.	495	0	0	0	0	0	640	870	925	995	940	780	870
90% Exceed.	0	0	0	0	0	0	0	235	340	489	635	80	0
To Lost River diversion channel (PacifiCorp daily database)													
Mean	3	1	0	1	1	5	28	53	132	156	101	15	42
Median	0	0	0	0	0	0	0	0	70	88	63	0	0
Max.	99	52	0	52	68	160	304	492	657	642	605	265	657
Min.	0	0	0	0	0	0	0	0	0	0	0	0	0
10% Exceed.	0	0	0	0	0	0	105	207	375	421	256	62	142
90% Exceed.	0	0	0	0	0	0	0	0	0	0	0	0	0
From Lost River diversion channel (PacifiCorp daily database)													
Mean	116	77	124	254	337	409	229	152	52	4	29	138	159
Median	102	71	103	142	157	174	75	9	0	0	0	85	69
Max.	755	580	1,164	3,008	2,945	2,805	2,051	2,724	1,324	197	531	1,066	3,008
Min.	0	0	0	0	0	0	0	0	0	0	0	0	0
10% Exceed.	245	132	221	655	989	1,298	502	348	131	0	95	304	343
90% Exceed.	0	0	38	47	49	19	0	0	0	0	0	0	0
North canal (Reclamation daily database)													
Mean	28	31	63	73	40	22	26	39	70	91	65	51	50
Median	8	4	31	46	12	9	15	38	75	95	66	47	38
Max.	226	265	258	261	296	211	163	129	160	300	149	139	300

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Yearly
Min.	0	0	0	0	0	0	0	0	0	0	0	0	0
10% Exceed.	79	123	170	184	126	61	71	81	115	137	97	99	120
90% Exceed.	0	0	0	0	0	0	0	0	0	33	30	0	0
Klamath Straits drain (Reclamation daily database)													
Mean	31	46	63	111	195	249	160	161	130	79	82	64	114
Median	26	28	38	61	154	220	134	170	129	88	71	58	88
Max.	121	320	351	503	595	592	592	475	338	215	300	254	595
Min.	0	0	0	0	0	0	0	0	0	0	0	0	0
10% Exceed.	73	118	188	324	449	484	294	267	208	133	192	115	259
90% Exceed.	0	0	0	17	28	100	46	50	25	8	13	0	8
To Ady canal (PacifiCorp daily database)													
Mean	140	127	191	217	157	114	105	117	204	229	204	183	166
Median	139	123	161	178	138	109	102	121	215	239	201	188	158
Max.	457	499	637	656	1,062	430	375	379	537	499	428	387	1,062
Min.	0	0	0	0	0	0	0	0	0	0	21	0	0
10% Exceed.	259	266	381	438	308	201	223	232	308	344	300	283	307
90% Exceed.	12	6	0	62	0	11	0	0	79	87	114	63	11

Before development of the Klamath Irrigation Project, the surface area of Lower Klamath Lake was often larger than Upper Klamath Lake. Flows from the Klamath River, supplemented by springs around the lake, supported a complex of wetlands and open water covering about 80,000 to 94,000 acres in the spring, during high water, and 30,000 to 40,000 acres in late summer. By 1924, however, development of the Klamath Irrigation Project eliminated more than 90 percent of its open water and marsh. Only about 4,700 acres of open water and wetland remain. Connections between the Klamath River and Lower Klamath Lake were severed by development, which changed the hydrology of both the lake and the river. Current connectivity between Lower Klamath Lake and the rest of the basin is limited to water pumped from Tule Lake and water from irrigation structures that lead to and from the present day Keno reservoir.

Before the Klamath Irrigation Project, Tule Lake varied in surface area from 55,000 to more than 100,000 acres, averaging about 95,000 acres, at times larger than the former expanse of Upper Klamath Lake. Lost River was the main source of water to Tule Lake. Similar to Lower Klamath Lake, Tule Lake was connected seasonally to the Klamath River. During periods of high runoff, water from the Klamath River flowed into the Lost River slough and down the Lost River to Tule Lake. The direction of the river's flow is now determined by operators of the Klamath Irrigation Project depending on water needs. Most of the former bed of Tule Lake has been drained for agriculture, leaving about 9,450 to 13,000 acres of shallow lake and marshland.

Water Bank

The NMFS BiOp (NMFS, 2002) required Reclamation to establish a water bank to facilitate providing flows during critical times of the year for endangered coho salmon in the Klamath River downstream of the Klamath Irrigation Project and Iron Gate dam. Reclamation meets the water bank requirements with water storage, paying farmers to idle normally farmed land, and substituting groundwater for agricultural irrigation needs instead of Reclamation-supplied surface water. Some water can be stored in Upper Klamath Lake for the water bank, but this is not always possible during drought years and there are some conflicts with the requirements of the 2002 FWS BiOp, which governs water levels in Upper Klamath Lake for the endangered suckers. The primary methods that Reclamation uses to meet the water bank requirements are land idling and groundwater substitution. Storage volume requirements of the water bank were 50,000 acre-feet in 2003, 75,000 acre-feet in 2004, and 100,000 acre-feet in 2005 and until March 2011. Table 3-15 summarizes how the first three years of the water bank requirements were met.

Table 3-15. Water bank summary for 2003 through 2005. (Source: Reclamation, 2006b)

Year	Water Bank Requirement (acre-feet)	Idled land (acres)	Groundwater substitution	Other means	Total Water Bank volume supplied (acre-feet)
2003	50,000	14,400	11,000 acres	NA	59,000
2004	75,000	4,400	6,900 acres	Water purchased from groundwater suppliers	81,000
2005	100,000	25,600	13,900 acre-feet; acres not available.	50,000 acre-feet of water from groundwater suppliers and 15,000 acre-feet of storage in the Lower Klamath National Wildlife Refuge	118,738

By March 31 each year, NMFS and Reclamation determine the water distribution and release periods that will be used for the water bank storage volume. These releases require project coordination due to the interconnection of the Klamath Irrigation Project and the mainstem dams and reservoirs of the Klamath Hydroelectric Project. See our later discussion on Iron Gate dam for further information on how the water bank volumes have been used in 2003 through 2005.

Keno Reservoir and Reach

Keno reservoir is shallow and long (table 3-16) and receives most of its water from Upper Klamath Lake via Link River. Keno reservoir also loses and receives a substantial amount of water from the Lost River diversion channel, North canal, Klamath Straits drain, and the Ady canal (figure 3-6). PacifiCorp is required by the Commission, in accordance with a 1965 license amendment, to operate Keno reservoir in accordance with an agreement with Reclamation that specifies that the maximum water surface elevation should be at 4,086.5 feet and the minimum water surface elevation should be at 4,085 feet. However, at the request of irrigators, PacifiCorp generally operates Keno dam to maintain the reservoir at elevation 4,085.4 +/-0.1 foot from October 1 to May 15 and elevation 4,085.5 +/-0.1 foot from May 16 to September 30 (figure 3-7) to allow consistent operation of irrigation canals and pumps. The occasional 2-foot drawdowns shown in figure 3-7 are generally implemented to allow irrigators to clean out their water withdrawal systems before the irrigation season. According to the Oregon Water Resources Department, in addition to the larger Reclamation diversions, there are numerous much smaller water permits and claims along Keno reservoir extending to the J.C. Boyle reservoir, mostly for irrigation on adjacent privately owned agricultural lands. Flows released from Keno dam to the Keno reach, as measured at USGS gage no. 11509500, about 2.5 miles downstream of the dam, are shown in table 3-17.

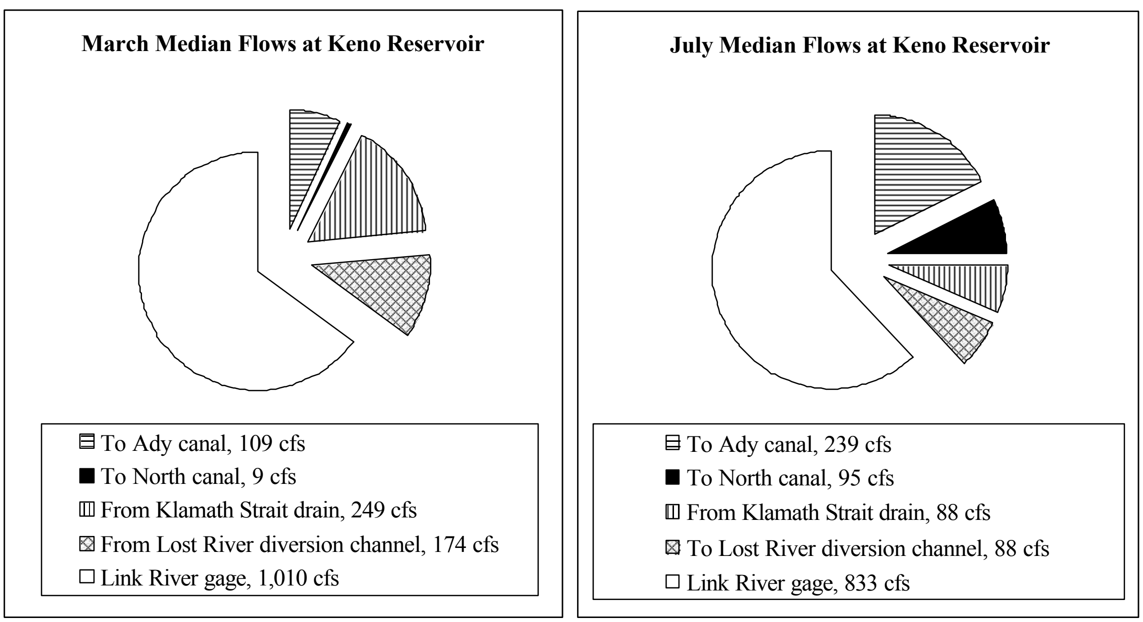


Figure 3-6. Keno reservoir March and July median inflows and outflows upstream of Keno dam. (Source: Reclamation, 2006a; PacifiCorp, 2005f)

Table 3-16. Reservoir area, inflow, storage, and retention[a] times. (Source: PacifiCorp, 2004a; USGS, 2006)

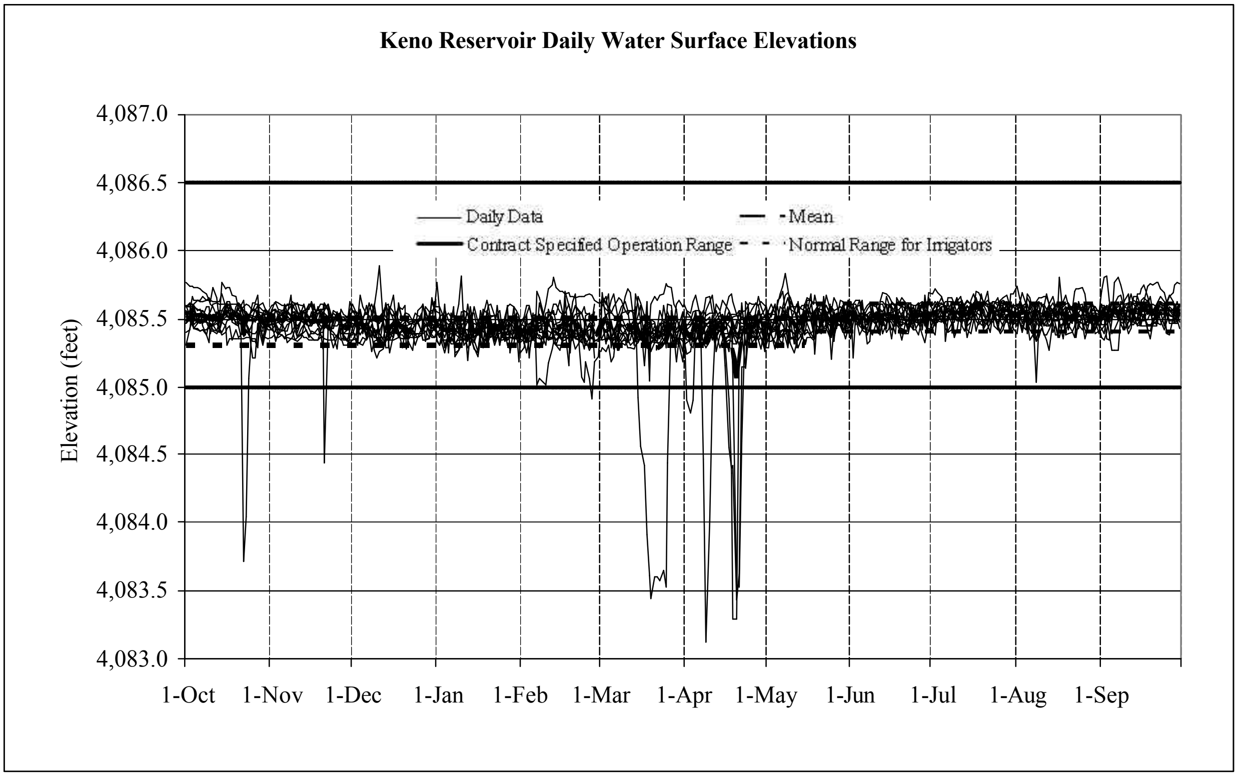
Reservoir	Surface Area (acres)	Average Yearly Inflow (cfs)	Average Depth (feet)	Maximum Depth (feet)	Active Storage[b] (acre-feet)	Total Storage[b] (acre-feet)	Retention Time (days)
Upper Klamath Lake	67,000	1,450	9	60	486,830	629,780	219
Keno	2,475	1,575	7.5	20	495	18,500	5.9
J.C. Boyle	420	1,575	8.3	40	1,724	3,495	1.1
Copco	1,000	1,585	47	108	6,235[d]	33,724	10.7
Copco No. 2	40	1,585	[c]	[c]	0	73	0.0
Iron Gate	944	1,733	62	167	3,790[d]	50,941	14.8

[a] Retention time is storage divided by average yearly inflow.

[b] Storage volumes are from table A2.1-1 of PacifiCorp's exhibit A. These values appear to be the most recent values and contain the updated storage volumes based on recent bathymetric surveys for Copco reservoir and Iron Gate reservoir.

[c] Very small reservoir, no information on depth provided.

[d] Storage for Copco reservoir between the normal maximum water level and the invert of the penstock intakes is approximately 20,000 acre-feet. Storage for Iron Gate reservoir between the normal maximum water level and invert of the penstock intake is approximately 24,000 acre-feet.



Note: Data for January 2, 1990, to December 5, 2004.

Figure 3-7. Keno reservoir daily water surface elevations. (Source: PacifiCorp, 2005f)

Table 3-17. Monthly discharge (cfs) statistics in the Klamath Project area. (Source: USGS, 2006)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Yearly
Klamath River at Keno, OR, USGS gage no. 11509500 (water years 1963 to 2004). Drainage area, 3,920 square miles, excluding Lost River.													
Mean	1,250	1,620	2,040	2,249	2,385	2,849	2,279	1,552	733	431	639	919	1,575
Median	1,050	1,300	1,775	1,920	2,110	2,165	1,750	1,070	440	376	676	942	1,020
Max.	4,210	5,210	8,160	9,310	9,250	9,780	8,000	6,640	6,640	2,750	1,350	2,240	9,780
Min.	268	292	300	251	184	200	203	201	147	131	144	145	131
10% Exceed.	2,360	2,691	3,770	4,090	4,978	6,339	4,982	3,479	1,451	692	885	1,381	3,250
90% Exceed.	621	620	721	631	480	514	571	395	275	252	322	462	348
Klamath River below J.C. Boyle powerhouse, USGS gage no. 11510700 (water years 1963 to 2004). Drainage area, 4,080 square miles, excluding Lost River.													
Mean	1,499	1,856	2,228	2,403	2,541	2,899	2,516	1,901	1,061	678	880	1,165	1,767
Median	1,390	1,540	2,010	2,000	2,285	2,380	2,160	1,450	738	656	939	1,190	1,280
Max.	4,170	5,100	8,260	9,860	10,200	9,630	7,810	6,790	6,740	1,890	1,650	2,290	10,200
Min.	320	355	342	318	316	313	306	317	321	309	302	309	302
10% Exceed.	2,520	2,850	3,600	3,912	5,333	6,120	5,034	3,860	1,921	985	1,176	1,600	3,430
90% Exceed.	855	855	868	816	646	691	760	630	495	385	502	700	566
Fall Creek near Copco, CA, USGS gage no. 11512000 (water years 1933 to 1959). Drainage area, 15 square miles.													
Mean	35	37	43	46	51	49	45	38	35	34	33	34	40
Median	34	36	37	40	45	46	44	36	33	33	32	33	36
Max.	77	137	474	249	200	130	187	65	58	52	47	52	474
Min.	27	26	28	28	27	29	28	25	24	24	24	24	24
10% Exceed.	44	45	57	65	75	69	61	49	44	42	43	44	55
90% Exceed.	28	30	30	30	31	32	31	29	28	28	27	28	29
Klamath River below Iron Gate dam, CA, USGS gage no. 11516530 (water years 1963 to 2004). Drainage area, 4,630 square miles, excluding Lost River													
Mean	1,601	2,028	2,615	2,938	3,097	3,621	2,995	2,158	1,153	791	969	1,268	2,098
Median	1,370	1,750	1,965	2,490	2,650	2,860	2,370	1,685	796	733	1,020	1,330	1,380
Max.	4,550	5,830	25,000	18,500	16,100	16,200	12,500	6,950	7,710	3,570	1,650	2,500	25,000
Min.	846	848	865	598	508	495	508	484	402	406	389	408	389
10% Exceed.	2,729	3,260	4,508	5,478	5,948	7,439	5,883	4,298	1,990	1,040	1,080	1,691	4,220
90% Exceed.	944	918	1,290	1,290	918	960	1,020	1,010	708	672	696	835	725

J.C. Boyle Reservoir

PacifiCorp states J.C. Boyle reservoir is operated within a range of 5.5 feet[34] from full pond and that daily fluctuation from peaking operations at the J.C. Boyle powerhouse is generally between 1 and 2 feet. This reservoir is relatively small (420 acres) and inflow is retained for a comparatively short amount of time (see table 3-16). Figure 3-8 shows the daily fluctuations for 1990 to 2005. Spillage at the dam typically occurs only when river flows exceed the capacity of the J.C. Boyle powerhouse and the low-flow requirements. As table 3-18 shows, spillage is rare except during the higher flow months of January through May.

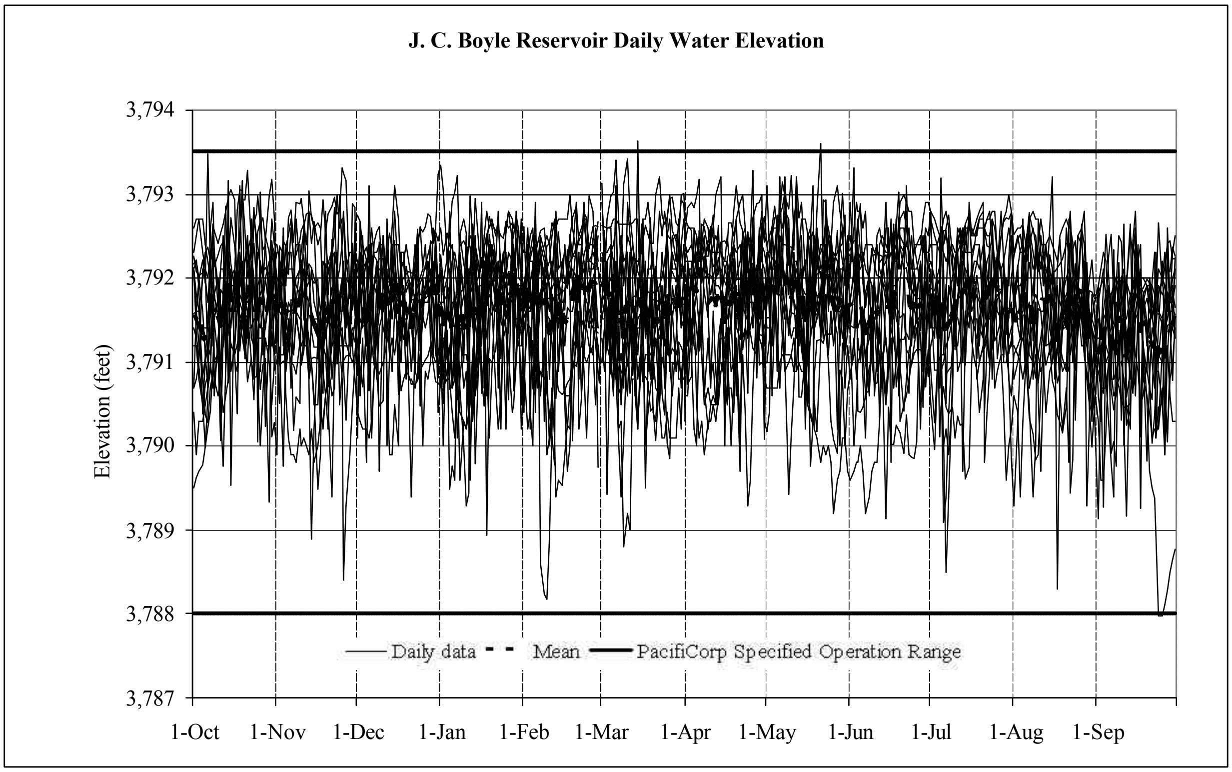


Figure 3-8. J.C. Boyle reservoir daily water surface elevations for January 2, 1990, to December 5, 2004. (Source: PacifiCorp, 2005f, as modified by staff)

J.C. Boyle Bypassed Reach

The 4.3-mile-long J.C. Boyle bypassed reach is a steep gradient section of the Klamath River from the dam to the powerhouse. Substantial groundwater enters the bypassed reach starting about 0.5 mile downstream of the dam. The average accretion in the bypassed reach is between 220 and 250 cfs and is relatively constant on a seasonal basis. Accretion estimates are measured through calculating the difference between the flow released from the dam (bypass pipe and fish ladder) and the USGS gage downstream of J.C. Boyle powerhouse during non-generating periods.

[34] Table A2.1-1 of PacifiCorp's license application states 5 feet, and figure B9.6-1 of the application indicates 5.5 feet.

Table 3-18. Average spillage at J.C. Boyle, Copco No. 1, and Iron Gate dams for January 2, 1990, through December 5, 2004. (Source: PacifiCorp, 2005f, as modified by staff)

	J.C. Boyle			Copco No. 1			Iron Gate		
	Average # of days	**Average[a] (cfs)**	**Average Monthly Spill[b] (acre-feet)**	**Average # of days**	**Average[a] (cfs)**	**Average Monthly Spill[b] (acre-feet)**	**Average # of days**	**Average[a] (cfs)**	**Average Monthly Spill[b] (acre-feet)**
October	1.8	553	2,271	0.0	-	-	1.9	132	552
November	0.0	-	-	0.4	756	772	2.4	523	2,911
December	0.2	1,215	552	1.8	1,783	7,488	5.1	1,395	18,046
January	4.3	2,803	28,235	5.2	3,682	44,378	11.0	1,379	35,539
February	7.1	2,368	37,812	8.4	2,672	50,957	12.1	2,934	79,987
March	7.8	1,738	41,677	7.4	2,774	46,219	17.3	2,297	89,676
April	5.8	1,728	22,750	5.9	2,026	27,205	15.7	1,595	56,608
May	4.7	2,207	21,483	5.3	2,031	24,122	15.0	1,643	55,979
June	1.8	801	3,148	1.1	1,136	2,732	6.1	790	10,930
July	0.1	266	61	0.0	-	-	2.1	56	246
August	0.0	-	-	0.3	96	61	0.2	656	307
September	0.9	456	950	0.0	-	-	0.0	-	-
Yearly	35	2,032	161,272	36	2,506	206,834	89	1,726	352,196

Note: Most of water year 1993 is missing for this data set.

[a] Average flow during spill events.

[b] Includes non-spill events.

J.C. Boyle Peaking Reach

Monthly flow statistics for the peaking reach are shown in table 3-19. Under current operations, when inflow to J.C. Boyle reservoir is below 3,000 cfs, water is typically stored at night and flows during the day, the period of peak energy demand, are ramped up to either one unit operation (up to 1,500 cfs) or two unit operation (up to 3,000 cfs). According to PacifiCorp, the preferred flow through the powerhouse is 2,500 cfs due to turbine efficiencies, but as shown in table 3-19, this preferred flow is infrequently achieved on a daily average basis, during most months. When generation is not occurring and J.C. Boyle dam is not spilling, normal flows in the peaking reach are about 320 to 350 cfs, consisting of 80 cfs from the fish ladder, 20 cfs from the juvenile fish bypass system, and the rest from spring accretion in the bypassed reach. PacifiCorp states that because of the popularity of whitewater boating on the J.C. Boyle peaking reach, PacifiCorp considers the timing demands of commercial whitewater rafters as well as power demand, during May through mid October as discussed in greater detail in section 3.3.6, *Recreational Resources*. The current license requires a ramping rate of 9 inches per hour for both upramping and downramping. Figure 3-9 shows the July flows at USGS gage no. 11510700 Klamath River below J.C. Boyle powerhouse which is located at RM 219.7, about 0.7 mile downstream of the powerhouse, this type of a flow regime is typical in this reach during low flows. PacifiCorp has two direct diversion water rights along this reach for irrigation and stock watering at Copco ranch: 10 cfs and 2,300 acre-feet per year at the Owens ditch diversion and 5 cfs and 600 acre-feet per year at the Owens Island diversion, both of which are gravity-fed diversions along the river.

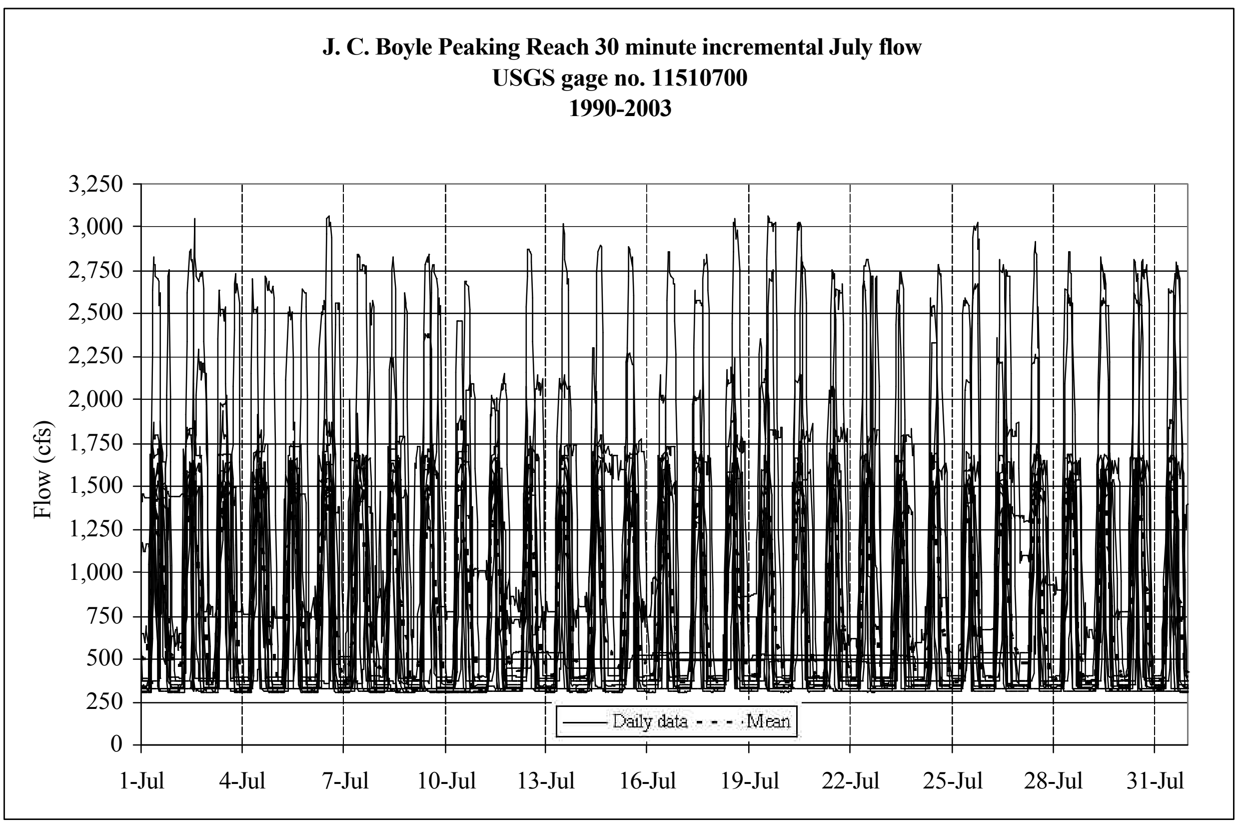


Figure 3-9. Klamath River flows (cfs) during July for the J.C. Boyle peaking reach for water years 1990 to 2004. (Source: USGS, 2005, as modified by staff)

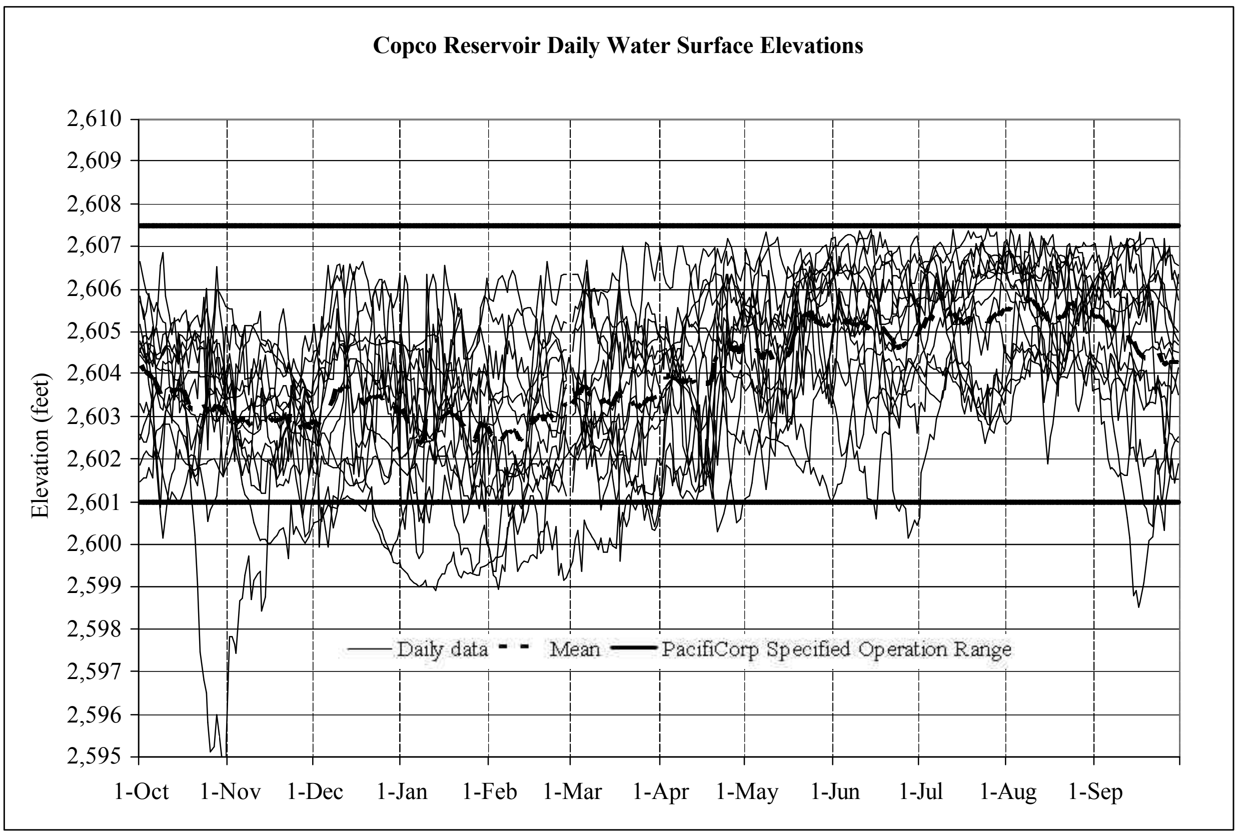
Substantial tributaries in this reach include Rock Creek, at RM 213.9, and Shovel Creek at RM 206.5. Up to 15 cfs is currently diverted from Shovel Creek and Negro Creek (a tributary of Shovel Creek) for irrigation purposes by local landowners during the summer.

Table 3-19. Monthly discharge (cfs) statistics for J.C. Boyle, Copco No. 1, and Iron Gate powerhouses. (Source: PacifiCorp, 2005f, as modified by staff)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Yearly
J.C. Boyle powerhouse PacifiCorp daily database (Jan 2, 1990 to Dec 5, 2004)													
Mean	750	858	1,107	1,329	1,338	1,557	1,523	1,289	801	395	491	637	1,005
Median	831	850	861	968	952	1,659	1,435	1,134	647	378	556	606	759
Max.	1,698	2,929	2,949	2,996	2,978	2,965	3,016	3,023	2,665	1,328	1,094	1,433	3,023
Min.	0	0	0	0	0	0	0	0	0	0	0	0	0
10% Exceed.	1,109	1,303	2,322	2,806	2,933	2,862	2,873	2,547	1,552	715	791	1,046	2,535
90% Exceed.	334	428	433	403	200	185	232	190	179	0	129	232	216
Copco No. 1 powerhouse PacifiCorp daily database (Jan 2, 1990 to Dec 5, 2004)													
Mean	1,106	1,177	1,359	1,545	1,554	1,894	1,781	1,572	1,135	702	804	974	1,299
Median	1,182	1,209	1,232	1,329	1,271	1,972	1,690	1,430	988	671	847	976	1,124
Max.	2,111	3,205	3,225	3,238	3,266	3,356	3,247	3,179	3,167	1,482	1,672	2,116	3,356
Min.	289	316	128	101	264	0	0	0	0	0	0	0	0
10% Exceed.	1,448	1,688	2,258	2,957	3,100	3,063	3,040	3,018	1,990	1,096	1,136	1,336	2,864
90% Exceed.	714	718	761	712	514	493	553	459	450	380	436	563	548
Iron Gate powerhouse PacifiCorp daily database (Jan 1, 1993 to Dec 5, 2004)													
Mean	1,166	1,212	1,378	1,417	1,353	1,509	1,578	1,325	1,206	847	902	1,081	1,247
Median	1,218	1,207	1,503	1,610	1,545	1,669	1,676	1,624	1,184	765	962	1,180	1,227
Max.	1,703	1,799	1,801	1,868	1,963	2,481	1,784	1,796	1,755	1,330	1,245	1,736	2,481
Min.	629	0	642	630	316	607	604	30	30	269	554	689	0
10% Exceed.	1,314	1,703	1,711	1,722	1,737	1,765	1,768	1,728	1,712	1,064	1,053	1,314	1,720
90% Exceed.	850	814	835	865	823	812	1,264	565	735	607	608	843	725

Copco Reservoir

As table 3-16 shows, Copco reservoir is substantially deeper than the two upstream reservoirs (Keno and J.C. Boyle) with much greater total storage capacity (33,724 acre-feet) and active storage volume (6,235 acre-feet, the most active storage of all project reservoirs). PacifiCorp states that water levels in Copco reservoir are normally maintained within a range of 6.5 feet from elevations 2,602 to 2,607.5 feet, and daily fluctuations in reservoir water levels of about 0.5 feet are due to peaking operation of the of the Copco No. 1 powerhouse and the variance in the inflow from the J.C. Boyle peaking reach. Figure 3-10 shows the daily water elevations for Copco reservoir for 1990 to 2004 and indicates that the reservoir range is often lower than elevation 2,602.5 feet during the winter months. Spillage at Copco No. 1 dam occurs most frequently during January through May (see table 3-16).



Note: Data for January 2, 1990, to December 5, 2004.

Figure 3-10. Copco reservoir daily water surface elevations. (Source: PacifiCorp, 2005f, as modified by staff)

Copco No. 2 Reservoir and Bypassed Reach

The Copco No. 1 powerhouse can discharge up to 3,560 cfs directly into the 0.25-mile-long Copco No. 2 reservoir. PacifiCorp states that since the Copco No. 2 reservoir has virtually no storage, the powerhouse (maximum hydraulic capacity of the flowline is 3,200 cfs) acts as a virtual slave to discharge from Copco reservoir and the water level within Copco No. 2 reservoir rarely fluctuates more than several inches. Spillage at Copco No. 2 dam would typically only occur when inflow exceeds the capacity of Copco No. 2 powerhouse, which according to table 3-19, occurs infrequently from November through

April. There is a 1.5-mile-long bypassed reach between Copco No. 2 reservoir and powerhouse. There is currently no minimum flow requirement at this bypassed reach but according to PacifiCorp, it normally releases 5 to 10 cfs via a 24-inch-diameter pipe at the dam. This pipe discharges onto downstream boulders, based on our observations during the May 19, 2004, site visit. PacifiCorp states that in the bouldered and steeply sloping bypassed reach, accretion adds very little natural flow, unlike the J.C. Boyle bypassed reach. Discharge from Copco No. 2 powerhouse enters the upper reaches of the Iron Gate reservoir.

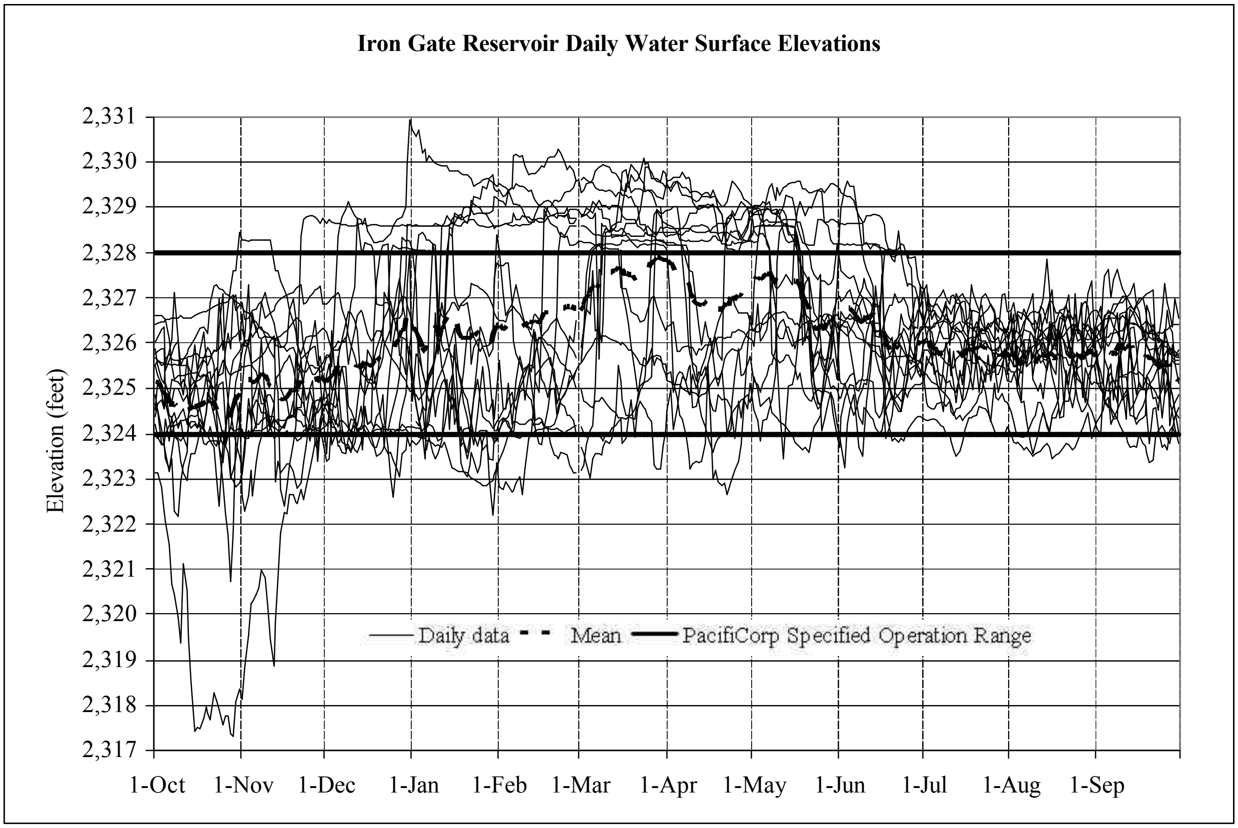
Spring, Fall, and Jenny Creeks

Two perennial tributaries, Jenny and Fall creeks, enter Iron Gate reservoir (see figure 2-6). As shown in figure 2-7, Spring Creek is a tributary to Jenny Creek, which flows for a distance of 1.2 miles from its source at Shoat Springs before it enters Jenny Creek at RM 5.5. The flow in Jenny Creek is altered by upstream reservoirs that are part of the Rogue River Irrigation Project that store water during the high runoff season for irrigation, and about 30 percent of the mean annual runoff (or 24,000 acre-feet) of the Jenny Creek watershed is diverted north into the Rogue River Basin. PacifiCorp estimates that normally between 30 and 500 cfs enters Iron Gate reservoir from Jenny Creek.

PacifiCorp operates a small diversion dam on Spring Creek that diverts up to 16.5 cfs into Fall Creek, and another dam on Fall Creek which diverts flow into a canal and penstock system that leads to the Fall Creek powerhouse (see figure 2-7). PacifiCorp states that the Spring Creek diversion was unusable for most of the 1990s, and until 2003, due to a water rights lawsuit with a local landowner, but that the lawsuit was decided in favor of PacifiCorp in 2003. The Spring Creek diversion is located 0.5 miles upstream of its confluence with Jenny Creek, and the diverted flow is carried through a 1.3-mile-long canal where it enters Fall Creek about 1.7 miles upstream of the Fall Creek diversion. The diversion dam on Fall Creek diverts up to 50 cfs of flow that bypasses 1.2 miles of a very steep gradient section of Fall Creek, leading to the Fall Creek powerhouse. The project's current license requires a minimum flow of 0.5 cfs below the Fall Creek diversion and a minimum flow of 15 cfs (or natural stream flow, whichever is less) downstream of the powerhouse. The USGS operated gage no. 115120000 on Fall Creek a short distance downstream of the Fall Creek powerhouse during most of 1933 to 1959 and the monthly and annual flow statistics are provided in table 3-17. According to data from this gage, flow within Fall Creek does not vary much on a seasonal basis due to a reliable baseflow from groundwater springs and is typically within the 30 to 50 cfs range. The city of Yreka, California, operates a water supply intake located downstream of the Fall Creek powerhouse and has water rights to withdraw up to 15 cfs. Intakes to the currently non-operating Fall Creek fish hatchery are located below the Yreka intake, and water rights include 10 cfs and 5,465 acre-feet per year between March 15 and December 15 for Cal Fish & Game and 10 cfs between June 1 to November 1 for PacifiCorp.

Iron Gate Reservoir

Iron Gate reservoir is the deepest project reservoir with the greatest total storage (50,941 acre-feet) (see table 3-16). The dam was constructed as a re-regulating facility to dampen the effects of the peaking operations of J.C. Boyle, Copco No. 1, and Copco No. 2 developments on the Klamath River. PacifiCorp states that water levels in Iron Gate reservoir are normally maintained within 4 feet of the full pond (elevation 2,328.0 feet) resulting in an active storage volume of 3,790 acre-feet. PacifiCorp notes that daily water level fluctuations within Iron Gate reservoir due to upstream peaking operations are about 0.5 foot. Figure 3-11 shows daily water levels at Iron Gate reservoir.



Note: Data for January 2, 1990 to December 5, 2004.

Figure 3-11. Iron Gate reservoir daily water surface elevations. (Source: PacifiCorp, 2005f, as modified by staff)

The Iron Gate powerhouse is located at the base of the dam and has a maximum hydraulic capacity of 1,735 cfs. The invert of the intake leading to the 12-foot-diameter Iron Gate penstock is at elevation 2,293 feet about 35 feet below the normal full pool elevation. Estimated monthly and annual flows through the powerhouse are shown in table 3-19. Water is also withdrawn from Iron Gate reservoir via a 30-inch-diameter pipe at an invert of 2,260 feet with a maximum direct diversion water right of 48 cfs to provide cool water to the Iron Gate Fish Hatchery, located about 0.25 mile downstream of the dam. There is a second hatchery intake at elevation 2,309 feet which PacifiCorp states is used infrequently.

USGS gage no. 11516530, Klamath River below Iron Gate dam, is a real-time gage with 15 minute interval data available at RM 189.6, about 0.5 mile downstream of Iron Gate dam. The flow recorded at this gage includes the contributions of the following sources:

- discharge from the Iron Gate powerhouse;
- spillage from Iron Gate dam;
- discharge water from the Iron Gate Fish Hatchery; and
- flow from Bogus Creek, a relatively small tributary to the Klamath River.

Figure 3-12 provides a long-term representation of yearly flow for water years 1963 to 2004. Data for the same period are summarized in table 3-17.

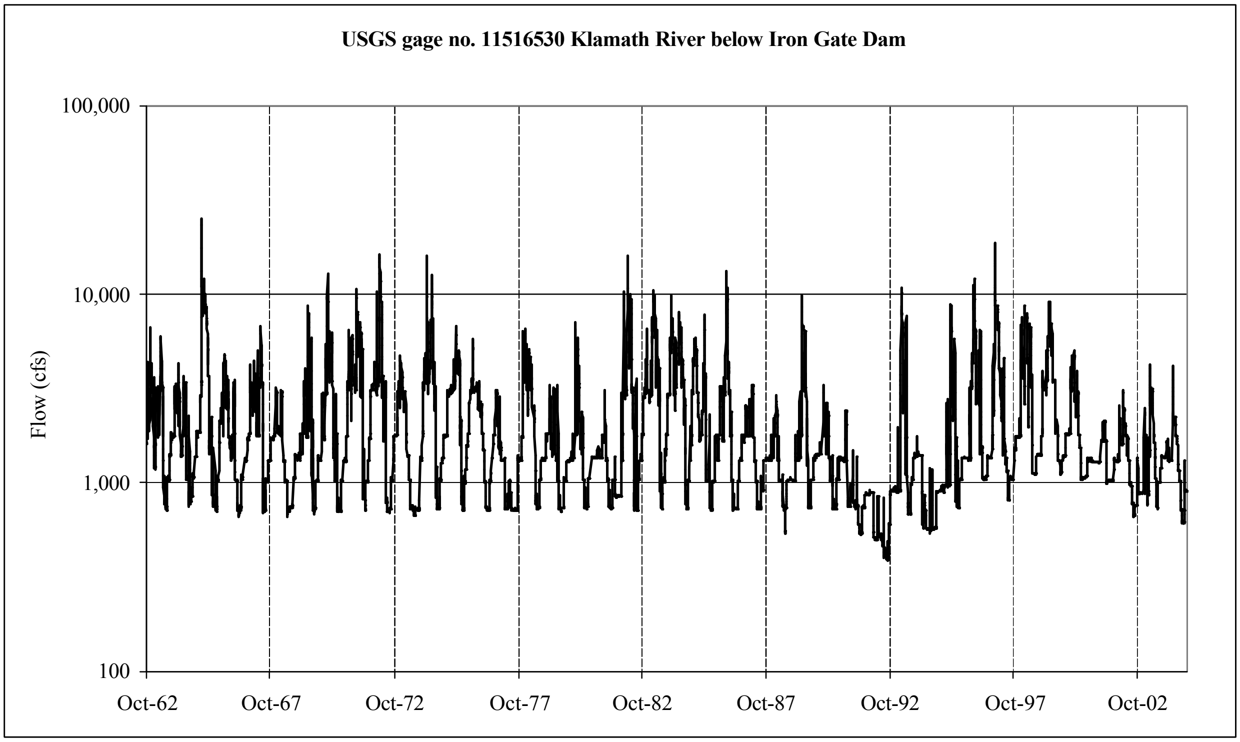


Figure 3-12. Flow below Iron Gate dam for water years 1963 to 2004. (Source: USGS, 2006)

PacifiCorp uses data from USGS gage no. 11516530 to ensure and monitor compliance with a complicated set of flow criteria that apply to Iron Gate development, some of which are established by the existing license and others by the BiOps issued by NMFS to Reclamation for the operation of the Klamath Irrigation Project. Table 3-20 shows the ramping rate criteria for Iron Gate.

Table 3-20. Ramping rate requirements for Iron Gate dam. (Source: PacifiCorp, 2004a; staff)

Flow Range	Maximum Decrease	Source
General	250 cfs per hour or 3 inches per hour whichever is less	FERC 1961 license amendment
Above 1,750 cfs	not more than 125 cfs per 4 hour period and not exceeding 300 cfs per 24 hours	NMFS 2002
1,750 cfs or less	not more than 50 cfs per 2 hour period and not exceeding 150 cfs per 24 hour period	NMFS 2002

The current license (as amended in 1961) stipulates a minimum flow release of 1,300 cfs from September through April; 1,000 cfs in May and August; and 710 cfs in June and July. Since 1997, PacifiCorp has operated the development to provide flow releases based on Reclamation's annual operating plans. To comply with the recent (2002) BiOps for protecting the federally listed coho salmon (NMFS, 2002) and Lost River and shortnose suckers (FWS, 2002a), Iron Gate development is currently operated under a river flow release regime based on the projected water year type as determined on April 1 of each year (table 3-21).

Table 3-21. NMFS 2002 BiOp Iron Gate dam releases criteria based on water year. (Source: Reclamation, 2005b)

	Water Year Type and Flow (cfs)				
Time Step	**Wet**	**Above Normal**	**Average**	**Below Average**	**Dry**
April 1-15	5,932	2,955	1,863	1,826	822
April 16-30	5,636	2,967	2,791	1,431	739
May 1-15	3,760	2,204	2,784	1,021	676
May 16-31	2,486	1,529	1,466	1,043	731
June 1-15	1,948	1,538	827	959	641
June 16-30	1,921	934	1,163	746	617
July 1-15	1,359	710	756	736	516
July 16-30	1,314	710	735	724	515
August	1,149	1,039	1,040	979	560
September	1,341	1,316	1,300	1,168	731
October	1,430	1,346	1,345	1,345	907
November	1,822	1,414	1,337	1,324	899
December	1,822	1,387	1,682	1,621	916
January	2,792	1,300	3,618	1,334	1,030
February	4,163	1,300	1,300	1,806	673
March 1-15	8,018	1,953	2,143	2,190	688
March 16-30	6,649	4,009	2,553	1,896	695

Reclamation Classification (Klamath Irrigation Project 2003 Operations Plan) for River Flow Planning

Water Year Type	**Based on predicted Upper Klamath Lake Net Inflow (acre-feet) for April–September**
Wet	Above 785,2000
Above Average	785,200 to greater than 568,600
Average	568,500 to greater than 458,400
Below Average	458,300 to greater than 286,800
Dry	Less than 286,800

In addition, pursuant to the NMFS BiOp, Reclamation, in consultation with NMFS and FWS, develops a schedule to use storage from the water bank associated with the Klamath Irrigation Project to supplement flow releases at Iron Gate development as discussed previously. The storage volume requirements of the water bank and actual volumes supplied in 2003, 2004, and 2005, are shown in table 3-15. Figures 3-13 through 3-15 show how the water bank flows were used and the actual flows at the USGS gage downstream of Iron Gate dam in 2003, 2004, and 2005.

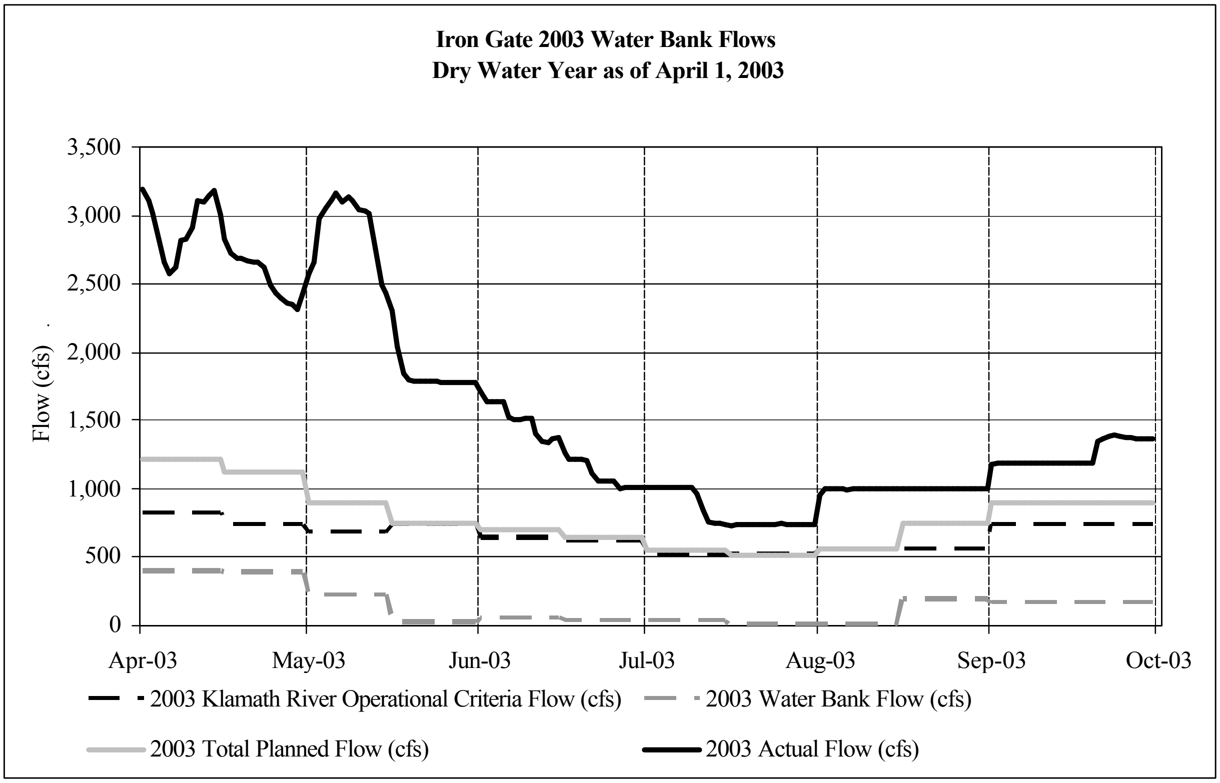


Figure 3-13. Iron Gate flows for April 1 through September 30, 2003. (Source: Reclamation, 2005b; USGS, 2006, as modified by staff)

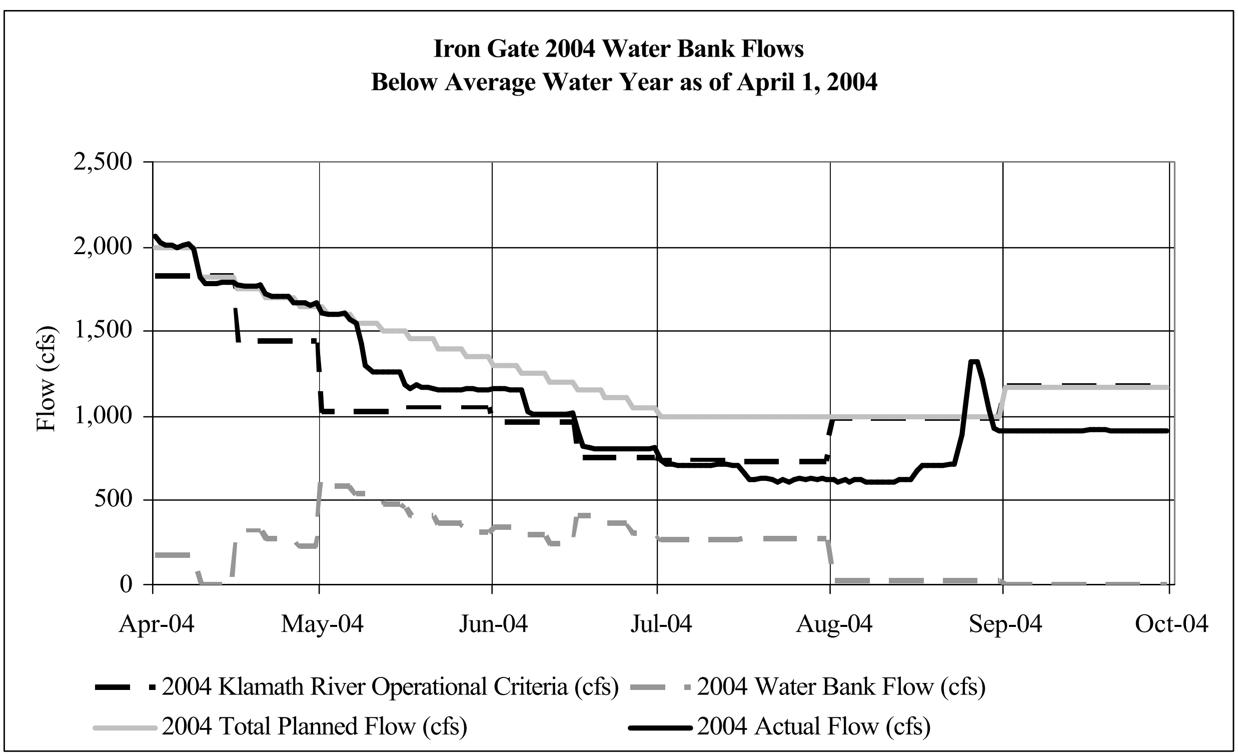


Figure 3-14. Iron Gate flows for April 1 though September 30, 2004. (Source: Reclamation, 2005b; USGS, 2006, as modified by staff)

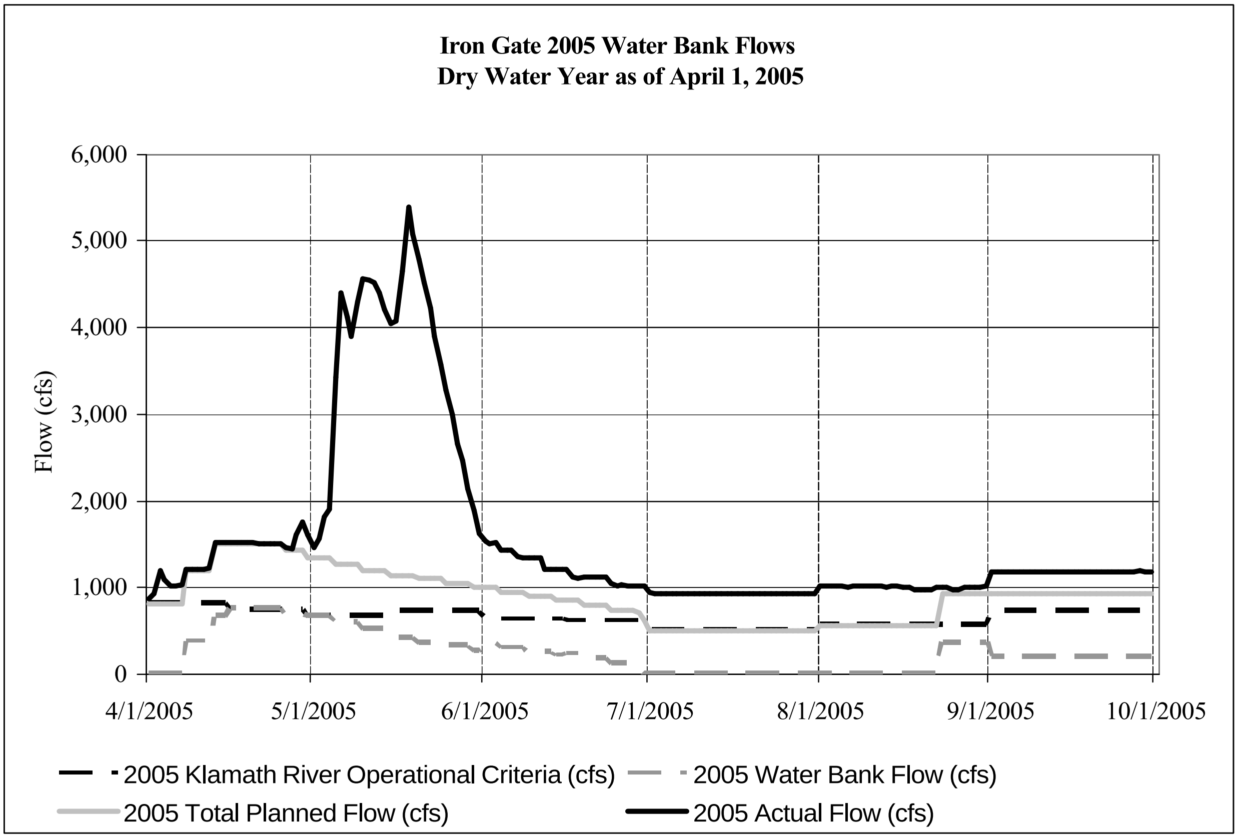


Figure 3-15. Iron Gate flows for April 1 though September 30, 2005. (Source: Reclamation, 2005b; USGS, 2006, as modified by staff)

Flow releases at Iron Gate dam have recently been revised based on a ruling by the U.S. Ninth Circuit Court of Appeals, settling a lawsuit between the Pacific Coast Federation of Fisherman's Associations, Institute for Fisheries Resources, Northcoast Environmental Center, Klamath Forest Alliance, Oregon Natural Resources Council, the Wilderness Society, Waterwatch of Oregon, Defenders of Wildlife, Headwaters, Representative Mike Thompson, the Yurok Tribe, and the Hoopa Valley Tribe versus Reclamation, NMFS, and the Klamath Water Users Association. This ruling, issued on March 27, 2006, ordered:

- NMFS and Reclamation to reinitiate consultation on the Klamath Irrigation Project;
- NMFS to issue a new BiOp based on the current scientific evidence and the full risks to threatened coho salmon and to provide a copy of the new BiOp to the plaintiffs and to the Court when it is completed;
- Reclamation to limit Klamath Project irrigation deliveries if they would cause water flows in the Klamath River at and below Iron Gate dam to fall below 100 percent of the Phase III flow levels specifically identified by NMFS in the BiOp as necessary to prevent jeopardy, until the new consultation for the Klamath Irrigation Project is completed and reviewed by the U.S. Ninth Court (Earthjustice, 2006).

This ruling has caused implementation of Phase III flows from the NMFS BiOp (table 3-22).

Table 3-22. Phase III, NMFS 2002 BiOp Iron Gate dam releases criteria based on water year. (Source: Reclamation, 2006c).

Water Year Type and Flow (cfs)					
Month	Wet	Above Average	Average	Below Average	Dry
April	2,050	2,700	2,850	1,575	1,500
May	2,600	3,025	3,025	1,044	1,500
June	2,900	3,000	1,500	1,525	1,400
July	1,000	1,000	1,000	1,000	1,000
August	1,000	1,000	1,000	1,000	1,000
September	1,000	1,000	1,000	1,000	1,000
October	1,300	1,300	1,300	1,300	1,300
November	1,300	1,300	1,300	1,300	1,300
December	1,300	1,300	1,300	1,300	1,300
January	1,300	1,300	1,300	1,300	1,300
February	1,300	1,300	1,300	1,300	1,300
March	2,300	2,525	2,750	1,725	1,450

Downstream of Iron Gate Dam

Downstream of Iron Gate dam, the Klamath River flows freely for 190 miles to its estuary and the Pacific Ocean. Four major tributaries enter this reach: the Shasta, Scott, Salmon, and Trinity rivers. These four tributaries contribute about 44 percent of the Klamath River Basin's mean annual runoff and have a substantial influence on the timing of peak and low flow rates within the Lower Klamath River. Table 3-23 summarizes drainage areas and mean monthly and annual flows for these four main tributaries and for three USGS gages along the Lower Klamath River.

Shasta River

The Shasta River enters the Klamath River at RM 176.6, 13.5 miles downstream from Iron Gate dam. The Shasta River watershed includes the glaciated slopes of Mt Shasta, but is largely rangeland with substantial amounts of irrigated pastureland and agricultural area. The average precipitation in the watershed varies greatly with exposure and elevation, but is about 15 inches per year due to the rain shadow effects of the mountains to the west of the watershed. The hydrograph for the Shasta River near the confluence with the Klamath River shows a peak in the winter and minimum median flows under 40 cfs during July and August (see table 3-23). The current hydrology of the Shasta River is affected by surface-water diversions, alluvial pumping, and the Dwinnell dam which creates Lake Shastina (see figure 1-1). Historically, springs and seeps dominated the hydrograph of the Shasta River resulting in a cool and stable river flow (NAS, 2004). Dwinnell dam, about 25 miles upstream from the Klamath River at a location that controls 15 percent of the total drainage area of the Shasta River, was constructed in 1928 and has a normal storage capacity of 50,000 acre-feet. The majority of the water in Lake Shastina is retained during the winter and early spring and then used for irrigation during the later spring and summer. Other than during above average and wet water years, the only release from Lake Shastina is flow needed to meet downstream water user requirements. Farther downstream, there are seven major diversion dams and numerous smaller dams or weirs on the Shasta River and its tributaries. When these diversions are in operation during the irrigation season, they substantially and rapidly reduce flows in the mainstem causing complete dewatering of the main channel in some reaches of the river during the late summer of dry years (NAS, 2004).

Table 3-23. Monthly discharge (cfs) statistics for USGS gages along the Lower Klamath River and for the Shasta, Scott, Salmon, and Trinity rivers. (Source: USGS, 2006, as modified by staff)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Yearly
Shasta River near Yreka, CA, USGS gage no. 11517500 (water years 1963 through 2004). Gage data prorated by 1.0485 to the confluence with the Klamath. Shasta River drainage area, 800 square miles													
Mean	161	215	303	388	345	342	212	156	110	52	41	75	199
Median	157	195	219	250	278	268	167	121	82	39	33	68	166
Max.	1,311	910	10,904	8,828	2,558	2,726	2,768	1,143	969	285	245	475	10,904
Min.	34	129	138	146	148	48	18	13	6	2	2	5	2
10% Exceed.	212	279	435	658	577	569	399	295	203	105	74	129	373
90% Exceed.	105	160	167	178	182	151	56	49	26	16	14	25	27
Scott River at Fort Jones, CA, USGS gage no. 11519500 (water years 1963 through 2004). Gage data prorated by 1.2557 to the confluence of the Klamath River. Scott River drainage area, 820 square miles.													
Mean	120	426	1,041	1,426	1,394	1,425	1,255	1,394	850	213	65	59	803
Median	80	148	420	707	1,008	1,069	1,186	1,175	618	124	53	55	377
Max.	8,514	8,062	49,602	38,802	16,953	16,325	8,213	6,065	5,776	1,695	701	556	49,602
Min.	5	6	16	68	100	80	63	88	12	9	5	4	4
10% Exceed.	158	1,052	2,422	2,838	2,763	2,648	2,160	2,598	1,884	534	119	95	1,946
90% Exceed.	21	63	117	159	300	466	428	454	157	36	10	12	26
Klamath River at Seiad Valley, CA, USGS gage no. 11520500 (water years 1963 to 2004). Drainage area, 6,940 square miles, does not include Lost River.													
Mean	1,990	2,978	4,805	6,102	5,976	6,637	5,582	4,720	2,754	1,313	1,186	1,484	3,784
Median	1,735	2,280	3,320	4,120	4,790	5,120	5,045	4,015	2,180	1,120	1,230	1,540	2,370
Max.	14,900	15,000	115,000	108,000	42,400	51,900	31,600	14,100	12,900	7,200	2,650	2,710	115,000
Min.	963	1,080	1,180	1,210	1,070	1,020	1,070	954	603	552	398	464	398
10% Exceed.	3,219	5,231	8,293	12,000	11,100	13,000	9,873	8,620	4,923	2,010	1,470	2,010	8,100
90% Exceed.	1,171	1,399	1,761	1,910	1,816	2,013	2,140	1,831	1,160	838	799	914	1,050
Salmon River at Somes Bar, CA, USGS gage no. 11522500 (water years 1963 to 2004). Drainage area of the gage and the Salmon River, 751 square miles.													
Mean	340	1,209	2,492	3,375	3,034	3,148	2,859	2,952	1,796	612	273	214	1,853
Median	207	436	1,310	1,970	2,240	2,360	2,660	2,630	1,400	481	251	196	1,050
Max.	12,300	22,000	100,000	64,400	31,200	43,600	15,200	11,000	8,800	4,160	3,950	1,990	100,000
Min.	83	119	179	182	182	281	399	570	224	107	72	60	60
10% Exceed.	504	3,021	5,887	6,500	5,534	5,440	4,690	5,150	3,602	1,170	417	285	4,210
90% Exceed.	122	200	362	550	843	1,120	1,269	1,130	560	233	138	121	173

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Yearly
Klamath River at Orleans, CA, USGS gage no. 11523000 (water years 1963 through 2004). Drainage area, 8,475 square miles does not include Lost River.													
Mean	2,814	6,353	12,023	16,011	15,153	15,252	12,731	10,936	6,166	2,566	1,835	1,994	8,624
Median	2,320	3,690	7,075	9,460	11,500	12,100	11,700	9,335	4,820	2,210	1,840	2,010	4,840
Max.	33,400	83,900	240,000	240,000	229,000	151,000	72,900	34,000	28,500	12,200	7,970	7,630	240,000
Min.	1,110	1,510	1,880	2,150	2,150	2,240	2,330	1,930	1,380	824	652	652	652
10% Exceed.	4,218	14,810	25,190	31,200	27,200	27,290	21,800	19,100	11,810	4,220	2,400	2,520	19,200
90% Exceed.	1,501	2,180	2,931	3,651	4,516	5,264	5,050	4,002	2,369	1,420	1,220	1,260	1,590
Trinity River at Hoopa, CA, USGS gage no. 11530000 (water years 1912 to 1962, not including 1916 through 1931). Gage data prorated by 1.01647 to the confluence with the Klamath River. Trinity River drainage area, 2,900 square miles. Pre-Trinity River Diversion.													
Mean	919	2,563	6,475	8,999	11,927	10,456	10,102	8,510	4,682	1,620	661	515	5,584
Median	547	1,138	2,785	5,164	7,644	8,762	9,026	8,254	3,929	1,311	575	456	2,963
Max.	53,162	53,975	160,603	95,447	115,878	70,137	38,423	28,766	14,942	6,993	2,216	3,822	160,603
Min.	165	299	386	413	933	2,704	3,700	1,952	671	318	213	191	165
10% Exceed.	1,248	6,330	15,979	22,464	26,449	17,809	16,569	13,824	9,405	2,978	1,098	765	12,706
90% Exceed.	323	468	791	1,250	2,846	4,692	4,878	3,468	1,769	666	343	300	455
Trinity River at Hoopa, CA, USGS gage no. 11530000 (water years 1963 through 2004). Gage data prorated by 1.01647 to the confluence with the Klamath River. Trinity River drainage area, 2,900 square miles. Post Trinity River Diversion.													
Mean	905	2,983	7,230	10,859	10,321	9,993	6,967	5,004	2,882	1,285	775	691	4,969
Median	701	1,149	3,466	6,231	7,090	6,993	5,453	4,035	2,185	1,098	699	623	2,236
Max.	23,074	36,491	170,768	119,944	99,919	86,604	45,843	20,126	15,755	5,855	6,170	3,802	170,768
Min.	311	498	511	555	630	1,047	986	1,027	422	275	248	292	248
10% Exceed.	1,169	7,959	16,975	25,910	22,820	20,319	12,513	9,544	5,207	2,062	1,138	984	11,588
90% Exceed.	490	689	961	1,474	2,719	3,020	2,550	2,043	1,189	691	469	447	607
Klamath River near Klamath, CA, USGS gage no. 11530500 (water years 1963 to 2004).[a] Drainage area, 12,100 square miles, does not include Lost River													
Mean	4,720	13,811	25,967	34,535	33,348	33,525	25,718	19,445	11,156	4,667	3,125	3,219	17,667
Median	3,760	6,550	14,900	21,650	24,650	25,200	21,100	16,200	8,790	3,990	2,960	3,000	9,580
Max.	79,000	140,000	420,000	397,000	404,000	317,000	173,000	55,600	63,100	25,100	20,900	14,200	420,000
Min.	1,910	2,320	3,070	3,480	3,300	5,030	4,410	4,680	2,100	1,440	1,340	1,310	1,310
10% Exceed.	6,508	35,600	58,320	74,840	67,610	62,820	44,110	35,410	20,000	7,558	4,350	4,210	40,100
90% Exceed.	2,588	3,580	5,280	7,250	9,999	12,800	10,290	8,347	4,530	2,649	2,030	2,020	2,700

[a] For water years 1963 to 2004; data for December 31, 1994 to January 6, 1995 and October 30, 1995 to September 30, 1997 are missing.

Scott River

The Scott River enters the Klamath River at RM 143, 47.1 miles downstream from Iron Gate dam. The Scott River watershed includes the heavily forested and relatively wet Salmon Mountains on its western divide, but these mountains create a rain shadow for the rest of the watershed. Similar to the Shasta River valley, many areas in the Scott River valley have been extensively altered for grazing and agriculture. Although the Scott River watershed is almost the same size as the Shasta River watershed, the hydrograph for the Scott River near the confluence with the Klamath River has 4 to 5 times higher median monthly flows in the winter and spring months (see table 3-23). Somewhat similar to the Shasta River, the minimum monthly median flows near 50 cfs occur during August and September.

Klamath River at Seiad Valley

USGS gage no. 11520500, Klamath River at Seiad Valley at RM 128.5, is below the confluences with the Shasta and Scott rivers. Releases from Iron Gate dam represent more than 75 percent of the flow during the low flow months of August, September, October, and November, but less than 50 percent during the higher flow months of April, May, and June at this location. Figure 3-16 shows daily flow at the Klamath River at Seiad Valley from water years 1963 to 2004, the same period of record summarized for this gage in table 3-23.

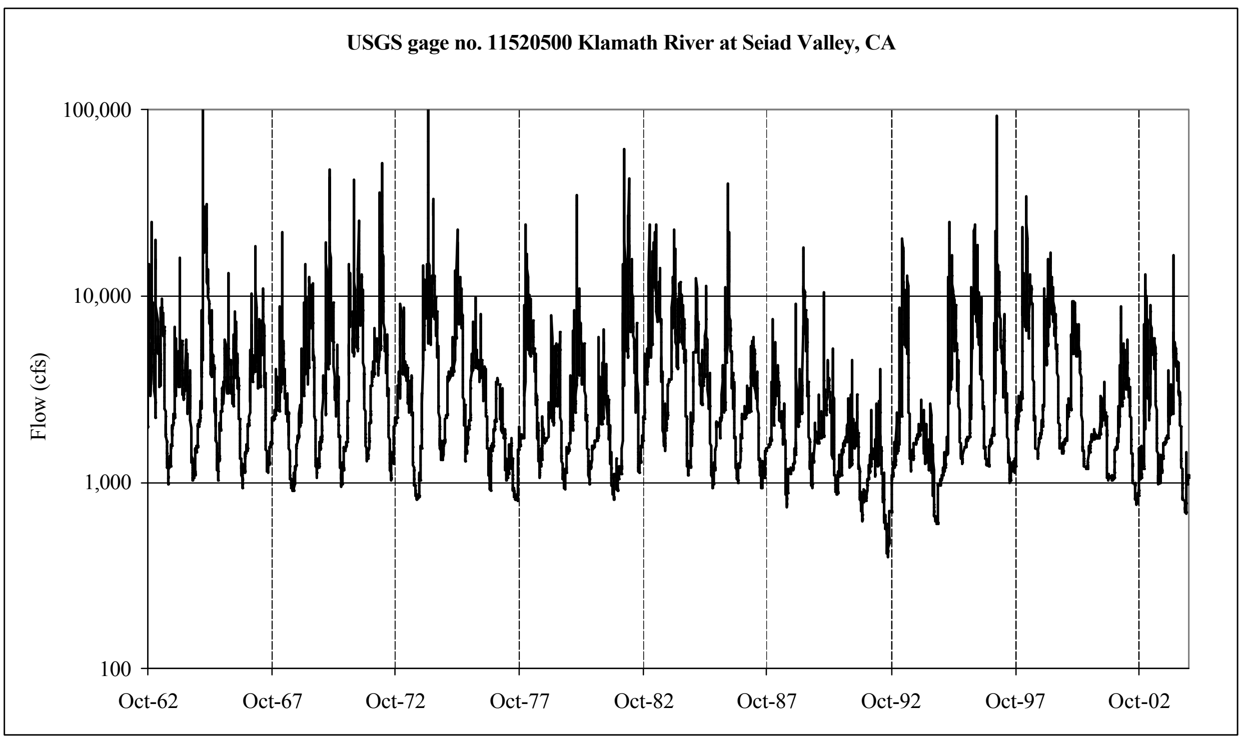


Figure 3-16. Daily Klamath River flow at Seiad Valley (USGS gage no. 11520500) for water years 1963 to 2004. (Source: USGS, 2006, as modified by staff)

Salmon River

The Salmon River enters the Klamath River at RM 66, 124.1 miles downstream from Iron Gate dam. The Salmon River watershed is generally steep, forested, and largely federally owned within the Klamath National Forest and several designated wilderness areas. The area is largely undisturbed except for logging, fires, and mining activity. As table 3-23 indicates, the Salmon River hydrograph at the confluence with the Klamath River shows high average flows (3,375 cfs) during January, representing rain or rain on snow events that are normally the peak flooding events during the winter, and a more sustained and consistent spring high flow period in April and May (median flow, 2,660 and 2,630 cfs, respectively) representing snowmelt from the higher terrain where a deep snowpack accumulates. The minimum monthly median flow of about 200 cfs occurs during September.

Klamath River at Orleans

USGS gage no. 11523000, Klamath River at Orleans at RM 60, is below the confluences with the Shasta, Scott, and Salmon rivers as well as other smaller tributaries. As the Klamath River flows generally westward, it enters an area of higher precipitation as compared to the Shasta, Scott, and the Klamath River above Iron Gate dam, resulting in much higher flows during the winter and spring months as compared to upstream areas. However, releases from Iron Gate dam still represent more than 50 percent of the flow during the low flow months of August, September, and October, but 20 percent or less during the higher flow months of April, May, and June at this location. Figure 3-17 shows daily flow here from water years 1963 to 2004, the same period of record summarized for this gage in table 3-23.

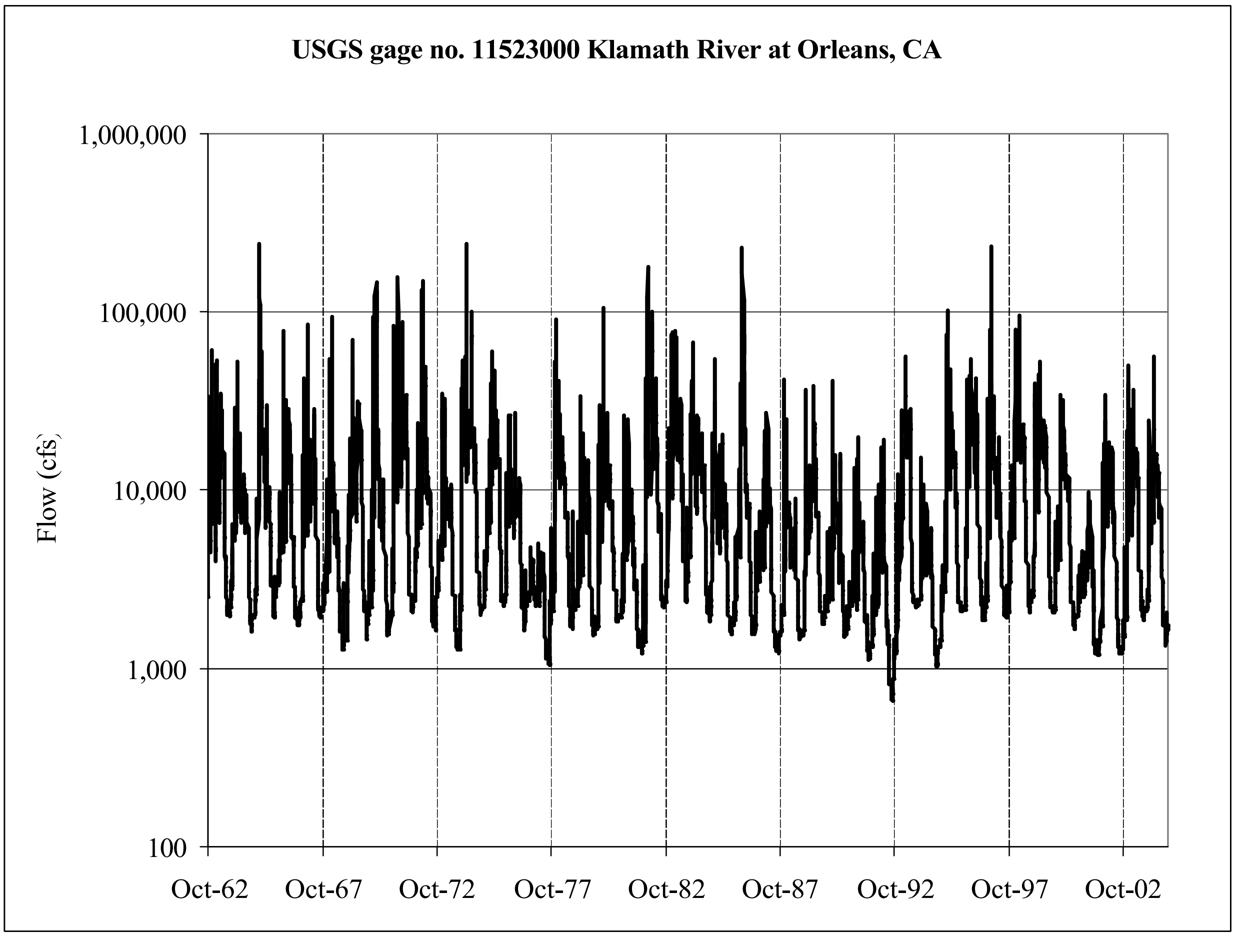


Figure 3-17. Daily Klamath River flow at Orleans (USGS gage no. 11523000) for water years 1963 to 2004. (Source: USGS, 2006, as modified by staff)

Trinity River

The Trinity River enters the Klamath River at RM 40, 150 miles downstream of Iron Gate dam. The Trinity River is the largest tributary to the Klamath River. The Trinity watershed is generally wet, steep, forested, and largely federally owned within several national forests and wilderness areas. As table

3-23 shows, the Trinity River hydrograph at the confluence with the Klamath River has peak median monthly flows in February and March near 7,000 cfs, gradually declining to about 600 cfs in September.

A main feature of the Trinity River watershed is Trinity Lake. This reservoir has a storage capacity of 2.4 million acre-feet and is located 119 miles upstream from the Klamath River along the main branch of the Trinity River (see figure 1-1). Both Trinity Lake and the much smaller downstream Lewiston reservoir were constructed in the early 1960s as part of the Central Valley Project's Trinity River Division. For the first 10 years of full operation, these reservoirs and the TRD, an average of nearly 90 percent or 1.2 million acre-feet of the annual river flow at the Lewiston reservoir (drainage area of 692 square miles) was been diverted via the Clear Creek Tunnel to Whiskeytown Lake and then to the Sacramento River system (Interior, 2000). CDWR estimates that about 1.1 million acre-feet per year were diverted during 1964 to 1986 and 0.73 million acre-feet during 1987 to 2000. Figure 3-18 illustrates the influence that diversion of flow has on the flow duration curves for the Trinity River at its confluence with the Klamath River. Data for pre- and post-TRD operation in table 3-23 shows the influence of these diversions on monthly Trinity River flows at the Klamath River confluence, which is most pronounced (lower) during April through July. Figure 3-19 shows the daily flow from the Trinity River at the confluence with the Klamath River for water years 1963 to 2004.

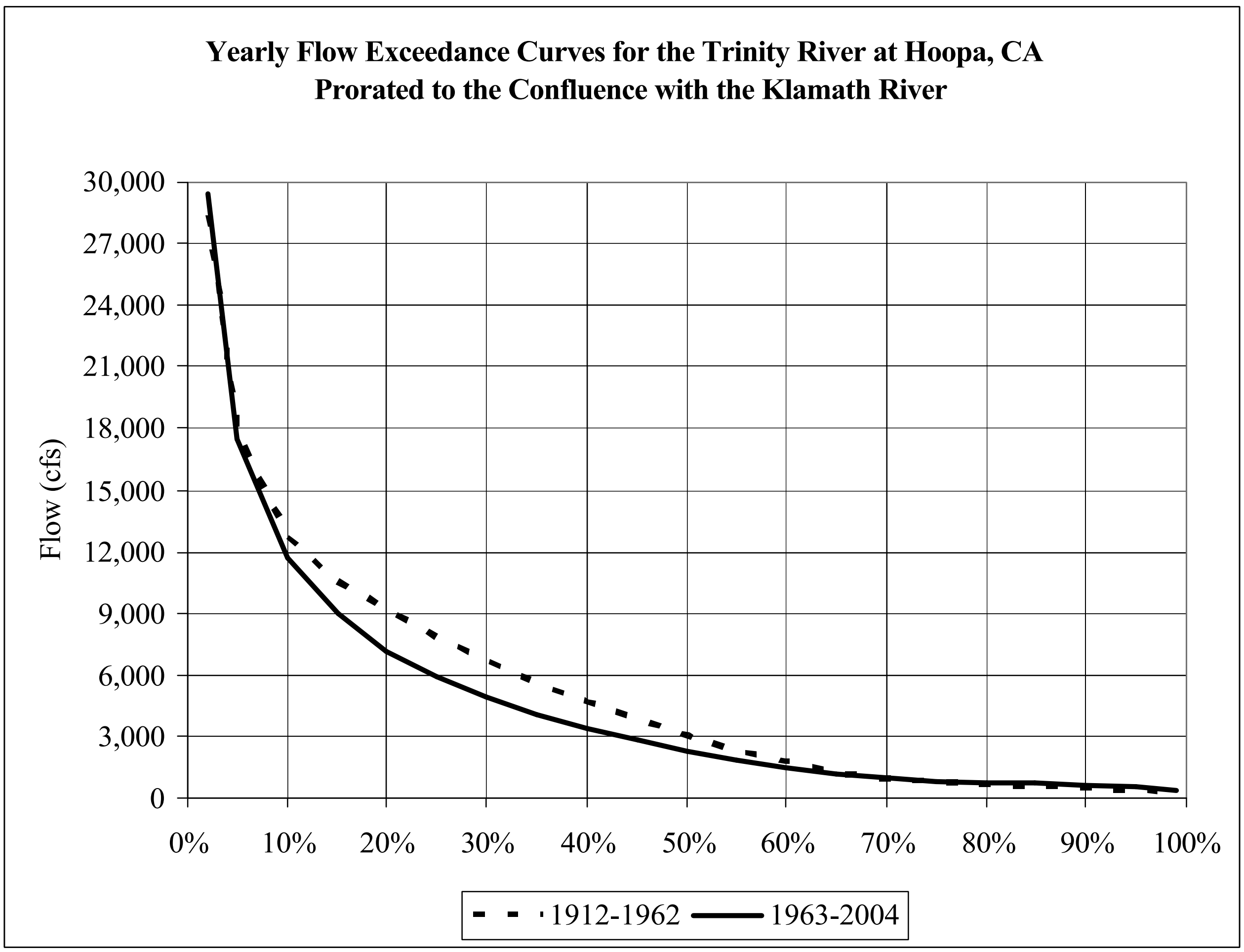
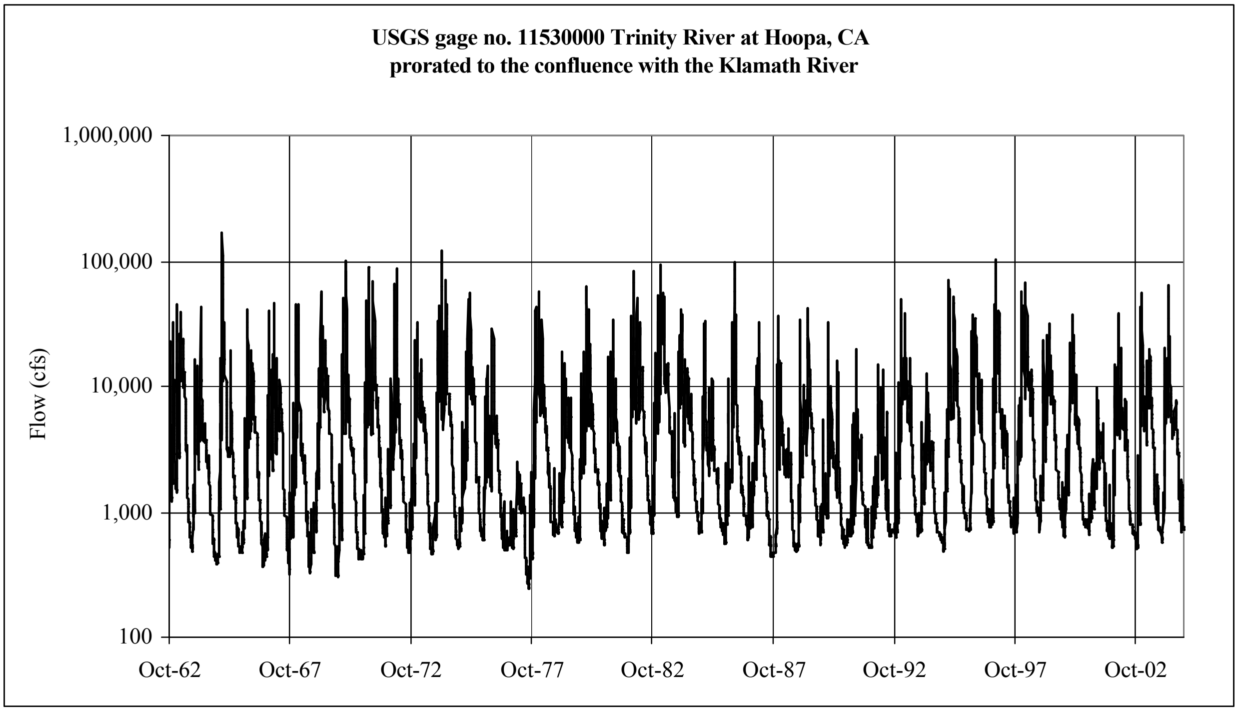


Figure 3-18. Yearly flow exceedance curves for gage no. 11530000 Trinity River at Hoopa, CA, representing pre- and post-TRD flow conditions. (Source: USGS, 2006, as modified by staff)



Note: Prorated by a factor of 1.01647 to the confluence with the Klamath River.

Figure 3-19. Daily inflow from the Trinity River at the confluence with the Klamath River for water years 1963 to 2004. (Source: USGS, 2006, as modified by staff)

The TRD has a substantial history of review and revisions to its flow regime. In 1973, the Cal Fish & Game requested that Reclamation release an annual volume of 315,000 acre-feet to reverse the steelhead and Chinook salmon declines. However, a combination of flood and drought resulted in a release of 705,000 acre-feet in 1974, 275,000 acre-feet in 1975, and 126,000 acre-feet in 1976 and Cal Fish & Game was not able to complete a formal evaluation of the effect of the flows (FWS and Hoopa Valley Tribe, 1999). In 1980, Interior prepared an EIS concerning a proposal to increase stream flows in the Trinity to restore steelhead and salmon populations. Based on this EIS, Interior issued a decision on January 14, 1981, to conduct the Trinity River Flow Evaluation to evaluate the effects on fish habitat by increasing annual releases to 340,000 acre-feet in normal and wet years, 220,000 acre-feet in dry years, and 140,000 acre-feet in critically dry years. In 1984, the Trinity River Basin Fish and Wildlife Management Act was signed by Congress, authorizing Interior to develop and implement a management program to restore the fish and wildlife populations in the Trinity River Basin to levels that existed prior to construction of the Trinity and Lewiston dams. The goals of the initial program (FWS and Hoopa Valley Tribe, 1999) included:

- Improve the capability of the Trinity River Hatchery to mitigate for salmon and steelhead fishery losses that have occurred above Lewiston dam.
- Restore natural (instream spawning) salmon and steelhead production in the mainstem and tributaries below Lewiston dam to pre-dam levels.
- Contribute to fish harvest management.
- Compensate for deer and other wildlife losses from flooding of habitat and reduced streamflow resulting from diversions to the Central Valley Project.

- Develop and implement land management activities to stabilize watersheds and reduce sediment yield to Trinity River tributaries.

The Central Valley Project Improvement Act of 1992 further supported restoration objectives and acknowledged the federal government's trust responsibilities by specifying minimum releases of 340,000 acre-feet per year pending completion of a flow evaluation study.

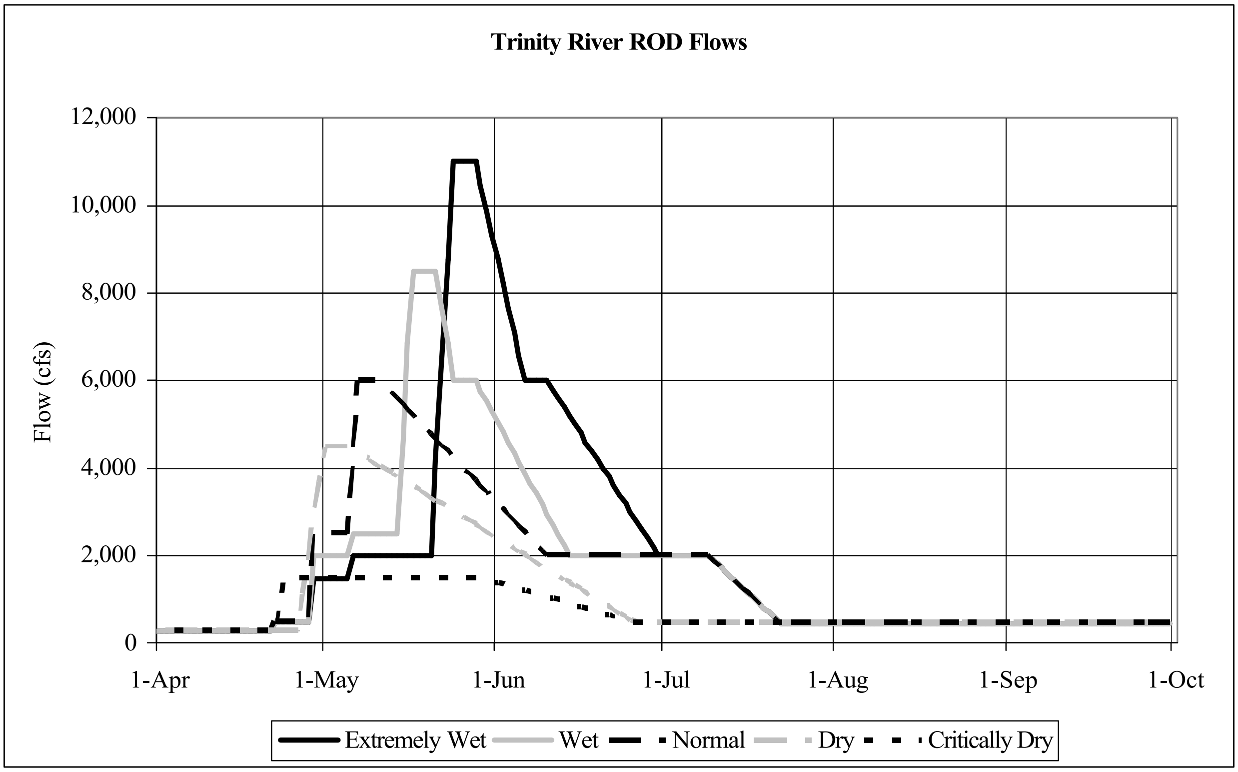
The current flow release program from Lewiston dam to the Trinity River is based on the Trinity River Mainstem Fishery Restoration EIS, completed in October 2000. In December 2000, Interior issued the Record of Decision (Trinity ROD) for the Trinity River Mainstem Fishery Restoration, but these flows did not go into full effect until November 2004. Shortly after the ROD was signed, a group of Central Valley Project water and power users filed suit to prevent its implementation. On March 19, 2001, the Eastern District Court decided that part of the decision that provided increased flows for the Trinity River, required preparation of a Supplemental EIS, and allowed other aspects of the program to proceed. Appeals were heard by the U.S. Ninth Circuit Court of Appeals, and a final ruling was issued on November 5, 2004, in favor of the defendants that directs all aspects of the program to proceed and overturned the lower court's requirement to complete the Supplemental EIS. The plaintiffs have indicated they will not appeal to the Supreme Court.

Included in the Trinity ROD, which was based partly on the Trinity River Flow Evaluation (FWS and Hoopa Valley Tribe, 1999) and other studies, was a requirement for releases from Lewiston reservoir during the spring and early summer based on the water year type. Interior states that these flows are necessary to restore and maintain the Trinity River fishery resources by:

- providing physical fish habitat (i.e., appropriate depths and velocities) and suitable temperature regimes for anadromous salmonids; and

- restoring the riverine processes that create and maintain the structural integrity and spatial complexity of the fish habitats.

In addition, the Trinity ROD provides guidelines for mechanical channel rehabilitation, sediment management, watershed restoration, infrastructure improvement, adaptive environmental assessment and management programs, and measures to minimize and mitigate effects (Interior, 2000). The Trinity ROD flow release schedule is based on five different water year types, as they are determined on April 1 each year and the total yearly releases are approximately 48 percent of the natural (pre-TRD) flow at Lewiston dam. Figure 3-20 shows the details of these releases.



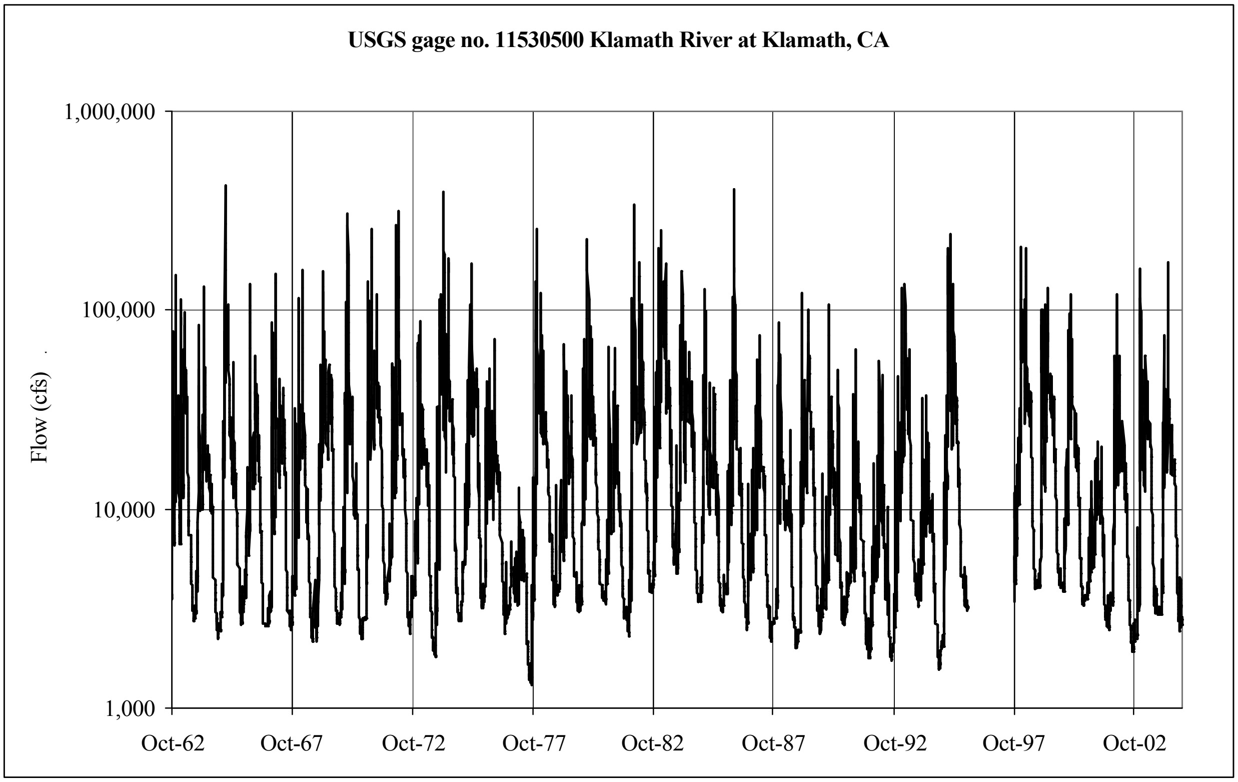
Note: Summer baseflow (late August to October 15) is 450 cfs, and winter baseflow (October 16 to late April) is 300 cfs.

Total volumes (thousand acre-feet): extremely wet 815, wet 701, normal 647, dry 453, and critically dry 369.

Figure 3-20. Flow release schedule from Lewiston reservoir based on the 2000 Record of Decision. (Source: Interior, 2000; FWS/HVT, 1999)

Klamath River at Klamath

Flows near the mouth of the Klamath River (RM 5) are measured by USGS gage no. 11530500 (see table 3-23). This gage is sometimes affected by tidal influences during low flow periods. Releases from Iron Gate dam still account for nearly 40 percent median flows of the low flow months of September and October, close to the drainage area ratio of 38 percent between Iron Gate dam and this location. During other months, especially during the winter and spring, over 85 percent of the hydrograph at this location is from sources other than releases from Iron Gate dam. Figure 3-21 shows daily flow from water years 1963 to 2004.



Note: Data for this gage during the 1963–2004 water year period do not include daily flow data for December 31, 1994 to January 6, 1995 and October 30, 1995 to September 30, 1997.

Figure 3-21. Daily flow at USGS gage no. 11530500 Klamath River at Klamath, CA for water years 1963 to 2004. (Source: USGS, 2006, as modified by staff)

3.3.2.1.2 Water Quality

The Klamath River watershed extends from southeastern Oregon to the coast of northern California. Water quality standards (referred to as objectives in California) are set by the Oregon Department of Environmental Quality (Oregon Environmental Quality) and NCRWQCB and published in the Oregon Administrative Rules (OAR) (Oregon Environmental Quality, 2003) and RWQCB Basin Plan (Basin Plan), respectively. According to Oregon Environmental Quality (2003), the existing beneficial uses within the Klamath River to the California border include: municipal and domestic supply, irrigation, stock watering, fish and aquatic life,[35] wildlife and hunting, fishing, boating, water contact recreation, aesthetic quality, hydropower, and commercial navigation and transportation.

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[35]Cool water species (no salmonid use) in the Klamath River from Upper Klamath Lake to Keno dam and redband trout from Keno dam to the California border.

According to the Basin Plan, which lists beneficial uses by hydrological area,[36] the existing and potential beneficial uses within the middle and lower Klamath River from the Oregon border to the Pacific Ocean include: municipal and domestic supply, agricultural supply, industrial service and process supply (excluding the Lower Klamath hydrological area), groundwater recharge (excluding the Copco and Iron Gate hydrological subareas), freshwater replenishment, navigation, hydropower generation, contact and non-contact water recreation, commercial and sport fishing, aquaculture, warm and cold freshwater habitat, estuarine habitat (Lower Klamath River hydrological area only), wildlife habitat, rare, threatened or endangered species, migration of aquatic organisms, spawning, reproduction, and/or early development of fish, and Native American culture (Middle Klamath hydrological area from Seiad Valley to the Pacific Ocean) (Basin Plan, 1993, as amended).

Table 3-24 shows state water quality criteria and objectives. In addition, Cal Fish & Game's management plan for the 6-mile portion of the peaking reach from the Oregon border to Copco reservoir has water quality goals consistent with its designation as a Wild Trout Area (discussed further in section 3.3.3, *Aquatic Resources*). Temperatures in this reach are not to exceed 21.1?C on an instantaneous basis and not to exceed 15.6?C for longer than 12 hours (Rogers et al., 2000).

The Oregon 2002 303(d) list reported that the Klamath River from upper Klamath Lake to the California state line was impaired because of pH, ammonia, nutrients, temperatures, dissolved oxygen (DO), and chlorophyll *a* that do not meet applicable standards (Oregon Environmental Quality, 2002). The California 2002 303(d) list reported that the entire length of the Klamath River was impaired from the state line to the river's confluence with the Pacific Ocean because of nutrients, organic enrichment, DO, and temperatures that do not meet applicable numerical or narrative water quality objectives (Water Board, 2002).

Water quality in the project area (i.e., downstream of Link River dam) is strongly influenced by the quality of water entering the Klamath River from not only Upper Klamath Lake, but also Lost River and Klamath Straits drain, in addition to its residence time within project impoundments. During wet months, sources other than the Link River provide about one-third of the total flow reaching Iron Gate dam; in midsummer, these sources may account for up to half of the total water reaching Iron Gate dam. As such, source water of diverse quality influences the quality of the water within the project-affected reaches (NAS, 2004).

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[36] The Basin Plan divides the Klamath River into two hydrological areas, the middle and lower Klamath River. The middle Klamath River is divided into seven hydrologic subareas which cover the Klamath River from the Oregon border to the confluence with the Salmon River. Copco hydrological subarea begins at the Oregon border and terminates directly above Iron Gate reservoir where the Iron Gate subarea begins. The Iron Gate hydrological subarea ends about 2 miles below the dam above the confluence with Willow Creek. The Lower Klamath River hydrological area begins at the confluence with the Salmon River and extends to the Pacific Ocean.

Table 3-24. Applicable water quality criteria and objectives for Klamath Basin in the vicinity of the Klamath Hydroelectric Project. (Source: Oregon Environmental Quality, 2003; Basin Plan, 1993)

Constituent	Oregon Criteria	California Objectives
Temperature[a]	7-day average maximum (max) not to exceed 20ºC in waters designated for redband trout. Designated cool water habitat may not be warmed more than 0.3ºC above ambient temperatures unless a greater increase would not reasonably be expected to adversely affect fish or other aquatic life.[b] If the natural thermal potential of a water body exceeds applicable criterion, the natural thermal potential becomes the applicable criterion. A cumulative temperature increase of 0.3ºC above the applicable criterion is allowed in all waters.	Shall not be altered unless demonstrated that such alteration does not adversely affect beneficial uses. At no time shall temperature be increased by more than 5ºF above natural receiving water temperature.
Dissolved Oxygen	At Oregon Environmental Quality's discretion, for waters designated for cool-water aquatic life, 30-day (D) mean minimum (min) 6.5 mg/L, 7-D mean min 5.0 mg/L, and absolute min 4.0 mg/L. At Oregon Environmental Quality's discretion, for waters designated for cold-water aquatic life, 30-D mean min 8.0 mg/L, 7-D min mean 6.5 mg/L, and absolute min 6.0 mg/L. Not less than 11.0 mg/L in active spawning areas used by resident trout species unless the minimum spatial median intergravel dissolved oxygen is 8.0 mg/L or more, in which case the criterion is 9.0 mg/L.	Minimum of 7.0 mg/L above Iron Gate dam and 8.0 mg/L below Iron Gate dam and 50% or more of the monthly means in a calendar year must be above 10.0 mg/L from the state line to the Pacific Ocean on the Klamath River. The portions of Jenny and Fall creeks in California (and all other streams in the Middle Klamath hydrologic area) must be above the minimum of 7.0 mg/L and 50% or more of the monthly means must be above 9 mg/L.
Nuisance phytoplankton growth (Oregon) and nutrients (California)	If chlorophyll *a* exceeds an action level of 0.015 mg/L,[c] Oregon Environmental Quality may conduct studies to determine impacts, causes, and control strategies. Where natural conditions exceed the action level, the action level may be modified to an appropriate value.	Waters shall not contain biostimulatory substances in concentrations that promote aquatic growths sufficient to cause nuisance or adverse effects.
pH	Values shall not fall outside the range of 6.5-9.0.[d]	Values shall not fall outside the range of 7.0-8.5.
Toxic Substances (including ammonia)	Shall not exceed criteria listed in OAR 340-041-0033, Table 20. Ammonia, as recommended by the EPA: At 20oC, the long term criteria (30 day average) when fish early life stages are present, (pH between 9.0 and 6.5) range from 0.34 mg/L to 4.68 mg/L. Acute criteria (pH between 9.0 and 6.5) range from 0.885 mg/L to 32.6 mg/L when salmonids present.	All waters shall be maintained free of toxic substances in concentrations that are toxic to, or that produce detrimental physiological responses in, human, plant, animal, or aquatic life. The Basin Plan uses the EPA recommended criteria for ammonia listed in the adjacent column.
Turbidity (NTU)	Except for certain limited duration activities, no more than a 10 percent increase above natural background levels, as measured relative to a control point immediately upstream of the turbidity causing activity.	No more than 20 percent increase above natural background levels (except as otherwise allowed by permit or waiver)

Constituent	Oregon Criteria	California Objectives
Sediment		Suspended sediment load and suspended sediment discharge rate of surface waters shall not be altered to cause nuisance or adversely affect beneficial uses.
Total Dissolved Gas	Shall not exceed 110 percent saturation[e] Shall not exceed 105 percent saturation in water < 2-feet deep	
Specific Conductance	Unless otherwise authorized by Oregon Environmental Quality, specific conductance shall not exceed a guideline value of 400 micromhos (measured at 77°F) at the Oregon-California border (RM 208.5).	At 77°F, 90% or more of the monthly mean values must be less than or equal to 425 micromhos and 50% of the values must be less than 275 micromhos above Iron Gate dam. Below Iron Gate dam 90% of the monthly mean values must be below 350 micromhos and 50% of the monthly mean values must be below 275 micromhos.
Taste and Odor	Creation of tastes or odors deleterious to aquatic life, potability of drinking water, or palatability of fish or shellfish may not be allowed	Shall not contain taste or odor producing substances that impart undesirable taste or odors to fish flesh or adversely affect beneficial uses.
Color	Objectionable discoloration may not be allowed	Waters free of coloration that adversely affects beneficial use
Floating Material	Objectionable floating solids are not allowed	Shall not contain floating solids, liquids, foams or scum that adversely affect beneficial uses.
Naturally Occurring Conditions	Less stringent natural conditions that exceed a numeric criterion become the standard	

[a] NCRWQCB has proposed amendments to the Basin Plan that would revise the instream water quality objectives for temperature and DO to fully protect salmonids by providing specific biologically based objectives for each salmonid life stage.

[b] Exceedances of temperature criteria are not violations if they occur during the warmest 7-day period of the year that exceeds the 90th percentile of the 7-day average daily max air temperature calculated in a yearly series over the historic record. Project related waters designated by Oregon Environmental Quality for redband trout include the Klamath River from Keno dam to the California state line including the J.C. Boyle bypassed and peaking reaches, and the Oregon portions of Fall, Jenny, and Spring creeks.

[c] Calculated from a minimum of three samples collected in any 3 consecutive months at a minimum of 1 representative location (e.g., mid river or deepest part of lake) from samples integrated from the surface to a depth twice the Secchi depth or the bottom, which ever is lesser of the two. The regulations also state that the standards could be met under any other methods approved by Oregon Environmental Quality.

[d] Exceedance of this criterion is not a violation if it occurs in waters impounded by dams existing on January 1, 1996, provided all practicable measures have been taken to bring pH into compliance.

[e] Exceedances of TDG criteria are not violations if they occur when stream flow exceeds 10-year, 7-day average flood.

Temperature

Oregon and California listed the Klamath River from Upper Klamath Lake to the Pacific Ocean, the Lost River, and Klamath Straits drain in 2002 on their respective 303(d) lists as temperature impaired. Monthly sampling results from March through November compiled by PacifiCorp indicate that water temperatures below Keno reservoir are typically below 10?C in March (table 3-25). Average summer temperatures (June, July, August, and September) over 20?C were observed along the Klamath River at almost all sampling sites during at least July and August. Water temperatures in Upper Klamath Lake and Link River are at or above 20?C from June through September. Water temperatures increase slightly in Keno reservoir due in part to the relatively shallow nature of the reservoir which enhances solar warming and warm agriculturally influenced water inputs from the Lost River and Klamath Straits drain. Average water temperatures below Keno dam were slightly cooler as the reach becomes steep, free flowing, and receives groundwater inputs.

In addition to the collection and compilation of longitudinal water temperature data for river reaches, PacifiCorp also conducted vertical water temperature profile monitoring near the dams in the major project reservoirs from 2000 through 2003. The results show that the shallow, upstream reservoirs (Keno and J.C. Boyle) do not exhibit long term, stable thermal stratification in the summer, and the difference between surface water temperatures and the bottom is typically less than 2?C.

Temperatures in the J.C. Boyle bypassed reach are modified by the contribution of about 250 to 300 cfs of groundwater spring flow within the reach. The associated cool water input from the bypassed reach during the summer, combined with the fluctuation in discharge from the J.C. Boyle powerhouse during normal operations, results in an increase in the daily water temperature range in the Klamath River in the peaking reach (figure 3-22, top plot). The diurnal pattern of water temperature variation is similar to sites not affected by peaking operation. The range of daily water temperature variation below the powerhouse is greatly reduced, relative to unaffected sites, under conditions of constant daily discharge (figure 3-22, lower plot).

PacifiCorp's vertical temperature profiles near the dams at Copco and Iron Gate reservoirs are based on continuously recording meters placed at 1 meter intervals from the surface to near the bottom. The profile data show seasonal (spring through fall) thermal stratification of both reservoirs into three layers: (1) the warm, upper layer referred to as the epilimnion; (2) the metalimnion, which has a strong thermal gradient; and (3) the cold, deep hypolimnion. The epilimnion begins to form in early spring, reaching maximum temperatures approaching 25°C during late July, and then gradually cools to winter minimum temperatures typically around 5°C. Year-round temperatures in the deeper portions (the hypolimnion when the reservoir stratifies) of Iron Gate reservoir typically remain below 10°C. The depth of the metalimnion varies by season, expanding as surface temperatures rise. By mid-summer, the depth of the metalimnion is around 50 feet in both Copco and Iron Gate reservoirs. Thermal stratification begins to break down by October (figure 3-23) and by November, relatively uniform temperatures, generally between 6 and 8°C, exist throughout the water column in Copco and Iron Gate reservoirs.

The surface waters of Copco and Iron Gate reservoirs are also subject to diurnal water temperature changes as a result of solar heating and variation on the order of several days in response to changing weather patterns. Diurnal variations are not evident in the deeper waters of these reservoirs because they are isolated by the thermal gradient.

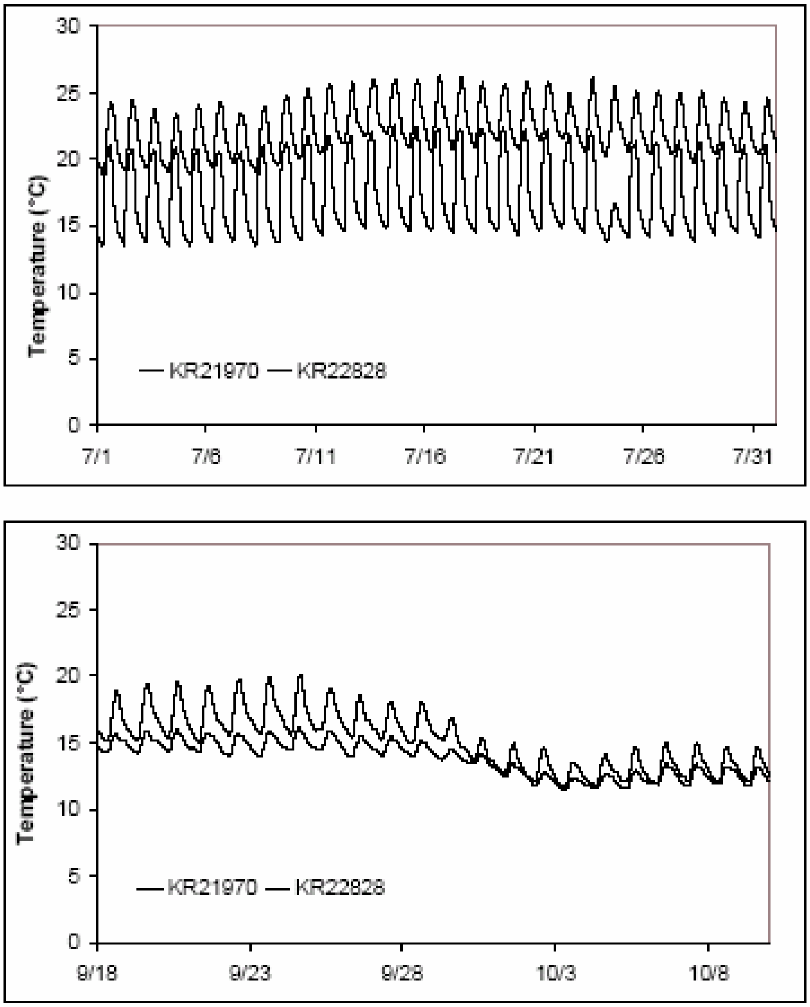
Table 3-25. Average water temperature data for stream reaches within the Klamath River Basin affected by project operation, 2000–2004. (Source: PacifiCorp, 2004a, as modified by staff).

	Average Monthly Temperature (°C)								
Station	**March**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**
Upper Klamath Lake at Freemont St. Bridge	7.3	18.6	12.9		20.4		21.1		
Link River[a]	7.7	10.2	12.8	18.6	22.3	21.4	17.5	13.1	5.6
Klamath Irrigation Project[b]			12.9	18.4	22.2	22.3	18.4	12.5	6.7
Keno reservoir[c]	7.8	9.4	12.9	18.7	22.4	20.8	18.0	12.8	7.3
Klamath River below Keno dam	8.2	10.6	13.7	19.9	23.2	21.1	16.9	14.1	5.6
Klamath River above J.C. Boyle reservoir	8.9	11.2	13.5	20.3	22.2	21.1	16.6	14.3	5.5
J.C. Boyle reservoir at log boom (top 8m)	7.7	11.9	13.5	19.7	21.9	22.5	17.2	12.8	6.2
J.C. Boyle bypassed reach, directly below J.C. Boyle dam	7.7	11.2	14.4	20.7	23.3	21.7	16.5	13.5	6.1
J.C. Boyle bypassed reach (bottom of reach)	9.7	10.8	12.0	14.8	15.8	14.9	12.7	12.0	9.0
J.C. Boyle powerhouse tailrace	7.9		13.7	13.1	22.0	21.8	16.7		11.2
Klamath River near state line (peaking reach)			12.8		18.7		14.0		
Klamath River below state line (peaking reach)			12.8		21.1		15.2		
Klamath River above Shovel Creek (peaking reach)	8.0	9.9	16.6	19.0	19.3	18.5	15.2	11.4	7.1
Copco reservoir (top 8 m) near Copco	7.2	12.1	15.1	19.8	21.9	22.2	18.1	15.3	9.1
Copco reservoir outflow	7.6	11.3	15.0	19.8	21.4	21.4	17.6	15.2	8.9
Fall Creek	9.8	8.8	10.2	12.7	12.5	13.3	10.1	11.1	8.9
Jenny Creek	6.4	11.7	14.5	19.6	22.2	22.5	19.5	16.2	10.5
Iron Gate reservoir (top 9 m) near Hornbrook	6.4	11.7	14.9	19.7	22.3	22.6	19.2	16.2	10.6
Iron Gate dam outflow			17.0	23.2	25.2	24.5	17.8	15.9	10.8
Klamath River upstream of Shasta River	8.0	5.4	10.8	16.7	20.8	20.7	13.0	13.1	7.2

[a] Sampling points include Link River near East Side powerhouse and Link River at mouth.

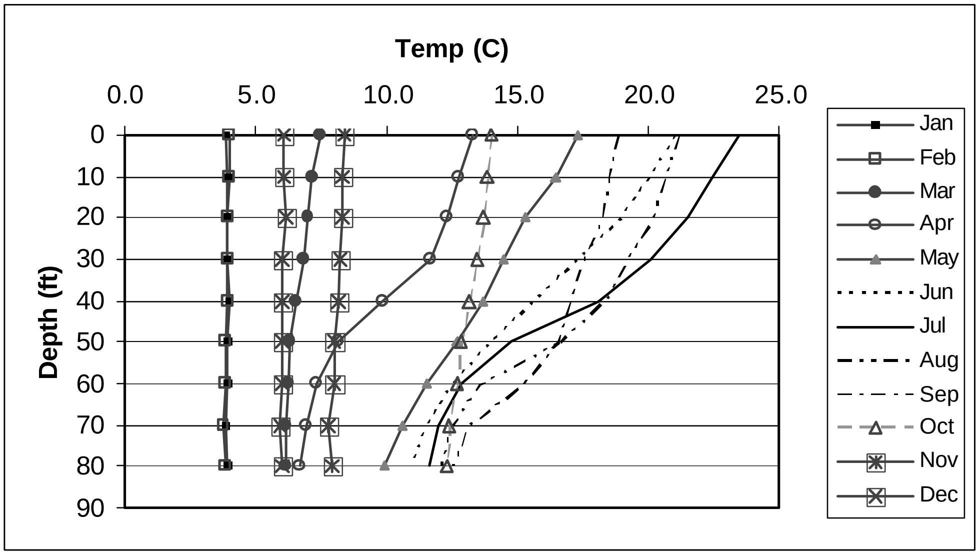
[b] Sampling points include: Lost River diversion canal at Klamath River, Klamath Straits drain pumping plant F, and Klamath Straits drain 200 feet downstream of pumping plant F. During March and April, only a single temperature reading was taken, and we do not consider those values to be representative of the average monthly inflow from the Klamath Irrigation Project; consequently, we do not report them.

[c] Sampling points include south-side bypass bridge, Miller Island boat ramp, upstream of Klamath Straits drain, between Klamath Straits drain and Keno dam, Keno Bridge (Highway 66), and Keno dam log boom.



Note: KR22828 (upper curve in both plots) – Klamath River above J.C. Boyle reservoir, KR21970 (lower curve in both plots) – Klamath River at the USGS gage below J.C. Boyle powerhouse.

Figure 3-22. Water temperatures measured above and below the J.C. Boyle development during peaking operation (top) and during non-peaking flow (bottom), 2002. (Source: PacifiCorp, 2004a)



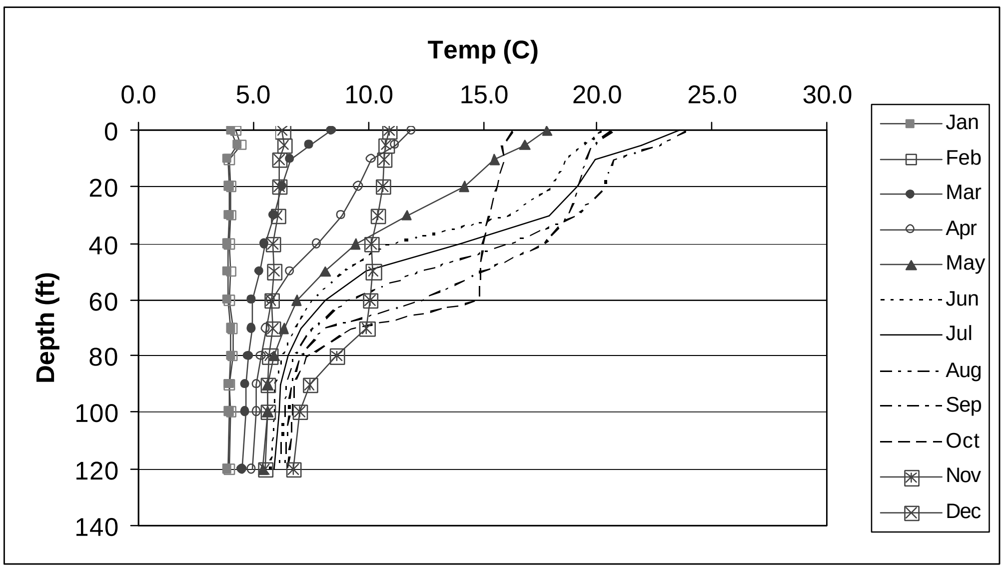


Figure 3-23. Average monthly temperature profiles for Copco (2002-top) and Iron Gate (2001-bottom). (Source: PacifiCorp, 2004a, as modified by staff)

The bottom of the Copco powerhouse intake structure is about 32 feet below full pool, and the bottom of the Iron Gate intake structure is about 30 feet below full pool. This results in water that passes through the Copco and Iron Gate powerhouses typically originating from the epilimnion during periods when the reservoirs are stratified. Figure 3-24 illustrates the close correlation of the water temperature discharged from the Iron Gate powerhouse to the water temperature measured 10 feet below the surface (epilimnetic water) immediately upstream of Iron Gate dam during the late fall and early spring months. Examination of PacifiCorp profile data indicates that, during the summer and early fall months when the reservoir is stratified, temperatures in the outfall are comparable to (within a few degrees of) water at depths between 10 and 30 feet in Iron Gate reservoir.

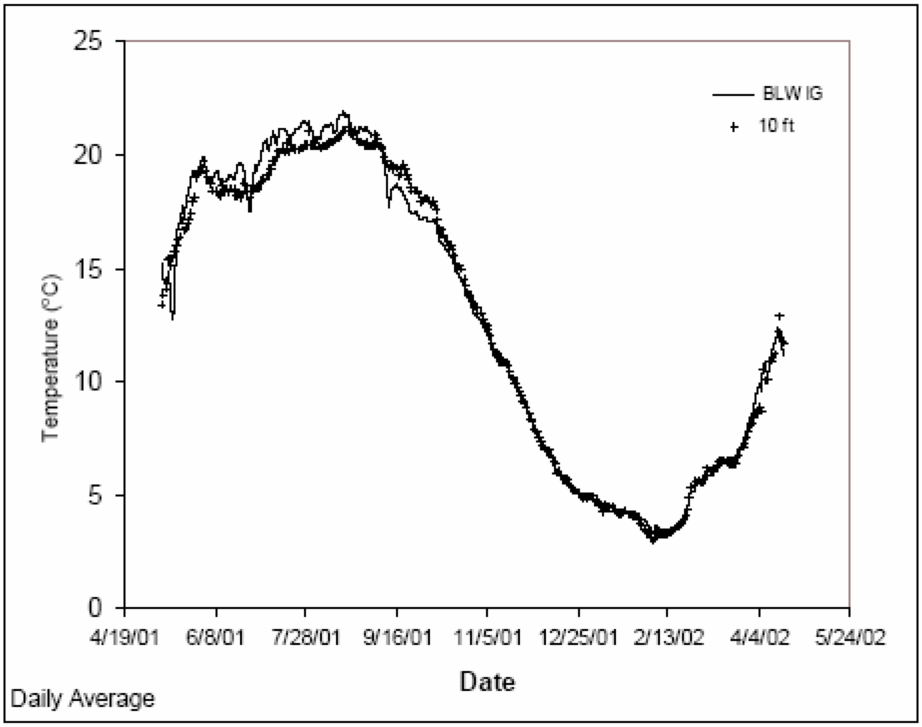


Figure 3-24. Daily average water temperature data from below Iron Gate dam and from a depth of 10 feet in the Iron Gate reservoir. (Source: PacifiCorp, 2004a)

PacifiCorp monitored the temperatures in Fall and Jenny Creeks in 2002 and Spring Creek in 2004 as part of the relicensing sampling effort to characterize the thermal regime. Fall Creek is generally cold year-round and did not exceed 14?C degrees during the summer. Temperatures in Jenny Creek experience strong seasonal variability. Monthly sampling results indicate that the creek warms from less than 10?C in the spring to above 20?C in July and August (see table 3-25), which corresponds to the period of the lowest flows of the year. The 7-day average daily maximum in Jenny Creek above the Spring Creek confluence exceeded 25?C during the warmest part of the year. PacifiCorp monitoring in Spring Creek below the diversion point indicated that temperatures never reached 20?C (PacifiCorp, 2004i). PacifiCorp concluded that, when it stopped diverting water from Spring Creek, water temperatures decreased by between 1 and 2ºC in Jenny Creek below the Spring Creek confluence with Jenny Creek; but that the actual benefit to Jenny Creek appears localized.

EPA has organized temperature data compiled for Klamath River TMDL[37] model development to present statistical trends in the data (mean, minimum, maximum) at sites downstream of Iron Gate dam. Figures 3-25 through 3-27 show the mean, minimum, and maximum water temperatures for seven sites below Iron Gate where there were more than 10 samples for each of the critical months of June, July, and August. In June, water temperatures range from about 16 to 22?C, while in July, temperatures range from 16 to 26?C. In August the minimum temperatures are higher but the maximum temperatures are lower than in July.

[37] Section 303(d) of the Clean Water Act requires that states establish a TMDL for any waterbody designated as water quality limited (CWA 303[d] list). TMDLs are written plans with an analysis that establishes what steps will be taken so that waterbodies will attain and maintain water quality levels specified in water quality standards.

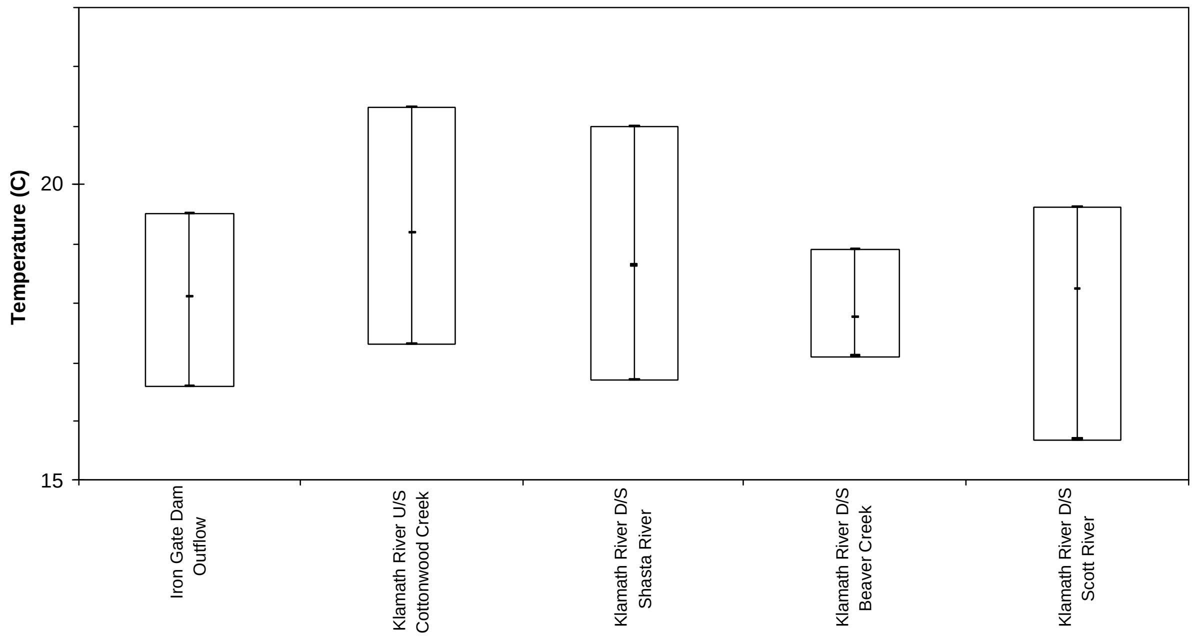


Figure 3-25. June minimum, average, and maximum temperatures along the Klamath River in 1996 and 1997. (Source: PacifiCorp, 2004a, as modified by staff).

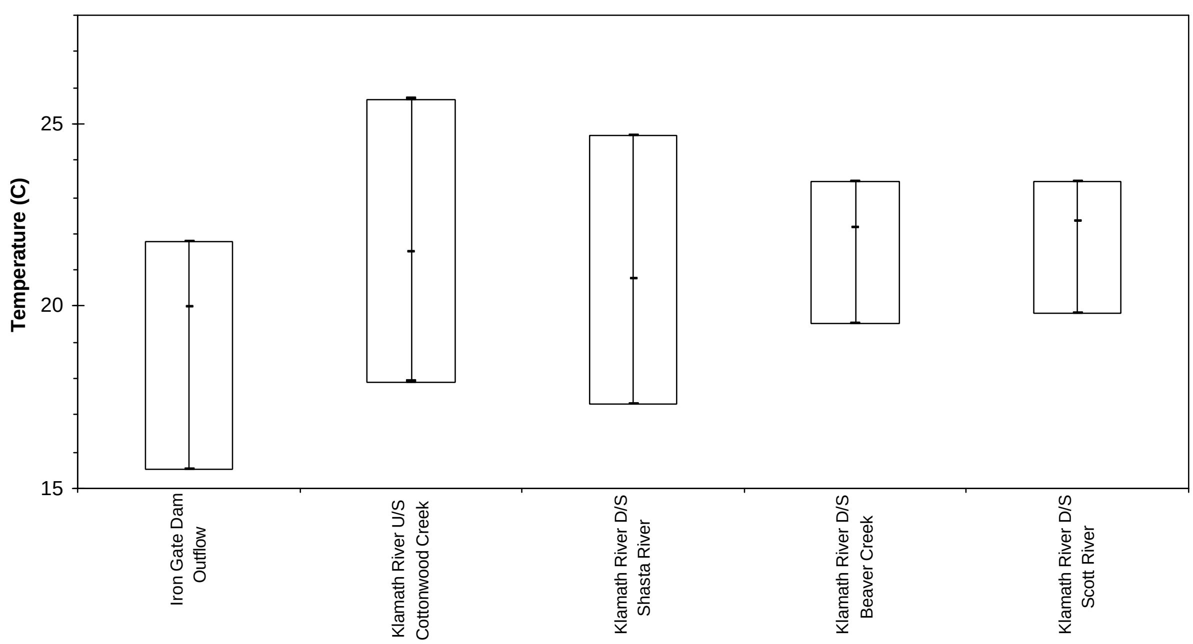


Figure 3-26. July minimum, average, and maximum temperature along the Klamath River in 1996 and 1997. (Source: PacifiCorp, 2004a, as modified by staff)

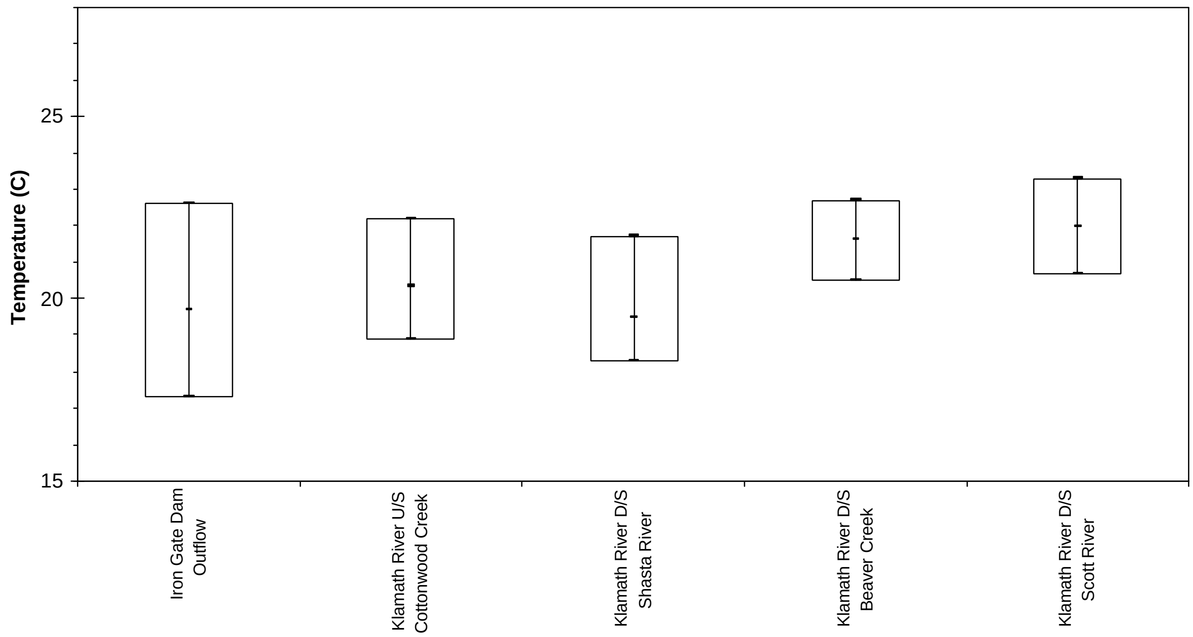


Figure 3-27. August minimum, average, and maximum temperature along the Klamath River in 1996 and 1997. (Source: PacifiCorp, 2004a, as modified by staff)

Dissolved Oxygen

Generally, average DO concentrations from samples near the surface are in compliance with applicable criteria; however, seasonal DO concentrations are quite variable (table 3-26). DO concentrations in Upper Klamath Lake respond to the primary production and respiration needs of the algal blooms and the biological oxygen demand from the aerobic decomposition of organic material in the water and, to a lesser extent, the bottom substrate. Low DO levels in Upper Klamath Lake have been associated with the period of declining algal blooms, typically in late summer and fall (Perkins et al., 2000).

PacifiCorp's DO sampling results from Keno reservoir show a longitudinal gradient; DO increases from Link River to RM 241 (near the mid-point of the reservoir), then decreases to a minimum at RM 238 downstream of Klamath Straits drain, before increasing again toward RM 235, about 2 miles upstream of Keno dam (table 3-27). This longitudinal gradient persists throughout the year. Overall, DO levels in Keno reservoir from June through September are below 6 mg/L, and some sites average below 4 mg/L in July and August.

Table 3-26. Average DO data for stream reaches and the top 9 meters of reservoirs within the Klamath River Basin affected by project operation, 2000–2004. (Source: PacifiCorp, 2004a, as modified by staff)

	Average Monthly DO (mg/L)								
Station	**March**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**
Upper Klamath Lake at Freemont St. Bridge	10.5	11.7	9.8		7.1		8.0		
Link River[a]	10.8	9.7	9.4	8.7	6.8	6.5	9.2	9.3	11.5
Klamath Irrigation Project[b]	8.5	10.0	7.4	6.5	2.4	2.3	4.1	9.1	7.1
Keno reservoir[c]	12.7	6.5	8.8	8.0	4.3	4.5	6.2	5.5	6.8
Klamath River below Keno dam	10.9	10.4	9.9	8.8	6.8	7.4	9.2	7.1	10.9
Klamath River above J.C. Boyle reservoir	10.4	10.4	9.9	8.6	7.3	8.2	8.7	8.3	12.5
J.C. Boyle reservoir at log boom (top 8 m)	10.0	9.0	10.4	7.3	5.9	4.5	7.9	8.2	10.3
J.C. Boyle bypassed reach, immediately below the dam	11.2	10.1	9.2	8.2	6.3	7.7	9.0	8.7	11.8
J.C. Boyle bypassed reach (bottom of reach)	11.2	10.8	10.3	9.8	8.9	9.8	10.0	9.4	11.7
J.C. Boyle powerhouse tailrace	11.3		8.6	10.2	6.8	5.3	8.7		9.9
Klamath River near state line (peaking reach)			8.9		7.2		7.7		
Klamath River below state line (peaking reach)			10.1		7.5		8.5		
Klamath River above Shovel Creek (peaking reach)	11.4	11.2	9.5	8.8	9.1	9.5	9.8	9.8	11.5
Copco reservoir (top 8m) near Copco	11.2	9.9	9.4	8.7	9.4	9.8	8.3	8.7	8.6
Copco reservoir outflow	10.6	9.7	9.1	8.5	6.9	8.0	7.4	7.4	9.8
Fall Creek	10.9	11.3	10.7	10.2	10.6	10.6	11.4	8.6	11.7
Jenny Creek	12.0	12.2	10.8	9.4	9.0	9.0	10.6	8.5	12.2
Iron Gate reservoir (top 9m) near Hornbrook	12.1	10.2	10.0	8.9	7.4	8.3	7.8	7.1	7.2
Iron Gate dam outflow	12.2	10.5	10.2	9.1	8.3	8.4	7.4	7.1	8.7
Klamath River upstream of Shasta River			11.2	10.4	10.5	10.2	9.7	8.4	11.5

[a] Sampling points include: Link River near East Side powerhouse and Link River at mouth.

[b] Sampling points include: Lost River diversion canal at Klamath River, Klamath Straits drain pumping plant F, and Klamath Straits drain 200 feet downstream of pumping plant F.

[c] Sampling points include: south-side bypass bridge, Miller Island boat ramp, upstream of Klamath Straits drain, between Klamath Straits drain and Keno dam, Keno Bridge (Highway 66), and Keno dam log boom.

Table 3-27. Average DO data within Keno reservoir, 2000-2004. (Source: PacifiCorp, 2004a, as modified by staff)

	Average Monthly DO (mg/L) in Keno reservoir								
Station	**March**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**
South-side bypass bridge (RM 250.79)		6.8	9.0	7.8	4.8	3.7	5.3	6.2	
Miller Island boat ramp (RM 245.89)		5.2	8.6	8.5	4.6	2.4	3.7	3.5	5.5
Upstream of Klamath Straits (RM 241.48)			9.2	8.9	5.6	7.6	8.6	5.6	
Directly south of hill 4315 (RM 238.28)		5.8	8.9	7.4	3.0	4.5	7.8	6.5	
Keno bridge (Highway 66) (RM 234.90)	12.7	7.3	8.5	7.9	3.7	5.0	6.7	6.0	7.5
Keno dam at log boom, near surface (RM 233.60)				8.8	7.1	3.2	6.4	4.7	6.9
Keno dam at log boom, near bottom (RM 233.60)			6.1	4.4	3.5	0.8	0.8	4.0	6.6

Table 3-28 shows average DO concentrations at three sampling locations within Keno reservoir during May, July, and October 2002. In May, the entire reservoir is fairly well oxygenated but by July the sites in the middle and downstream portions of the reservoir are experiencing low DO values at depth. In October, the reservoir at the Miller Island boat ramp site is still experiencing low DO values throughout the entire water column while further downstream at RM 238.28 the top 2 meters the average DO concentration is above 9.0 mg/L.

Table 3-28. Average DO concentrations from representative profiles in Keno reservoir during May, July, and October, 2002. (Source: PacifiCorp, 2004a, as modified by staff)

Depth (m)	Link River (mouth) RM 253.12			Miller Island boat ramp RM 245.89			Between Klamath Straits Drain and Keno dam RM 238.28		
	May	**July**	**October**	**May**	**July**	**October**	**May**	**July**	**October**
Surface	9.8	6.5	9.0	8.6	7.7	4.1	9.1	5.3	9.2
1	9.5	7.6	9.0	8.5	4.9	3.9	8.8	3.3	9.3
2	9.4	6.7	9.0	8.6	3.0	3.8	9.1	2.2	7.0
3	9.4	5.7	8.7	8.7	3.5	3.4	9.1	2.1	5.2
4					2.2	3.3	9.0	2.0	4.5
5					0.1	1.1	8.6	1.9	3.0
6								0.1	

Except for a localized area at the J.C. Boyle reservoir log boom where DO levels average less than 5.0 mg/L in July and August, DO levels were recorded near saturation in the free-flowing reach downstream of Keno dam to Copco reservoir. The operation of J.C. Boyle dam in peaking mode seems to have negligible effect on DO concentrations in the peaking reach because the free-flowing river upstream of J.C. Boyle provides ample opportunity for aeration (see table 3-26).

The thermal stratification in Copco and Iron Gate reservoirs isolates the bottom waters from the rest of the water column. Biological and sediment oxygen demand in Copco (and to a lesser extent in Iron Gate) reservoir in the summer (most likely resulting from aerobic decomposition of dead algae and other organic matter) cause the hypolimnion to lose oxygen.

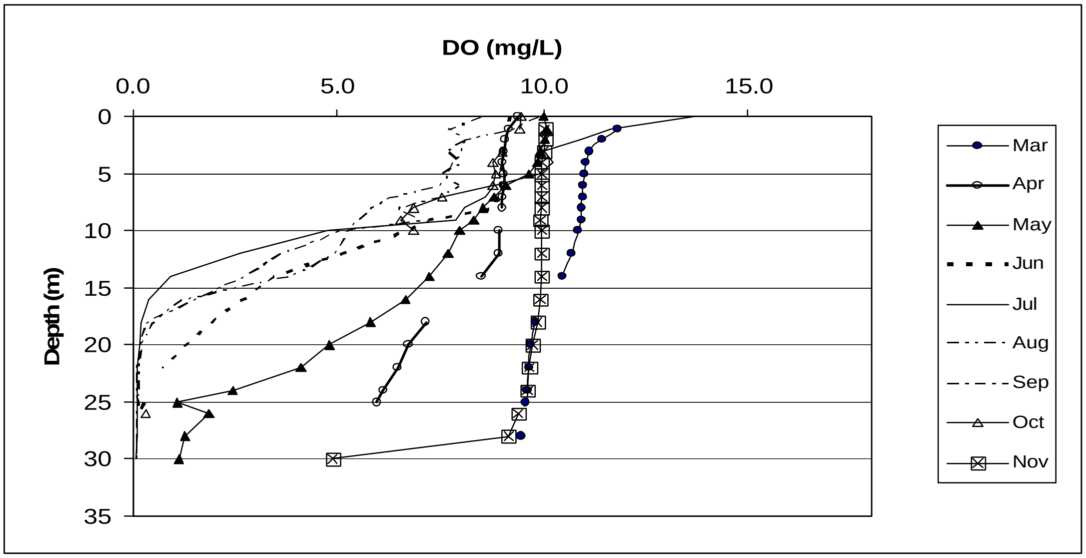
Figure 3-28 shows DO concentrations near the surface are high and near saturation at the corresponding water temperatures. However, as the summer progresses, the DO gradient between top and bottom becomes greater until the lake mixes in November. DO concentrations are similar throughout the water column as the water remains isothermal until around March when stratification begins to isolate the bottom waters. At 10 meters in Copco reservoir (approximate depth of intakes), DO concentrations in the water ranged between 4.7 and 6.8 mg/L in June, July, August, and September 2002. In Iron Gate reservoir, DO measurements taken during the same time period at 12 meters (approximate intake depth) ranged from 0.5 mg/L (September) to 6.1 mg/L (June). PacifiCorp recorded average values below the state instantaneous objective of 8.0 mg/L in September and October in the outflow from Iron Gate dam (see table 3-26). Average DO concentrations measured in the outflow from March through November ranged from 7.1 to 12.2 mg/L (six average monthly values were below 10 mg/L, which is at the limit of the annual state water quality objective; see table 3-24) with average values between June and October around 7.9 mg/L. The lowest values were observed in September and October (see table 3-26). Between the Iron Gate dam outflow and Shasta River, the water becomes oxygenated; average values in the Klamath River above the confluence with the Shasta River for June, July, and August were above 10 mg/L, with a minimum instantaneous value of 8.2 mg/L. The average DO values for September and October were 9.7 and 8.4 mg/L, respectively, showing that, at times, the river does not aerate the water to concentrations above the state's objective of 10 mg/L.

Nutrients

Water quality in the Klamath River is strongly influenced by the amount of nutrients (particularly the various forms of nitrogen and phosphorous) and algae entering project waters from Upper Klamath Lake. Sediment core studies performed by Eilers et al. (2001) concluded that Upper Klamath Lake has historically been a very productive lake with high nutrient concentrations and blue-green algae for the last 1,000 years. Walker (2001) concludes, based on sediment core analysis, that over the past 100 years the water quality of Upper Klamath Lake has changed substantially as consumptive water use practices (e.g., irrigation, municipal uses) and accompanying changes in land use practices throughout the upper Klamath and Lost River watersheds have increased. Mobilization of phosphorus from agriculture and other non-point sources (Walker, 2001), appears to have pushed the lake into its current hypereutrophic state, which includes algal blooms reaching or approaching theoretical maximum abundance. In addition, algal populations now are strongly dominated by a single blue-green algal cyanobacteria species, *Aphanizomenon flos-aquae* rather than the diatom taxa that dominated blooms before nutrient enrichment (Kann, 1998; Eilers et al., 2001). Blooms of the toxic blue green algae *Microcystis aeruginosa* have also been documented in Upper Klamath Lake (Environmental Health Perspectives, 1999)

The TMDL for Upper Klamath and Agency lakes developed in 2002 by Oregon Environmental Quality and approved by EPA identifies these interconnected lakes as hypereutrophic. They have high nutrient loading which promotes correspondingly high production of algae, which in turn, modifies physical and chemical water quality characteristics that can directly diminish the survival and production of fish populations. The TMDL identifies phosphorous loading targets as the primary strategy in improving water quality.

There is considerable water quality data available for Upper Klamath Lake, particularly from the past decade as Oregon Environmental Quality prepared the Upper Klamath Lake TMDL. Total phosphorus concentrations in Upper Klamath Lake and its outflow to the Klamath River can exceed 300 µg/L (figure 3-29).



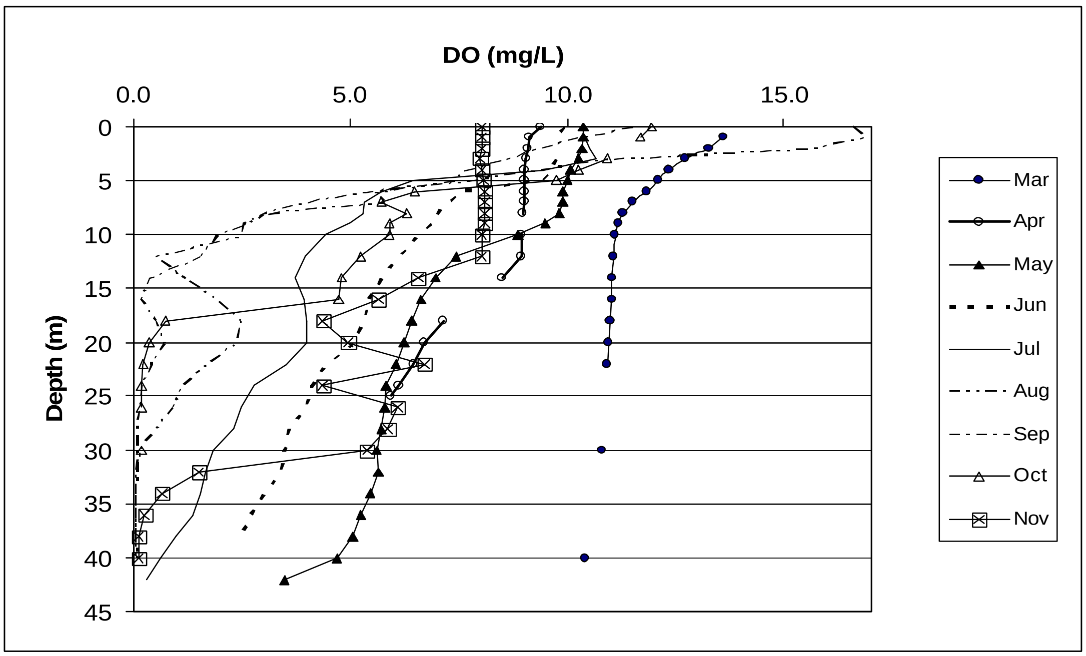


Figure 3-28. Average DO concentrations at 1 meter intervals in Copco (top) and Iron Gate (bottom) reservoirs from March through November, 2002. (Source: PacifiCorp, 2004a, as modified by staff)

Total phosphorus in Upper Klamath Lake tends to rise during spring and remains elevated through summer (figure 3-30). Oregon Environmental Quality (2002) reports that the spring rise in total phosphorus results mainly from increases in phosphorus loading during spring runoff events from sources external to the lake and that the continued high concentrations in outflow during summer is the result of internal loading to lake waters from nutrient rich sediments and algal bloom die-offs. Oregon Environmental Quality reports that the fall period is when phosphorous levels drop due to phosphorous settling out of the water column into the sediments. On an average annual basis, external sources make up 39 percent and internal sources make up 61 percent of the total phosphorus load (Oregon Environmental Quality, 2002).

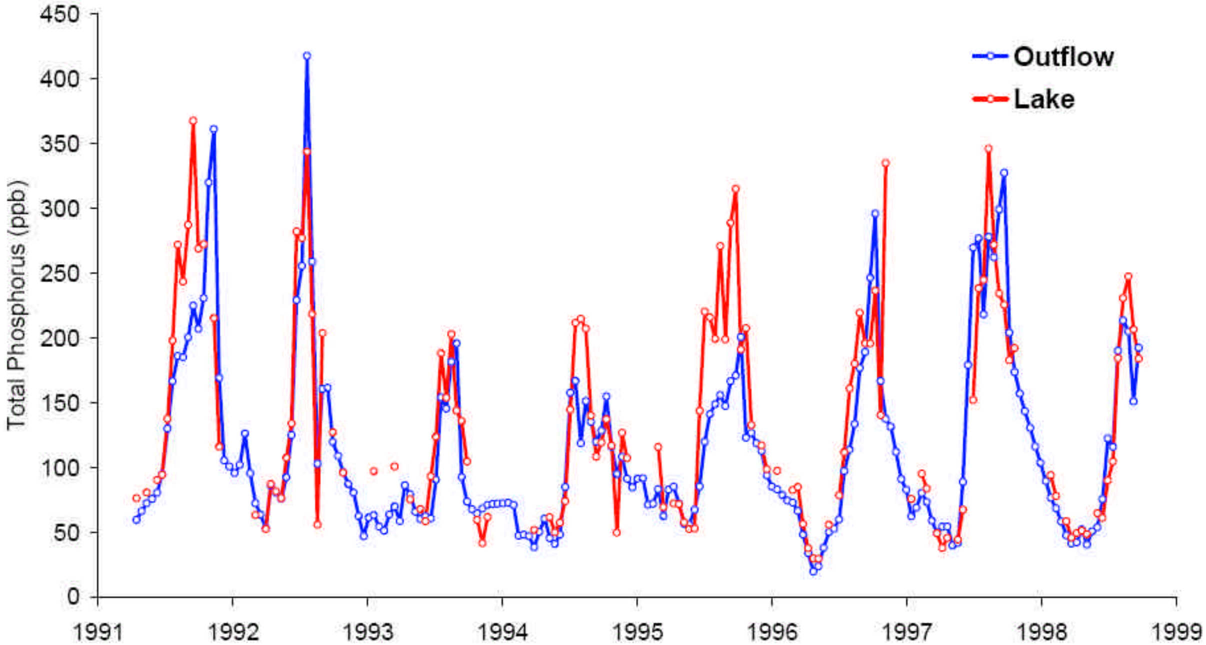


Figure 3-29. Total phosphorous values measured during 1991 to 1999 in Upper Klamath Lake and its outflow. (Source: Oregon Environmental Quality, 2002)

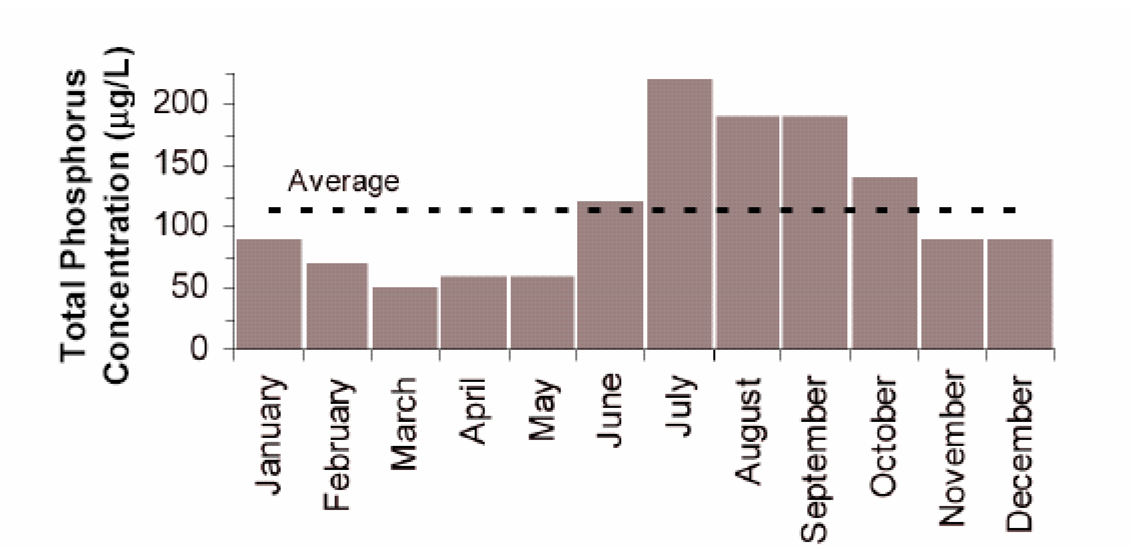


Figure 3-30. Upper Klamath Lake mean total phosphorus concentrations (1991 – 1998). (Source: Oregon Environmental Quality, 2002)

Upper Klamath Lake is also a seasonally substantial source of nitrogen (Kann and Walker, 2001; Oregon Environmental Quality, 2002). The primary source for this nitrogen loading is from nitrogen fixation by *Aphanizomenon*. Oregon Environmental Quality (2002) reports that the average outflow total nitrogen load was about 3.5 times the inflow load from 1992 to 1999. Another potential source is the mobilization of inorganic nitrogen from lake sediments during anaerobic bacterial decomposition.

Water quality in the project-affected reaches of the Klamath River exhibits the characteristics of its source waters—Upper Klamath Lake and agricultural returns into Keno reservoir. Agricultural returns have substantial amounts of sediments, nutrients, and higher temperatures resulting from its course through agricultural fields and canals. Municipal and industrial inflows to Keno reservoir, which represent about 1 percent of the inflow, are additional sources of nutrients.

Figure 3-31 shows PacifiCorp monthly total phosphorus and orthophosphate sampling data within Keno reservoir taken in June, July, August, and September from 2000 through 2003. The data show elevated total phosphorous and orthophosphate inputs from the Klamath Straits drain, as measured at pumping plant F. Overall, total phosphorous levels in this reach are high and continue to support extensive algae abundance during the summer months (see later discussion of algae).

Downstream of Keno dam, including the J.C. Boyle development, the Klamath River generally becomes steep and free flowing, providing good mixing and aeration. PacifiCorp sampling results from the top and bottom of J.C. Boyle reservoir near the dam show no substantial difference in total phosphorous, orthophosphate, nitrate, and ammonia.

Mean total phosphorus concentrations from summer sampling is lower in the J.C. Boyle bypassed reach than at sites upstream, and gradually increases downstream reaching the highest levels observed in PacifiCorp's sampling program in the bottom of Copco reservoir (figure 3-32, top). Mean orthophosphate phosphorus concentration, although slightly lower in the J.C. Boyle bypassed reach, is not markedly different in the peaking reach or waters entering Copco reservoir than it is below Keno dam (figure 3-32, bottom). A USGS water quality study initiated in 1996 (Campbell, 2001) to characterize water quality as it affects anadromous fish production concluded that both total and ortho-phosphorus concentrations have a tendency to increase in a downstream direction from Keno to Iron Gate dams. This conclusion is consistent with PacifiCorp's 2000-2003 data.

Oregon Environmental Quality included the Klamath River on the 303(d) list of water quality-impaired water bodies with respect to ammonia, based on data collected from 1985 to 1996. Conditions of pH, temperature, and ammonia-nitrogen concentration during 2000 through 2002 were such that PacifiCorp concluded that a number of sites exceeded the EPA-recommended ammonia toxicity criterion for un-ionized ammonia.[38] Thirty-four percent (178 of 519) of ammonia samples throughout the project area in 2000 through 2002 exceeded the acute toxicity criterion. Most of those samples (64) were from Keno reservoir and water near the bottom of J.C. Boyle (19), Copco (22), and Iron Gate reservoirs (13).

According to PacifiCorp's sampling results, nitrogen undergoes somewhat more complex changes than phosphorus. Figure 3-33 shows the minimum, mean, and maximum nitrate and ammonia concentrations in Keno reservoir. Mean concentrations of ammonia are high in the upstream portion of Keno reservoir and decrease downstream with distance from Keno dam (figure 3-34) with the exception of the bottom of Copco reservoir. The pattern of mean nitrate nitrogen concentration is the converse of ammonia nitrogen. Along the Klamath River, nitrate concentrations are quite low in the upper portion of Keno reservoir above Klamath Straits drain and then increase to a high in the bottom of J.C. Boyle reservoir (mean of 0.7 mg/L). Ammonia levels that exceed between 0.232 and 6.06 mg/L on a long-term basis (30-day average continuous concentration) and 0.885 and 32.6 mg/L on a short-term basis (1 hour average) are considered toxic to aquatic life (EPA, 1999). The range of values observed in the peaking reach is fairly narrow (0.1 to 0.8 mg/L) compared to Copco and Iron Gate reservoirs downstream (figure 3-34). Results from the 1996 USGS water quality study (Campbell, 2001) showed that ammonia, total Kjeldahl nitrogen, total nitrogen and total organic nitrogen concentrations showed a strong tendency to decrease in a downstream direction and nitrate concentrations tended to increase in a downstream direction. The USGS conclusion for the nitrogen-based nutrients, specifically ammonia and nitrate nitrogen, shows some inconsistencies with PacifiCorp's results.

[38] Ammonia toxicity depends on temperature and pH. When salmonids are present, the acute toxicity level is between 0.885 to 32.6 mg/L at 9.0 and 6.5 pH units, respectively. In general, higher temperatures and higher pH values in the water result in lower ammonia toxicity criteria.

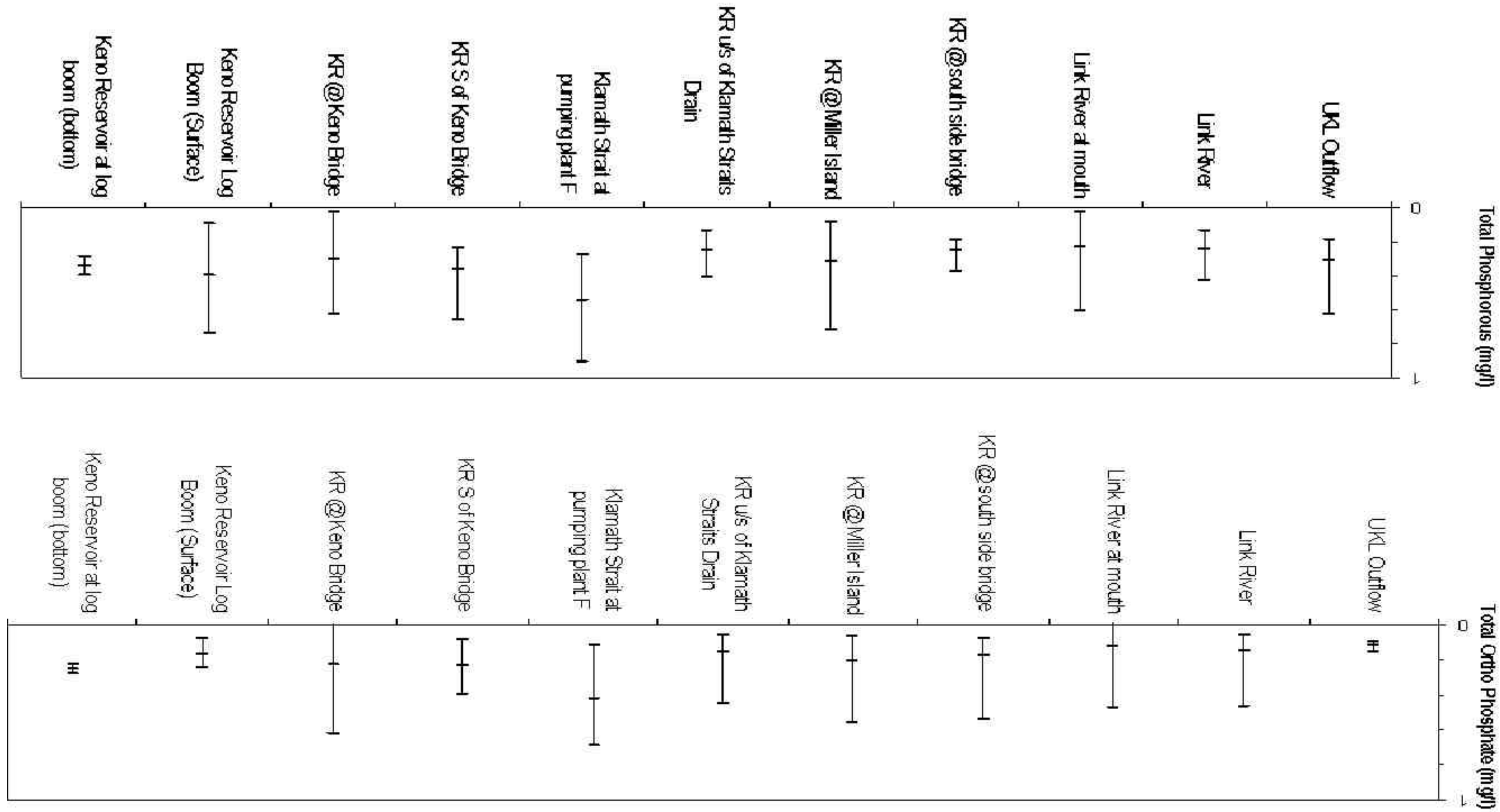


Figure 3-31. Minimum, mean and maximum total phosphorous (top) and orthophosphate (bottom) concentrations (mg/L) in the Klamath River between Upper Klamath Lake and Keno dam during June, July, August, and September 2000-2003. (Source: PacifiCorp, 2004a, as modified by staff)

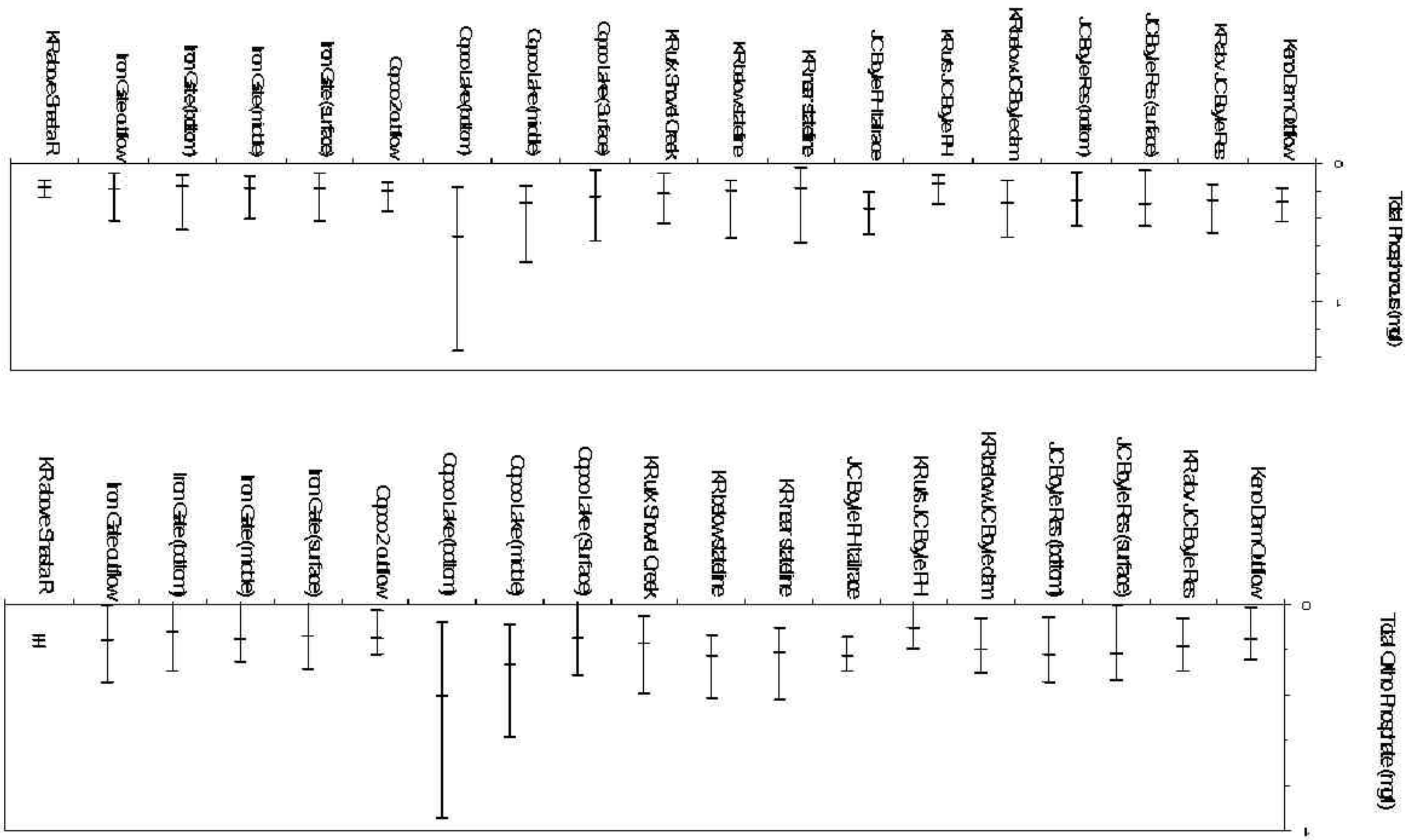


Figure 3-32. Minimum, mean and maximum total phosphorous (top) and orthophosphate (bottom) concentrations (mg/L) in the Klamath River from Keno dam to the confluence with the Shasta River during June, July, August, and September 2000-2003. (Source: PacifiCorp, 2004a, as modified by staff)

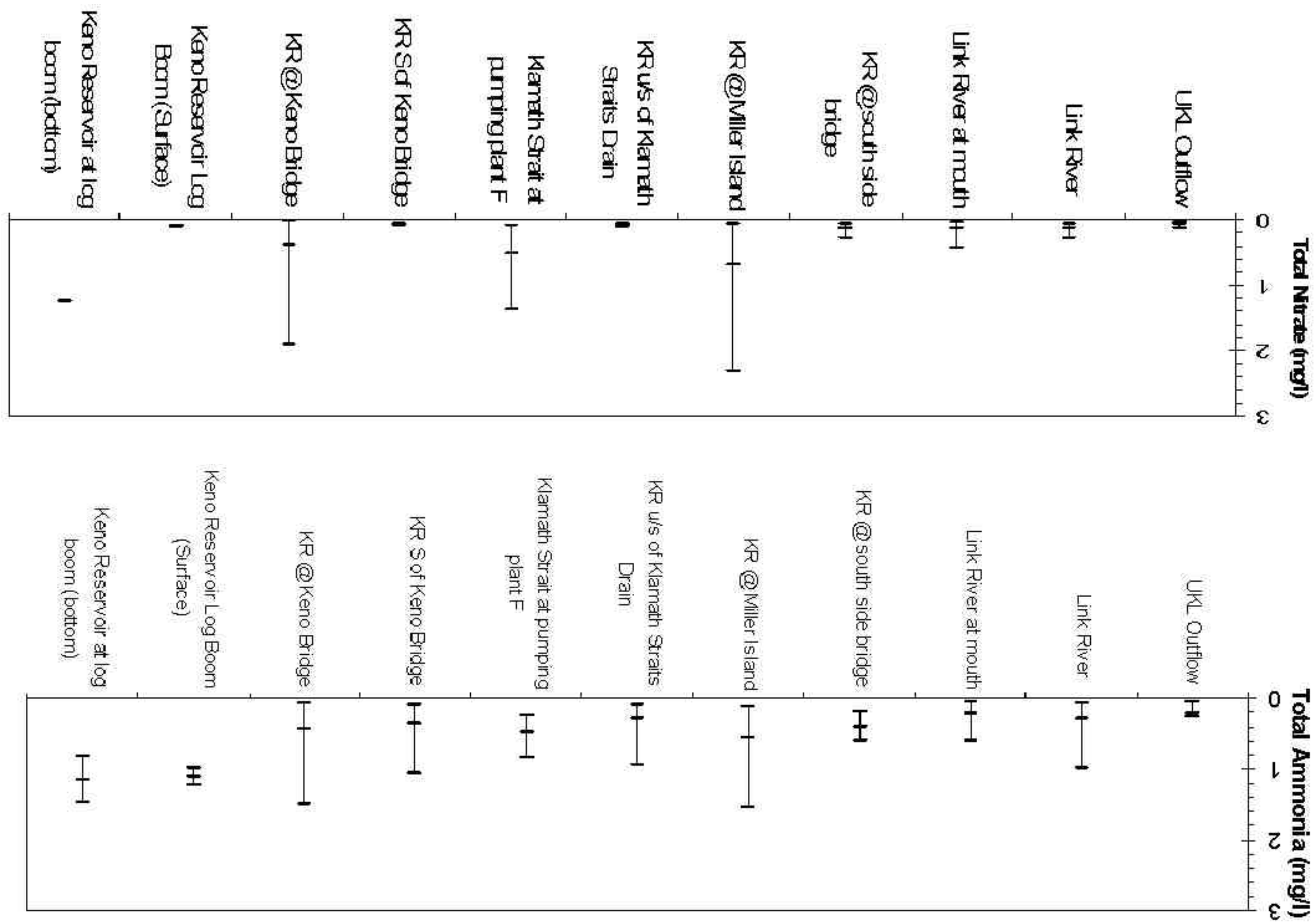


Figure 3-33. Minimum, mean, and maximum total nitrate (top) and ammonia (bottom) nitrogen (mg/L) concentrations in the Klamath River between Upper Klamath Lake and Keno dam during June, July, August, and September 2000–2003. (Source: PacifiCorp, 2004a, as modified by staff)

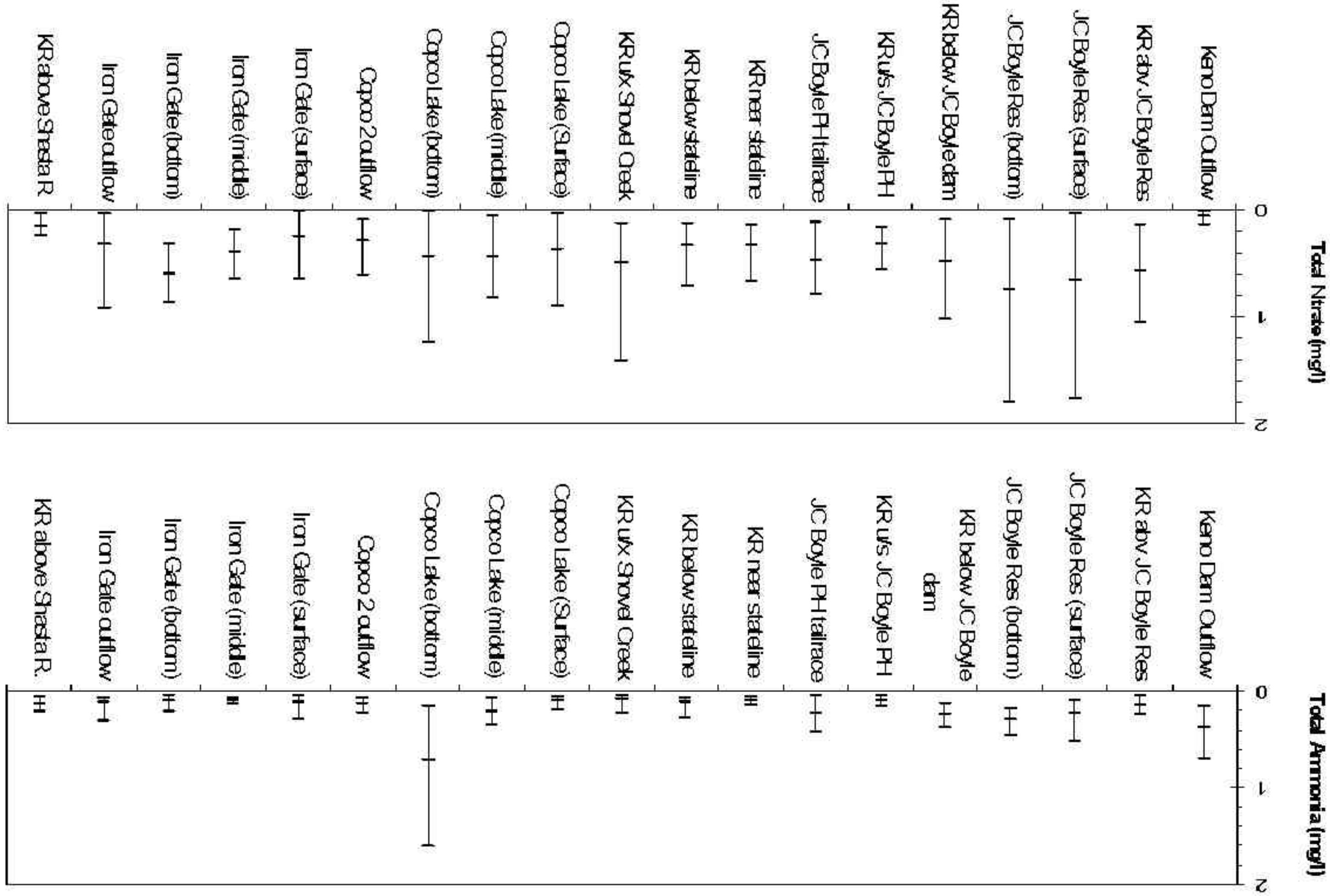


Figure 3-34. Minimum, mean, and maximum total nitrate (top) and ammonia (bottom) nitrogen (mg/L) concentrations in the Klamath River between Keno dam and the confluence with the Shasta River during June, July, August, and September 2000-2003. (Source: PacifiCorp, 2004a, as modified by staff)

Both Copco and Iron Gate reservoirs nutrient sampling results exhibit the characteristics of productive, stratified lakes. PacifiCorp's data show that Copco reservoir has a much higher annual concentration of ammonia, orthophosphate, total phosphorus, and nitrate in the hypolimnion than in the epilimnion (see figures 3-32 through 3-34). Concentrations of these constituents are at their greatest during the summer months as the reservoir thermally stratifies (table 3-29). PacifiCorp's total phosphorus sampling data from Copco reservoir indicates that the mean values from the hypolimnion are greatest in August and September (0.5 and 0.7 mg/L, respectively); however, by November, when the water column is isothermal, the concentration drops to 0.1 throughout the entire water column. In Iron Gate reservoir, total phosphorous concentrations are the same in both epilimnion and hypolimnion, or even lower in the hypolimnion than the epilimnion and at concentrations well below those seen in Copco reservoir in the summer (figure 3-32, top).

Table 3-29. Mean total phosphate, orthophosphate, and ammonia (mg/L) in Copco and Iron Gate reservoirs from samples collected between 2000 and 2004. (Source: PacifiCorp, 2004a, as modified by staff)

Station	**June**	**July**	**August**	**September**	**October**	**November**
Total Phosphorous						
Copco (top 8 m)	0.2	0.2	0.2	0.2	0.1	0.1
Copco (9-19 m)	0.2	0.3	0.3	0.2	0.2	0.1
Copco (20-32 m)	0.3	0.3	0.5	0.7	0.5	0.1
Iron Gate (top 9 m)	0.2	0.1	0.1	0.2	0.1	0.1
Iron Gate (9-19 m)	0.1	0.1	0.1	0.2	0.1	0.1
Iron Gate (20-45 m)	0.1	0.1	0.1	0.2	0.2	0.2
Orthophosphate						
Copco (top 8 m)	0.1	0.1	0.2	0.1	0.1	0.0
Copco (9-19 m)	0.2	0.2	0.4	0.2	0.1	0.1
Copco (20-32 m)	0.2	0.3	0.4	0.6	0.5	0.0
Iron Gate (top 9 m)	0.1	0.1	0.1	0.2	0.1	0.1
Iron Gate (9-19 m)	0.1	0.1	0.1	0.2	0.1	0.1
Iron Gate (20-45 m)	0.1	0.1	0.1	0.1	0.2	0.1
Ammonia						
Copco (top 8 m)	0.1	0.1	0.1	0.2	0.2	0.1
Copco (9-19 m)	0.2	0.1	0.2	0.3	0.3	0.1
Copco (20-32 m)	0.3	0.3	0.7	1.1	1.0	0.1
Iron Gate (top 9 m)	0.1	0.0	0.1	0.1	0.2	0.1
Iron Gate (9-19 m)	0.1	0.1	0.1	0.1	0.4	0.1
Iron Gate (20-45 m)	0.1	0.0	0.1	0.2	0.3	0.3

The amount of oxygen present in the water also affects nutrient chemistry. Extended periods of anoxia (low or zero oxygen) promote conditions that result in the reduction of nitrate to ammonia and can lower the oxidation-reduction potential (redox potential – a measure of the electrical potential of ions in the water) to the point that phosphorus is released from the sediment. Such conditions occur regularly in Copco reservoir, especially in August and September, but rarely in Iron Gate reservoir (PacifiCorp, 2004a). The differences in redox potential in the reservoirs are reflected in nutrient concentrations in the hypolimnion. Orthophosphate and ammonia are noticeably more abundant in the hypolimnion of Copco reservoir than in Iron Gate reservoir (figures 3-32 and 3-34 and table 3-29).

Seasonal changes in water quality constituents below Iron Gate dam are not large (table 3-30). Orthophosphate and total phosphorous concentrations are highest in March with little variability throughout the rest of the year and little difference between the two sampling locations. Ammonia concentrations remain fairly constant throughout the year, with occasional high values in May, September, and October. Notably, ammonia values near Shasta River are considerably higher in October compared to concentrations measured below Iron Gate dam. Nitrate tends to increase slightly in the fall at both sampling locations.

Table 3-30. Water quality constituents at sites sampled downstream from Iron Gate dam. (Source: PacifiCorp, 2004a; as modified by staff)

Month	Iron Gate dam outflow, mean 2000-2004 (mg/L)				Above Shasta River, mean of 2002 and 2004 data (mg/L)			
	TP	PO_4	NH_3	NO_3	TP	PO_4	NH_3	NO_3
March	0.38	0.36	0.07	0.23				
April	0.16	0.08	0.05	0.34				
May	0.14	0.10	0.13	0.15	0.09	0.06	0.16	0.09
June	0.17	0.15	0.10	0.18	0.13	0.09	0.06	0.02
July	0.17	0.13	0.11	0.23	0.15	0.13	0.04	0.06
August	0.14	0.14	0.08	0.16	0.15	0.15	0.10	0.09
September	0.19	0.14	0.14	0.44	0.14	0.11	0.15	0.21
October	0.13	0.12	0.14	0.38	0.12	0.12	1.99	0.24
November	0.10	0.10	0.2	0.4	0.12	0.10	0.07	0.36

The ratio of total nitrogen to total phosphorus in the Klamath River system is below 7 (median = 6.6). This ratio has been used as an approximate indicator of relative nutrient limitation of phytoplankton in lakes. A ratio of N:P more than about 10:1 (by weight) generally indicates phosphorus limitation. The median N:P ratio in the project area equals 6.6:1, and only about 20 percent of all values are greater than 10:1. This condition holds from Link River dam to Iron Gate dam, which suggests that phytoplankton growth in the Klamath River is strongly nitrogen-limited. Abundant phosphorus, coupled with limited nitrogen and warm water, provides advantageous conditions for nitrogen-fixing species, so it is not surprising that the project reservoirs support blooms of the nitrogen-fixing cyanophyte, *Aphanizomenon flos-aquae.*

Sediment Oxygen Demand

PacifiCorp commissioned a sediment oxygen demand (SOD) study to analyze sediment core samples from Keno, J.C. Boyle, Copco, and Iron Gate reservoirs in 2003. More recently, Eilers and Raymond (2005) performed a similar study in Lost River and Keno reservoir to enhance current TMDL model development. USGS also commissioned SOD sampling in Keno reservoir in 2003.

PacifiCorp's study showed that SOD in project reservoirs ranged from 1.5 to 4.7 g/m^2/day. SOD in reservoirs above J.C. Boyle dam was all above 2.0 g/m^2/day, while SOD in Copco and Iron Gate reservoir was between 1.0 and 2.0 g/m^2/day. Results from Eilers and Raymond (2005) are consistent with PacifiCorp's work where SOD in the Lost River and Lake Ewauna ranged from 1.32 to 3.61 g/m^2/day. The results indicate that the oxygen dynamics of the upper study area, especially at Keno reservoir, are controlled to a large extent by the nature of the water entering the system rather than sediment/water interactions in the impounded areas. Where anaerobic conditions exist for extended periods, nutrients and other constituents can be released from the sediment, and such effects may play a larger role in water quality dynamics in the hypolimnion in Copco and Iron Gate reservoirs.

SOD rates measured by USGS in June 2003 (USGS, 2003) at 16 sites in Keno reservoir and published as provisional results ranged from 0.6 to 3.11 (median of 2.15) g/m^2/day. Results from the Eilers and Raymond 2005 study are consistent with results of the earlier Eilers and Gubala study and USGS (2003). PacifiCorp concludes that, although sediments exert an oxygen demand, the SOD in the water column is less than the biological demand in Keno and J.C. Boyle reservoirs.

Water enters Keno reservoir with a substantial biological oxygen demand (BOD) present, presumably derived from decomposition of the entrained cyanobacteria (Eilers and Gubala, 2003). Eilers and Gubala (2003) conclude that BOD in the waters of the Lake Ewauna (upper) portion of Keno reservoir overshadows the effects of the sediment in the lower portion of Keno reservoir and J.C. Boyle reservoir to a considerable degree. In Copco and Iron Gate reservoirs, BOD is lower and sediment effects become a more important influence on the quality of the overlying water.

Algae

Algae within the Klamath River are an important component to the overall water quality and water chemistry processes affecting water quality within the system. The seasonal blooms and die offs of algae in response to conditions within the water at various locations throughout Upper Klamath Lake and the project waters have consequences throughout the entire system. In Upper Klamath Lake, algae productivity is associated with DO that shows extreme daily variation (high during the day and low at night) and elevated pH and free ammonia concentrations that do not meet Oregon's water quality standards (Kann and Walker, 2001; Walker, 2001), and chlorophyll *a* concentrations (a surrogate measure of planktonic algae abundance) exceeding 200 µl/L are frequently observed during the summer months[39] (Kann and Walker, 2001). Carlson Trophic State Index (TSI)[40] values calculated from PacifiCorp monitoring data (based on chlorophyll *a* concentrations) for Upper Klamath Lake at the Freemont St. Bridge range from 55 in May to 77 in June.

As expected, chlorophyll *a* concentrations are higher in the reservoirs than the river sections directly upstream except for Link River. The average chlorophyll *a* concentration entering Keno reservoir from Link River is 57 µg/L with a peak concentration of 257 µg/L in July. Peak algal abundance (chlorophyll *a* concentrations near 300 µg/L) in Keno reservoir occurs in June. TSI index values based on monthly chlorophyll *a* in Keno in July, August, and September ranged from 64 to 70.

Water entering J.C. Boyle reservoir has an average chlorophyll *a* concentration of 14.5 µg/L with a peak concentration of 58 µg/l. Chlorophyll *a* concentrations steadily decrease downstream of the J.C. Boyle powerhouse. The average and peak chlorophyll *a* concentration in the peaking reach is 7.8 µg/L and 23 µg/L, respectively. Sampling results near the Copco and Iron Gate dams show that both reservoirs are highly productive. The average and peak chlorophyll *a* values at Copco reservoir were 10.7 µg/L and 44 µg/L, respectively, and at Iron Gate reservoir, 10.3 µg/L and 58.0 µg/L, respectively. The chlorophyll *a* concentrations in both reservoirs varies seasonally (figure 3-35). Generally, monthly Carlson TSI values for chlorophyll *a* decrease from upstream to downstream in Keno, J.C. Boyle, and Copco reservoirs with all values in Copco in the 40 to 50 range. TSI values in Iron Gate are slightly higher than those calculated for Copco, but within the same range. There is a predictable sequence of algal taxa in both reservoirs. During March there is typically a bloom of diatoms, followed by a period of relatively low chlorophyll abundance. Chlorophyll usually peaks in August and September when dense blooms of the nitrogen-fixing cyanophyte (blue-green alga) *Aphanizomenon flos-aquae* occur.

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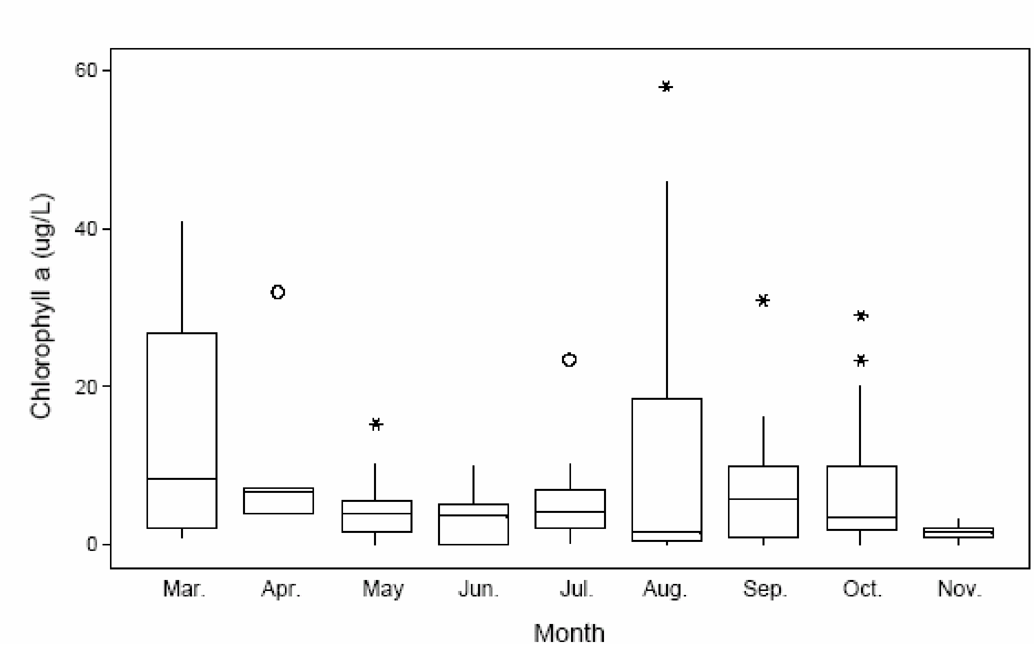
[39] The Organization for Economic Cooperation and Development has established lake classifications for various levels of biological productivity. Lakes with a mean of 25 ug/L or a peak concentration of 75 µl/L of chlorophyll *a* respectively are considered hypereutrophic (Phillip Williams and Associates, 2001). Wetzel (2001) defines freshwater lakes with concentrations of chlorophyll *a* greater than 10 µg/L as eutrophic (Wetzel, 2001).

[40] Carlson TSI is a generally accepted index of trophic status of lakes based on the relationship of the seasonal means of Secchi disk, chlorophyll *a*, and total phosphorus. Generally, the "greener" the lake, the higher the TSI number, and the lower the water visibility. Conditions are considered eutrophic when TSI values are between 51 and 70, and hypereutrophic when values are above 70.



Notes: The limits of the box enclose the central 50 percent of the distribution. The horizontal line in the middle of the box represents the median value. The vertical lines (whiskers) at the top and the bottom of the box indicate the range of "typical" data values. Whiskers extend to the largest or smallest data point that is within 1.5 times the IQR from the limits of the box. Any values beyond 1.5 times the IQR (possible outliers) are represented individually by asterisks if they are within three times the IQR, and by open circles if they are beyond three times the IQR (probable outliers)

Figure 3-35. Box plot showing the distribution by month of combined chlorophyll *a* values measured in Copco and Iron Gate reservoirs during 2000 to 2003. (Source: PacifiCorp, 2004a)

Chlorophyll *a* data filed as part of PacifiCorp's historical water quality database (part of the final license application) shows chlorophyll *a* values below Iron Gate dam. Figure 3-36 shows the monthly values for sites below Iron Gate dam available in the database. Chlorophyll *a* concentrations experience the greatest range and highest average at the station closest to Iron Gate dam. Downstream of the RM 182.38 sampling point, the mean remains relatively even while the range in reported values increases with distance downstream.

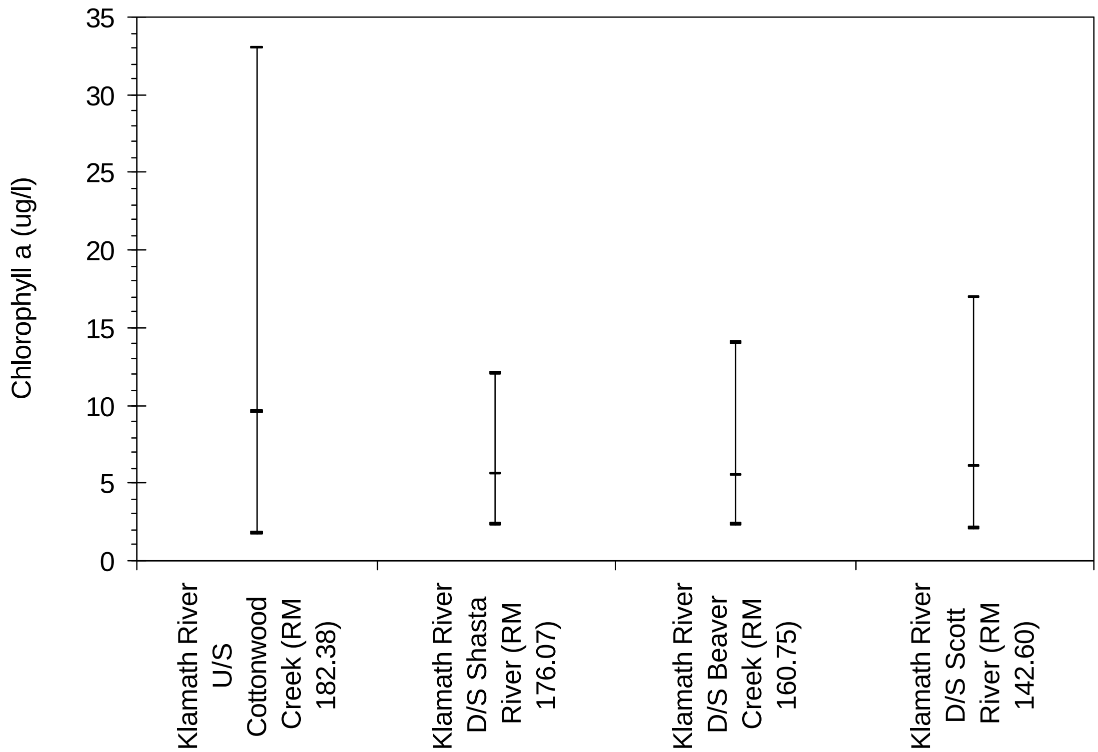


Figure 3-36. Maximum, mean, and minimum chlorophyll *a* concentrations at four stations below Iron Gate dam from data collected in 1996 and 1997. (Source: PacifiCorp, 2004a, as modified by staff)

On January 30, 2005, the Quartz Valley Indian Community filed a letter with the Commission documenting the presence of *Microcystis aeruginosa* and the liver toxin microcystin at Copco reservoir in 2004 (letter from A. Peters, chairman of the Quartz Valley Indian Community, to the Commission, dated January 30, 2005). *Microcystis aeruginosa* blooms historically have been observed in Upper Klamath Lake (Environmental Health Perspectives, 1999) and throughout the Klamath River Basin. Shoreline and open water locations within Copco and Iron Gate reservoirs sampled by Kahn et al. in 2005 exhibited the presence of the cyanobacteria *Microcystis aeruginosa*, which, in previous samples collected in September 2004 and July 2005, produced the potent hepatotoxin (liver toxin) microcystin. Although toxicity data for the most current samples are not available, it is clear from phytoplankton density data that cyanobacterial blooms have increased in intensity and extent as summer monthly sampling progressed.

Cell densities of *Microcystis aeruginosa* exceeded World Health Organization and EPA moderate risk levels[41] at all sampled stations on August 10 and 11, 2005, including at the open-water stations in front of Iron Gate (916,548 cells/mL) and Copco (151,004 cells/mL) dams. Several of the shoreline stations exceeded the moderate risk cell count level by more than 20 times (memo from Dr. J. Kahn, Aquatic Ecosystem Sciences, LLC., to the Karuk Tribe, the Water Board, and NCRWQCB, dated August 19, 2005, filed with the Commission by NCRWQCB, in its letter dated November 15, 2005). As a result of these recent samples, the Water Board issued a public health advisory (Water Board and California

[41] The World Health Organization and EPA state that, for recreational bathing waters, a moderate risk level is 50 μg/L chlorophyll *a*, 100,000 cells/mL or 20 μg/L microcystin in the top 4 meters of surface waters (Falconer et al., 1999; Chorus and Cavalieri, 2000).

EPA, 2005). The advisory stated that the concentrations of the *Microcystis aeruginosa* cyanobacteria levels and resulting microcystin toxin detected in samples collected from both shoreline and open water locations in Copco and Iron Gate reservoirs pose a significant potential threat of adverse health effects in human and animals exposed through direct ingestion of contaminated water as well as incidental ingestion during recreational water activities and bathing.

PacifiCorp also performed phytoplankton sampling from 2001 to 2004 at 21 sites along the Klamath River in the vicinity of the Klamath Hydroelectric project including Upper Klamath Lake and its tributaries. Results show that the highest mean algal abundance (measured as over 7,500 units/ml), were observed in the Klamath River at the Keno Bridge (Highway 66), Link River, Upper Klamath Lake (at Freemont St. Bridge). Results also show that the blue green algae *Microcystis aeruginosa* was found in about 12 percent of the 462 samples taken throughout the project vicinity; however, the spatial and temporal variability has not been disclosed at this time.

Attached algae and rooted vegetation within the Klamath River also play an important role in nutrient dynamics, as well as general river ecology. Because attached algae are in continuous contact with the river, the growth and distribution of the algal communities can affect nutrient fluxes and result in short-term changes in water quality parameters such as dissolved oxygen and pH. The Upper Klamath Lake TMDL recognized that aquatic plants are abundant in portions of the upper Klamath River and in areas dominated by nuisance filamentous green algae species such as *Cladophora,* an algae common in nutrient enriched waters. Field work contracted by EPA sampled 10 sites in the Klamath River below Iron Gate dam to characterize the benthic algae (periphyton) community. Results suggest that there are some major changes in the periphyton community that appear to be controlled to some degree by differences in nutrient availability (Eilers, 2005).

Species composition results showed a transition from a *Cocconeis/Diatoma*-dominated community upstream to a system heavily dominated by *Epithemia* downstream. *Cladophora* exhibited the greatest percentage of cover at the Shasta River sampling site where it represented one-half the periphyton community (by bio-volume). The study authors felt compelled to note that the biomass of periphyton was generally low to moderate, which was contrary to their expectations prior to the survey and reasoned that changes in the flow regime (possibly due to Reclamation orders) resulted in a doubling of flow from about 600 cfs around August 15 to about 1,200 cfs near the end of the month, settling at about 800 cfs by September 1, the start of the study. This increase in discharge may have been capable of dislodging filamentous algae that had proliferated under the previous lower flow regime (Eilers, 2005).

pH

The high concentration of algae in Upper Klamath Lake and Keno reservoir influences pH levels because photosynthesis and associated uptake of carbon dioxide results in high pH (basic conditions) during the day and respiration by algae and other organisms at night decreases the pH to more neutral conditions. Monthly average alkalinity (measured as $CaCO_3$) levels in Upper Klamath Lake, Link River, and Keno reservoir are fairly similar ranging between 40 and 50 mg/L with little variability throughout the sampling period. Values of 20 to 200 are typical of freshwater systems, however at lower levels freshwater systems have less buffering capacity, increasing their susceptibility to changes in pH. As expected, Link River water is more alkaline with strong seasonal trends. Concentrations ranged between 141 and 259 mg/L with the lowest levels recorded during the summer. PacifiCorp sampled pH as part of its water quality sampling program and collected almost 3,800 pH readings between March and November 2000 to 2004. Average pH values from all PacifiCorp sampling stations on the Klamath River and project reservoirs collected during the 2000 to 2003 study were between 7 and 10 standard units with the higher values coinciding with high algal densities, which typically occur from spring through fall.

Annual mean pH values show little variability between Keno reservoir and the bottom of the peaking reach. Water in Keno reservoir has an average pH of 8.2 with a peak pH of 9.4 standard units.

Average pH in J.C. Boyle reservoir is 7.8 with a peak of 9.3 standard units. Downstream of J.C. Boyle development in the peaking reach (Klamath River just above Shovel Creek) the average pH was 8.1 with a peak of 8.9 standard units.

The pH values in Copco and Iron Gate reservoirs are similar to each other in that the average pH at the surface was 8.2 and 8.1, respectively, while below 20 meters the average pH was 7.3 in Copco and 7.2 in Iron Gate with very little difference during June through September (range in Copco epilimnion was 0.7 units and 0.5 in Iron Gate). The range in the hypolimnion of both Copco and Iron Gate reservoirs during the summer was 0.2, indicating that there is little variability in pH at depth within these reservoirs during the summer. Monthly average alkalinity levels within Copco and Iron Gate reservoirs is slightly higher than those recorded in Keno, however none is above 75 mg/L.

Water Clarity

Water clarity is a function of how much suspended material exists in the water and how far light can penetrate. The depth at which light extinction occurs in lakes and reservoirs can be easily measured by using a Secchi disk, which provides an indication of the depth at which the disk is no longer visible to the naked eye. The higher Secchi depth measurements mean greater water clarity. Table 3-31 shows Secchi disk measurements at five representative locations within the project area (the mouth of Link River to Iron Gate reservoir). Water clarity is often influenced by planktonic algae, discussed earlier, and total suspended solids (TSS).

Table 3-31. Secchi depth[a] measurements at representative locations along the Klamath River in 2001 to 2003. (Source: PacifiCorp, 2004a)

Site Name	Number	Min.	Average	Max.
Link River Mouth (RM 253)	8	2.0	2.3	3.3
Keno Reservoir at Highway 66 Bridge (RM 234)	14	1.3	3.3	5.2
J.C. Boyle Reservoir (RM 224.8)	17	1.3	3.9	6.6
Copco Reservoir (RM 198.7)	25	0.6	6.2	11.2
Iron Gate Reservoir (RM 190.2)	25	3.0	7.5	13.8

[a] The average of the depths at which the Secchi disk disappears and the depth at which it reappears.

Measuring water clarity in river reaches requires a more complex sampling device designed to measure the water’s turbidity, however, the instrument can be used in both lake and river conditions. A common unit of measure of turbidity is the nephelometric turbidity unit (NTU), which is a standardized measure of clarity based on light scattering in a water sample measured by the meter. The greater the amount of TSS in the water, the murkier it appears and the higher the measured turbidity.

Turbidity in project influenced reaches ranged from 0.9 to 184 NTUs (mean of the majority of the sites is below 10 NTUs) between 2002 and 2003 at many of the same locations as temperature and nutrient sampling; however, samples were not collected in the peaking reach. Table 3-32 shows the monthly mean turbidity values reported by PacifiCorp. The maximum reading of 184 NTUs was recorded in the epilimnion of Copco reservoir in May 2003.

Table 3-32. Mean turbidity (NTUs) in the Klamath River, 2002-2003. (Source: PacifiCorp, 2004a, as modified by staff)

Stations	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Link River[a]	10.1	8.5	8.1	12.9	11.0	11.0	12.0	11.8
Klamath Irrigation Project[b]		7.1	6.9	3.3	5.8	5.2	7.7	
Keno reservoir[c]	7.8	7.0	5.0	7.2	5.6	6.7	6.0	8.8
Klamath River below Keno dam	13.6	9.7	5.3	31.4	14.9	4.4	6.1	8.5
Klamath River above J.C. Boyle reservoir	13.4	9.5	6.0	7.3	11.9	3.4	4.9	8.4
J.C. Boyle reservoir at log boom (top 8 m)		8.9		6.5		2.8		
J.C. Boyle bypassed reach immediately below dam	14.4	10.0	6.0	7.6	4.8	2.9	3.1	7.8
J.C. Boyle bypassed reach (downstream end)	3.6	3.9	2.3	1.7	1.0	0.9	1.0	2.2
Klamath River above Shovel Creek (peaking reach)	11.4	7.5	4.8	6.8	2.1	2.0	3.1	3.8
Copco reservoir (top 8 m) near Copco		95.2		5.9		4.1		
Copco reservoir outflow	7.0	6.1	3.0	1.7	6.7	4.0	2.3	3.8
Iron Gate reservoir (top 9 m) near Hornbrook		7.1		2.1		2.3		
Iron Gate dam outflow	5.9	6.1	3.2	1.9	1.6	2.7	2.0	1.4

[a] Sampling points include: Link River near East Side powerhouse and Link River at mouth.

[b] Sampling points include: Lost River diversion canal at Klamath River, Klamath Straits drain pumping plant F, and Klamath Straits drain 200 feet downstream of pumping plant F.

[c] Sampling points include south-side bypass bridge, Miller Island boat ramp, upstream of Klamath Straits drain, between Klamath Straits drain and Keno dam, Keno Bridge (Highway 66), and Keno dam log boom.

TSS sampling results from 2003 (the only year sampled by PacifiCorp) indicate that TSS concentration ranged from 0 to 280 mg/L with the mean of Klamath River samples and reservoirs (including the metalimnion and hypolimnion of Copco and Iron Gate reservoir) of 7.9 mg/L. The maximum reading of 280 mg/L was recorded in the epilimnion of Copco reservoir in May, which corresponds to the same time frame when the maximum turbidity value was measured. The maximum TSS level recorded in the Copco outflow during the same month was 4.8 mg/L.

Toxics (Metals and Pesticides)

PacifiCorp conducted a screening level assessment of chemical contaminants in fish tissue samples taken from Upper Klamath Lake, Keno, J.C. Boyle, Copco, and Iron Gate reservoirs to assess potential threats to humans from the bioaccumulation of toxic substances (PacifiCorp, 2004h). The Water Board (2004) considers the sampling a screening level analysis only, which provides direction on additional fish tissue and/or sediment sampling, yet to be determined. Screening level values (based on EPA criteria) for protection of human health used in the study are for recreational fishers and subsistence fishers. The results of the fish tissue analysis represent an indication of the degree to which toxics may be present in project-influenced water and sediment. However, because in some cases fish are known to migrate substantial distances, if contaminants are found in fish tissue, they may have originated from habitat outside the project area.

All measured fish tissue concentrations for total mercury are well below the screening values for human health. Total mercury concentrations (ppb dry weight) ranged from 0.154 to 2.527. The screening value for wildlife exposure used by PacifiCorp was 2.27 ppb, dry weight. Concentrations measured in largemouth bass from Iron Gate reservoir (two composite samples, 2.299 and 2.527 ppb) and Copco reservoir (a single composite totaling 2.438 ppb) are slightly above the screening value for wildlife exposure. All other measured mercury values were below the screening value for wildlife.

Although arsenic was detected in several samples, no concentration exceeded the method reporting limit[42] of 0.3 ppm. Estimated values (those values between the method reporting limit and the method detection limit [0.1 ppm]) for arsenic concentration in samples of largemouth bass from J.C. Boyle, Copco, and Iron Gate reservoirs are below the toxicity screening value for recreational fishers, but equal or exceed the toxicity screening value for subsistence fishers, a level of 0.147 ppm. Estimated arsenic concentrations exceeded the subsistence fishers' toxicity screening value in fish taken from J.C. Boyle (0.19 ppm), Copco (0.19 ppm) and Iron Gate (0.17 ppm) reservoirs. Cadmium and selenium values are below all screening values in all samples. No screening values were available for other metals.

DDE and hexachlorobenzene were the only two pesticides or pesticide byproducts detected in the study and were detected below the human health screening values. Some of the fish tissue samples from Upper Klamath Lake and Keno, J.C. Boyle, Copco, and Iron Gate reservoirs exceeded the suggested wildlife screening value for total DDTs, of which DDE is a component. Concentrations of DDE ranged from between the method detection limit of 0.56 ppb and the reporting limit of 2.0 ppb and a maximum of 2.91 ppb reported in J.C. Boyle fish. Hexachlorobenzene was detected in only two samples and at levels below the method reporting limit.

PCBs were detected in all samples from all of project reservoirs. Total PCB concentrations were less than the screening value for recreational fishers in all samples. Total PCB concentrations exceed the screening value for subsistence fishers in black bullhead from Keno reservoir, and in largemouth bass from J.C. Boyle, Iron Gate, and Copco reservoirs (table 3-33). Total PCB concentrations in all the samples analyzed were less than the toxicity screening value for protection of wildlife.

Table 3-33. Total PCBs found in composite fish tissue samples in Project reservoirs, 2003. (Source: PacifiCorp, 2004h)

Site	Species	Total PCB (ppb)
Upper Klamath Lake	Black Bullhead	0.846
Upper Klamath Lake	Black Bullhead	2.015
Keno Reservoir	Black Bullhead	2.926
J.C. Boyle	Largemouth Bass	0.885
J.C. Boyle	Largemouth Bass	1.397
J.C. Boyle	Largemouth Bass	3.521
Copco Reservoir	Largemouth Bass	2.822
Copco Reservoir	Largemouth Bass	2.158
Iron Gate Reservoir	Largemouth Bass	6.574
Iron Gate Reservoir	Largemouth Bass	4.909

Notes: Method Detection Limit: Varies
Method Reporting Limit: 0.200 ppb
Screening Values: Recreational fishers (0.2 ppb); Subsistence fishers (2.45 ppb); Wildlife (100 ppb).

[42] The method detection limit is a statistically derived value, such that if an analyte is measured above this value the laboratory is 99 percent confident that the constituent is present at a value above this level. The method reporting limit is the limit at which the laboratory is confident about the measurement of the presence of the actual target analyte as determined within the sample matrix. Hence, values measured above the method detection limit but below the reporting detection limit are considered estimated values.

Aesthetics

Recreational user surveys conducted by PacifiCorp in the project area in 2001 contained information from some respondents on the public's perception of water quality. Thirty-eight percent of respondents in the project area said that water quality had detracted from their visit. Table 3-34 summarizes their responses.

Table 3-34. Perceived effect of water quality on recreational visits in the Klamath Hydroelectric Project study area (yes/no). (Source: PacifiCorp, 2004c)

Survey Question: Has water quality ever affected your visit to the Klamath River area?

Resource Area	Yes (percent)	No (percent)
Link River/Lake Ewauna/Keno Reservoir	32	68
J.C. Boyle Reservoir	39	61
Upper Klamath River/Hell's Corner Reach	61	39
Copco Reservoir	35	65
Iron Gate Reservoir	32	68
Study Area (Total)	38	62

Of those persons who felt that water quality detracted from their visit, the most commonly cited factor was algae or aquatic plants (respondents mentioned "algae, green stuff, muck, seaweed, moss, slime") and the attendant odor. Other factors that were mentioned included dead fish and turbidity. We discuss project-related aesthetics in more detail in section 3.3.7.1.3, *Aesthetic Resources*.

3.3.2.2 Environmental Effects

3.3.2.2.1 Water Quantity

Flow and Water Level Monitoring

PacifiCorp's proposed flow and water level regimes for project-influenced reaches and reservoirs and the recommendations of other entities for flow and water level management cover a variety of alternative measures for each project development. Because measures related to flow and water level management primarily pertain to protecting and enhancing aquatic and riparian habitat and recreational opportunities, we discuss the specific aspects of these measures in sections 3.3.3.2, *Aquatic Resources*, 3.3.4.2, *Terrestrial Resources*, and 3.3.6.2, *Recreational Resources*.

Regardless of the flow and reservoir and river levels that may be specified in a new license, the Commission would require a means to ensure compliance with such license conditions. We discuss means for monitoring flow and water levels for compliance purposes in the following section. Flow and water level gages are in place on many project-affected reaches and reservoirs (table 3-35).

Table 3-35. Current gages in the vicinity of the Klamath Hydroelectric Project. (Source: PacifiCorp, 2004a; USGS, 2006; Oregon Water Resources Department, 2006).

Gage Number	Location and or Name	Equipment Ownership	Responsible Party	Comments
11505800	Upper Klamath Lake at Rocky Point, OR	USGS and PacifiCorp	Reclamation and PacifiCorp	Real time at the USGS website: http://waterdata.usgs.gov/or/nwis/rt
11505900	Upper Klamath Lake at Rattlesnake, OR	USGS and PacifiCorp	Reclamation and PacifiCorp	Real time at the USGS website: http://waterdata.usgs.gov/or/nwis/rt
11507000	Upper Klamath Lake at Pelican, OR	USGS and PacifiCorp	Reclamation and PacifiCorp	Real time at the USGS website: http://waterdata.usgs.gov/or/nwis/rt
11507001	Upper Klamath Lake near Klamath Falls, OR	USGS and PacifiCorp	Reclamation and PacifiCorp	Real time at the USGS website: http://waterdata.usgs.gov/or/nwis/rt
	West Side powerhouse	PacifiCorp	PacifiCorp	generation records by PacifiCorp
	East Side powerhouse	PacifiCorp	PacifiCorp	generation records by PacifiCorp
11507500	Link River at Klamath Falls, OR	USGS and PacifiCorp	USGS	Real time at the USGS website: http://waterdata.usgs.gov/or/nwis/rt
	Keno reservoir, Weed Bridge, OR.	USGS and PacifiCorp	USGS	Records by PacifiCorp
	Keno reservoir at Keno dam, OR	PacifiCorp	PacifiCorp	Hourly readings recorded by PacifiCorp
11509500	Klamath River at Keno, OR (below Keno dam)	USGS and PacifiCorp	USGS	Real time at the USGS website: http://waterdata.usgs.gov/or/nwis/rt
11510000	Spencer Creek	ORWD	ORWD	Active from Nov 2002 to Sep 30, 2003
	J.C. Boyle reservoir	PacifiCorp	PacifiCorp	Hourly readings recorded by PacifiCorp
	J.C. Boyle powerhouse	PacifiCorp	PacifiCorp	generation records by PacifiCorp
11510700	Gage below J.C. Boyle powerhouse	USGS and PacifiCorp	USGS	Real time at the USGS website: http://waterdata.usgs.gov/or/nwis/rt
11511400	Copco reservoir[a]	PacifiCorp	PacifiCorp	Hourly readings recorded by PacifiCorp
	Copco No. 1 powerhouse	PacifiCorp	PacifiCorp	generation records by PacifiCorp
	Copco No. 2 reservoir	PacifiCorp	PacifiCorp	Records by PacifiCorp
	Copco No. 2 powerhouse	PacifiCorp	PacifiCorp	generation records kept by PacifiCorp
11512000	Fall Creek at Copco, CA	USGS	USGS	reactivated from May 2003 until September 2005
11516510	Iron Gate reservoir[a]	PacifiCorp	PacifiCorp	hourly readings recorded by PacifiCorp
11516530	Klamath River below Iron Gate dam, CA	USGS and PacifiCorp	USGS	Real time at the USGS website: http://waterdata.usgs.gov/ca/nwis/rt

[a] Daily readings provided to USGS. Daily data for the A canal, Lost River diversion channel, North canal, Klamath Straits drain and Ady canal are available from the Reclamation website at: http://www.usbr.gov/mp/kbao/operations/water/index.html.

PacifiCorp did not include Keno development as part of its proposed project, citing its lack of influence on hydropower production. PacifiCorp would continue to own the dam and appurtenant facilities; however, it would relinquish all hydropower responsibilities associated with the current license and would operate the development according to direction from the state of Oregon and Reclamation. Future jurisdictional authority could affect environmental stewardship, which could affect the water levels within Keno reservoir and flow releases downstream. We cannot pre-judge the Commission's determination of whether Keno development should continue to be under its jurisdiction. Therefore, we discuss the management of the reservoir and its role in water quantity in the event that Keno development remains jurisdictional.

PacifiCorp proposes to install a stream gage in the J.C. Boyle bypassed reach to measure minimum flow and ramping rates immediately below the dam. PacifiCorp also proposes to install a Parshall flume at the Spring Creek diversion to measure the flows that are either routed to the diversion channel or to Spring Creek downstream of the diversion dam.

Oregon Fish & Wildlife recommends that PacifiCorp provide for the installation of gages above all project reservoirs or diversions and outflow below each project dam at the head of the dewatered reach to provide compliance points for minimum flows and ramping rates. The gages would measure the full range of stage and flows that may occur at each site and include telemetry to record and transmit hourly streamflow data to the project control room, in accordance with applicable USGS standards. Oregon Fish & Wildlife's recommendation would involve the installation of the following new stream gages:

- One gage in the bypassed reach below Link River dam to ensure that East Side and West Side developments are only operated when flows from Link River dam exceed 500 cfs if these developments are not decommissioned.
- One gage in the bypassed reach below J.C. Boyle dam.
- One gage on Shovel Creek to quantify the amount of flow from this tributary, which would be used to help determine inflow to Copco reservoir and the amount of flow to be released to the Copco No. 2 bypassed reach.
- Two gages upstream and downstream of the diversion on Spring Creek to determine flow diversion compliance.
- Two gages at Fall Creek, one upstream of the power canal diversion to determine the inflow for minimum flows within the bypassed reach and another within the bypassed reach to determine minimum flow compliance.

The Oregon Water Resources Department recommends that PacifiCorp fund the operation of USGS gage no. 11509500, Klamath River at Keno, Oregon, so that flows into J.C. Boyle reservoir can be monitored. NMFS recommends that PacifiCorp install gages where needed to appropriately monitor flow and reservoir elevation at each facility. Cal Fish & Game recommends that PacifiCorp measure and record inflow above all project reservoirs and outflow below each project dam. Gages would be installed where needed to appropriately monitor inflow and outflow from each facility. Flow records would be made available to resource agencies upon request.

The Bureau of Land Management specifies that PacifiCorp install or maintain continuously measurement stream gages at the following four locations:

- below Keno dam at existing USGS gage no. 11509500;
- at Spencer Creek, currently Oregon Water Resources Department gage no. 11510000, Spencer Creek near Keno, Oregon;
- in the bypassed reach below J.C. Boyle dam; and
- in the J.C. Boyle peaking reach at existing USGS gage no. 11510700, Klamath River below J.C. Boyle powerhouse, Oregon.

PacifiCorp offers two alternatives to the Bureau of Land Management 4(e) condition. The first is to eliminate the condition, because PacifiCorp states that all aspects of flows in the river channel are not within the Bureau's jurisdiction. PacifiCorp's second alternative 4(e) condition is essentially the same as the Bureau's condition.

Our Analysis

Measuring Flows in Link River. Link River dam, owned by Reclamation, controls the water level of Upper Klamath Lake and is not within the existing or proposed project boundary. Its operation, including the gates at the dam, is therefore not within the Commission's jurisdiction. PacifiCorp proposes to decommission East Side and West Side developments. USGS gage no. 11507500 is located downstream of the discharge from East Side development, but is upstream of the discharge from West Side development. West Side development has a rated hydraulic capacity of 250 cfs and is normally either operated near its capacity or not operated. East Side development has a rated hydraulic capacity of 1,200 cfs and a minimum capacity of 200 cfs. As table 3-11 shows, flow at the existing gage no. 11507500 is often below the combined capacity of the powerhouses and the current minimum flow. Water levels and releases from Upper Klamath Lake are managed by Reclamation based on requirements of the FWS 2002 BiOp, and, due to the large storage volume and surface area, flows released by Link River dam do not vary rapidly. One exception to the stable water level of Upper Klamath Lake is very rare high wind events that can change the water level of the lake at Link River dam and result in unexpected variations in the flow releases at Link River dam. Such variations, however, would have nothing to do with operations at either East Side or West Side developments.

PacifiCorp's operation of the two developments enables some degree of control over discharges from the dam because, if West Side development is not operating, the 250 cfs flow capacity could be passed over Link River dam or through East Side. Because East Side has some ability to adjust flows that pass through it (from 200 to 1,200 cfs), any downward adjustment of flow could result in an increase in flow released at Link River dam into the bypassed reach. The existing real-time gage with web-accessible half hour reporting intervals in the Link River below the discharge of the larger development, and the ability of PacifiCorp to monitor the flow through powerhouses, should be sufficient to monitor the flow regime that is controllable by PacifiCorp's project operations in Link River, without adding an additional gage upstream of East Side development.

Measuring Flows from Keno Development. USGS gage no. 11509500, which is located less than 1 mile below Keno dam, measures flow releases from Keno dam. Currently, equipment at this real-time gage, with half hour reporting of gage height and flow, is owned by USGS and PacifiCorp, and USGS is the responsible party for gage operation. The existing gage would be sufficient to measure any reasonable flow regime that may be included in a new license. However, some entities recommend that the flow regime in the Keno reach reflect a percentage of inflow. Inflow from Link River can be reasonably determined by the existing USGS gage. If such a provision is included in a new license, however, PacifiCorp would need to establish a means to obtain hourly inflow and outflow data from Reclamation's Klamath Irrigation Project, which both diverts and returns water to Keno reservoir (see table 3-14 and figure 3-6). The complexity of inflow and outflow from Keno reservoir would make measuring compliance with a flow regime tied to percentage of inflow to Keno reservoir exceedingly difficult.

The responsibility for continued operation of the USGS gage in the Keno reach would depend on the nature of the flow regime specified in a new license for Keno (if it remains within the Commission's jurisdiction) and J.C. Boyle developments. If Keno development is determined by the Commission to be non-jurisdictional, continued operation of this gage could be necessary if the flow regime for the J.C. Boyle bypassed or peaking reaches are calculated as a percentage of inflow to J.C. Boyle reservoir, as recommended by some entities. If the flow regime is not based on continuous monitoring of inflow to Boyle reservoir, there would be no nexus of the USGS gage at Keno to project purposes. If this gage does not serve project purposes, it would still serve an important non-project purpose, which would be to measure and document flows released by Reclamation in accordance with its BiOps.

Measuring Flows in Spencer Creek. With a drainage area of more than 35 square miles, Spencer Creek is the largest stream providing inflow to J.C. Boyle reservoir that is not measured at the USGS gage in the Keno reach. This gage has been active in the past, most recently from November 2002 until the end of September 2003, and was operated by the Oregon Water Resources Department. The need for this gage depends on the flow regime requirement downstream of J.C. Boyle dam (see discussion in section 3.3.3.2.1, *Instream Flows*). Reactivation and likely upgrades to allow for the continuous and real-time reading of this gage only would be required if the flow regime for the J.C. Boyle bypassed or peaking reaches is calculated as a percentage of inflow to J.C. Boyle reservoir. If the flow regime is not based on a percentage of inflow to J.C. Boyle reservoir, the Spencer Creek gage would serve no project purpose, and its operation would not be PacifiCorp's responsibility.

<u>Measuring Flows in the J.C. Boyle Bypassed Reach.</u> Flow compliance monitoring for any alteration of the existing flow regime in the J.C. Boyle bypassed reach would likely require a gage downstream of J.C. Boyle dam. The ideal location for a new gaging station would be below both the dam and the water conveyance structures such as the fish ladder and fish bypass outflow. Placing the new gage upstream of the springs that add more than 200 cfs to the bypassed reach about 0.5 mile below the dam would ensure that compliance monitoring is not complicated by inflow not controlled by PacifiCorp. Access to the river channel to construct and maintain a gaging station is also more favorable upstream of the major spring inflow site. Depending on the substrate and stability of the channel in the limited length of the reach that appears to be generally suitable for a gage, it is possible that the construction of a weir would be needed to establish an accurate stage/discharge relationship. Such a weir could serve as a fish passage barrier at low flow levels, which would also need to be considered in the design of this gage site. Installation of a flow gaging station in the bypassed reach would result in environmental consequences associated with the construction of the gage station itself, the associated access road (if a new access road is needed), and provision of electricity to operate the gaging station instrumentation (e.g., potential erosion and sedimentation, destabilization of existing slopes, disturbance of aquatic and riparian habitat, potential degradation of the local visual quality, and potential disturbance of cultural sites). Plans for a gaging station could provide site-specific details regarding how each of these effects would be addressed. Consultation with USGS for the development of this gage site would help ensure future compliance with USGS standards for flow measurement.

<u>Measuring Flows in the J.C. Boyle Peaking Reach.</u> Flow compliance monitoring for the flow regime that may be specified for the J.C. Boyle peaking reach would likely necessitate the continuing operation of gage no. 11510700 at RM 219.7 about 0.7 mile downstream of the J.C. Boyle powerhouse. Currently, equipment at this real-time gage, with half hour interval readings of gage height and flow accessible via the USGS website, is owned by USGS and PacifiCorp, and USGS is the responsible party for gage operation. This existing gage should be sufficient to measure flows in the J.C. Boyle peaking reach that are under PacifiCorp's control regardless of the flow regime specified in a new license.

<u>Measuring Flows in Shovel Creek.</u> Shovel Creek enters the J.C Boyle peaking reach about 3.5 miles upstream of Copco reservoir and contributes the largest single inflow to the J.C. Boyle peaking reach prior to its confluence with Copco reservoir. The need for this gage depends on the flow regime that is specified in a new license for the Copco No. 2 bypassed reach. Installation of this gage could be required if the flow regime is based on a percentage of inflow to Copco reservoir, as recommended by some entities, and if synthetic hydrograph relationships based on other nearby streams such as Fall Creek or Spencer Creek are not suitable. The ideal location of this gage, at least for access issues, would be near Ager-Beswick Road, which crosses over Shovel Creek just above the confluence with the Klamath River. Depending on the substrate and stability of the channel at accessible locations along Shovel Creek, a weir may need to be constructed to establish an accurate stage/discharge relationship. However, a weir could restrict or prevent upstream fish passage at low flow levels.

Shovel Creek is the primary redband trout spawning habitat along the peaking reach. Installation of a flow gaging station at Shovel Creek would result in environmental consequences associated with the construction of the gage station itself and provision of electricity to operate the gaging station instrumentation (e.g., potential erosion and sedimentation, disturbance of aquatic and sensitive riparian habitat along Shovel Creek, potential degradation of the local visual quality, and potential disturbance of cultural sites). Plans for a gaging station could provide site-specific details on how each of these effects would be addressed. Consultation with USGS for the development of this gage site would help ensure future compliance with USGS standards for flow measurement. If the flow regime at the Copco No. 2 bypassed reach is not based on a percentage of inflow to Copco reservoir, the Shovel Creek gage would serve no project purpose, and its construction and operation would not be the responsibility of PacifiCorp.

Measuring Flows Downstream of Copco Nos. 1 and 2 Dams. Cal Fish & Game recommends that PacifiCorp measure and record outflow from all project dams. This would include outflow from Copco No. 1 dam. Flows from the Copco No. 1 powerhouse or spillage at Copco No. 1 dam discharge directly into Copco No. 2 reservoir, and no entity has made any flow recommendations that pertain to releases from the Copco No. 1 development. Therefore, the need to measure and record outflow from Copco No. 1 dam is not established.

Flow compliance monitoring for a new flow regime for the Copco No. 2 bypassed reach would likely necessitate a new gage downstream of Copco No. 2 dam. The ideal location for a flow gaging station would be downstream of the dam and any water conveyance structure, such as the proposed flume for providing minimum flows to the bypassed reach. Depending on the substrate and stability of the channel in the location, it is possible that the construction of a weir would be needed to establish an accurate stage/discharge relationship. A weir could restrict or prevent upstream fish passage at low flow levels, so a stable natural cross section location would be best. Installation of a flow gaging station in the Copco No. 2 bypassed reach would result in environmental consequences associated with the construction of the gage station itself, the associated access road, if needed, and provision of electricity to operate the gaging station instrumentation (e.g., potential erosion and sedimentation, disturbance of aquatic habitat, potential degradation of the local visual quality, and potential disturbance of cultural sites). Plans for a gaging station could provide site-specific details regarding how each of these effects would be addressed. Consultation with USGS for the development of this gage site would help ensure future compliance with USGS standards for flow measurement, if appropriate.

Measuring Flows in Spring Creek. PacifiCorp maintains an earthen dam on Spring Creek, a tributary of Jenny Creek, which it uses to divert up to 16.5 cfs to Fall Creek and the Fall Creek powerhouse. Spring Creek has a relatively stable baseflow from groundwater accretion. Depending on the flow regime specified for Spring Creek in a new license, a gage could be required upstream of the diversion dam, downstream of the diversion dam, or in the diversion canal. Installation of one or two flow gaging stations, as several entities recommend (one upstream and one downstream of the diversion dam) would result in environmental consequences associated with the construction of the gage stations and provision of electricity to operate the gaging station instrumentation (e.g., potential erosion and sedimentation, disturbance of aquatic and riparian habitat, and potential disturbance of cultural sites). Plans for a gaging station could provide site-specific details regarding how each of these effects would be addressed. Consultation with USGS for the development of this gage site (or sites, depending on the flow requirements of a new license) would help ensure future compliance with USGS standards for flow measurement.

A Parshall flume, proposed by PacifiCorp at this site to measure minimum flow downstream of the diversion dam, is one of the most widely used types of flumes for fixed flow monitoring. Depending on the flow regime requirements for the Spring Creek diversion dam, a Parshall flume could provide a lower maintenance and stable flow regime to Spring Creek downstream from the diversion than a USGS compatible gaging station.

Measuring Flows in Fall Creek. Fall Creek enters the upper part of Iron Gate reservoir. USGS gage no 11512000, downstream from the powerhouse, was in operation from April 1, 1933, to September 30, 1959, and recently from October 1, 2003, until September 30, 2005. Similar to Spring Creek, Fall Creek has a stable baseflow due to a large amount of groundwater accretion. Currently a flow of 0.5 cfs is provided via a notch in the stop logs at the diversion dam to the bypassed reach. A minimum flow of 15 cfs is provided downstream of the powerhouse through operation of the powerhouse, including a turbine bypass valve, and flow through the bypassed channel. Downstream of the powerhouse on Fall Creek there are flow intakes for the city of Yreka and for the currently inactive Fall Creek rearing facility. The need for one or two (as some entities have recommended) new gages at the Fall Creek diversion dam and or in the bypassed reach depends on the flow regime specified in a new license. Installation of one or two flow gaging stations (one upstream and one downstream of the diversion dam) would result in environmental consequences associated with the construction of the gage stations and provision of electricity to operate the gaging station instrumentation (e.g., potential erosion and sedimentation, disturbance of aquatic and riparian habitat, and potential disturbance of cultural sites). Plans for a gaging station could provide site-specific details regarding how each of these effects would be addressed. Consultation with USGS for the development of this gage site (or sites, depending on the flow requirements of a new license) would help ensure future compliance with USGS standards for flow measurement, if appropriate.

If the flow regime within the bypassed reach varies based on inflow, as some entities recommend, a gage upstream of the diversion dam would be needed. If flow released to the bypassed reach is required to vary seasonally, then a gage in the bypassed reach would likely be needed. If flow released to the bypassed reach is constant, similar to existing conditions, or with only a few yearly variations, then an orifice, weir, or Parshall flume could be suitable to maintain and document compliance with the flow regime. Installation of a fully automated flow gaging station at the diversion dam or especially in the bypassed reach would result in environmental consequences associated with the construction of the gage station itself and provision of electricity to operate the gaging station instrumentation (e.g., potential erosion and sedimentation, disturbance of aquatic habitat, and potential disturbance of cultural sites). Plans for a gaging station could provide site-specific details on how each of these effects would be addressed. Consultation with USGS for the development of these gage sites would help ensure future compliance with USGS standards for flow measurement, if appropriate. Construction of an orifice, weir, or Parshall flume at the diversion dam would have a more limited disturbance footprint, and any expected environmental effects associated with its construction likely would be minimal.

Measuring Flows Downstream of Iron Gate Dam. Flow compliance monitoring for releases from Iron Gate reservoir would necessitate the continuing operation of gage no. 11516530 at RM 189.5 about 0.5 mile downstream of the dam. This gage is a real-time gage with flows and gage heights available on the USGS website at 15 minute intervals. Currently, equipment at this gage is owned by USGS and PacifiCorp, and USGS is the responsible party for gage operation.

Monitoring Reservoir Water Levels. As part of the regular facility monitoring, PacifiCorp monitors the water level at Keno, J.C. Boyle, Copco, and Iron Gate reservoirs and reports daily values to USGS. This type of monitoring is needed for project operations. Because the reporting is done in accordance with USGS standards of hydrological accuracy, we see no reason to conclude that this would not continue for the developments that are included in the project during the term of the new license.

Plans for Water Level and Flow Monitoring and Project Operation

Oregon Fish & Wildlife and the Hoopa Valley Tribe recommend that PacifiCorp develop and submit to the Commission for approval, within 1 year of license issuance, a project operations resource management plan, in consultation with Oregon Fish & Wildlife and other state, federal, and tribal resource agencies. This plan would be updated every 5 years, in consultation with the agencies, to reflect new information and management needs and updated implementation strategies. An annual report would be submitted to the Commission and the agencies and would include the plan for the upcoming year and a compilation of monthly information and daily project inflow; graphical plots of hourly flow data below Link River, Keno, and J.C. Boyle dams and J.C. Boyle powerhouse; a graphical plot of hourly ramping rates; and a summary of non-compliance reports. Oregon Fish & Wildlife and the Hoopa Valley Tribe also recommend that PacifiCorp develop a coordinated gage installation and data reporting plan in consultation with appropriate agencies.

Reclamation specifies that PacifiCorp provide it with the area-capacity curves for all project facilities and real-time access to reservoir elevation and release data for project facilities. The Bureau of Land Management specifies that PacifiCorp, within 1 year of license issuance, provide instantaneous 30-minute real-time streamflow data via remote access in a format that is readily available and accessible to the public; and design and maintain a database, similar to the most current version of the USGS National Water Information System, for reporting on surface water. The Bureau of Land Management also states that, within 2 years of license issuance, PacifiCorp should begin submitting annual water year reports to the Bureau within 6 months of the end of each water year.

PacifiCorp's first alternative 4(e) conditions would be to eliminate Reclamation's and Bureau of Land Management's conditions pertaining to provision of project-related flow and reservoir water level information. PacifiCorp states that both conditions are beyond the authority of each land management agency. As a second alternative to the Bureau of Land Management's conditions, PacifiCorp would provide, within 1 year of license issuance, instantaneous real-time streamflow data (in cfs) at 30-minute intervals via remote access that is readily available and accessible to the public. It would maintain a database similar to the most current version of the USGS National Water Information System that stores gage network data and streamflow tracking procedures. PacifiCorp also would submit annual streamflow data reports to the Bureau of Land Management within 2 years of license issuance and within 6 months of the end of the water year. This second alternative condition is essentially the same as the Bureau of Land Management's condition.

Our Analysis

PacifiCorp already monitors, or in some case provides assistance to USGS for monitoring and recording, many hydrologic indicators, such as reservoir water levels and stream gage sites in the project area (see table 3-35). Daily and, in many cases, hourly or shorter interval data recording allows PacifiCorp to manage its facilities for hydroelectric generation and document environmental compliance with the terms of its existing license. The configuration of future flow and water level monitoring gages would depend on the operating conditions that may be specified in a new license. Flows that are provided to the Klamath Hydroelectric Project and released from Iron Gate development are based on conditions specified in BiOps that pertain to the operation of the Klamath Irrigation Project by Reclamation, as discussed in the following section. Developing a project operations management plan, as recommended by Oregon Fish & Wildlife and the Hoopa Valley Tribe, would provide an effective forum to establish the basis for reporting flow-related information to resource and land management agencies that have a need for this information, as well as for Commission staff to document compliance with conditions that may be specified in a new license for this project. Developing a coordinated gage installation plan, in consultation with resource and land management agencies, as well as USGS, would ensure that any new gages necessary to measure the flows and water levels that may be specified in a new license would provide accurate data consistent with applicable USGS standards. It also would enable the justification for the type of new gage (i.e., a gage with real-time, telemetry capabilities, or a gage without such capabilities) that is installed at each site to be documented, and any needed modifications to existing flow gages (either USGS or PacifiCorp) identified. However, it is unclear why a separate project operations management plan and gage installation plan would be needed, because both plans would be designed to establish the means to effectively monitor and report project-related flows and water surface elevations that may be specified in a new license. Consolidating the plans into a single project operations coordination and monitoring plan would be an efficient approach to addressing issues related to documenting and reporting project-related flows. Many project-related flows would depend on flows released from the Klamath Irrigation Project that are subject to the provisions of annual operations plans and conditions of Reclamation's BiOps. In addition, the adaptive nature of many flow-related measures, discussed in detail in sections 3.3.3.2, *Aquatic Resources*, and 3.3.4.2, *Terrestrial Resources*, may result in future changes in how the project is operated. Consequently, including provisions to periodically update a project operations coordination and monitoring plan appears to be warranted. The 5-year interval for such updates recommended by Oregon Fish & Wildlife and the Hoopa Valley Tribe seems reasonable.

Reclamation specifies that PacifiCorp provide it with area capacity curves for all project developments. However, PacifiCorp already provided the area capacity curves for each reservoir in exhibit B of its license application (the license application is available on the Commission's website). It is also unclear why Reclamation would need real-time access to all project reservoir water elevations and flows released from each project development. Such information could be needed if it pertains to operations of the Klamath Irrigation Project, as would be the case if Keno development is determined by the Commission to be jurisdictional, or if it pertains to documentation of flows specified in Reclamation's BiOps, as would be the case for flows released from the Iron Gate development. As table 3-35 shows, real-time flow information is already available from the USGS gage downstream of Iron Gate dam. However, by including Reclamation among the consulted parties during the development of a project operations coordination and monitoring plan, Reclamation could make its case as to why it should be afforded access to real-time project-related water level and flow information that is not also available to the general public. We consider the Bureau of Land Management's measure to provide real-time streamflow data in a format readily accessible to the public to be primarily related to establishing when riverine recreational opportunities exist at the J.C. Boyle bypassed and peaking reaches, and we discuss this measure in section 3.3.6.2.2, *River Recreation*. The remainder of the Bureau of Land Management's measure pertains to establishing the format and frequency of reporting flow and water level data to the Bureau and other entities. As previously discussed, such details would be appropriately addressed during the development of a project operations coordination and monitoring plan.

Coordination of Project Operations with those of the Klamath Irrigation Project

Flow reaching PacifiCorp's facilities largely depends on releases from Upper Klamath Lake and from withdrawals and return flows from the Klamath Irrigation Project. Upper Klamath Lake provides about 83 percent of the total water storage of the reservoirs along the mainstem of the Klamath River, and about 97 percent of active storage. Reclamation's 2002 BiOps (FWS, 2002a; NMFS, 2002) require water level management in Upper Klamath Lake to protect the federally listed Lost River and shortnose suckers and seasonal specified minimum flows from Iron Gate dam to protect the federally listed coho salmon in the Klamath River downstream of the project. Operation of Keno reservoir helps to manage the irrigation withdrawals and return flows from the Klamath Irrigation Project.

Until April 2006, PacifiCorp operated and maintained Link River dam under a contract with Reclamation. This contract provided PacifiCorp with some operational flexibility with respect to releases from Link River dam, in exchange for operating the dam and providing low-cost power to Reclamation and its Klamath Irrigation Project irrigators. PacifiCorp currently operates Keno dam under an agreement with Reclamation which was required by article 55 of the existing license. A stable water level in Keno reservoir facilitates consistent water delivery to dependent water users, including about 41 percent of the lands irrigated by the Klamath Irrigation Project and the Lower Klamath Lake National Wildlife Refuge (see figure 3-5). There are also a large number of privately owned diversions from Keno reservoir for irrigation of non-federal lands.

Reclamation specifies that PacifiCorp continue to operate and maintain Link River dam in a manner consistent with the Klamath Irrigation Project annual project operation plans and develop, in consultation with Reclamation, operational criteria for the coordination of Link River and Iron Gate dam to allow Reclamation to meet its responsibilities. Reclamation similarly specifies that PacifiCorp in consultation with Reclamation develop operational criteria that provide for the coordination of Keno and Iron Gate dams to allow Reclamation to meet its responsibilities. In addition, Reclamation specifies that

PacifiCorp, at its own expense, maintain the approach channel to Reclamation's A canal to allow it to carry at least 1,200 cfs when Upper Klamath Lake is at elevation 4,137 feet. The justification for this condition hinges on PacifiCorp's continued operation of Link River dam, which Reclamation states "…must ensure that the primary diversion facility for the Klamath Reclamation Project is not affected by PacifiCorp's operation for power generation." Reclamation specifies that nothing in the new contract that it specifies should be developed between Reclamation and PacifiCorp for operation and maintenance of Link River and Keno dams should curtail the rights of Reclamation to Klamath water or lands along Upper Klamath Lake and that no water should be used by PacifiCorp if it is needed by Reclamation or by any other party that obtains water from the United States for use for domestic, municipal, and irrigation purposes on "project land (we assume this relates to Klamath Irrigation Project lands)." Reclamation also specifies that PacifiCorp should operate Keno dam so the water level does not fall below elevation 4,085.0 feet, as measured at or near the present location of the Highway 66 Bridge at Keno, and that PacifiCorp operate Keno dam to accommodate a discharge of 3,000 cfs from the Lost River diversion channel and 600 cfs from the Klamath Straits drain.

Our Analysis

Under a contract that expired in April 2006, PacifiCorp operated and maintained Link River dam at Reclamation's direction. As discussed in section 2.1.1.1, *East Side and West Side Developments*, in April 2006 the Commission issued its order setting the government dam use charges at the rates established in its regulations. Link River dam is not within the current project boundary and would not be within any new project boundary. Consequently, direct operation of the dam is not within the Commission's jurisdiction. Reclamation, as the owner of Link River dam, would be free to arrange for operation and maintenance of this dam with a qualified entity, and it is logical to assume that such operational responsibilities would include ensuring that the operations are consistent with the annual project operations plans and Reclamation's BiOp responsibilities. PacifiCorp's operation of East Side and West Side developments, over which the Commission has jurisdiction, has the potential to influence flows in Link River, but any such influence would be eliminated with the decommissioning of both developments, as PacifiCorp proposes. Reclamation's A canal approach channel is located about 0.3 mile above Link River dam, and the water levels of Upper Klamath Lake are specified in Reclamation's BiOp that is protective of federally listed suckers (FWS, 2002a). Based on available information, we have been unable to establish a nexus of maintaining the approach channel to Reclamation's A canal to any Klamath Hydroelectric Project purpose.

PacifiCorp already closely coordinates its operation of Keno and other facilities with Reclamation due to the interconnectivity between the Klamath Hydroelectric Project and the Klamath Irrigation Project. PacifiCorp is currently required by the Commission, under a 1965 license amendment, to operate Keno reservoir in accordance with an agreement with Reclamation that specifies that the maximum water surface elevation should be 4,086.5 feet and the minimum should be 4,085.0 feet. However, at the request of irrigators, PacifiCorp generally operates Keno dam to maintain the reservoir at elevation 4,085.4 +/-0.1 foot from October 1 to May 15 and elevation 4,085.5 +/-0.1 foot from May 16 to September 30 (see figure 3-7) to allow reliable operation of irrigation canals and pumps. Occasional 2-foot drawdowns are implemented following coordination with Reclamation to allow irrigators to clean out their water withdrawal systems before the irrigation season. If Keno dam remains within the project, we expect this operation regime to continue as it has since at least 1990 (see figure 3-7), with the water level of Keno reservoir generally remaining above elevation 4,085.0 feet. Provisions for documenting compliance with this minimum water level, which is necessary for gravity fed irrigation channels that divert water from Keno reservoir, would be appropriately addressed in a project operations coordination and monitoring plan, discussed previously. However, there are circumstances (such as an extreme flood event), that could prevent any entity that is operating Keno dam from ensuring that a discharge of 3,000 cfs from the Lost River diversion channel and 600 cfs from the Klamath Straits dam could be accommodated while maintaining Keno reservoir within a specified operating band. These types of exceptions (i.e., to accommodate routine maintenance of withdrawal systems of irrigators and other consumptive water users at Keno reservoir and extreme natural flow events) emphasize the importance of establishing a project operations coordination plan to ensure that operation of Keno development, if it remains under the Commission's jurisdiction, is consistent with the resource needs of those parties affected by its operation.

However, should the Commission determine that Keno development is not jurisdictional, PacifiCorp would still need to coordinate with Reclamation to ensure that flows released from Iron Gate development are consistent with Reclamation's BiOp for the protection of coho salmon (NMFS, 2002). Including Reclamation among the consulted entities during the development of a project operations coordination and monitoring plan would ensure that Reclamation's BiOp responsibilities are met by PacifiCorp's operation of the Klamath Hydroelectric Project, regardless of which specific developments are included in a new license for the project.

Oregon law, as interpreted by the Oregon Water Resources Department, determines water rights related to withdrawals from Upper Klamath Lake or Keno reservoir. Any water rights disputes that arise in Oregon between Reclamation and PacifiCorp would be for that department to resolve. The Commission would not attempt to resolve any issues regarding whether Klamath River water should be used for consumptive purposes by clients of the Klamath Irrigation Project or for hydroelectric purposes, if such use would conflict with established consumptive purposes.

3.3.2.2.2 Water Quality

Keno Reservoir Water Quality Management

Currently, water quality within Keno reservoir does not meet state objectives and a TMDL for the Klamath River is currently underway to address elevated pH, ammonia, nutrients, temperatures, chlorophyll *a*, and low DO concentrations. PacifiCorp states that poor quality of inputs and not project operations are the cause of poor water quality throughout the project area. The combination of hypereutrophic water in Upper Klamath Lake, coupled with the extensive amount of irrigated lands supported by the Klamath River, supply (at times), nutrient enriched water to Keno reservoir. During summer, conditions in Keno reservoir are ideal for algal blooms; elevated water temperatures, ample sunlight, and elevated nutrient levels from the greater percentage of enriched flow from Klamath Straits drain. The resultant algal blooms exacerbate water quality problems by affecting pH and DO, and may potentially include blooms of *Microcystis aeruginosa*, which produce a toxin that can be a threat to human health (discussed later in this section). Isolating the nutrient loading and the effect of Keno reservoir on water quality from Upper Klamath Lake, non-point sources, and internal loading has yet to be performed; however, the TMDL analysis currently underway will identify these loads.

In its license application, PacifiCorp did not include Keno development as part of its proposed Klamath Hydroelectric Project, and it stated that it does not believe Keno dam is rightly under the Commission's jurisdiction, due to its lack of influence on hydropower production. PacifiCorp states that it would continue to own the dam and appurtenant facilities; however, it would relinquish all hydropower responsibilities associated with the current license and would operate the development according to state of Oregon and Reclamation direction. Future jurisdictional authority could affect environmental stewardship, which could affect the water quality within Keno reservoir and downstream. We cannot pre-judge the Commission's determination of whether Keno development should continue to be under its jurisdiction. Therefore, we discuss the management of the reservoir and its role in water quality in the event that Keno development remains jurisdictional and a part of the project.

NMFS recommends that within 1 year of license issuance, PacifiCorp develop, in consultation with the agencies, a plan to manage Keno reservoir to improve water quality for fish habitat and meet water quality standards as measured immediately downstream of Keno dam. NMFS indicates that possible measures that could be implemented under this plan include restoration of wetlands, treatment wetlands, mechanical aeration, and mechanical removal of algae. Should Reclamation develop such a plan that addresses water quality issues at Keno reservoir before, PacifiCorp would incorporate Reclamation's plan into its plan under NMFS' direction. FWS makes a similar recommendation to that of NMFS except as a precursor to the development of the plan, PacifiCorp would form and lead a regional team within 1 year of license issuance whose purpose would be to study and develop a Keno reservoir water quality plan. The plan would be filed with the Commission within 2 years of license issuance (rather than the 1 year specified by NMFS).

Oregon Water Resources recommends that PacifiCorp should be prepared to address Keno dam's share of TMDL effects on temperature, algae, and DO levels in Keno reservoir and the Klamath River. The Klamath Tribe recommends that PacifiCorp fund efforts to plan and implement measures to ameliorate water quality problems generated within Keno reservoir.

Our Analysis

There is no disputing that the quality of water entering, within, and leaving Keno reservoir is degraded. However, the degree to which the presence of Keno dam influences that water quality is not as clear. The dam and its impoundment affect water quality primarily by increasing surface area and hydraulic retention time. This increases water temperature and facilitates photosynthetic and microbial processes that can degrade water quality, by causing DO and pH fluctuations, and increases in concentrations of nitrogenous compounds, including ammonia and other nitrogen species. Because the rate of flow through the reservoir is largely a function of Reclamation's need to meet the 2002 BiOp flows below Iron Gate dam, it appears that water quality problems in Keno reservoir would be the same whether or not Keno dam remains part of the project. In that sense, it is the presence of the dam (and associated reservoir), rather than its specific use, that contributes to the observed water quality degradation.

Ongoing TMDL studies are designed to establish the appropriate load for various pollutants that the Klamath River can assimilate. If point sources of pollution are identified in the watershed that cause the allocated TMDL to be exceeded, corrective actions would be identified through the National Pollution Discharge Elimination System (NPDES) permit process. However, past precedent has not identified water that passes through a hydroelectric dam as representing a point source of pollution, and thus an NPDES permit is typically not required. In a proposed rule that would amend the Clean Water Act, issued on June 7, 2006, EPA seeks to clarify that water transfers are not subject to NPDES permit requirements because no addition of a pollutant occurs (Federal Register: June 7, 2006. Volume 71, Number 109, pages 32,887 to 32,895). The proposed rule specifically states that "the movement of water through a dam is not water transfer because the dam merely conveys water from one location to another within the same waterbody." EPA notes in its proposed rule that pollutants in transferred water would best be addressed at the source by the states through such mechanisms as water resource planning, land use regulations, and conditions of a water quality certification.

We agree with EPA that an effective approach to addressing water quality issues for water passing through hydroelectric dams is through water resource planning. Such planning is already occurring in the project area through the TMDL process and the ongoing development of Reclamation's Conservation Implementation Program for the Klamath Irrigation Project (the most recent version of the plan was issued in February 2006). If Keno development is determined to be jurisdictional, it would be appropriate for PacifiCorp to participate in cooperative water resource planning with the relevant agencies to identify feasible means for improving the quality of water released from Keno dam. We consider measures to reduce nutrient loading in Keno reservoir and in downstream project waters to be the most likely remedial measure that would come out of such cooperative planning. If nutrients are reduced, algal production would decrease and the resultant DO regime would be enhanced. By assessing feasible methods of reducing nutrient loading from Keno dam to downstream project waters, it may be possible to curtail project-related effects at Copco and Iron Gate reservoirs. However, because the water quality at Keno reservoir influences water quality at all downstream project developments, development of a water quality management plan that encompasses all project waters, not just Keno reservoir, should be considered when specific remedial measures are developed. Consultation with appropriate resource agencies during the development of such a project-wide plan would ensure that water quality enhancement measures implemented by PacifiCorp would be developed with input from technical experts within resource agencies and coordinated with measures implemented by other parties pursuant to parallel water quality management initiatives. We discuss this approach later in this section under *Project-wide Water Quality Management*.

Water Temperature Remediation

Project operations have the potential to alter the temperature regime of affected waters. Keno and J.C. Boyle reservoirs generally do not stratify during the warmer months of the year (as indicated in section 3.3.2.1.2), and water entering and leaving the reservoir are approximately the same temperature. Lacking a hypolimnion, there are no controllable actions that can be taken to cool water released from either Keno or J.C. Boyle developments. Because Copco and Iron Gate reservoirs thermally stratify during the warmer months of the year (see figure 3-23), the potential exists that structural or operational changes at these projects could be used to reduce the temperature of water released downstream.

Figure 3-37 shows simulated water temperatures downstream of Iron Gate dam with and without the project, illustrating the effects of project operations on the downstream temperature regime. In general, the “without project scenario” has warmer temperatures in the spring and cooler temperatures in the summer and fall than the existing condition. This reflects the slower warming and slower cooling associated with the large water mass contained within the reservoir. Temperatures during much of July and August are usually higher than 20^{0}C with little variability. Figure 3-37 is based on 2002 data and represents a dry year resulting in more extreme summer temperatures. Modeling results for other years between 2000 and 2004 can be found in PacifiCorp’s response to AIR AR-2 filed by letter dated October 14, 2005, which exhibit similar, albeit less extreme, temperature trends. As discussed in section 3.3.2.1, PacifiCorp regularly recorded average daily water temperatures below Iron Gate dam of more than 20°C in June, July, and August between 2000 and 2004. In this section, we discuss the effects of various operational procedures, potential structural modifications, and monitoring. We discuss the relationship between temperatures and aquatic resource needs in section 3.3.3.2, *Aquatic Resources*.

In its license application, PacifiCorp originally proposed to evaluate the feasibility and effectiveness of a low-level release of cooler hypolimnetic water from Iron Gate and Copco reservoirs during the summer to provide some cooling downstream of the project. We asked PacifiCorp to conduct this analysis in our AIR dated February 17, 2005 (AR-1). In its response, filed by letter dated August 1, 2005, PacifiCorp indicated that none of the preliminary facility or operational modifications they considered would result in any substantial relief to the warm summer and fall temperatures downstream of Iron Gate dam.

The Forest Service recommends that the temperature of water released from Copco and Iron Gate dams should be managed to compensate for project cooling effects in spring and warming effects in late summer and early fall. Studies to determine a preferred design of intake structures and an outflow schedule would be conducted, and an effective combination of structure(s) and release operations should be required that would result in the greatest change in degree-days.

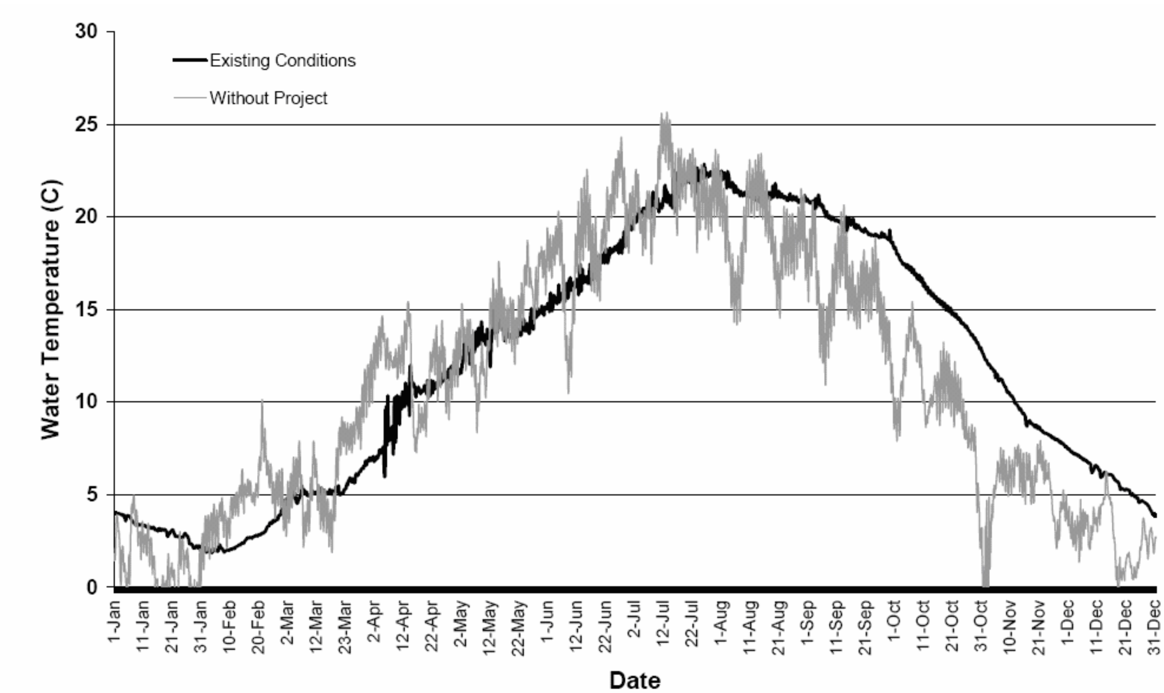


Figure 3-37. Simulated hourly water temperature below Iron Gate dam (RM 190.5) based on 2002 (considered a dry year) for existing conditions compared to hypothetical conditions without the existing Klamath Hydroelectric Project. (Source: PacifiCorp, response to AIR-AR-2, dated October 2005)

NMFS recommends that within 1 year of license issuance, PacifiCorp file a temperature control device feasibility and implementation plan developed in consultation with the resource agencies. Feasibility would be conducted by an independent third party approved by the agencies to determine the potential effectiveness of a temperature control device at Copco No. 1 and Iron Gate dams to improve habitat resources for anadromous salmonids downstream of Iron Gate dam. The goal of the plan would be the development and implementation of a comprehensive management plan to improve water temperature conditions downstream of Copco No. 1 and Iron Gate dams. Methods and results would be reviewed by the agencies, and if the results of the feasibility study are favorable, PacifiCorp would implement the recommended temperature control measures. The plan would fully model, compare, and evaluate a variety of technologies, including but not limited to construction and operation of a multi-port selective withdrawal structure. It would also include an assessment of effectiveness, cost, and potential effects. FWS makes a similar recommendation, however it also recommends the study should include an uncertainty analysis to quantify model performance for all years simulated, establish a realistic target water temperature schedule, and assess the effect of temperature control options on Iron Gate Hatchery operations.

Siskiyou County recommends "…appropriate terms and conditions that result in the aeration and management of cold water in the project reservoirs if these practices have appropriate benefits." Conservation Groups recommend that PacifiCorp operate the project in a run-of-river mode such that the amount of water entering an impoundment is equal to the sum of water passed over the dam, through fish passage facilities, and through the turbines at any given point in time at every relevant facility structure to enhance water temperature. Conservation Groups also recommend that PacifiCorp install adequate temperature monitoring devices and develop an effectiveness monitoring plan that includes the Klamath River downstream of Iron Gate dam to the confluence of the Shasta River to track compliance with water temperature objectives and force adjustments if temperature targets are not met. Conservation Groups also recommend that in the absence of project decommissioning, PacifiCorp should pass sufficient water through the J.C. Boyle and Copco No. 2 bypassed reaches to minimize thermal effects from warming throughout each reach.

Our Analysis

We have seen no evidence that operation of the project in a run-of-river mode as recommended by the Conservation Groups would result in downstream temperatures being more suitable for salmonids. Operating J.C. Boyle in a run-of-river mode is not likely to induce measurable differences in temperature in the peaking reach because of the relatively small volume of the reservoir and lack of substantial stratification. Operating Copco No. 1 and No. 2, and Iron Gate developments in a run-of-river mode would result in the continuous seasonal release of relatively warm epilimnetic water from Copco and Iron Gate reservoirs, resulting in little expected change from the existing temperature regime.

The Conservation Group's desire to minimize thermal effects from warming in the J.C. Boyle bypassed reach would best be achieved by releasing no flow to the bypassed reach, not more flow. The more than 200 cfs of springwater accretion in the bypassed reach ensures optimal thermal conditions for salmonids during the warm months of the year and any additional flow released from the dam would serve to further warm the bypassed reach water. We consider it inappropriate to manage the J.C. Boyle bypassed reach solely to reduce water temperature. As discussed in section 3.3.3.2.1, *Aquatic Resources*, *Instream Flows*, both temperature and physical habitat (depth, velocity, and substrate) should be assessed when determining an appropriate flow regime for any stream reach.

Similarly, passing an alternative water flow through the Copco No. 2 bypassed reach, as recommended by the Conservation Groups, would likely have little effect on thermal regime. The bypassed reach is relatively short and much of it is shaded by encroaching riparian vegetation which, given the relatively low volume of flow currently passing through the reach (about 10 cfs), likely maintains water temperatures. Releasing additional flow from Copco No. 2 dam would pass warm water (originating from the epilimnion of Copco reservoir and passing through Copco No. 1 powerhouse) to the bypassed reach, most likely resulting in little change to current conditions. As indicated in the following paragraph, releasing cooler hypolimnetic water through a valve or gate at the base of the dam, may be possible, but such water would also be low in DO (see figure 3-28). Striking a balance between cooler temperature and DO that is likely to be acceptable for salmonids and resident fish in the bypassed reach would be difficult. Consideration of temperature, DO, and physical habitat collectively should be used to select an appropriate flow regime for the Copco No. 2 bypassed reach (see section 3.3.3.2.1, *Aquatic Resources, Instream Flows*).

PacifiCorp modeling (response to AIR AR-2, October 17, 2005) of existing conditions compared to the without project scenario indicates that the project can have a noticeable effect on temperatures as far downstream as the confluence of the Scott River, 47 miles downstream of Iron Gate dam. The magnitude, downstream extent, and duration of project effect on temperatures is variable and influenced by numerous factors such as, but not limited to, water year type, climatic and meteorological conditions, and season. Differences in temperature between the modeled existing condition and the without project scenario are most noticeable during the summer and early fall months as the thermal mass of the reservoirs alter the downstream temperature regime. Modeling results indicate that effects of the project on temperature are difficult to discern by the confluence with the Salmon River, about 124 miles downstream of Iron Gate dam, which indicates that the likely downstream limit of project effects on water temperature is between the confluence of the Scott and Salmon rivers.

Thermal stratification and the associated cool water in the hypolimnion during warmer times of the year in Copco and Iron Gate reservoir provide the potential to allow selective withdrawals of water from depths within the reservoir to provide relief from peak summer temperatures downstream of Iron Gate. PacifiCorp analyzed the hypothetical release of hypolimnetic water from both Copco and Iron Gate reservoirs using the CE-QUAL-W2 modeling system which has since been incorporated by the EPA into their technical analysis of the forthcoming Klamath River TMDL, giving the model a high level of credibility. PacifiCorp estimates the maximum useable cold water volume in Copco reservoir to be about 3,100 acre-feet and 4,800 acre-feet at less than 14°C and 16°C, respectively. This maximum volume of cold water typically occurs around September 1, which is when it would most likely be needed to provide downstream temperature relief for migrating salmon. PacifiCorp's modeling results show that the duration of hypolimnetic releases from that storage would last about 1.8 days at 1,000 cfs. It may be possible to extend this release period by a small amount by reducing the release volume to less than 1,000 cfs. However, if inflow to Copco reservoir exceeds the amount released from near the base of Copco No. 1 dam, the reservoir would fill and spill, or epilimnetic water would need to be released through the powerhouse; both actions would release warm water into Copco No. 2 reservoir and negate the temperature benefits of the cool, hypolimnetic releases. As table 3-19 shows, the average flow at the Copco No. 1 powerhouse is 702 cfs in July, 804 cfs in August, and 974 cfs in September, which are the months when temperature relief would most likely to be needed. We independently reviewed PacifiCorp's area-capacity curves and vertical temperature profiles for Copco reservoir and concur with PacifiCorp's assessment of the relatively limited coldwater release capabilities at Copco No. 1 dam. To achieve releases of the magnitude and duration specified by PacifiCorp, releases would need to be made from a valve or gate near the base of the dam and water used in any such releases could not be used to generate electricity. PacifiCorp refurbished these low level outlets in 2005 to comply with state of California dam safety requirements (PacifiCorp, 2005i). As we note in the previous paragraph, any such hypolimnetic flow release would likely be very low in DO.

PacifiCorp's modeling indicates that at Iron Gate reservoir, the maximum volume of cold water (8°C or less) during the summer is about 8,000 to 10,000 acre-feet. If all of this cold water were passed through a point near the base of them dam at a release rate of 1,000 cfs, this cold water pool would last about 5 days. Our independent review of PacifiCorp's area-capacity curves and vertical temperature profiles for Iron Gate reservoir confirms PacifiCorp's assessment of the size of the cold water pool. We also estimate the approximate volume of the cold water pool available at Iron Gate reservoir in the hypolimnion that would be at or 15°C, to be about 20,000 acre-feet. A release of about 1,000 cfs from near the base of the dam could be sustained for about 10 days. PacifiCorp refurbished these low level outlets in 2005 to comply with state of California dam safety requirements (PacifiCorp, 2005i). As with hypolimnetic releases at Copco dam, the DO of water released from near the bottom of Iron Gate reservoir would generally be very low.

PacifiCorp's modeling efforts of selective withdrawal alternatives for Copco and Iron Gate show the cold water pool within the reservoirs could be used for modifying temperatures below the dam; however effects would be short term and would not affect the entire length of river below Iron Gate dam to the ocean. Our review of PacifiCorp's modeling efforts leads us to conclude that it is a valid tool to help understand the limitations of releases of cold, hypolimnetic water from Copco and Iron Gate reservoirs in relation to the temperature regime of project waters. If releases from Iron Gate dam are managed to sustain decreased temperatures for the longest duration, hourly temperatures would be reduced by about 1.1°C on average, with a maximum decrease of 1.8°C, for a period of up to 1 -1/2 months in late summer and early fall. Modeling of selective withdrawals from Iron Gate alone designed to maximize the decrease in downstream water temperatures showed promise but the benefits end within 2 weeks, as the cold water pool is depleted. Temperature benefits are reduced at Seiad Valley, with almost no benefit below Clear Creek (about 90 miles below Iron Gate) leaving the lower 100 miles of river unaffected. PacifiCorp's modeling results show that selective withdrawals could reduce temperatures below existing conditions by a maximum reduction of 10°C, which would last for about a day midway through the withdrawal period. As the distance downstream from Iron Gate dam increases, observed and modeled temperatures show greater variability as the river becomes more responsive to changes in meteorological conditions. The magnitude of the benefit is related to the hydrological conditions, as temperatures during drier years with less tributary inflow are more sensitive to releases from Iron Gate dam because they make up a greater percentage of the flow, whereas during wet years the opposite would be true. Selective withdrawal modeling scenarios designed to prolong greater temperature differences by incorporating Copco reservoir into a coordinated effort to lower water temperature downstream of Iron Gate dam showed negligible benefits.

Sustained temperature relief of more than 2 weeks to the Klamath River via releases from Iron Gate dam is not feasible. However the cold water pool in Iron Gate has some potential to cool downstream temperatures on a short term basis, and could be considered for extreme circumstances should environmental conditions trigger such a need (e.g., when large numbers of juvenile salmonids are present in the river under extreme temperature stress). Depletion of the cold water pool to reduce warm temperatures below Iron Gate dam would also likely decrease the DO concentration downstream of Iron Gate dam, through the release of oxygen depleted water from the hypolimnion, as previously noted. In addition, the sole water supply for Iron Gate Hatchery withdraws cold water from the deeper water of Iron Gate reservoir, and depleting or exhausting this cold water pool during the summer would likely seriously impair hatchery operations during any year that such hypolimnetic releases occur (see section 3.3.3.2.6, *Aquatic Resources, Iron Gate Hatchery Operations*). Development of a temperature control plan would provide the framework necessary to address cold water withdrawals while integrating water quality monitoring and aquatic resource needs. Addressing the feasibility of renovating the existing Iron Gate dam diversion tunnel to make controlled hypolimnetic releases or installing alternative hypolimnetic release valves or gates that could be activated in emergency circumstances to provide short-term downstream temperature relief could be included in a temperature control plan. In addition, conducting a feasibility study to assess alternative or supplemental Iron Gate Hatchery water supply options that could provide temporary cool water supplies to the hatchery (during any use of hypolimnetic water under emergency circumstances) would provide a basis to determine the overall feasibility of an emergency coolwater flow augmentation program. Alternative supply options to be studied could include: groundwater source availability, piping water from coldwater tributaries, or a combination of several options. NMFS and FWS recommendations for additional, third party, selective withdrawal modeling for the purposes of comparing and evaluating a variety of technologies would be unnecessary based on the limited amount of cold water storage available within Iron Gate reservoir and the current capability to release available cold water, if needed, at Iron Gate dam. An emergency water release plan that specifies environmental target temperatures by season and environmental triggers could be used to signal the release of cool water from storage in Iron Gate reservoir to provide short term benefits to anadromous fish experiencing temperature stress and may improve relief through critical early fall temperature extremes.

Addressing operational measures to be considered to increase the temperature of late spring releases from Iron Gate dam, including spills, to reduce the thermal lag in the Klamath River downstream could assist fall Chinook growth and early emigration (discussed in section 3.3.3.2.5, *Aquatic Resources, Disease Management*). Initially this option could rely on existing facilities to achieve the benefits of limited short-term temperature relief. An adaptive management approach would allow the most flexibility in achieving temperature objectives while incorporating monitoring results to promote the appropriate conditions for aquatic resources. Details of such an approach could be specified in a temperature management plan.

Dissolved Oxygen Remediation

PacifiCorp's sampling and modeling efforts under "existing conditions" and "without project" scenarios show that operation of the project has an effect on the downstream DO regime. Specifically, the results show that project operations under existing conditions result in reduced DO releases, often below California's numerical objectives (listed previously in table 3-24), downstream of Iron Gate dam from late spring, through the summer and fall. The modeling results indicate that the project influences DO concentrations at least as far downstream as the confluence of the Klamath and Shasta rivers. Distinguishing project-related influences from non-project influences on the DO regime further downstream is difficult using either modeling or field measurements because of the number of variables that influence DO (e.g., degree of turbulence, time of year, time of day, influences of tributary inflow, and non-project-related BOD and SOD). Figure 3-38 shows DO concentrations below Iron Gate dam that are representative of dry, low flow conditions. Under the “without project” scenario, DO concentrations could drop below the state objectives of 8 mg/L; however, the duration of these conditions would be short lived compared to the modeled existing conditions. Modeling results for other years illustrate similar trends, with increased variability. These results can be found in PacifiCorp’s response to AIR AR-2 dated October 17, 2005.

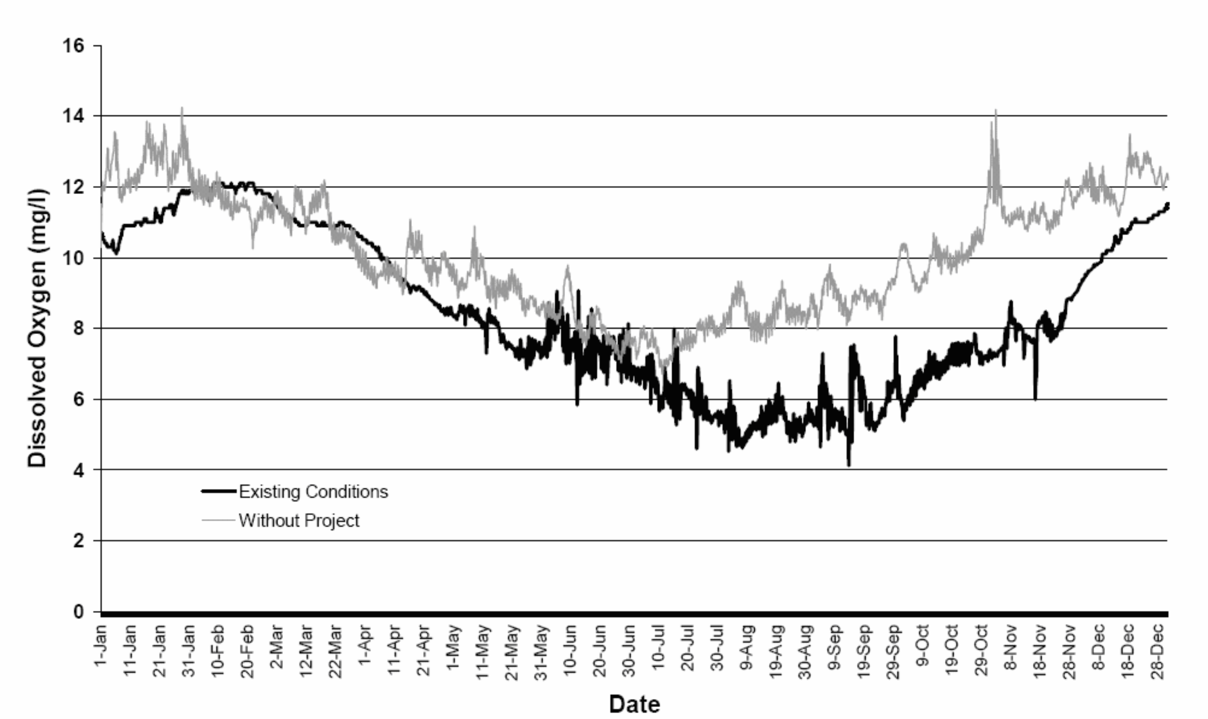


Figure 3-38. Simulated hourly DO levels below Iron Gate dam based on the year 2002 (a dry year) for existing conditions compared to hypothetical conditions without the Klamath Hydroelectric Project. (Source: PacifiCorp, response to AIR AR-2, dated October 17, 2005)

To address the reduced DO levels below Iron Gate dam, PacifiCorp proposes to install an oxygen diffuser system in Iron Gate reservoir to assist with compliance with the state water quality objective for DO downstream of the project (PacifiCorp, 2005, response to AIR AR-1 part [b]). The diffuser system would include a single diffuser line about 4,000 feet long, located in the deepest portion of the reservoir, designed to supply oxygen to the hypolimnion. The diffuser system would be operated seasonally each year beginning in the spring, as bottom water DO levels start to drop, and continue until reservoir turnover in the fall. Should conditions require, additional oxygen would be placed in the turbine water flow using three shorter diffusers in front of the intake tower. PacifiCorp proposes to monitor DO levels in the tailrace to provide guidance on potential adjustments of oxygen injection. As a separate, but related measure, PacifiCorp also proposes to develop and implement comprehensive water quality management plans for the reservoirs of the proposed project which would include an evaluation of the effectiveness and feasibility of several technologies, including further evaluation of hypolimnetic oxygenation and epilimnetic or surface aeration and circulation. We discuss PacifiCorp’s proposed water quality management plans later in *Project-wide Water Quality Management*.

NMFS recommends that, within 1 year of license issuance, PacifiCorp file a DO enhancement plan, developed in consultation with the resource agencies, for the project reaches and Klamath River downstream of Iron Gate dam to improve habitat resources for anadromous salmonids. The goal of the plan would be the development and implementation of a comprehensive management plan to enhance DO downstream of Iron Gate dam that would include (1) measures to meet salmonid requirements for the geographic extent of the project DO effect; (2) further study of PacifiCorp's proposal to install a hypolimnetic oxygenation system in Iron Gate reservoir to demonstrate downstream effectiveness and evaluate the potential for adverse effects on nutrient levels and thermal stratification; and (3) provisions to fully model, compare, and evaluate a variety of technologies, including but not limited to liquid oxygen injection (intake and draft tube), gaseous oxygen injection (intake and draft tube), construction and operation of a multi-port selective withdrawal structure, and turbine venting, and include an assessment of effectiveness, cost, and potential effects.

FWS recommends that PacifiCorp's proposal to install a hypolimnetic oxygenation system at Iron Gate reservoir be studied further to demonstrate downstream effectiveness and the potential for adverse effects on nutrient levels and thermal stratification. PacifiCorp would also study the potential effectiveness of a hypolimnetic oxygenation system at Copco No. 2, and J.C. Boyle dams and the potential for adverse effects on nutrient levels and thermal stratification. These studies would provide recommendations to control DO content of reservoirs and released waters from reservoirs to meet salmonid fish requirements for the geographic extent of project DO effects without exacerbating algal blooms or disrupting reservoir thermal stratification. As part of these studies, the role of nutrient input and cycling would also be studied and remedies to the problems of hyper-eutrophication proposed. PacifiCorp would develop and submit to the Commission for approval a DO enhancement plan that would specify measures proposed for implementation, based on these studies. The studies and plan would be developed in consultation with the agencies and be fully implemented within 3 years of license issuance.

The Forest Service recommends that the DO level of water released from Iron Gate dam should be controlled to meet salmonid fish requirements for the geographic extent of project DO effect, without exacerbating algal blooms. The PacifiCorp-preferred design (hypolimnetic oxygen diffuser) would be studied further to demonstrate downstream extent of effectiveness.

Siskiyou County states they are in favor of appropriate terms and conditions that result in aeration of water in the reservoirs, if these practices have appropriate benefits. Conservation Groups recommend that PacifiCorp operate the project in a run-of-river mode to enhance DO, such that the amount of water entering an impoundment is equal to the sum of water passed over the dam, through fish passage facilities, and through the turbines at any given point in time, at every relevant facility structure.

Our Analysis

We have seen no evidence that operation of the project in run-of-river mode, as recommended by the Conservation Groups, would increase the DO in the outflows of any of the project reservoirs. Low DO concentrations observed in project reservoirs are likely the result of high BOD in the water column, stemming from high levels of organic material, rather than the peaking and re-regulating operations of the dams. Operating the project in run-of-river mode would continue to draw water from the existing intakes and comparable depths and would result in DO levels that are similar to levels released from project structures under existing conditions.

Currently, DO concentrations measured at flows that range from 370 to 2,400 cfs in the J.C. Boyle peaking reach meet applicable state objectives. When the J.C. Boyle powerhouse is operating in peaking mode, generation flows are released only during the day. Typically, summer DO concentrations are higher in a reservoir during the day, when photosynthesis produces oxygen, than at night, when respiration depletes oxygen. If J.C. Boyle were to operate in a run-of-river mode during the summer, generation flow releases from the powerhouse would be relatively constant over a 24-hour period.

Releases during the daytime would contain higher concentrations of DO, and the increase in concentrations in the peaking reach via natural aeration would be limited. The resultant increased flow at night would create more favorable conditions for a re-aeration from the turbulence in the peaking reach because oxygen dissolves more readily in water with low DO. It is uncertain whether increased DO uptake at night in the peaking reach would influence the DO regime in downstream Copco reservoir.

Our review of available DO data and modeling results from downstream of Iron Gate dam indicates that during the warmer months of the year, project operations results in DO that does not meet applicable water quality objectives. Therefore, measures to enhance DO downstream of Iron Gate should be implemented. Implementation of PacifiCorp's proposal to inject oxygen into the bottom waters of Iron Gate reservoir during times of low DO concentrations would increase DO concentrations within the reservoir; however, based on our review of PacifiCorp's assumptions of oxygenation efficiency and the measured DO concentrations at a depth of 40 feet (the powerhouse intake depth) during the summer and fall months, we conclude that the proposed diffuser technology may not be sufficient to meet state water quality objectives for DO downstream of the dam. The average DO concentration in Iron Gate reservoir from July to October at a depth of 40 feet was between 1.1 and 4.9 mg/L during 2000 to 2004 and the oxygen delivery capacity of the conceptual design is based on providing 1 to 3 mg/L of DO uptake.

In addition to our concerns regarding effectiveness, implementation of a hypolimnetic oxygenation system, although designed to enhance DO concentrations, may produce undesirable or unanticipated secondary effects. PacifiCorp's hypolimnetic oxygenation modeling (PacifiCorp, 2005i) predicts there would be a slight rise in outflow temperatures in August and September when forced oxygenation or aeration is applied. PacifiCorp credited this to a complex relationship with algae shading; however, several agencies question the ability of the model to capture the complex interactions created by adding oxygen to the bottom of such a eutrophic reservoir. Wells (2004) points out that it is difficult to account for the complex relationship of nutrients, algae, and DO concentrations in models that are currently available. However, he suggests that without factoring such considerations into the modeling, the results may not predict actual DO and temperature outcomes. Although we agree that modeling temperature and DO in stratified eutrophic reservoirs may have drawbacks, it is the best available tool for predicting outcomes of various alternatives, and general trends shown by the model results can serve a valuable purpose with regard to the potential results of implementing environmental measures. However, the uncertainty of modeling results emphasizes the importance of verifying actual environmental responses by data collection in the field.

Turbulence created as oxygen rises through the water column would also likely alter the location of the thermocline, or possibly eliminate it. If this occurs, the potential for cool, hypolimnetic releases to lower the water temperature downstream of Iron Gate dam would be reduced. PacifiCorp's modeling results show that conditions with higher DO concentrations exhibit greater concentrations of inorganic nutrients (e.g., nitrate-nitrite) compared to nutrients bound to organic molecules, which may exacerbate algae blooms because algae can more readily assimilate inorganic nutrients. The modeling results showed oxygenation of the reservoir slightly decreased ammonia, noticeably decreased orthophosphate, and substantially increased nitrate-nitrite in the outflow between mid-July and mid-October. The ammonia and orthophosphate results are consistent with monitoring results taken before and after installation of a hypolimnetic oxygenation system in Comanche reservoir in California (Beutel, 2005). Chlorophyll *a* concentrations in Comanche reservoir decreased to about a quarter of that measured prior to hypolimnetic oxygenation, which is the opposite of what PacifiCorp's model predicts.

Increased amounts of inorganic nitrogen released downstream could affect the growth of attached algae in the river below the dam because the Klamath is nitrogen limited, as described in our discussion of the affected environment (see section 3.3.2.1.2). This could have other unwanted effects, such as increasing suitable habitat for the intermediate host of the salmonid pathogen *C. shasta*, discussed in the following subsection, *Monitoring and Control of Algae that Pose a Risk to Fish, Wildlife, and Public Health*. In light of our analysis, additional study of hypolimnetic oxygenation is warranted prior to implementing such a program in order to determine if the expected environmental benefits would outweigh any adverse environmental effects.

Oxygen or air injection into the turbines would increase DO levels in project outflows without the associated potential consequences of a hypolimnetic oxygenation system. The need for DO enhancement downstream of Iron Gate dam is immediate, especially during dry or critically dry years. Turbine air venting, which PacifiCorp's consultant estimates could increase DO in the Iron Gate dam tailwaters by at least 2.2 to 2.7 mg/L, depending on the configuration (Mobley, 2005), could be implemented with relatively minor adjustments to the turbine headcover or draft tube. Implementing turbine venting would provide some short-term relief during periods of low DO, enabling alternative long-term DO enhancement solutions to be further evaluated (in the context of remedial measures) to address other water quality issues in project waters. Depending on the results of DO monitoring in the tailwaters, turbine venting may also represent a viable long-term solution to the existing DO problem. Monitoring DO in the tailrace as well as in the reservoir adjacent to the Iron Gate powerhouse would provide data regarding the effectiveness of this approach, whether modifications to the venting system are needed, and whether supplemental or alternative DO enhancement measures should be considered.

Improving the DO concentration of the upstream hydro releases could further assist PacifiCorp in meeting DO objectives downstream of Iron Gate dam. As a supplement to air or oxygen injection at Iron Gate, injection could also be provided at Copco No. 1 or No. 2 powerhouse turbines which would increase DO concentrations of water entering Iron Gate reservoir. Flows from Copco No. 2 powerhouse would be discharged to the epilimnion of Iron Gate reservoir and the density of the relatively warm, oxygenated water would not likely be great enough to penetrate the thermocline. This would shorten the residence time of this water as it passes through Iron Gate reservoir because the oxygenated inflow would pass over the denser water to the intake of Iron Gate powerhouse. As figure 3-24 shows, water that flows through the powerhouse is primarily drawn from a location near the surface. Figure 3-28 (DO profiles) shows that, during the summer, the top few meters have high concentrations of DO while concentrations drop off substantially after 5 meters. Increasing the DO concentration in the top 10 meters of Iron Gate reservoir should translate to enhanced DO concentrations in the Klamath River downstream of Iron Gate dam. DO monitoring in Copco No. 2 and Iron Gate reservoirs coupled with DO monitoring in the Iron Gate tailwaters would document the effectiveness of such an approach, if implemented.

Spillage from project dams would increase downstream DO and may be appropriate for consideration in a comprehensive DO enhancement plan. This method could be used at times when spills would not result in inappropriate increases in water temperature downstream of Iron Gate dam, such as in May or June; however, DO concentrations at this time of year are typically above state objectives. Spillage at Copco No. 2 dam during certain times would increase DO of water entering Iron Gate reservoir through the relatively steep Copco No. 2 bypassed reach by using natural aeration from turbulence. This approach could be triggered by target DO concentrations in Iron Gate reservoir or downstream and may be more effective than direct air or oxygen injection at Copco No. 2 powerhouse. Using spillage to increase DO downstream of Iron Gate could also be achieved without the potential negative effects on nutrients and temperature that could occur with hypolimnetic oxygenation.

Monitoring DO concentrations in the outflows of Iron Gate near the USGS gage would assist in the management of an air or oxygen injection system at the turbines or within the waters of the reservoir while providing data for compliance monitoring. Incorporation of additional water quality parameters and locations would further assist PacifiCorp and appropriate parties in evaluating the effectiveness of any implemented measure and its effects on water in the reservoir. Development of additional studies to increase the understanding of relationships between enhanced DO concentrations and nutrient and algae dynamics, as recommended by NMFS, FWS, and FS, are actions similar to measures that would occur in PacifiCorp's proposed reservoir management plans, discussed later under *Project-wide Water Quality Management.* Distribution of PacifiCorp's plans to appropriate agencies for review and comment prior to filing with the Commission would ensure that the study plans address the best available technologies, resources, and monitoring techniques to ensure the chosen strategy would improve water quality. Implementation of air or oxygen injection systems at Copco No. 1 and 2 powerhouses, spillage at dams, or hypolimnetic oxygenation, if appropriate, could be initiated over time under an adaptive tiered approach, based on feasibility analysis and monitoring. A reasonable time frame for completing this adaptive approach would be 5 years (during which one or more additional DO enhancement measure may be implemented, if needed).

Monitoring and Control of Algae that Pose a Risk to Fish, Wildlife, and Public Health

During summer 2005 (Kann et al., 2006), and 2006 (Water Board, 2006), Copco and Iron Gate reservoirs experienced substantial and sustained blooms of the blue-green algae, *Microcystis aeruginosa*, and accompanying high levels of microcystin a toxin often produced by this algae. These algal blooms were detected starting in mid-July and lasted through most of October. During much of this period, cell density levels of *Microcystis aeruginosa* and microcystin toxin concentrations exceeded threshold levels identified by the World Health Organization as posing a Moderate Probability of Adverse Health Effects. There are no federal or California regulatory guidelines for cyanobacteria and their toxins. Although the toxic algae M*icrocystis aeruginosa* has been known to occur regularly in Upper Klamath Lake (Gilroy et al., 2000), where it may degrade the quality of commercially harvested populations of the blue-green algae, *Aphanizomenon flos-aquae*, and as far as 125 miles downstream of the project reservoirs (Kann et al., 2006), this was the first time the extent of the blooms and their toxicity, at locations other than Upper Klamath Lake, had been documented and health advisories issued by public agencies (Water Board) for project waters.

In addition to the toxic algae, the fish pathogens *C. shasta* and *Parvicapsula minibicornis* occur throughout the Klamath Basin and are a source of mortality to migrating salmonids throughout the Klamath River. PacifiCorp's investigation into *C. shasta* and its intermediate polychaete host *Manayunkia speciosa (M. speciosa)* indicates that habitat for the polychaete is available in areas of the project, primarily in free-flowing stretches of the river and riverine segments of the reservoirs (PacifiCorp, 2004f). The study of *C. shasta* is complicated by the fact that the pathogen changes form and apparently function, and has multiple hosts (juvenile fish and a polychaete alternate host) (Stocking and Bartholomew, 2004). Benthic sampling efforts within the Klamath River discovered the highest densities of the polychaete worms were always found within dense populations of the attached algae *Cladophora* (PacifiCorp, 2004f). One hypothesis for the high incidence of *C. shasta* in the Klamath River is that the polychaete populations have increased as a result of an increase in available habitat, most notably *Cladophora* (Stocking and Bartholomew, 2004). Bartholomew and Cone (2006) recently found the fish pathogen *P. minibicornis* requires the same worm host as *C. shasta*, thus, conditions that support *Cladophora* growth could enhance the prevalence of both fish pathogens. *Cladophora* populations, as well as other populations of aquatic vegetation, increase when nutrients enrich areas of suitable habitat. Whether or not the project contributes to nutrient enrichment is a complex issue. We discuss the effects of *C. shasta* and *P. minibicornis* on salmonids in section 3.3.3.2.5, *Aquatic Resources, Disease Management.*

PacifiCorp proposes to implement Reservoir Management Plans aimed at reducing algae concentrations, increasing dissolved oxygen, and improving pH. The Reservoir Management Plans would be designed to evaluate the effectiveness and feasibility of several technologies and measures (specifically hypolimnetic oxygenation, epilimnetic or surface aeration and/or circulation, and copper sulphate algaecide treatment) for more effectively controlling water quality conditions in the reservoirs. Although relevant to the control of algae in project waters, we discuss this measure, as well as recommendations of others that could reduce nutrient loading and thus control algal blooms, in the following section, *Project-wide Water Quality Management.*

FWS recommends that PacifiCorp develop a monitoring program, in consultation with other agencies, to assess the risk of toxic cyanobacteria blooms in Iron Gate and Copco reservoirs on fish health and the environmental factors that lead to such blooms and their adverse effects on fish. A plan would be developed, in consultation with the agencies, and implemented to reduce the risk of cyanobacteria blooms on fish.

Siskiyou County recommends that PacifiCorp provide for the removal of those species of blue-green algae that are a hazard and risk to health and safety of people and animals during the summer period when algae blooms occur. Conservation Groups recommend that PacifiCorp monitor for *Microcystis aeruginosa* in Copco and Iron Gate reservoirs and locations on the Klamath River affected in past years, downstream to the estuary, and at appropriate trigger points take appropriate actions (consult with public health authorities and public notification).

Our Analysis

Microcystis aeruginosa has appeared regularly in Upper Klamath Lake and the extent of the blooms and toxicity documented in 2005 indicates that the algae has dispersed downstream and may have bloomed in project reservoirs prior to last year's documentation. However, in the absence of a structured monitoring program, any previous occurrence of toxic algal blooms would have been undetected. The persistence of *Microcystis* in Upper Klamath Lake suggests that there would be continuing availability of algal cells to seed *Microcystis* blooms under favorable conditions in all project reservoirs. Commission regulations specify that hydropower project licensees provide reasonable public access to project lands and waters, as long as public safety is protected. The public currently enjoys water-based recreational activities, such as swimming, angling, and boating at facilities at all project reservoirs. The toxin produced by *Microcystis* represents a threat to public safety. A structured monitoring program, developed in consultation with resource and public health agencies, based on known life history characteristics of *Microcystis,* would enable monitoring to occur and, if necessary, public health advisory notices to be posted when microcystin levels in the water reach threshold values. A monitoring plan to identify conditions when blooms could potentially occur in each project reservoir would enable triggers for the initiation of monitoring events to be established, and avoid unnecessary monitoring. Provisions for updating the plan would enable the monitoring program to be modified to reflect new information about *Microcystis* as it becomes available, and conditions that could lead to monitoring prior to potential blooms refined.

If a monitoring program is implemented for *Microcystis* and its toxin in project reservoirs, monitoring results that trigger public health agency notification would enable such agencies to make a determination regarding whether there is a health risk to the public who come in contact with Klamath River water downstream of Iron Gate dam. Because algal blooms typically occur in reservoirs, not in free flowing river reaches, we expect the concentration of microcystin downstream of reservoirs where trigger levels may be detected, to be lower and less toxic. Consequently, we find that monitoring for *Microcystis* in free-flowing portions of the Klamath River from Iron Gate dam to the estuary, as Conservation Groups recommend, would be inappropriate to include as a condition of any new license that may be issued for this project. This would not preclude public health agencies from conducting such downstream monitoring if deemed necessary. Once detected, it may not be possible or feasible to remove *Microcystis* from project waters, as recommended by Siskiyou County. However, consideration of methods to reduce nutrient loading that create algal blooms and environmentally acceptable methods to control algal blooms when they occur, could be incorporated into the development of an overall water quality management plan, discussed in the following section.

Cladophora spp. is considered a nuisance algae capable of covering the entire stream bed. Schönborn (1996, as cited in Stocking and Bartholomew, 2004) found that *Cladophora* can displace all other aquatic macrophytes (individual aquatic plants large enough to be seen with the naked eye) due, in part, to a competitive advantage in nutrient enriched waters. This prolific, complex, and aggressive organism is considered an "ecosystem-reorganizer" capable of altering benthic food webs and centralizing the ecosystem by collecting fine organic matter and creating its own habitat (Schönborn 1996 as cited in

Stocking and Bartholomew, 2004). Stocking and Bartholomew (2004) link increases in *C. shasta* infections in juvenile salmonids with the spread of *Cladophora* in the Klamath River, as the upstream eutrophic reservoirs supply a steady flow of warm, nutrient-rich water to downstream river reaches. Stocking (2006, as cited by Resighini Rancheria, 2006) has shown that the primary habitat for the polychaete host for both *C. shasta* and *P. minibicornis* is sand with fine benthic organic matter and that the filamentous green algal *Cladophora* is a secondary habitat type. Polychaetes living on sand with fine benthic organic matter substrate are restricted to low-velocity areas, whereas polychaetes can exist in *Cladophora* in areas with higher water velocities (Stocking 2006, as cited by Resighini Rancheria). Furthermore, sand substrate is susceptible to scour and active bed movement in response to increased velocities, whereas attached algae such as *Cladophora* may be able to withstand higher velocities providing a relatively stable habitat for the intermediate polychaete host. Stocking (2006, as cited by Resighini Rancheria) sampled an extremely large and dense population of polychaetes at Tree of Heaven (around RM 170) in March 2005. When Stocking returned to sample again in July, after a high-flow event (discharge below Iron Gate Dam peaked at 5,380 cubic feet per second on May 18), much of the organic matter was gone and all polychaetes had disappeared (presumably both had been washed downstream). In contrast, polychaete populations in *Cladophora* beds remained intact. Eilers (2005) recorded decreased biomass of attached algae downstream of Iron Gate dam following a doubling of released flow (from about 600 cfs to about 1,300 cfs) a week prior to his field work.

FWS pathogen monitoring of juvenile salmonids in the Klamath River during spring of 2006 showed 10 incidences of *C. shasta* infection out of 391 (2.6 percent) samples taken through the second week of June (True, 2006).). Flows in spring of 2006 (up to 10,000 cfs) were substantially above median levels (as described in section 3.3.2.1, *Water Quantity*) suggesting that increased flows may be capable of moderating the infection rates in juvenile salmonids, possibly by displacing or disrupting the growth of either the attached algae or the ability of the host polychaete to exist within the *Cladophora* habitat. FWS pathogen monitoring in 2005 detected juvenile salmonid infection rates of up to 100 percent of both *C. shasta* and *P. minibicornis* (FWS memo undated. Accessed on the web, July 7, 2006, via: http://ncncr-isb.dfg.ca.gov/KFP/uploads/KR%20pathogen%20monitoring%20summary%2005-26-05.doc; last updated May 31, 2005). Reclamation classified 2005 as a "below average water year" (Reclamation, 2005c) where flows were well below the median during the time of recorded infections. Continued high nutrient levels in the Klamath River that create ideal colonization conditions for *Cladophora*, at sites with favored flow and substrate conditions, would enable the host polychaete to become reestablished, and *C. shasta* and *P. minibicornis* would likely continue to pose a serious threat to downstream salmon for the foreseeable future. However, by using information gathered during years when *C. shasta* infestations are low, such as 2006, it may be possible to develop methods to minimize future infestations by using controlled flows that displace either *Cladophora*, the hard substrate on which it grows, or the intermediate polychaete hosts that use this algae as its preferred habitat. We discuss the threat of *C. shasta* and *P. minibicornis* on anadromous fish and plans to control such threats in section 3.3.3.2.5*, Aquatic Resources-Disease Management* and the influence of flow on substrate conditions and active bed transport are discussed in section 3.3.1.2, *Geology and Soils*.

The presence of the blue-green algae *Aphanizomenon flos-aquae* in Upper Klamath Lake and its ability to fix nitrogen (convert inert nitrogen gas to more biologically available forms such as nitrite or nitrate) has been identified as a seasonally substantial source of nitrogen to Upper Klamath Lake (Walker, 2001; Oregon Environmental Quality, 2001). Dense blooms of *Aphanizomenon flos-aquae* occur in Copco and Iron Gate reservoirs during July and August (PacifiCorp, 2004a), and are a source of nitrogen into project waters and releases downstream.

A reservoir management plan that limits the amount of inorganic nitrogen inputs would reduce suitable conditions for *Cladophora* colonization and reduce the risk of *Microcystis* as these organisms thrive under nitrogen rich conditions. Because *Aphamizonmeon flos-aquae* algae fixes nitrogen, which increases the amount of available inorganic nitrogen and could enhance the proliferation of downstream aquatic algae such as *Cladophora*, a reservoir management plan should address factors or conditions that support *Aphamizonmeon flos-aquae* blooms and identify measures that could be implemented to reduce such blooms in project reservoirs.

Project-wide Water Quality Management

As previously discussed, water quality within the Klamath River and throughout the mainstem portion of the project, is compromised for a number of water quality parameters which has triggered CWA 303(d) listings and the development of TMDLs, as well as other actions throughout the upper Klamath Basin. Numerous entities have filed comments that the project is a source of the poor water quality in the Klamath River and have filed recommendations designed to improve water quality to meet state standards.

Basin wide monitoring results show that Upper Klamath Lake is nutrient-rich, with hypereutrophic conditions observed during the summer. Project wide monitoring results show eutrophic conditions in all project reservoirs during the same time period. Project waters are typically high in total phosphorous and nitrogen, and experience extensive algae blooms during summer months resulting in high chlorophyll *a* concentrations. Upper Klamath Lake is undoubtedly responsible for a large portion of the nutrient loading downstream of Link River dam; however, there are additional inputs from the Lost River, Klamath Straits Drain, and other non-point sources downstream of Keno dam (e.g., runoff from agricultural lands along the downstream portion of the peaking reach and adjacent to J.C. Boyle, Copco and Iron Gate reservoirs). In addition, nutrient cycling in the project reservoirs (Kann and Asarian, 2005; Campbell, 1999) increases the complexity of readily using predictive modeling to accurately understand the nutrient regime within the Klamath River. PacifiCorp states that the project does not contribute to nutrient loading on a net annual basis, arguing that the reservoirs act to trap sediments and the nutrients associated with them, thus improving downstream water quality. Previous nutrient loading investigations by Campbell (1999) and Kann and Asarian (2005) suggest that the project reservoirs act as both sinks and sources depending on the seasonal conditions within the reservoirs. Regardless, nutrient availability contributes to algae blooms of *Aphanizomenon flos-aquae,* a nitrogen fixing algae, in all mainstem Klamath River reservoirs, and attached algae growth downstream of the project which, as discussed in the previous section, has other undesirable environmental effects.

PacifiCorp, as part of their water quality certification application, proposes to develop comprehensive reservoir management plans aimed at reducing algae concentrations, improving DO, and improving pH in J.C. Boyle, Copco, and Iron Gate reservoirs (letter from C. Scott, Project Manager, PacifiCorp, to the Commission, dated May 12, 2006). The plans would include evaluation of technologies and potential effects of implementing them on the conditions resulting from the high nutrient and organic inputs. The plans would also provide for evaluating the appropriateness of treating algal blooms with copper-based algaecide. In addition, the plans would include further evaluation of hypolimnetic aeration (as previously discussed in *Dissolved Oxygen Remediation*) and epilimnetic or surface aeration/circulation. PacifiCorp expects that actions identified in the plans would achieve the following: reduced hypolimnetic BOD and ammonia (through oxidation of these compounds), reduced orthophosphate (through retention in sediments), and a decrease in algae populations in surface waters that would lead to decreased fluctuations in pH.

The Forest Service recommends that PacifiCorp work cooperatively to address cumulative effects on water quantity and quality in the Klamath basin through appropriate remediation such that water influenced by the project is of sufficient quality to meet or exceed applicable state objectives. The Forest Service further recommends that PacifiCorp study the feasibility of improving Klamath River nutrient levels in and downstream of project reservoirs by mitigating nutrients released in project river reaches and reservoirs, including offsite remediation to improve nutrient loading from Upper Klamath Lake.

Oregon Fish & Wildlife recommends that within 1 year of license issuance, PacifiCorp develop a water quality resource management plan, in consultation with Oregon Fish & Wildlife, and other state, federal, and tribal resource agencies. The plan would be updated every 5 years, in consultation with the agencies. PacifiCorp would submit annual reports to the Commission and the agencies that would include the annual work plan for the upcoming year and a report with narrative and graphs demonstrating compliance with water quality requirements and standards for project reservoirs and reaches. The report would also include a summary of non-compliant events for the following parameters: water temperature, DO, TDG, pH, chlorophyll *a*, nutrients (including nitrogen and phosphorus), and toxic algae.

Oregon Fish & Wildlife and the Hoopa Valley Tribe recommend that PacifiCorp implement mitigation measures and conduct water quality monitoring pursuant to the water quality management and monitoring plan(s) approved by the Oregon Environmental Quality and the Water Board in connection with the water quality certificates.

Our Analysis

Our review of available water quality information indicates that the Klamath River experiences tremendous nutrient inputs from upstream of the project and elevated nutrient concentrations within project reservoirs and downstream of Iron Gate dam. Generally, mean nutrient concentrations are reduced in the riverine reaches as compared to project reservoirs. Upper Klamath Lake and the surrounding agricultural lands are undoubtedly the source of much of the nutrient load in project waters; however, due to complex nutrient cycling dynamics, project reservoirs act as both a sink and a source of nutrients depending on the time of year.

PacifiCorp suggests that Copco and Iron Gate reservoirs trap and remove nutrients from the Klamath River. Table 3-29 shows the concentrations of total phosphorous, orthophosphate phosphorus, and ammonia in the hypolimnion of Copco reservoir increase in the summer, which could be used to support such conclusions; however, the concentration data alone are not enough to irrefutably support PacifiCorp's position. A nutrient mass balance study conducted on behalf of the Karuk Tribe and summarized by the Water Board (2005) indicates that the reservoirs have periods in which they both trap and generate nutrients. Nutrient load estimates by Kann and Asarian (2005) indicate that Copco and Iron Gate reservoirs act as sinks for the nutrients phosphorous and nitrogen during April, May, parts of July and August and October, but both reservoirs can act as a nutrient source to the Klamath River below Iron Gate dam during most of June and September. Likely pathways for this increased load include internal sediment loading and nitrogen fixation by cyanobacteria such as *Aphanizomenon flos-aquae*, according to Kann and Asarian (2005). Nutrient loading analysis was not available for the period from November through March, which could include the period of reservoir turnover when nutrients within the hypolimnion could become either available for transport downstream or undergo aerobically induced chemical processes that result in the formation of insoluble precipitates, which could settle out rather than be passed downstream. After settling to the bottom, nutrients would be released from the precipitates under anaerobic conditions the following year, resulting in an internal cycling of nutrients. Due to the limited field data, the net fate of the nutrients is not entirely clear. Our review of available temperature profiles for Copco and Iron Gate reservoirs (figure 3-23) indicates that in 2002, fall turnover likely occurred between September and October at Copco reservoir. In 2001, fall turnover likely occurred between October and November at Iron Gate reservoir. The potential effect of nutrient releases from Iron Gate development associated fall turnover on downstream aquatic habitat is unknown. Spawning adult fall Chinook salmon would be in the river during this time frame. The Water Board is conducting a follow-up study that broadens the temporal and spatial data collection that limited the Kann and Asarian (2005) study.

Results from Kann and Asarian (2005) are supported by an earlier investigation by Campbell (1999) who also concluded that the project reservoirs act as both nutrient sinks and sources. Campbell concluded that there is a general increase in phosphorus loading longitudinally from Keno to below Iron

Gate dam which is not completely explained by increases in flow between the two sites and may be caused by internal nutrient cycling in the project reservoirs. Campbell further notes that although internal nutrient cycling in the project reservoirs was not quantified, the reservoirs in series do not seem to be functioning as a substantial nutrient sink between Keno and Iron Gate dam.

PacifiCorp acknowledges that Keno reservoir is seeded with algae passed from Link River, such that the same nutrient cycling dynamics occurring in Upper Klamath Lake also would be likely to occur in Keno and other downstream reservoirs. The total nitrogen balance developed for the Upper Klamath Lake TMDL indicates that Upper Klamath Lake is a seasonally important source of nitrogen (Kann and Walker, 2001). The primary source for this increase is internal nitrogen loading from nitrogen fixation by the blue-green alga *Aphanizomenon flos-aqaue* (Kann, 1998 as cited by Oregon Environmental Quality, 2002). The ongoing Water Board nutrient balance study for Copco and Iron Gate reservoir should provide resolution of this complex issue at these reservoirs. We conclude, based on our review of the available information that Copco and Iron Gate reservoirs act as sources of inorganic nitrogen during the summer, at least during relatively dry years primarily because the reservoirs create conditions that foster algal blooms of *Aphanizomenon flos-aqaue* and associated nitrogen fixation.

DO and pH in project-influenced waters are indirectly affected by nutrients because they are related to background water quality conditions, photosynthetic activity, and the amount of organic material exerting biological oxygen demand in the water. A shift in nutrient cycling in project reservoirs and outflow to inorganic nitrogen could act as a stimulant to enhance growth of attached algae in the Klamath River downstream of Iron Gate dam. Based on our review of available information, project reservoirs contribute to increased nutrient enrichment both within and downstream of project reservoirs on a seasonal basis, with associated related adverse affects (i.e., low DO during the summer and early fall and increased habitat for the *C. shasta* polychaete host, discussed in the previous subsection). Table 3-29 shows ammonia accumulates in the hypolimnion of both Copco and Iron Gate during the summer into October. Ammonia concentrations in the Klamath River above the confluence with the Shasta River were recorded at the highest levels in October, which is not unexpected under reduced conditions; however high levels in a well mixed environment such as the Klamath River at the confluence of the Shasta River (over 13 miles downstream of Iron Gate dam) suggests turnover at Copco and Iron Gate reservoirs or fish hatchery effluent could be responsible for the elevated ammonia concentrations. Ammonia can be toxic to fish. Therefore, we conclude that it is appropriate for PacifiCorp to assess measures to reduce such nutrient-related project effects, as PacifiCorp proposes and others recommend.

Development of reservoir management plans, as proposed by PacifiCorp, would address conditions stemming both directly and indirectly from the high levels of nutrients in project waters. Assessing a variety of technologies for reducing algae concentrations and enhancing the DO and pH of project waters would identify potentially effective measures to be implemented to address known water quality problems. However, development of separate management plans for each project reservoir would make it more difficult to take a comprehensive approach to addressing water quality issues, as previously discussed in *Keno Reservoir Water Quality Management*. We consider a more effective approach to water quality management to include all project-affected waters in a single comprehensive water quality resource management plan, as recommended by Oregon Fish & Wildlife. By including all project reservoirs and free-flowing reaches influenced by the project (e.g., project bypassed reaches, the peaking reach, and project-influenced portions of the Klamath River downstream of Iron Gate dam) in such a plan, water quality monitoring and potential remedial measures would incorporate inter-relations of reservoir dynamics with those of free-flowing project reaches into deliberations regarding measures that should be implemented.

We consider consultation with appropriate resource agencies in the development of any comprehensive water quality resources management plan to be essential. In some instances, potential measures for controlling water quality issues within project waters may entail balancing benefits against potential adverse effects. For example, using an algaecide to control a *Microcystis* bloom could be effective in reducing the amount of microcystin toxin, and associated human health risk, in project reservoirs. However, depending on the algaecide used, there could be associated adverse water quality effects. In addition, as treated algae die and settle to the bottom of the reservoir, nutrients within the algal cells become susceptible for release and reintroduction to the water column at a later time. Resource agencies that represent the local natural resources and the related public health interests should be involved in such decisions.

Although we agree with the Forest Service that offsite measures to reduce nutrient loading coming into the project could help control nutrient levels within the project-influenced portion of the Klamath River, we consider it appropriate to consider such measures in plans that address loading to the Klamath River from throughout the entire basin. For example, we conclude the forthcoming TMDL and Reclamation's CIP would address loads entering the Klamath River and we consider it unreasonable to assign to PacifiCorp the responsibility of nutrient removal prior to reaching the project. However, provisions for periodic updates to a comprehensive water quality management plan specific to the Klamath Hydroelectric Project would enable parallel water quality enhancement initiatives to be incorporated into the plan, as appropriate. Although the outcome of PacifiCorp's proposed assessments of measures to control algae and related water quality problems associated with high nutrient and organic input may identify techniques that could be used directly in project waters, another possible outcome could be that it may be more effective to treat water before it is influenced by the project. Cooperation and coordination with other entities with an interest in addressing basin-wide water quality issues could lead to creative solutions to such issues. As discussed in *Keno Reservoir Water Quality Management*, assessing measures that would reduce the nutrient load of water passing from Keno dam, could effectively address project-related water quality issues at Copco and Iron Gate reservoirs. We discuss the basin-wide efforts targeting nutrients and other water quality analytes in section 3.3.2.3, *Cumulative Effects.*

Project operations contribute to water quality conditions that affect the taste and odor of project waters and could affect the flesh of harvestable salmonids and other aquatic resources that occur within the river. Table 3-34 indicates that two-thirds of recreational users in the project area had negative perceptions of the water quality, commenting on its color, turbidity, and odor. Given the eutrophic conditions within the reservoirs and the nutrient and organic matter loading to the river, it is not unreasonable to imagine the water would have a distinctive taste. We have no information regarding what specific conditions are causing taste and odor complaints by recreational users, but given the prevalence of algal blooms in project reservoirs, we suspect that such blooms are the likely cause of taste and odor problems. In addition to algal blooms, taste and odor issues at reservoirs are often associated with hydrogen sulfide, which produces a "rotten egg" taste and smell. Hydrogen sulfide production typically occurs as a byproduct of anaerobic decomposition of organic matter. Conditions that would allow hydrogen sulfide production (high organic matter and anoxic conditions) are present when Copco and Iron Gate stratify in the summer. We have no direct evidence that this is the case at any of the project reservoirs, but it would not be unexpected. Methane production, which is strongly suspected as occurring under certain similar anoxic conditions, at least in Iron Gate reservoir (Eilers and Eilers, 2004), can also produce taste and odor problems. Additional unpleasant odors could stem from the decomposition of algal mats that are attached to the shoreline providing a source of odors in areas visited by shoreline recreationists. A water quality management plan that includes measures that would reduce the likelihood of algae blooms, as well as enhance the DO of hypolimnetic water in Copco and Iron Gate reservoirs would also likely serve to reduce the taste and odor issues of project waters.

Dam Removal to Enhance Water Quality

Oregon Fish & Wildlife and the Hoopa Valley Tribe recommend that if it is not feasible to meet water quality objectives for water quality certification through modification of project facilities and operations, PacifiCorp should prepare a decommissioning amendment application for the subject facility, in consultation with state, federal, and tribal stakeholders, in order to achieve compliance with applicable water quality objectives.

The Hoopa Valley Tribe states that "PacifiCorp's own analyses make it clear that the Klamath Hydro Project's effects on water temperature are immitigable; therefore, the only way to substantially reduce the impacts is to remove all KHP dams and drain the reservoirs." We consider this to be a recommendation for project dam removal to enhance the downstream water temperature regime for salmonids.

Conservation Groups recommend that PacifiCorp prepare a decommissioning plan in consultation with federal state, tribal, and other relicensing parties that results in the modification or removal of project facilities and operations to achieve compliance with all applicable water quality objectives.

Our Analysis

Both Oregon and California have listed project waters as "impaired" because they fail to meet applicable water quality objectives. We assess the potential effects on water quality resulting from removal of each mainstem dam because numerous parties have recommended the removal of some or all project dams. Many parties suggest that dam removal may be the only means to effectively address adverse project-related water quality effects. If project operation can be demonstrated to be responsible for continued violations of applicable water quality objectives after implementation of reasonable measures, and it is not feasible to correct the problem, we consider it appropriate to consider decommissioning the development. However, we expect considerable effort to be expended to identify all options to correct the problem before decommissioning is considered. If water quality objectives are not met for reasons that aren't related to project operations (e.g., the quality of water entering the development is similar to the quality of water leaving the development), it would be inappropriate to consider decommissioning the development. We do not expect the Fall Creek diversion dams to have any long-term effect on water quality. We do not consider removal of either diversion dam to be a reasonable option because applicable water quality objectives are currently being met. Therefore, we do not further discuss removal of these dams to achieve water quality objectives.

PacifiCorp's temperature modeling results show a Klamath River without hydroelectric dams would generally be warmer in the spring, more variable in the summer and fall (in particular, downstream of Iron Gate dam, as shown in figure 3-37), and similar to existing conditions between December and March. Unfortunately, because many of the other parameters in the model (e.g., pH, nutrients, and algae) are driven by much more complex biochemical processes than temperature,[43] modeling results for these parameters are contingent on the quality of the entire dataset and subject to variable interpretation. We base much of our analysis of the potential effects of dam removal on our review of existing water quality data from the riverine reaches and general principles that typically influence water quality. Without project dams and their associated reservoirs, the river would become well-oxygenated below the Keno dam site, due to mixing and reaeration afforded by natural river systems in steep, fast flowing environments. The Klamath River without project dams would still experience high levels of nutrients and organic matter originating from upstream sources, unless measures are implemented by other entities to reduce nutrient input. Given the high inputs to project waters, nutrients would continue to persist in project area waters in the absence of water treatment by other parties, and it is likely that without treatment of water entering the Klamath River from Link River and the Klamath Irrigation Project, Klamath River water quality would continue to be impaired. More importantly, conditions that support planktonic algae, including *Microcystis, Aphamizonmeon flos-aquae*, and other species that cause blooms in project reservoirs, would be diminished because such algae do not thrive in free-flowing reaches with

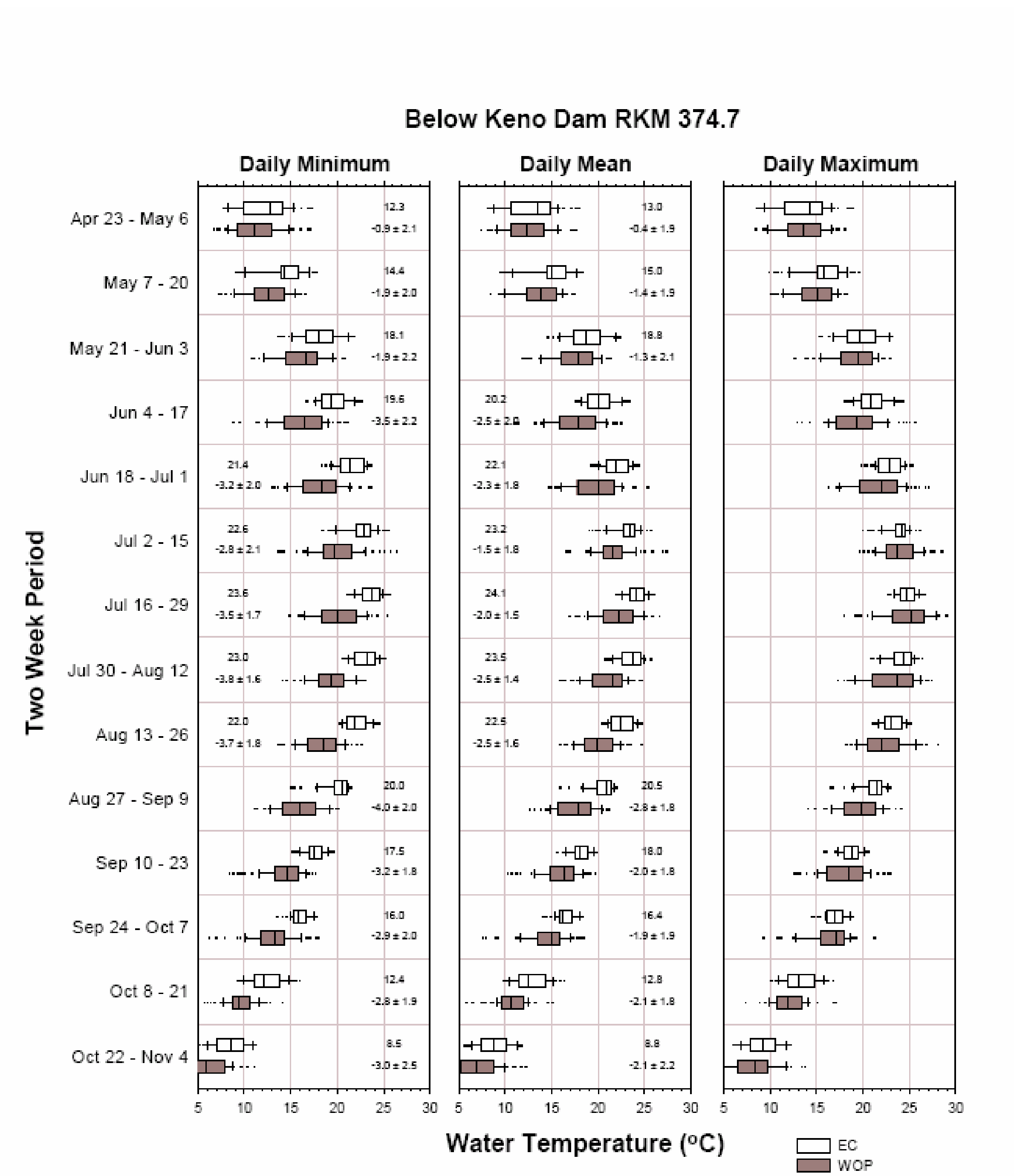
[43]Temperature is a physical process and as such is relatively simple to model, as the physics that affect it are well understood.

turbulent conditions, such as would exist in the Klamath River without project dams. Therefore, the geographical extent of Klamath River impairment would likely be reduced with mainstem project dam removal.

Removal of Keno dam would result in substantial changes to the thermal regime in the formerly impounded area, as the surface area would be substantially reduced and the residence time of water passing through the former reservoir site would be decreased, thus reducing solar warming of the impounded water. However, inflow to the Klamath River from irrigation runoff and from Upper Klamath Lake would still be warm. Figure 3-39 shows the expected temperatures below Keno dam under a "without project" scenario summarized by 2 week time periods. Daily maximums under the without project scenario would be similar to existing conditions; however, the greatest differences would be in the daily minimums, which could be almost 4°C lower than the existing conditions during the warmest periods in July. Similarly, daily average temperatures would be lower without the project, with temperatures about 2°C lower during the same time period. We discuss the effects of such temperature differences on salmonid refugia in section 3.3.3.2, *Aquatic Resources*.

High nutrient inputs would be expected to continue, but because the reach would be free flowing there would be a decrease in planktonic algae and a likely increase in attached algae (including *Cladophora spp*.) and submergent and emergent vegetation. Biggs (2000, as cited by Resighini Rancheria, 2006) reports that rivers around the world follow common patterns in response to localized nutrient enrichment. He states that, as long as additional nutrient inputs do not occur, nutrient concentrations typically diminish as the river flows downstream. Increased nutrient uptake by periphyton below a source is documented by USGS investigations on the South Fork Umpqua River in Oregon. USGS concluded that periphyton acts as an effective sink for nutrients entering the South Umpqua River (Tanner and Anderson, 1996). The free-flowing Oregon portion of the Klamath River below Keno dam is currently dominated by nuisance filamentous green algae species (i.e., *Cladophora*) (Oregon Environmental Quality, 2002), which would likely continue in the future. However, the distribution might shift depending on any future changes in the nutrient regime and whether or not any dams are removed.

The continued loading of organic material from Upper Klamath Lake and the shallow nature of the relatively low gradient of the Klamath River currently submerged by Keno reservoir (see figure 3-2) are conditions that would persist post-dam removal and may continue to exert an elevated biological oxygen demand throughout the water column. This may result in a continuation of DO conditions that are similar to current conditions in that the high biological demand would compromise DO concentrations resulting in low DO levels. Because the portion of the Klamath River now impounded by Keno dam would be returned to a shallow river, high nutrient inputs would stimulate aquatic plant growth, which would also contribute to fluctuations in DO concentrations (NAS, 2004). If Keno dam is removed, the former Lake Ewauna would not serve to retain fine-grained sediment and associated nutrients and other contaminants, because the bedrock sill that formed Lake Ewauna was removed when the original regulating dam was constructed at Keno (see section 3.3.1.1, *Geology and Soils*). This could allow for some turbulence causing reaeration; however given the shallow, meandering nature of the reach this may only result in modest aeration and may not overcome the biological oxygen demand. In general, we expect changes in nutrient and DO concentrations in the former Keno reservoir area and the downstream Keno reach, if Keno dam should be removed, to be related to a shift from free floating planktonic algae to attached algae and emergent vegetation which could begin the nutrient assimilation process closer to the source of inputs.



[a] Box plots (line inside box is median, box ends are 25th and 75th percentiles, whisker ends are 10th and 90th percentiles, dots are outliers) of daily minimum, mean, and maximum temperatures predicted by PacifiCorp's Klamath River Water Quality Model below Keno dam.

[b] Models estimate Existing Condition (EC) and Without Project (WOP). Numbers adjacent to the box plots are the mean temperature under EC (top) and the mean difference (WOP-EC) ± 1 SD (bottom).

Figure 3-39. Composite box plots[a] of two week summaries of modeled[b] water temperature from April to November for the years 2000 through 2004 below Keno dam. (Source: Resighini Rancheria, 2006)

The Keno reach upstream of J.C. Boyle reservoir is generally steep, free flowing, and has a boulder type substrate, and waters entering Boyle reservoir are well aerated. Residence time in J.C. Boyle reservoir is short compared to other reservoirs (about 3 days), which limits the amount of time for alteration of water quality directly related to the project. Little sediment has accumulated in the reservoir according to available information (see table 3-1). If J.C. Boyle dam would be removed, we expect there would be little effect on downstream water quality. The exception would be a substantial increase in water temperature in the J.C. Boyle bypassed reach because the increased volume of water would dilute the coldwater inflow from springs in this area. Similarly, the temperatures in what is now the peaking reach would be modified by eliminating the swings caused by peaking operations and the influence of the spring water in this reach during non-generation periods. However, we expect that daily averages would be similar to existing conditions. We discuss the loss of cold water salmonid refugia associated with this scenario in section 3.3.3.2, *Aquatic Resources*.

Removal of Copco No. 1 and Iron Gate dams would result in the greatest effects on Klamath River water quality due to loss of their associated reservoirs. Without these two dams, we expect the Klamath River would experience reduced ammonia and pH fluctuations, as these conditions are associated with algae blooms, anaerobic decomposition, and stratification processes within the reservoirs, as well as a reduced risk of *Microcystis* blooms. Removal of Copco No. 1 and Iron Gate dams would likely result in changes in the distribution of attached algae and moderate DO and pH. Without Copco and Iron Gate, temperatures below Iron Gate would experience more diurnal variability than existing conditions; however this variability would not be as extreme as without project scenario predictions (PacifiCorp, 2005).

Removal of Copco No. 2 dam would return flows to the Copco No. 2 bypassed reach providing natural aeration from the turbulent passage of water over the coarse, steep gradient in this reach, thus improving DO. However, because of the lack of a sizeable impoundment we do not expect additional effects on water quality.

With an abundance of nutrients in the water, aquatic plants thrive in the Klamath River and the mainstem reservoirs (Campbell, 1999). Without Iron Gate and Copco No. 1 dams in place, planktonic algae densities would substantially decrease, allowing opportunistic attached algae and rooted vegetation to capitalize on the nutrient-rich waters within the river in areas with suitable substrate. The dense algae blooms that currently occur in Copco and Iron Gate in July and August are dominated by the same nitrogen fixing algae that contributes to increased nitrogen in Upper Klamath Lake. Removal of the dams would reduce the seasonal nitrogen loading potential by the algae, thereby reducing nitrogen availability within the area or downstream. The greatest amount of nutrient uptake by attached algae or rooted vegetation would most likely occur close to the source of nutrient inputs, which without Copco or Iron Gate would be closer to Keno reservoir and nutrient uptake would continue through the project area and beyond.

Should *Cladophora* become established in formerly impounded river reaches at Copco and Iron Gate, as figure 3-34 suggests could occur, we expect it to thrive, given the high nutrient concentrations entering the river from the upper basin. This could have implications for anadromous fish restoration, discussed in section 3.3.3.2.3, *Anadromous Fish Restoration*. However, the nutrient dynamics in the Klamath River would be altered if one or more mainstem dams were to be removed, and predicting future nutrient conditions and associated *Cladophora* colonization in the vicinity of the current Copco and Iron Gate dam sites would be difficult. Because the river would be free flowing for a longer portion of the reach, there would be ample opportunity for waters to be well-aerated from natural turbulence, dampening the current extremes in DO concentrations in the middle section of what is now Copco and Iron Gate reservoirs. When oxygen is present, phosphate typically is bound to sediment particulates, becoming unavailable for plant growth.

Hazardous Substances

The Bureau of Land Management specifies that PacifiCorp file a hazardous substances plan for oil and hazardous substance storage, spill prevention, and clean up with the Commission prior to planning, construction, or maintenance that may affect Bureau of Land Management-managed land. At least 90 days prior to filing the plan with the Commission, PacifiCorp would submit the plan to the Bureau of Land Management for review and approval. The plan would outline procedures for reporting and responding to releases of hazardous substances and make provisions for maintaining emergency response and HAZMAT cleanup equipment sufficient to contain any spill from the project.

The Bureau of Land Management also specifies that PacifiCorp should semi-annually provide the Bureau of Land Management with information on the location of spill cleanup equipment on Bureau of Land Management-managed land and the location, type, and quantity of oil and hazardous substances stored in the project area. PacifiCorp would inform the Bureau of Land Management immediately as to the nature, time, date, location, and action taken for any spill affecting Bureau of Land Management-managed land.

PacifiCorp submitted alternative 4(e) conditions to the Bureau of Land Management (filed with the Commission on April 28, 2006). PacifiCorp's alternative 4(e) condition modifies the Bureau of Land Management condition by stating that it would implement and maintain spill prevention control and countermeasure plans at all project facilities in compliance with 40 CFR Part 112. PacifiCorp states that the plans would be made available to the Commission and the Bureau of Land Management as requested. Finally, PacifiCorp states that the scope of this condition would only include Bureau of Land Management lands within the project boundary.

PacifiCorp also provided an alternative 4(e) condition to semi-annually provide the Bureau of Land Management with information on the location of spill cleanup equipment on Bureau-managed land and the location, type, and quantity of oil and hazardous substances stored in the project area. PacifiCorp states that it would maintain spill clean-up equipment on Bureau of Land Management lands within the project boundary in accordance with the required spill prevention and cleanup plans. PacifiCorp proposes to submit annually a copy of its annual emergency and hazardous chemical inventory (Tier II form) to the appropriate state jurisdictional agencies in accordance with federal regulations. PacifiCorp does not say that it would provide this Tier II form to the Bureau of Land Management. It agrees to notify the Bureau of Land Management of any spills on Bureau lands within the project boundary, but does not provide for notification if spills affect, but do not occur on, Bureau lands.

Our Analysis

In accordance with 40 CFR §112.1 of EPA's regulations, a hazardous substance plan (also referred to as a spill prevention control and countermeasure plan) is required to be in place for any facility where unburied storage capacity exceeds 1,320 gallons of oil or a single container has capacity in excess of 660 gallons. In addition to the onsite storage of lubricants and other oil products, transformers at the J.C. Boyle, Copco No. 1, Copco No. 2, and Iron Gate powerhouses are oil-cooled and would be of sufficient capacity to exceed the threshold to require a hazardous substances plan to be in place, independent of this relicensing procedure. This plan would provide a quick reference to procedures and notifications in case of oil spills and reduce the possibility of oil or other hazardous substances reaching the Klamath River if a spill occurs. A hazardous substances plan would minimize the amount of petroleum products that would enter project waters in the unlikely event of a spill. There is no evidence that PacifiCorp stores smaller quantities of oil than those that would trigger preparation of a hazardous substances plan or additional hazardous substances besides petroleum products within the existing or proposed project boundary. However, if such is the case, extending the hazardous substances plan to include smaller quantities of oil and other hazardous substances would reduce the risk of contamination of project lands and waters by these products and would reduce the extent of contamination should a spill occur. If hazardous substances not covered under PacifiCorp's existing hazardous substances plan should be needed prior to any planned construction or maintenance activities, we consider inclusion of a site specific addendum to PacifiCorp's existing plan to cover this construction or maintenance activity to be reasonable and consistent with documented Best Management Practices. For construction or modifications of existing project facilities, the site-specific hazardous substances plan addendum, with the base plan, could be submitted for approval as part of the final plan for the site.

We are not aware of any actions proposed by PacifiCorp as part of this relicensing proceeding that would entail new construction or maintenance that would not be addressed in a plan proposed by PacifiCorp or recommended by the staff. The type of construction or maintenance that would require a new plan for oil and hazardous substances storage and spill prevention and cleanup would typically require a licensee to file a request for a license amendment with the Commission. The need for such a new plan would be addressed in the license amendment proceeding.

PacifiCorp already reports information on the location of spill cleanup equipment and the location, type, and quantity of oil and hazardous substances stored in the project area to the appropriate state agencies on an annual basis. This report includes Bureau of Land Management managed lands within the project boundary. The Bureau of Land Management has not made its case why the existing annual reporting should be shortened to semi-annual reporting and why the existing reports provided to state agencies are not sufficient to document on-site hazardous material inventories. Coordinated efforts between the Bureau of Land Management and the state agencies would alleviate the need for PacifiCorp to prepare duplicative inventory and reporting information as specified by the Bureau of Land Management. Providing copies of the reports that PacifiCorp provides to state agencies to the Bureau of Land Management should not be burdensome and would keep the Bureau of Land Management informed regarding the location of project-related hazardous material storage sites and spill clean-up equipment.

3.3.2.3 Cumulative Effects

Construction of the project dams resulted in areas of the river where the physical processes that control water quality have experienced a shift, as the processes in lakes are markedly different relative to the river environment. Although at times water quality meets applicable state water quality objectives (typically during the winter, high flow months) the water quality within some of the project impoundments (i.e., Keno, Copco, and Iron Gate reservoirs) has evolved to mimic highly productive lakes, which experience algal blooms and complex nutrient cycling and loading processes. Diversion of water for hydroelectric generation has substantially altered flow and temperature regimes in the bypassed reaches; however, under the existing hypereutrophic conditions, diversion of water from the J.C. Boyle bypassed reach has resulted in an improvement to that reach's water quality. Other actions throughout the upper Klamath River Basin that could cumulatively affect water quality include management plans and policies, land use practices, and changes in agricultural market conditions. We discuss below the potential effects of other activities not directly under the Commission's control that have a bearing on project water quantity and quality.

Implementation of the TMDL for Upper Klamath Lake and the subsequent reduction in phosphorous loading to the lake should, over time, improve water quality within the lake and in releases to the Link River, in addition to releases to the Klamath Irrigation Project through the A canal. Development of the TMDL for the Klamath River would build on the existing TMDL for Upper Klamath Lake and allocate acceptable nutrient loads to the Klamath River from point and non-point sources throughout the Upper Klamath Basin. Once loads have been established, NPDES permit holders and agricultural land owners would become eligible to apply for funding to implement measures to reduce the nutrient loads leaving their properties and entering the Klamath River. This program would provide benefits to water quality throughout the Klamath River over the anticipated term of a new license. The TMDL program relies on voluntary involvement for loads identified from non-point sources; therefore, nutrient load reductions to the allocated size may not be fully realized as farmers and ranchers choose between converting portions of their land to best management practices or maximizing their property's agricultural potential.

Reclamation's CIP would work to bring agencies and non-governmental organizations interested in protecting water quality and other affected resources together to develop policies and plans to alleviate the current stresses on water quality and aquatic resources. Currently the CIP is in its third draft and provides a framework of interagency collaboration to aid existing ecosystem restoration and water management efforts developed at the local level to advance more rapidly by providing resources, coordination, and communication. The CIP can also fund research to increase understanding of the Klamath River system and monitoring to evaluate progress toward program goals. Implementation of a final CIP would provide the framework to coordinate basin-wide restoration and monitoring efforts in a collective effort to improve water quality and other resources.

Reclamation must maintain certain lake elevations and river flows through implementation of the conditions specified in Biological Opinions issued by FWS and NMFS. At the same time, Reclamation must operate the Klamath Irrigation Project, which includes water in Upper Klamath Lake and releases to the Link River and A canal, consistent with its tribal trust obligations, contracts for the delivery of water throughout the Klamath Irrigation Project, and water supply to the Lower Klamath and Tule Lake National Wildlife refuges. As such, water availability for other purposes (e.g., flushing flows, additional spillage, etc) is limited and during dry years becomes a highly contested resource. Over time, the overall limitations on water availability and dynamic hydrographs contribute to conditions that result in a channel that becomes stable and prone to other undesirable consequences to water quality and aquatic resources. The ability to store additional water at Long Lake is currently under study as a means to increase water availability throughout the Klamath River Basin.

Inflow to the Klamath Hydroelectric Project is largely the result of releases from Link River dam and withdrawals or return flows from the Klamath Irrigation Project. The limited active storage of the project reservoirs greatly limits the effects of project operations during flooding events or extremely dry periods along the middle and lower reaches of the Klamath River. Maintenance of the current water level regime within Keno reservoir would ensure the continued supply of water to and from the Klamath Irrigation Project. We discuss cumulative water quantity effects on aquatic and riparian habitat in section 3.3.1.3, *Geology and Soils*; and effects on aquatic biota in section 3.3.3.3, *Aquatic Resources*, and 3.3.5.3 *Threatened and Endangered Species*.

Water demands in other tributary watersheds to the Klamath River can put an additional strain on the resources that rely on the Klamath River. The California State Water Project controls releases from the Trinity River to the Klamath through diversions to the Central Valley, which, depending on the water year type, can have a substantial effect on flows in the lower Klamath River. Diversions of water result in reduced volume entering the Klamath River, exacerbating high temperatures, especially during low flow years, and further stressing anadromous fish. The headwaters of the Trinity are largely undeveloped resulting in good water quality that, before the California State Water Project, would help dilute the naturally high nutrient loads within the Klamath River and buffer temperature extremes. Demand for these tributary sources limits the ability of the natural system to provide protection to the resources that rely on it. Collaboration between interbasin water users (including transfers from the Klamath Basin to the Rogue River Basin to the north and the California State Water Project to the southeast) and diverters could lead to more effective management of flow releases to the Klamath River, which could provide relief from extreme temperatures. In addition, during non-dry years, collaboration may provide flushing type flows to mobilize the substrate which could reduce attached algae distribution and may lower *C. shasta* infection rates among salmonids within the lower Klamath River.

The expiration of the 1956 contract between PacifiCorp and Reclamation which provided reduced electrical rates to Klamath Irrigation Project irrigators may result in changes in agricultural practices that change the amount of Klamath River water that is used for irrigation. Because much of the water initially used for irrigation is returned to the Klamath River, any reduction in irrigation water use would reduce the amount of nutrients and other agricultural byproducts entering the Klamath River during the summer growing season. Allowing fair market practices to determine resource allocation could lead to distribution patterns throughout the basin that could improve water quality as water users choose not to irrigate, change crops, or reduce farming efforts. On the other hand, a change to less expensive, less efficient irrigation practices (such as flood irrigation) may result in increased diversions which may reduce the quantity of water that is returned to the Klamath River

Extensive timber harvesting and conversion of land for resource extraction purposes (e.g., mining for gravel, gold, and other materials) throughout the watershed results in increased sediment and nutrient loads to the Klamath River. Increased sediment loading degrades water quality by increasing bedload and suspended solids in the water. As the solids settle, they create a shallower river channel susceptible to warming during months with the most daylight. During high flow events, previously settled sediments could become re-suspended, generating a deeper channel that would buffer the river from daily temperature swings. If the above-mentioned land types become reforested, the area would experience less direct runoff, increased potential groundwater contributions, and reduced pollutants. Effects would be dynamic and ongoing as land uses throughout the basin change due to numerous socioeconomic factors.

3.3.2.4 Unavoidable Adverse Effects

The project, as proposed, would continue to affect temperatures in the Klamath River. Implementation of strategic operations or facility modifications that use cool water stored in project reservoirs, as discussed previously, could temporarily alleviate project effects on temperatures downstream of Iron Gate dam; however these effects would be limited to a few degrees Celsius and last from a few days to at most a couple of weeks. In addition, even with implementation of best management practices that may be developed as part of a project-wide water quality management plan, it is likely that algal blooms would continue to occur in project reservoirs, albeit at a smaller scale and less frequently, and some degree of project-related nutrient enrichment would occur in the Klamath River downstream of Iron Gate dam.

Removal of any project dam(s) as recommended by various stakeholders would expose sediment previously trapped behind project reservoirs to scour, increasing the turbidity of the water downstream of any dam that might be removed. The magnitude and duration of this effect would be related to the amount of sediment trapped behind the dam (see section 3.3.1, *Geology and Soils*), which dam(s) are removed, the removal methods, and any actions taken prior to breaching the dam (e.g., dredging). Based on these factors, we expect the adverse effects from increased turbidity during and following dam removal to range from relatively short-term, minimal increases in turbidity, to increases in turbidity that could last for several years. If sediments should be contaminated, any release of such contaminants during dam removal could also adversely affect water quality.

3.3.3 Aquatic Resources

3.3.3.1 Affected Environment

In this section we describe aquatic resources in the project vicinity including the conditions of aquatic habitats and populations of anadromous fish, resident fish, and macroinvertebrates that have the potential to be affected by relicensing. For anadromous fish, we include additional sections on hatchery operations, fish diseases, and harvest management. We provide additional information on the listing status, biology, and abundance of the federally listed coho salmon, Lost River sucker, and shortnose sucker in section 3.3.5, *Threatened and Endangered Species*. Table 3-36 lists the 64 fish species that are known to occur in the project area or are likely to occur downstream of the project. Fourteen of these species are or may be anadromous, and nine are considered to be occasional marine visitors. Native fish species constitute 20 out of the 38 fish species upstream of Iron Gate dam and 32 out of the 50 species considered likely to occur in downstream areas. Table 3-37 shows the seasonal timing of migration, spawning, incubation, and rearing life stages for important anadromous and resident fish species.

3.3.3.1.1 Aquatic Habitat Conditions

The facilities associated with the existing project are located over a 64-mile reach of the Klamath River, extending from Link River dam at RM 254.3 to Iron Gate dam at RM 190.1 (see figure 1-1). In our description of aquatic habitat conditions, we also include Upper Klamath Lake and its tributaries, upstream of the project, due to their potential influence on downstream water quality conditions and to support our evaluation of the potential for restoration of anadromous fish runs to upstream historic habitats. We also describe the mainstem Klamath River downstream of Iron Gate dam and its tributaries due to the potential effects of project operation on anadromous fish mainstem spawning and rearing habitats, and on the migration corridor extending downstream to the Klamath River estuary (the portion of the river that is tidally influenced). In section 2.1.1, *Existing Project Facilities*, of this EIS, table 2-1 lists the Klamath River's primary tributaries and mainstem reservoirs including their location by river mile.

Upper Klamath Lake and its Tributaries

Upper Klamath Lake and its tributaries contain a large amount of habitat that historically produced anadromous fish. The lake currently supports populations of two species of suckers that are federally listed as endangered (the Lost River and shortnose suckers), and a fishery for trophy-sized rainbow trout.[44]

[44] Upper Klamath redband rainbow trout is the subspecies of rainbow trout that is native to the upper Klamath River Basin, while coastal rainbow trout appears to be the predominant subspecies in most areas downstream of Upper Klamath Lake, especially in areas that are accessible to anadromous steelhead downstream of Iron Gate dam. Because some degree of genetic mixing is likely, we refer to the resident form as rainbow trout and the anadromous form as steelhead.

Table 3-36. Fish species known to occur in the Klamath River and reservoirs upstream of Iron Gate dam and that are likely to occur downstream of Iron Gate dam. (Sources: PacifiCorp, 2004e; NAS, 2004; Moyle, 2002; Behnke, 1992)

Common Name	Scientific Name	Origin[b]	Status[c]	Temperature Preference[d]	Pollution Tolerance[e]	Present upstream of Iron Gate dam[f]	Present Downstream of Iron Gate dam[f]
Lampreys	**Petromyzontidae**						
Pit-Klamath brook lamprey	*Lampetra lethophaga*	N	N	Cool	I	R	--
Klamath River lamprey	*Lampetra similis*	N	N	Cool	I	R	R
Pacific lamprey	*Lampetra tridentata*	N	N, S	Cool	I	R	A
Miller Lake Lamprey	*Lampetra minima*	N	N	Cool	I	R	--
Sturgeons	**Acipenseridae**						
Green sturgeon	*Acipenser medirostris*	N	S	Cold	S	--	A
White sturgeon	*Acipenser transmontanus*	N	G	Cold	I	Stocked by ODFW in UKL[b]	A[g]
Herrings	**Clupeidae**						
American shad	*Alosa sapidissima*	I	G	Cool	I	--	A
Pacific herring	*Clupea pallasi*	N	G	n/a	n/a	--	O
Carps and Minnows	**Cyprinidae**						
Klamath Tui chub	*Siphateless bicolor bicolor*	N	N	Cool	T	R	R
Blue chub	*Gila coerulea*	N	N	Cool	T	R	R
Golden shiner	*Notemigonus crysoleucas*	I	N	Warm	T	R	R
Fathead minnow	*Pimephales promelas*	I	N	Warm	T	R	--
Klamath speckled dace	*Rhinichthys osculus*	N	N	Cool	I	R	R
Goldfish	*Carassius auratus*	I	N	Warm	T	R	R
Suckers	**Catostomidae**						
Klamath smallscale sucker	*Catostomus rimiculus*	N	N	Cool	I	R	R
Klamath largescale sucker	*Catostomus snyderi*	N	S	Cool	I	R	R
Shortnose sucker	*Chasmistes brevirostris*	N	E, S	Cool	S	R	R
Lost River sucker	*Deltistes luxatus*	N	E, S	Cool	I	R	--
Bullhead catfishes	**Ictaluridae**						
Yellow bullhead	*Ameiurus natalis*	I	G	Warm	T	R	R
Brown bullhead	*Ameiurus nebulosus*	I	G	Warm	T	R	R
Black bullhead	*Ameiurus melas*	I	G	Warm	T	R	--

Common Name	Scientific Name	Origin[b]	Status[c]	Temperature Preference[d]	Pollution Tolerance[e]	Present upstream of Iron Gate dam[f]	Present Downstream of Iron Gate dam[f]
Channel catfish	*Ictalurus punctatus*	I	G	Warm	T	R	--
Smelts	**Osmeridae**						
Surf smelt	*Hypomesus pretiosus*	N	G	Cold	S	--	O
Delta smelt	*Hypomesus transpacificus*	I	T,S	--	--	--	R
Longfin smelt	*Spirinchus thaleichtys*	N	G	Cool	I	--	A
Eulachon	*Thaleichthys pacificus*	N	G	Cool	I	--	A
Trouts and Salmon	**Salmonidae**						
Cutthroat trout	*Oncorhynchus clarki*	N	G	Cold	S	--	R, A
Pink salmon	*Oncorhynchus gorbuscha*	N	G	Cold	S	--	A[h]
Chum salmon	*Oncorhynchus keta*	N	G	Cold	S	--	A
Coho salmon	*Oncorhynchus kisutch*	N	G, T	Cold	S	--	A
Coastal Rainbow trout/Steelhead	*Oncorhynchus mykiss irideus*	N	G	Cold	S	--	R, A
Redband/rainbow trout	*Oncorhynchus mykiss newberrii*	N	G, S	Cold	S	R	--
Sockeye salmon	*Oncorhynchus nerka*	N	G	Cold	S	--	O, A
Kokanee	*Oncorhynchus nerka kennerlyi*	I	G	Cold	S	--	R
Chinook salmon	*Oncorhynchus tshawytscha*	N	G	Cold	S	--	A
Brown trout	*Salmo trutta*	I	G	Cold	I	R	R, A
Brook trout	*Salvelinus fontinalis*	I	G	Cold	I	R	R
Arctic grayling	*Thymallus arcticus*	I	G	Cold	S	--	R
Bull trout[i]	*Salvelinus confluentus*	N	T	Cold	S	R	--
Silversides	**Atherinidae**						
Topsmelt	*Atherinops affinis*	N	G	n/a	n/a	--	O
Sticklebacks	**Gasterosteidae**						
Threespine stickleback	*Gasterosteus aculeatus*	N	N	Cool	T	--	R, A
Brook stickleback	*Culaea inconstans*	N	N	Cool	T	--	R
Sculpins	**Cottidae**						
Sharpnose sculpin	*Clinocottus acuticeps*	N	N	n/a	n/a	--	O
Coastrange sculpin	*Cottus aleuticus*	N	N	Cool	I	--	R
Prickly sculpin	*Cottus asper*	N	N	Cool	I	--	R
Marbled sculpin	*Cottus klamathensis*	N	N	Cool	I	R	R
Klamath Lake sculpin	*Cottus princeps*	N	N	Cold	I	R	--

Common Name	Scientific Name	Origin[b]	Status[c]	Temperature Preference[d]	Pollution Tolerance[e]	Present upstream of Iron Gate dam[f]	Present Downstream of Iron Gate dam[f]
Slender sculpin	*Cottus tenuis*	N	N,S	Cool	I	R	--
Pacific staghorn sculpin	*Leptocottus armatus*	N	N	Cold	I	--	R, O
Sunfishes	**Centrarchidae**						
Sacramento perch	*Archoplites interruptus*	I	G	Warm	T	R	R
Green sunfish	*Lepomis cyanellus*	I	G	Warm	T	R	R
Pumpkinseed	*Lepomis gibbosus*	I	G	Cool	T	R	R
Bluegill	*Lepomis macrochirus*	I	G	Warm	T	R	R
Largemouth bass	*Micropterus salmoides*	I	G	Warm	T	R	R
Smallmouth bass	*Micropterus dolomieu*	I	G	Warm	T	--	R
Spotted bass	*Micropterus punctulatus*	I	G	Warm	T	--	R
White crappie	*Pomoxis annularis*	I	G	Warm	T	R	--
Black crappie	*Pomoxis nigromaculatus*	I	G	Warm	T	R	--
Perches	**Percidae**						
Yellow perch	*Perca flavescens*	I	G	Cool	I	R	R
Surfperches	**Embiotocidae**						
Shiner perch	*Cymatogaster aggregata*	N	N	Cold	S	--	O
Gobies	**Gobiidae**						
Arrow goby	*Clevelandia ios*	N	N	n/a	n/a	--	O
Righteye Flounders	**Pleuronectidae**						
Starry flounder	*Platichthys stellatus*	N	G	Cold	S	--	O

Notes: -- None collected, n/a not available.

[a] Species upstream of Iron Gate dam from city of Klamath Falls (1986) and PacifiCorp (2000). Species downstream of Iron Gate dam based on Moyle (1976).

[b] N = native, I = introduced; ODFW = Oregon Fish & Wildlife; UKL = Upper Klamath Lake.

[c] N = nongame, G = game, E = federally listed as endangered, T = federally listed as threatened, S = federal or state sensitive species or species of concern.

[d] From Zaroban et al. (1999).

[e] T = tolerant, I = intermediate, S = sensitive. From Zaroban et al. (1999).

[f] R = resident, A = anadromous, O = occasional marine visitor.

[g] NAS (2004) indicates that pink salmon are extinct in the Klamath River Basin.

[h] NAS (2004) notes that white sturgeon may migrate into the Klamath River but may not spawn there.

[i] Bull trout in the Klamath River Basin occur in the headwaters of the four tributaries to the Sprague River, four tributaries to the Sycan River, and two tributaries to Upper Klamath Lake (NAS, 2004).

Table 3-37. Estimated lifestage periodicity of key fish species occurring in the Klamath River.[a] (Source: PacifiCorp, 2004e, FWS, 1998; Trihey & Associates., 1996; NAS, 2004; Scheiff et al., 1991)

Species/Life Stage	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Spring Chinook												
Adult migration	4	4	2						4	4	4	4
Adult spawning			**4**	**2**								
Incubation			4	4	**4**	**4**	**4**	**4**	**4**	4	2	
Fry emergence						4	4	**4**	**4**	**4**	4	
Rearing	4	4	4	4	4	4	4	4	4	4	4	4
Juv. outmigration							2	4	4	4	**4**	4
Fall Chinook												
Adult migration		4	**4**	**4**								
Adult spawning				**4**	2							
Incubation				4	4	4	4	4	4			
Fry emergence							4	**4**	**4**	**4**		
Rearing							4	**4**	**4**	**4**	**4**	**2**
Juv. outmigration	**4**	4	4	4	2					4	**4**	**4**
Coho												
Adult migration				4	**4**	**4**						
Adult spawning						**4**	2					
Incubation						4	4	4	4			
Fry emergence								**4**	**4**	**2**		
Rearing	4	4	4	4	4	4	4	4	4	4	4	4
Juv. outmigration	4							4	**4**	**4**	4	4
Steelhead Fall/Winter[b]												
Adult migration			4	4	4							
Adult spawning						4	4	4	**4**	4		
Incubation						4	4	4	4	4		
Fry emergence									4	4	**4**	4
Rearing	4	4	4	4	4	4	4	4	4	4	4	4
Juv. outmigration	2								4	4	4	4

Species/Life Stage	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Redband/Rainbow Trout												
Adult migration				4	4			2	**4**	**4**	2	
Adult spawning								2	4	4	2	
Incubation									4	4	4	4
Fry emergence	2									4	4	4
Rearing	4	4	4	4	4	4	4	4	4	4	4	
Juv. emigration[c]	4	4	4	4						4	4	4
Pacific Lamprey												
Adult migration	2	2	2			4	4	4	4	4	4	4
Adult spawning	2								2	4	4	4
Incubation	4								2	4	4	4
Rearing	4	4	4	4	4	4	4	4	4	4	4	4
Juv. outmigration	4	4	4	4	4	4	4	4	4	4	4	4
Shortnose and Lost River Suckers												
Adult migration								2	4	4	2	
Adult spawning									4	4	4	
Incubation									4	4	4	2
Larval emergence										4	4	4
Rearing	4	4	4	4	4	4	4	4	4	4	4	4

[a] Numbers shown in table represent duration in weeks, numbers shown in bold indicate peaks in use or occurrence.

[b] FWS (1998) reports that small runs of summer and fall-run steelhead also occur, and that adult steelhead may migrate into the Klamath River throughout the year.

[c] The resident trout juvenile emigration indicates when fish are leaving their natal streams and entering the mainstem Klamath River.

Upper Klamath Lake is a very large, shallow, and nutrient-rich lake (NAS, 2004). When Upper Klamath Lake is at its normal maximum level (elevation 4,143 feet), it has a surface area of about 67,000 acres, a volume of 603,000 acre-feet, and a mean depth of only 9 feet, although there are substantial areas where depths exceed 20 feet. The lake has several large marshes at its margins, although approximately 40,000 acres of the marshland surrounding the lake have been drained and converted to agricultural production. The remaining marshes are strongly connected to the lake at high water and are progressively less connected at lower water levels down to about 4,139 feet, where they become isolated from the lake.

Before Link River dam was constructed in 1921, the water level of Upper Klamath Lake fluctuated within a relatively narrow range of about 3 feet (NAS, 2004). When that dam was constructed, the natural rock dam at the outlet of Upper Klamath Lake was removed so that the storage potential of the lake could be used to better support irrigated agriculture. Since 1921, lake levels have varied over a range of about 6 feet, and drawdown of about 3 feet from the original minimum water level has occurred in years of severe water shortages. Since about 1992, Reclamation has maintained higher lake levels developed in consultation with FWS to protect the federally listed Lost River and shortnose suckers (NAS, 2004). The lake levels identified in Reclamation's current operation plan are managed in accordance with FWS's most recent BiOp (FWS, 2002a) on Reclamation's 10-year operating plan[45] (Reclamation, 2002). As described in section 3.3.2, *Water Resources*, lake levels and irrigation diversions are also managed to meet seasonal minimum flows downstream of Iron Gate dam to protect the federally listed coho salmon in accordance with NMFS' BiOp (NMFS, 2002) on Reclamation's 10-year operating plan.

Poor water quality in Upper Klamath Lake has been implicated in the mass mortality of federally listed suckers, and may suppress their growth, reproductive success, and resistance to disease or parasitism. Potential agents of stress and death include high pH, high concentrations of ammonia, and low DO (FWS, 2002a). Extremes in these variables are caused by dense populations of phytoplankton (primarily the nitrogen-fixing blue-green algae *Aphanizomenon flos-aquae*), especially in the last half of the growing season (see discussion under *Nutrients* in section 3.3.2.1.2, *Water Quality*). Despite the occurrence of poor water quality conditions, Upper Klamath Lake supports a fishery for large rainbow trout that consistently produces trout in excess of 10 pounds (Messmer and Smith, 2002). Oregon Fish & Wildlife manages the trout fishery in Upper Klamath Lake, its major tributaries, and in the Klamath River downstream to the California state line (including the Keno and J.C. Boyle reservoirs) for natural production; no hatchery fish are stocked in these waters (Oregon Fish & Wildlife, 1997).

Section 3.3.3.1.2, *Anadromous Fish Species,* summarizes available information on historic use of Upper Klamath Lake and its tributaries by anadromous fish, and section 3.3.5, *Threatened and Endangered Species*, provides information on the biology and status of the federally listed Lost River sucker, shortnose sucker, and coho salmon.

Reclamation A Canal

The headworks of the A canal, which is the primary diversion point on Upper Klamath Lake for Reclamation's Klamath Irrigation Project, is located approximately 0.3 mile upstream of Link River dam. The A canal is capable of diverting up to 1,150 cfs of water during the peak of the irrigation season. The canal was equipped with fish screens in 2003 to protect the federally listed sucker species from entrainment. The fish screens include a primary pumped bypass that returns fish to Upper Klamath Lake and a secondary gravity flow bypass that can be used to route fish to the Link River immediately below

[45] Based on the March 26, 2006, ruling by the U.S. Ninth Circuit Court of Appeals, until the new consultation for the Klamath Irrigation Project is completed and reviewed by the U.S. Ninth Circuit Court, Reclamation is to limit irrigation deliveries if they would cause water flows in the Klamath River at Iron Gate dam to fall below Phase III flow levels specified in the 2002 NMFS BiOp.

Link River dam. The secondary bypass was included to provide managers with the flexibility to bypass fish to the Link River when adverse water quality conditions exist in Upper Klamath Lake near the outlet of the primary bypass.

Link River Dam

Link River dam, which Reclamation owns, is located at RM 254.3 (see figure 2-2). The dam is 16 feet high and includes a fish ladder, which was rebuilt in 2005 to improve upstream passage for federally listed sucker species. Intake gates on each side of the dam regulate flow into the canals that lead to East Side and West Side developments, which PacifiCorp proposes to decommission.

Link River

The 1.2-mile-long segment of the Klamath River that extends from Link River dam to Keno reservoir is commonly known as the Link River (see figure 2-2). The streambed in this section of the river is mostly bedrock, and at lower flows the river breaks into smaller braided channels. Reclamation manages flows that are released from Upper Klamath Lake into the Link River to meet flow requirements downstream of Iron Gate dam as specified in the NMFS 2002 BiOp (see table 3-10 in section 3.3.2.1.1, *Water Quantity*); these flows are designed to protect coho salmon in the lower Klamath River (Reclamation, 2002). Historically, up to 1,450 cfs of the flow released to Link River passed through the East Side and West Side development powerhouses, rather than being released at Link River dam. The amount of water that must be released into the Link River to meet the required flows below Iron Gate dam is affected by irrigation diversions and return flows and accretions from springs and tributaries between the Link River and Iron Gate dam. These accretion flows typically amount to about 300 to 500 cfs during low precipitation periods in the summer and fall.

In addition to the flow releases that are required to meet minimum flows downstream of Iron Gate dam, PacifiCorp has an agreement with Oregon Fish & Wildlife to maintain an instantaneous minimum flow of 90 cfs downstream of Link River dam. This minimum flow is increased to 250 cfs from July 27 through October 17 to comply with a requirement of the 2002 FWS BiOp to provide this flow when water quality conditions are adverse. Ramping rates below Link River dam that were developed in consultation with Oregon Fish & Wildlife during the 1980s limit the downramping rate to 20 cfs per 5 minutes when flows are between 0 and 300 cfs; 50 cfs per 30 minutes when flows are between 300 and 500 cfs; and 100 cfs per 30 minutes when flows are between 500 and 1,500 cfs.

Water quality conditions in Link River are similar to those that occur in Upper Klamath Lake, and include periods of high water temperatures, low DO levels, and high pH levels (see section 3.3.2.1.2, *Water Quality*). Fish populations in the Link River are limited primarily to species that are able to tolerate these poor water quality conditions. Fisheries sampling conducted by PacifiCorp in 2001 and 2002 indicates that the fish population in this reach is dominated by blue chub, tui chub, and fathead minnows (table 3-38). A small number of Lost River suckers were collected in the spring of 2002, and none were collected in the other three sampling periods. Shortnose suckers were collected in both years, and they were the third most abundant species collected in the spring of 2002.

Table 3-38. Summary of fishery sampling conducted in the Link River using electrofishing techniques. (Source: PacifiCorp, 2004e, as modified by staff)

	Catch Per Unit Effort (fish per hour)			
Species	**2001 Backpack Electrofishing**	**2002 Backpack Electrofishing**	**2002 Spring Boat Electrofishing**	**2002 Summer Boat Electrofishing**
Rainbow trout	--	2.4	9.1	--
Blue chub	479.5	116.6	182.3	1361.7
Tui chub	112.5	132.5	437.5	466.3
Speckled dace	278.1	26.3	--	--
Sculpin spp.	35.8	123.8	--	--
Shortnose sucker	18.5	0.8	109.4	--
Lost River sucker	--	--	9.1	--
Klamath sucker spp.	--	--	18.2	18.7
Largemouth bass	--	0.8	--	--
Bluegill	1.2	--	--	--
Fathead minnow	608.0	175.6	--	56.0
Yellow perch	1.2	0.8	--	--
Unknown	--	47.1	--	--

Keno Reservoir

Keno reservoir is narrow and riverine in character, and is confined within a diked channel that was once part of Lower Klamath Lake. The reservoir is 20.1 miles long, has a surface area of 2,475 acres, an average depth of 7.5 feet and a maximum depth of 20 feet, and a total storage capacity of 18,500 acre-feet. Water levels in Keno reservoir are normally maintained within 0.5 foot of elevation 4,085.5 feet, during the irrigation season, although the reservoir may be drawn down by another 2 feet for 2 to 3 days in April or May to allow irrigators to conduct maintenance on pumps and canals that draw water from the reservoir (see table 3-11 in section 3.3.2.1.1, *Water Quantity*).

As described in section 3.3.2.1.2, W*ater Quality*, water quality conditions in Keno reservoir are heavily influenced by the high nutrient content of inflowing water from Upper Klamath Lake, but they are exacerbated by wastewater effluent from the city of Klamath Falls, Reclamation irrigation return water, and accumulated wood waste from lumber mill operations. Summer water quality is generally poor with heavy algae growth, high temperatures (> than 20$^{?}$C) and pH (an average pH of 8.2 with a peak pH of 9.4 standard units), and low DO (4.5 to8.8 mg/L). Respiration demands from abundant algal populations combined with decomposition of organic matter (biological oxygen demand) can result in near-complete anoxia during certain time periods, and fish kills are sometimes observed in and downstream of Keno reservoir, as they are in the upstream Upper Klamath Lake (see previous description of sucker die-offs, from FWS, 2002a).

Sampling conducted by PacifiCorp in 2001 and 2002 indicates that fish populations in Keno reservoir are very similar to those in the Link River, and are dominated by the same pollution-tolerant species: blue chub, tui chub, and fathead minnows (table 3-39). Small numbers of the endangered shortnose and Lost River suckers were collected in Keno reservoir in both 2001 and 2002.

Table 3-39. Keno reservoir electrofishing catch during fall 2001, and spring, summer and fall 2002. (Source: PacifiCorp, 2004e)

Species	Fall 2001			Spring 2002			Summer 2002			Fall 2002			Total		
	Number Collected	Percent of Total (%)	CPUE[a]	Number Collected	Percent of Total (%)	CPUE[a]	Number Collected	Percent of Total (%)	CPUE[a]	Number Collected	Percent of Total (%)	CPUE[a]	Number Collected	Percent of Total (%)	CPUE[a]
Fathead minnow	68	12.1	48.9	79	16.8	42.9	2,657	70.4	6,480.5	261	37.6	121.4	3,065	55.7	529.4
Blue chub	241	42.7	173.4	68	14.5	37.0	717	19.0	1,748.8	255	36.8	118.6	1,281	23.3	221.3
Tui chub	229	40.6	164.7	310	65.9	168.5	292	7.7	712.2	73	10.5	33.9	904	16.4	156.2
Yellow perch	5	0.9	3.6	3	0.6	1.6	16	0.4	39.0	8	1.2	3.7	32	0.6	5.5
Klamath largescale sucker	0	0	0	4	0.9	2.2	0	0	0	26	3.8	12.1	30	0.5	5.2
Shortnose sucker	15	2.6	10.8	4	0.9	2.2	0	0	0	6	0.9	2.8	25	0.5	4.3
Largemouth bass	3	0.5	2.2	0	0	0	0	0	0	4	0.6	1.9	7	0.1	1.2
Sacramento perch	0	0	0	0	0	0	1	<0.1	2.4	5	0.7	2.3	6	0.1	1.1
Sucker spp.	0	0	0	0	0	0	0	0	0	4	0.6	1.9	4	0.1	0.7
Pumpkinseed	1	0.2	0.7	0	0	0	1	<0.1	2.4	1	0.1	0.5	3	0.1	0.5
Sculpin spp.	0	0	0	0	0	0	1	<0.1	2.4	2	0.3	0.9	3	0.1	0.5
Klamath smallscale sucker	0	0	0	0	0	0	0	0	0	3	0.4	1.4	3	0.1	0.5
Bluegill	0	0	0	0	0	0	1	<0.1	2.4	1	0.1	0.5	2	<0.1	0.3
Lost River sucker	1	0.2	0.7	0	0	0	0	0	0	1	0.1	0.5	2	<0.1	0.3
Klamath speckled dace	0	0	0	0	0	0	2	<0.1	4.8	0	0	0	2	<0.1	0.3
Sucker (hybrid)	1	0.2	0.7	1	0.2	0.5	0	0	0	0	0	0	2	<0.1	0.3
Unidentified	0	0	0	1	0.2	0.5	87	2.3	212.2	44	6.3	20.4	132	2.4	22.8
Total	**564**	**100.0**	**405.7**	**470**	**100.0**	**255.4**	**3,775**	**100.0**	**9,207.3**	**694**	**100.0**	**322.8**	**5,503**	**100.0**	**950.4**

[a] CPUE — catch per unit of effort.

Keno Dam

Keno dam is equipped with a 24-pool weir and orifice type fish ladder, which rises 19 feet over a distance of 350 feet, designed to pass trout and other resident fish species. PacifiCorp has an agreement with Oregon Fish & Wildlife to release a minimum flow of 200 cfs at the dam per article 58 of its existing license. Similar to Link River dam, the average daily flow released from Keno dam generally follows the instream flow requirements downstream of Iron Gate dam, less anticipated accretion flows. Hourly flows released from Keno dam are affected by the rate of irrigation return flows delivered via the Klamath Straits drain and the Lost River diversion channel, which can vary by about 775 cfs over a 24-hour period.

Keno Reach

Downstream of Keno dam, the Klamath River flows freely for 4.7 miles until it enters J.C. Boyle reservoir (see figure 2-3). This section runs through a canyon area with a relatively high gradient of 50 feet/mile (1 percent) (PacifiCorp, 2000). The channel is generally broad, with rapids, riffles, and pocket water among rubble and boulders. Although summer water temperatures in the Keno reach are generally warmer than optimum for trout (the 7-day mean maximum daily water temperature in the reach can rise as high as 25°C), turbulence maintains DO levels that support a rainbow trout fishery. Like the rest of the Klamath River within Oregon, Oregon Fish & Wildlife manages the trout fishery for natural production with a daily bag limit of one fish per day. The fishery in the Keno reach is closed from June 15 through September 30, the warmest part of the year, when trout are subject to stress from high water temperatures.

Fisheries sampling conducted by PacifiCorp in 2001 and 2002 indicates that the fish population in the Keno reach is dominated by marbled sculpin, fathead minnows, blue chub, speckled dace, and tui chub (table 3-40). Rainbow trout were consistently collected, but in relatively small numbers. Of the federally listed sucker species, only the Lost River sucker was represented, and it was only collected in the lower part of the reach in 1 out of 2 years that were sampled. Creel surveys conducted by Oregon Fish & Wildlife between 1979 and 1982 and hook and line sampling conducted by PacifiCorp in 2002 both indicate that large rainbow trout are more common in the Keno reach than they are in the downstream J.C. Boyle bypassed and peaking reaches. In both data sets, about 25 percent of the trout collected in the Keno reach exceeded 15 inches in length, while fish of this size were rarely observed in the downstream reaches (PacifiCorp, 2004e).

Table 3-40. Summary of fishery sampling conducted in the Keno reach using backpack electrofishing techniques. (Source: PacifiCorp, 2004e, as modified by staff)

	Catch Per Unit Effort (fish per hour)		
Species	**2001[a] Lower reach RM 229 to 231.5**	**2002[b] Lower reach RM 229 to 231.5**	**2002[b] Upper reach RM 231.5 to 233**
Rainbow trout	3.0	3.0	69.7
Blue chub	184.0	222.3	10.4
Tui chub	120.0	142.5	21.4
Speckled dace	--	165.7	204.1
Marbled sculpin	264.0	469.8	93.8
Lamprey	--	--	0.5
Lost River sucker	--	1.0	--
Klamath suckers	16.0	--	--
Bluegill	--	1.0	--
Pumpkinseed	--	--	0.5
Fathead minnow	216.0	231.4	40.1
Unknown	--	99.0	11.0

[a] Sampling was conducted in the fall only.
[b] Average of spring, summer and fall sampling.

J.C. Boyle Reservoir

The upstream half of the J.C. Boyle reservoir is shallow and is surrounded by a low-gradient, gently sloping shoreline, while the reservoir deepens in the lower half, where the canyon narrows again. The upper end of the reservoir contains a large amount of macrophytes during the summer and several fairly large shoreline wetland areas. Like the upstream Keno reservoir, water quality is often degraded, particularly during the summer. The reservoir is 3.6 miles long, has a surface area of 420 acres, an average depth of 8.3 feet, a maximum depth of 40 feet, and a total storage capacity of 3,495 acre-feet. Water levels in J.C. Boyle reservoir are normally maintained within 5.5 feet of full pool, and daily fluctuations due to peaking operation of the J.C. Boyle development are typically between 1 and 2 feet.

PacifiCorp contracted Oregon Fish & Wildlife to sample J.C. Boyle, Copco, and Iron Gate reservoirs to assess the abundance and distribution of endangered suckers in the project reservoirs during 1998 and 1999. The sampling effort also provided information on the abundance of other fish species that occur in these reservoirs. Sampling conducted in the J.C. Boyle reservoir indicates that the fish community is dominated by chub species, fathead minnows, and bullheads (table 3-41). A total of 64 rainbow trout were collected over the 2 years representing 0.9 percent of all fish collected. Of the two federally listed sucker species, a total of 44 shortnose suckers and 2 Lost River suckers were collected. Another 415 unidentified suckers were also collected, as were 187 Klamath smallscale suckers and 1 Klamath largescale sucker. The investigators reported that this was the only one of the three project reservoirs sampled where they collected all three life stages of suckers (larvae, juvenile, and adult), and they speculated that the reservoir may be seeded with larval suckers emigrating from Upper Klamath Lake (Desjardins and Markle, 2000).

Spencer Creek enters J.C. Boyle reservoir and provides spawning habitat for rainbow trout in the Keno reach, and to a lesser extent, the J.C. Boyle bypassed and peaking reaches. Counts of trout passing the fish ladder at J.C. Boyle dam in 1959, the year after J.C. Boyle dam and fish ladder were constructed, showed an estimated upstream passage of 5,529 rainbow trout. These fish were apparently moving upstream to spawn in Spencer Creek or in potential spawning habitat near the mouth of Spencer Creek that was inundated by the reservoir. More recent data indicate that the number of fish ascending the ladder has declined. An estimated 3,882 trout ascended the ladder in 1961, and 2,295 trout ascended the ladder in 1962. The next period when passage was monitored was from 1988 through 1991. Rainbow trout passage in these 4 years was 507, 588, 412, and 70 fish, respectively. Flows contributed from Spencer Creek normally range between 20 and 200 cfs.

J.C. Boyle Dam

PacifiCorp constructed J.C. Boyle dam, which is 68 feet high, in 1958 (see figure 2-3). The dam is equipped with a 569-foot-long pool and weir fishway, with 63 pools, which operates over a gross head range of approximately 55 to 60 feet. The dam diverts flow into a 2.56-mile-long flow line (combination of steel flow line, canal, tunnel, and penstock) to a powerhouse, creating a 4.3-mile-long bypassed reach. The intake to the flow line at J.C. Boyle dam is equipped with vertical traveling screens and a fish bypass pipe that delivers screened fish and debris along with a 20 cfs bypass flow to the base of the dam. The existing fish screens do not meet current agency velocity criteria.

Table 3-41. Number of fish collected by gear type during 1998 and 1999 in the J.C. Boyle reservoir.[a] (Source: PacifiCorp, 2004e)

Species	Trammel Net (A)		Trap Net (A, J)		Beach Seine (J)		Larval Trawl (J, L)		Dip Net (J, L)		Larval Drift Net (J, L)		Total	
	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999
Lamprey spp.	2	0	4	3	0	0	0	0	0	0	0	1	6	4
Tui chub	123	166	133	70	10	2	0	2	0	0	0	0	266	240
Blue chub	39	30	25	87	8	5	2	0	0	0	0	0	74	122
Chub spp.	0	0	0	402	13	633	618	34	35	36	0	0	666	1,105
Golden shiner	0	0	0	0	0	1	0	1	0	3	0	0	0	5
Fathead minnow	0	0	5	280	65	190	168	14	0	198	0	0	238	682
Klamath speckled dace	0	0	0	61	8	62	11	28	0	349	0	0	19	500
Klamath smallscale sucker	62	97	2	26	0	0	0	0	0	0	0	0	64	123
Klamath largescale sucker	1	0	0	0	0	0	0	0	0	0	0	0	1	0
Shortnose sucker	5	13	0	31	0	0	0	0	0	0	0	0	5	44
Lost River sucker	0	2	0	0	0	0	0	0	0	0	0	0	0	2
Sucker spp.[b]	4	2	0	8	75	105	49	34	0	126	5	7	133	282
Bullhead spp.	167	207	88	290	7	11	1	0	0	0	0	0	263	508
Redband/rainbow trout	33	24	1	3	0	0	0	0	0	0	2	1	36	28
Sculpin spp.	0	0	0	0	0	25	0	7	0	0	0	0	0	32
Sacramento perch	8	4	178	31	0	0	0	0	0	0	0	0	186	35
Pumpkinseed	1	1	415	59	5	89	0	2	0	0	0	0	421	151
Bluegill	0	0	0	0	2	0	0	0	0	0	0	0	2	0
Largemouth bass	9	4	0	0	17	65	0	0	0	0	0	0	26	69
Sunfish spp.	0	0	14	0	242	0	127	0	19	0	0	0	402	0
Crappie spp.	34	6	128	27	2	1	0	0	0	0	0	0	164	34
Yellow perch	35	4	0	5	0	1	1	1	0	0	0	0	36	11
Unidentified	0	0	0	0	0	0	0	27	0	32	3	11	3	70
Total Individuals	523	560	993	1,383	454	1,190	977	150	54	744	10	20	3,011	4,047
Total Taxa	14	13	11	15	12	13	8	10	2	5	3	4	20	20
Sampling Effort														
Sets/Pulls	16	8	10	13	17	18	19	17	7	10	7	16		
Hours	173	119	118	197	—	—	—	—	—	—	25	79		

[a] Target lifestyles codes: A= adult, J=juvenile, L=Larvae.

[b] Data presented in Desjardins and Markle (2000) indicate that 48 percent of the unidentified sucker spp. collected in J.C. Boyle reservoir in 1998 and 23 percent of the unidentified sucker spp. collected in 1999 were juveniles. The remaining 52 percent of the unidentified sucker spp. collected in 1998 and 77 percent of the unidentified sucker spp. collected in 1999 were larvae.

J.C. Boyle Bypassed Reach

The J.C. Boyle bypassed reach is 4.3 miles long, extending from the dam to the J.C. Boyle powerhouse. This reach of the Klamath River has a relatively steep gradient of about 2 percent. The river channel is approximately 100 feet wide, and consists primarily of rapids, runs, and pools among large boulders with some large cobbles interspersed. Gravel is scarce, in part because recruitment from upstream areas is blocked by the presence of J.C. Boyle dam. Although erosion caused by operation of the emergency overflow spillway contributed a large volume of sediment to the lower third of the reach, as noted previously in section 3.3.1, *Geology and Soils*, this section of the river also has substantial capacity to transport sediments due to its high stream gradient (2.3 percent) in the vicinity of the emergency overflow spillway. When spill from the dam is substantial, habitat in the bypassed reach consists of a series of rapids and fast runs.

PacifiCorp releases a 100 cfs minimum flow at the dam into the J.C. Boyle bypassed reach. An additional 220 to 250 cfs of spring flow accrues in the bypassed reach, beginning about 0.5 mile downstream from the dam. The existing license limits the rate of upramping and downramping in the bypassed reach to 9 inches per hour.

Fisheries sampling conducted by PacifiCorp in 2001 and 2002 indicates that the fish population in the J.C. Boyle bypassed reach is dominated by rainbow trout, speckled dace, and marbled sculpin (table 3-42). The shortnose sucker was the least common of the five species that were collected in 2001, and none were collected in 2002. No Lost River suckers were collected in either year.

Table 3-42. Fishery sampling conducted in the J.C. Boyle bypassed reach using backpack electrofishing techniques. (Source: PacifiCorp, 2004e, as modified by staff)

	Catch Per Unit Effort (fish per hour)		
Species	**2001[a] (entire reach)**	**2002[b] upper 1 mile (above springs)**	**2002[b] lower 3 miles (below springs)**
Rainbow trout	112	12.2	22.6
Blue chub	--	4.9	0.8
Tui chub	16	5.5	0.4
Speckled dace	24	38.3	1.5
Marbled sculpin	16	17.0	31.1
Lamprey	--	0.6	--
Shortnose sucker	8	--	--
Largemouth bass	--	1.2	0.4
Sacramento perch	--	0.6	--
Bluegill	--	7.9	--
Pumpkinseed	--	7.9	0.8
Black crappie	--	0.6	--
White crappie	--	0.6	--
Fathead minnow	--	--	0.8
Bullhead spp.	--	12.2	--

-- none collected

[a] Sampling was conducted in the fall only.

[b] Average of spring, summer and fall sampling.

J.C. Boyle Peaking Reach

The J.C. Boyle peaking reach is 17.3 miles long, extending from the J.C. Boyle powerhouse at RM 220.4 to the upper end of Copco reservoir (see figures 2-3 and 2-4). The upstream 11.1 miles of this reach are in Oregon, and this segment has been federally designated as a Wild and Scenic River (discussed further in section 3.3.6, *Recreational Resources*, and section 3.3.7, *Land Use and Aesthetic*

Resources). The downstream 6.2 miles are in California, and the segment is designated by Cal Fish & Game as a Wild Trout Area. Both sections are managed for wild trout. The Oregon reach has not been stocked with hatchery trout since 1978, and the California reach has not been stocked since 1974.

In the Oregon portion of the reach, habitat includes cascades, deep and shallow rapids, runs, riffles, and occasional deep pools. Substrate is heavily armored and consists primarily of boulders and large cobbles, with a few small pockets of gravel behind boulders. The California segment of the peaking reach is wider and lower in gradient, and contains more riffles and runs, and infrequently exhibits pools and quiet water. Substrate is primarily bedrock, boulders, and cobbles, with a few gravel pockets behind boulders. The California portion exhibits good riparian and instream cover including boulders, rooted aquatic plants, and undercut banks.

Stream flows in the reach are affected by peaking operation of the J.C. Boyle development. Under current operations, water is typically stored at night and flows during the day ramp up to either one unit operation (up to 1,500 cfs) or two unit operation (up to 3,000 cfs, but typically 2,750 cfs). When generation ceases at night, flow at the powerhouse consists of the flow that is released from J.C. Boyle dam into the bypassed reach (with the exception of spill periods, this is normally the 100 cfs minimum flow), plus the 220 to 250 cfs of spring flow that accrues in the bypassed reach. The current licensed ramping rate is 9 inches per hour for both up-ramping and down-ramping.

Fisheries sampling conducted by PacifiCorp in 2001 and 2002 indicates that the fish population in the J.C. Boyle peaking reach is comprised primarily of speckled dace, marbled sculpin, and rainbow trout (table 3-43). Shortnose sucker was the least common of the four species that were collected in 2001, and none were identified in 2002 sampling, although some unidentified suckers were collected in 2002. No Lost River suckers were identified in either year.

Table 3-43. Fishery sampling conducted in the J.C. Boyle peaking reach using backpack and boat electrofishing techniques. (Source: PacifiCorp, 2004e, as modified by staff)

	Catch Per Unit Effort (fish per hour)				
	2001[a]	Oregon Reach-2002		Calif. Reach-2002	
Species	**(entire reach)**	**Backpack[b]**	**Boat[a]**	**Backpack[c]**	**Boat[a]**
Rainbow trout	112	1.0	25.3	71.9	27.9
Blue chub	--	5.9	--	--	--
Tui chub	16	6.9	--	--	--
Speckled dace	--	193.8	22.1	555.4	2.8
Marbled sculpin	--	126.6	3.16	46.0	--
Sculpin spp.	16	--	--	--	--
Lamprey	--	--	3.16	--	--
Shortnose sucker	8	--	--	--	--
Sucker spp.	--	40.5	9.5	--	60.0
Unknown[d]	--	--	12.6	--	1.4

[a] Sampling was conducted in the fall only.
[b] Average of spring, summer and fall sampling.
[c] Average of summer and fall sampling.
[d] Most likely fathead minnows and/or chubs

Key tributaries to the peaking reach are Rock Creek at RM 213.9 and Shovel Creek at RM 206.5. Cal Fish & Game considers the lower 2.77 miles of Shovel Creek an important spawning tributary for rainbow trout in the J.C. Boyle peaking reach. Based on extensive electrofishing during 1985 through 1990, Cal Fish & Game (2000) estimated that at least 250 to 300 pairs of adult rainbow trout spawn in Shovel Creek each year. Cal Fish & Game (2000) also concluded that spawning habitat limits production in Shovel Creek. A 1982 survey estimated that a total of 880 square feet of spawning gravel was available, of which only 406 square feet had water depths and velocities preferred by rainbow trout. Up to 15 cfs is currently diverted from Shovel Creek and Negro Creek (a tributary of Shovel Creek) for irrigation purposes during the summer, when fry would be present in both streams.

Copco Reservoir

Copco reservoir was formed when the Copco No. 1 dam was constructed in 1918. The dam is 126-feet high, and does not include any fish passage facilities. The reservoir is 4.5-miles long, has a surface area of 1,000 acres, an average depth of 34 feet, a maximum depth of 108 feet, and a total storage capacity of 33,724 acre-feet. Water levels in Copco reservoir are normally maintained within 6.5 feet of full pool, and daily fluctuations due to peaking operation of the J.C. Boyle and Copco No. 1 developments are typically about 0.5 feet.

The reservoir is located in a canyon area, and is quite large and deep compared to the Keno and J.C. Boyle reservoirs. It contains several coves with more gradual slopes, and large areas of thick aquatic vegetation are common in shallow areas. Nearshore riparian habitat is generally lacking, due to the cliff-like nature of shorelines, and only very small isolated pockets of wetland vegetation exist. As discussed in section 3.3.2.1.2, *Water Quality*, water quality in the reservoir is generally degraded during the summer months, and a predictable sequence of algae blooms occur as temperatures warm, including large blooms of the nitrogen-fixing blue-green algae *Aphanizomenon flos-aquae.*

Fish collections by Oregon Fish & Wildlife in Copco reservoir during 1998 and 1999 surveys were dominated by yellow perch, unidentified larval suckers, and golden shiners, which collectively comprised 95 percent of the catch (table 3-44). Approximately 13 percent of the adult fish that were collected in Copco reservoir were federally listed sucker species, nearly all of which were shortnose suckers. Few juvenile suckers were collected in the reservoir, which may reflect predation by non-native species such as yellow perch, largemouth bass, and crappie (Desjardins and Markle, 2000). The investigators speculated that adult suckers that occur in all three project reservoirs may have been produced in Upper Klamath Lake. The chairman of a local landowner association (Copco Lake Community Advisory Committee) reports that fishing derbies and tournaments are held regularly on Copco Lake. Records from several recent derbies (2003) indicate a reasonably healthy fishery, with winning entries for perch ranging from 11 to 12 inches, crappie from 8 to 11 inches, bass from 16 to 19 inches, and trout from 17 to 24 inches in length (letter from B. Davis, Chairman of the Copco Lake Community Advisory Committee, to M.R. Salas, Secretary, FERC, dated July 18, 2004.)

Copco No. 2 Reservoir and Bypassed Reach

The Copco No. 1 powerhouse discharges up to 3,560 cfs directly into Copco No. 2 reservoir, which is approximately 0.25 mile in length, and was formed by the construction of the 33-foot high Copco No. 2 dam in 1925. There are no fish passage facilities at Copco No. 2 development, and due to its small size, PacifiCorp did not conduct any fishery sampling in Copco No. 2 reservoir.

Copco No. 2 dam diverts up to 3,250 cfs into a flow line, leading to a powerhouse at the head of Iron Gate reservoir. Due to the small size of its reservoir, Copco No. 2 development operates in tandem with Copco No. 1 development. Although the existing license does not specify a ramping rate or minimum flow for the bypassed reach, PacifiCorp currently releases 5 to 10 cfs from the dam into the Copco No. 2 bypassed reach, which is 1.5 miles in length. The bypassed reach is in a deep, narrow canyon with a steep gradient similar to that of the upstream Klamath River reaches. The channel consists of bedrock, boulders, large rocks, and occasional pool habitat.

Fisheries sampling conducted by PacifiCorp in 2001 and 2002 indicate that the fish population in the Copco No. 2 bypassed reach is comprised primarily of marbled sculpin and speckled dace, with much smaller numbers of tui chub, rainbow trout, yellow perch, black crappie, largemouth bass, and blue chubs (table 3-45). No suckers of any kind were collected during sampling conducted in this reach.

Table 3-44. Number of fish collected by gear type during 1998 and 1999 in Copco reservoir.[a] (Source: PacifiCorp, 2004e)

	Trammel Net (A)		**Trap Net (A, J)**		**Beach Seine (J)**		**Larval Trawl (J, L)**		**Dip Net (J, L)**		**Larval Drift Net (J, L)**		**Total**	
Species	**1998**	**1999**	**1998**	**1999**	**1998**	**1999**	**1998**	**1999**	**1998**	**1999**	**1998**	**1999**	**1998**	**1999**
Lamprey spp.	2	0	0	0	0	0	0	0	0	0	0	0	2	0
Tui chub	136	101	2	8	0	0	0	0	0	0	0	0	138	109
Blue chub	52	17	0	1	0	0	0	0	0	0	0	0	52	18
Chub spp.	0	0	0	0	0	4	140	53	89	146	0	5	229	208
Golden shiner	0	0	3	1	593	129	0	397	0	5,616	0	0	596	6,143
Fathead minnow	0	0	0	1	0	1	0	0	0	1	0	0	0	3
Klamath speckled dace	0	0	0	0	0	10	0	0	0	0	0	0	0	10
Klamath smallscale sucker	16	1	0	0	0	0	0	0	0	0	0	0	16	1
Klamath largescale sucker	2	0	0	0	0	0	0	0	0	0	0	0	2	0
Shortnose sucker	94	64	0	0	0	0	0	0	0	0	0	0	94	64
Lost River sucker	2	0	0	0	0	0	0	0	0	0	0	0	2	0
Sucker spp.[b]	3	0	0	0	0	54	41	2,979	18	5,160	151	326	213	8,519
Bullhead spp.	182	221	15	178	5	0	0	0	0	0	0	0	202	399
Redband/rainbow trout	3	0	0	0	0	0	0	0	0	0	0	1	3	1
Sculpin spp.	0	0	0	0	0	3	0	0	0	0	0	0	0	3
Sacramento perch	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Pumpkinseed	8	3	30	31	0	5	0	8	0	1	0	0	38	48
Largemouth bass	12	6	2	0	128	8	18	1	0	2	0	0	160	17
Sunfish spp.	0	0	0	0	17	0	9	3	0	1	0	0	26	4
Crappie spp.	57	44	41	30	0	0	7	5	2	18	0	0	107	97
Yellow perch	480	75	92	1,504	16	16,301	5,000	3,274	400	183	2	0	5,990	21,337
Unidentified	0	0	0	0	0	1	12	71	0	73	5	14	17	159
Total Individuals	1,049	532	185	1,755	759	16,516	5,227	6,791	509	11,201	158	346	7,887	37,141
Total Taxa	14	9	7	9	5	10	7	9	4	10	3	4	18	19
Sampling Effort														
Sets/Pulls	17	8	2	14	21	21	18	32	5	14	8	16		
Hours	204	123	35	219	—	—	—	—	—	—	30	73		

[a] Targeted life stage in parentheses after gear type (A = adult, J = juvenile, L = larvae).

[b] Data presented in Desjardins and Markle (2000) indicate that only 3 of the unidentified sucker spp. collected in Copco reservoir in 1998 were juveniles. The rest of the unidentified sucker spp. collected in 1998 and all of the unidentified sucker spp. collected in 1999 in Copco reservoir were larvae.

Table 3-45. Fishery sampling conducted in the Copco No. 2 bypassed reach using backpack electrofishing techniques. (Source: PacifiCorp, 2004e, as modified by staff)

Species	Catch Per Unit Effort (fish per hour)			
	Fall 2001	Spring 2002	Summer 2002	Fall 2002
Rainbow trout	--	--	8.9	21.1
Blue chub	--	--	3.0	--
Tui chub	95.4	--	--	--
Speckled dace	254.3	447.4	608.9	473.0
Marbled sculpin	278.1	109.2	404.9	165.7
Largemouth bass	--	--	--	6.0
Black crappie	--	--	--	15.1
Yellow perch	--	20.8	5.9	--

Spring, Fall, and Jenny Creeks

Jenny and Fall creeks are the only perennial tributaries that enter Iron Gate reservoir (see figure 2-5). Spring Creek is a tributary to Jenny Creek, which flows for a distance of 1.2 miles from its source at Shoat Springs before it enters Jenny Creek at RM 5.5. The total flow delivered from Fall Creek to Iron Gate reservoir typically ranges between 30 and 100 cfs, and flows from Jenny Creek to Iron Gate reservoir typically range between 30 and 500 cfs. The flow in Jenny Creek is altered by upstream reservoirs that store water during the high runoff season for irrigation, and about 30 percent of the mean annual runoff in the basin is diverted into the Rogue River Basin to the north.

PacifiCorp operates a small dam on Spring Creek that diverts flow into Fall Creek, and another dam on Fall Creek diverts flow into a canal that leads to the Fall Creek powerhouse (see figure 2-6). The Spring Creek diversion is located 0.5 mile upstream from its confluence with Jenny Creek, and the diverted flow is carried through a 1.7-mile-long canal where it enters Fall Creek about 1.7 miles upstream of the Fall Creek diversion. The diversion on Fall Creek diverts flow into a canal that bypasses 1.2 miles of Fall Creek, leading to the Fall Creek powerhouse about 0.8 mile upstream from where Fall Creek enters Iron Gate reservoir. The Spring Creek diversion diverts up to 16.5 cfs of flow into Fall Creek, and the Fall Creek diversion diverts up to 50 cfs into the power canal that leads to the powerhouse. The project's current license requires a minimum flow of 0.5 cfs below the Fall Creek diversion and a minimum flow of 15 cfs (or natural stream flow, whichever is less) downstream of the powerhouse.

The Jenny Creek watershed supports several native fish species including the Jenny Creek sucker, rainbow trout, and Klamath speckled dace. PacifiCorp's 2005 sampling collected 5 rainbow trout and 3 suckers in Jenny Creek upstream of the Spring Creek confluence, and 24 rainbow trout and 3 suckers downstream of the confluence (PacifiCorp, 2005a). Sampling in Spring Creek collected 16 rainbow trout upstream of the diversion dam, 1 rainbow trout downstream of the diversion dam, and 6 trout in the diversion canal. Sampling in Fall Creek collected 9 rainbow trout upstream of the diversion, 15 rainbow trout in the bypassed reach, and 1 rainbow trout in the power canal (PacifiCorp, 2005a). Only two of the trout collected were more than 8 inches long. One was collected in Spring Creek upstream of the diversion and the other was collected in Jenny Creek upstream of its confluence with Spring Creek.

PacifiCorp concludes that the upstream migration of suckers from Jenny Creek is probably precluded by high stream gradient in the lower portion of Spring Creek (PacifiCorp, 2005b). A falls located less than 0.2 miles upstream of the confluence of the Fall Creek powerhouse tailrace is another likely barrier to fish passage. Downstream of the tailrace confluence, Fall Creek is fairly low in gradient, is well shaded with trees, and enters a wetland area at its confluence with Iron Gate reservoir.

Iron Gate Reservoir

Iron Gate reservoir was formed when Iron Gate dam was constructed at RM 190.1 in 1962. The dam is 173 feet high and does not include any fish passage facilities. The reservoir is 6.8 miles long, has a surface area of 944 acres, an average depth of 62 feet, a maximum depth of 167 feet, and a total storage capacity of 50,941 acre-feet. Water levels in Iron Gate reservoir are normally maintained within 4 feet of full pool, and daily fluctuations due to peaking operation of the upstream J.C. Boyle and Copco developments are typically about 0.5 foot.

The reservoir is similar to Copco reservoir in that it is located in a canyon area, and is large and deep with generally steep shorelines except for a few coves with more gradual slopes. Large areas of thick aquatic vegetation are common in shallow areas. Nearshore riparian habitat is generally lacking, except at the mouths of Jenny and Camp creeks, where well developed riparian habitat occurs. Due to the cliff-like nature of shorelines, only very small isolated pockets of wetland vegetation exist around the perimeter of the reservoir. Water quality in the reservoir during the summer is generally quite poor, large blooms of the *Aphanizomenon flos-aquae* occur annually, and surface water temperatures are warm.

Fish collected in Iron Gate reservoir during Oregon Fish & Wildlife's 1998 and 1999 surveys were dominated by golden shiners, tui chub, pumpkinseed, unidentified chubs, yellow perch, unidentified larval suckers, and largemouth bass, which collectively comprised 95.1 percent of all fish collected (table 3-46). The federally listed shortnose sucker made up only 1 percent of the total catch of adult fish, and no Lost River suckers were collected in Iron Gate reservoir. Although 1,180 sucker larvae were collected in the reservoir, no juvenile suckers were collected, which may reflect predation by non-native species such as yellow perch, largemouth bass, and crappie (Desjardins and Markle, 2000). Predation rates are probably also high in Copco reservoir, where only 3 juvenile suckers were collected.

Klamath River Downstream of Iron Gate Dam

The Iron Gate development reregulates flow fluctuations caused by peaking operation of the upstream J.C. Boyle and Copco Nos. 1 and 2 developments to provide stable flows downstream of Iron Gate dam. The powerhouse is located at the dam and has a maximum hydraulic capacity of 1,735 cfs. The current license stipulates a minimum flow release at the dam of 1,300 cfs from September through April; 1,000 cfs in May and August; and 710 cfs in June and July. However, since 1997, PacifiCorp has operated the project to provide flow releases dictated by Reclamation's annual operations plans. As discussed previously in section 3.3.2, *Water Resources*, Reclamation develops these annual plans in consultation with FWS and NMFS to comply with recent BiOps for protecting the federally listed coho salmon (NMFS, 2002) and Lost River and shortnose suckers (FWS, 2002a). Ramping rates downstream of Iron Gate dam are limited to 50 cfs per 2 hours not to exceed 150 cfs in 24 hours when flows are 1,750 cfs or less, and 135 cfs per hour not to exceed 300 cfs in 24 hours when flows exceed 1,750 cfs.

Downstream of Iron Gate dam, the Klamath River flows unobstructed for 190 miles before entering the Pacific Ocean. Four major tributaries enter this reach: the Shasta (RM 176.6), Scott (RM 143), Salmon (RM 66), and Trinity (RM 40) rivers. Each tributary supports substantial populations of anadromous salmon and steelhead. They also have a substantial influence on the flow volume and water temperatures in the lower portions of the Klamath River. Together, these tributaries contribute 44 percent of the basin's mean annual runoff. The long-term average annual flow of the Shasta, Scott, Salmon, and Trinity rivers is 199, 803, 1,853, and 4,969[46] cfs, respectively. This compares to a mean annual flow of 2,098 cfs at Iron Gate dam and 17,667 cfs at the mouth of the Klamath River. We describe habitat conditions in these tributaries and their use by anadromous fish later in this section. Section 3.3.2, *Water Resources*, provides additional information on the hydrology and water quality in these tributaries.

[46]Flows from the Trinity River have recently increased under the Trinity River ROD, which reduced the amount diverted from the Trinity River Basin by the State Water Project. The ROD was implemented, in part, in 2001 and went into full effect in November 2004.

Table 3-46. Number of fish collected by gear type during 1998 and 1999 in the Iron Gate reservoir.[a] (Source: PacifiCorp, 2004e)

Species	Trammel Net (A)		Trap Net (A, J)		Beach Seine (J)		Larval Trawl (J, L)		Dip Net (J, L)		Larval Drift Net (J, L)		Total	
	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999
Lamprey spp.	0	0	0	4	0	0	0	0	0	0	1	0	1	4
Tui chub	102	40	0	0	0	0	59	0	2,967	7	0	0	3,128	47
Blue chub	50	48	0	0	0	0	0	0	0	0	8	0	58	48
Chub spp.	0	0	0	0	9	0	1,298	9	0	0	7	6	1,314	15
Golden shiner	0	0	0	8	73	32	60	221	0	13,566	0	2	133	13,829
Fathead minnow	0	0	0	0	0	1	0	0	0	2	0	0	0	3
Klamath speckled dace	0	0	0	9	0	0	0	0	0	5	0	0	0	14
Klamath smallscale sucker	11	10	1	0	0	0	0	0	0	0	0	0	12	10
Shortnose sucker	2	11	0	0	0	0	0	0	0	0	0	0	2	11
Sucker spp.[b]	0	1	0	0	0	0	3	114	14	604	25	419	42	1,138
Bullhead spp.	87	83	25	273	1	0	0	0	0	0	0	0	113	356
Channel Catfish	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Redband/rainbow trout	6	2	0	1	0	2	2	4	0	16	0	0	8	25
Sculpin spp.	0	0	0	0	0	0	0	0	0	0	52	24	52	24
Pumpkinseed	18	8	1	41	22	90	6	5	0	2,179	0	2	47	2,325
Green Sunfish	0	0	0	2	2	1	0	0	0	0	0	0	2	3
Largemouth bass	7	5	1	1	277	62	51	9	0	342	0	0	336	419
Sunfish spp.	0	0	0	0	33	0	11	0	0	1	0	0	44	1
Crappie spp.	22	41	12	24	48	0	72	3	14	0	0	3	168	71
Yellow perch	52	247	38	180	9	18	1	17	0	1	33	645	133	1,108
Unidentified	0	0	0	0	0	0	0	4	0	17	7	217	7	238
Total Individuals	357	497	78	543	474	206	1,563	386	2,995	16,740	133	1,318	5,600	19,690
Total Taxa	10	12	6	10	9	7	10	9	3	11	7	8	18	21
Sampling Effort														
Sets/Pulls	19	10	3	12	13	13	17	27	6	25	12	20		
Hours	227	118	56	206	—	—	—	—	—	—	44	87		

[a] Targeted life stage in parentheses after gear type (A = adult, J = juvenile, L = larvae).

[b] Data presented in Desjardins and Markle (2000) indicate that all of the unidentified sucker spp. collected in Iron Gate reservoir in 1998 and 1999 were larvae.

The river basin downstream of Iron Gate dam supports a variety of species of anadromous fish including fall and spring Chinook salmon, coho salmon, steelhead, green sturgeon, and Pacific lamprey. Klamath fall Chinook contribute to important commercial, recreational, and tribal fisheries; steelhead support a popular recreational fishery; and green sturgeon support a small tribal fishery. Coho salmon that occur in the basin are part of the Southern Oregon Northern Coastal California evolutionarily significant unit (ESU), which is federally listed as threatened. Information on the abundance and distribution of anadromous fish, and the condition of aquatic habitat in the Klamath River and its tributaries, is summarized below. Section 3.3.3.1.2, *Anadromous Fish Specie*s, provides information on the biology and population status of these and other anadromous species that occur in the basin downstream of Iron Gate dam. Section 3.3.3.1.5, *Salmon and Steelhead Harvest and Harvest Management*, provides information on commercial, recreational, and tribal fisheries and harvest management.

The Klamath River downstream of Iron Gate dam supports the spawning and rearing life stages of fall Chinook, and it serves as the migratory corridor for fall Chinook and other anadromous fish that are produced in its tributaries. Between 1978 and 2002, the basin-wide escapement of adult fall Chinook has ranged from a low of 19,121 fish in 1991 to a high of 208,380 fish in 1995 (table 3-47). The number of fall Chinook that spawn in the mainstem Klamath River is a relatively small proportion of the total basin-wide escapement, with estimates between 1978 and 2002 ranging from 580 fish in 1991 to 10,848 fish in 2002. Spawner surveys conducted by FWS indicate that approximately half of the fall Chinook that spawn within the 82-mile survey reach construct their redds in the 13.5-mile section between Iron Gate dam and the Shasta River (table 3-48). We provide additional information on trends in the total escapement of fall Chinook in section 3.3.3.1.5, *Salmon and Steelhead Harvest and Harvest Management.*

Table 3-47. Annual escapement of fall Chinook by sub-basin and hatchery, 1978 through 2002. (Source: Cal Fish & Game, 2003, as modified by staff)

Year	Iron Gate Hatchery	Trinity River Hatchery	**Total Hatchery Spawners**	Trinity River Basin	Salmon River Basin	Scott River Basin	Shasta River Basin	Bogus Creek Basin	Mainstem Klamath River	Misc. Klamath and Trinity tributaries	**Total Natural Spawners**	**Total Spawner Escapement**
1978	7,840	7,359	**15,199**	35,764	4,000	5,332	18,731	5,579	2,000	3,500	**74,906**	**90,105**
1979	2,558	2,299	**4,857**	11,964	1,150	3,824	8,151	5,938	4,656	1,715	**37,398**	**42,255**
1980	2,863	6,355	**9,218**	24,537	1,000	4,277	8,096	5,070	3,335	2,150	**48,465**	**57,683**
1981	2,595	3,374	**5,969**	21,246	1,200	6,556	12,220	3,642	4,000	1,500	**50,364**	**56,333**
1982	10,186	6,293	**16,479**	17,423	1,300	10,176	8,455	7,143	4,000	2,100	**50,597**	**67,076**
1983	8,885	5,765	**14,650**	18,137	1,275	3,568	3,872	3,048	2,000	1,410	**33,310**	**47,960**
1984	6,094	2,932	**9,026**	9,070	1,442	1,801	2,842	3,504	1,550	1,140	**21,349**	**30,375**
1985	22,110	20,749	**42,859**	38,671	3,164	4,408	5,124	4,647	624	4,990	**61,628**	**104,487**
1986	18,557	19,404	**37,961**	113,007	3,665	8,041	3,957	7,308	799	5,525	**142,302**	**180,263**
1987	17,014	16,387	**33,401**	77,869	3,950	8,566	4,697	10,956	928	3,523	**110,489**	**143,890**
1988	16,715	22,104	**38,819**	55,242	3,600	5,200	2,842	16,440	3,146	5,460	**91,930**	**130,749**
1989	11,690	11,371	**23,061**	31,988	3,610	4,188	1,577	2,662	1,225	4,127	**49,377**	**72,438**
1990	7,025	1,719	**8,744**	7,923	4,667	1,615	533	785	564	859	**16,946**	**25,690**
1991	4,067	2,687	**6,754**	5,249	1,480	2,165	726	1,281	580	886	**12,367**	**19,121**
1992	7,318	3,990	**11,308**	9,702	1,325	2,838	586	1,154	600	966	**17,171**	**28,479**
1993	21,711	1,551	**23,262**	8,370	3,533	5,300	1,426	3,716	678	2,660	**25,683**	**48,945**
1994	12,233	7,706	**19,939**	13,411	3,493	2,863	5,203	8,260	3,874	1,474	**38,578**	**58,517**
1995	14,008	15,254	**29,262**	87,138	5,475	14,477	13,511	46,432	7,240	4,845	**179,118**	**208,380**
1996	14,165	6,660	**20,825**	47,124	5,463	12,097	1,450	10,797	3,008	7,561	**87,500**	**108,325**
1997	13,727	6,207	**19,934**	14,352	6,000	8,561	2,001	10,030	3,576	5,849	**50,369**	**70,303**
1998	15,326	14,488	**29,814**	26,434	1,453	3,327	2,542	6,835	3,022	1,730	**45,343**	**75,157**
1999	14,120	7,064	**21,184**	10,907	780	3,584	3,197	6,165	2,608	1,663	**28,904**	**50,088**
2000	72,474	27,046	**99,520**	26,844	1,772	6,253	12,296	35,051	3,455	3,451	**89,122**	**188,642**
2001	38,568	18,175	**56,743**	37,327	3,350	6,142	11,093	12,575	10,848	4,245	**85,580**	**142,323**
2002	24,961	4,549	**29,510**	13,332	2,558	4,308	6,818	17,834	22,308	2,129	**69,287**	**98,797**
Average	15,472	9,660	**25,132**	30,521	2,828	5,579	5,678	9,474	3,625	3,018	**60,723**	**85,855**
% of total	18.0%	11.3%	**29.3%**	35.5%	3.3%	6.5%	6.6%	11.0%	4.2%	3.5%	**70.7%**	**100.0%**

Table 3-48. Distribution of fall Chinook spawning redds observed from 1993 through 2002 from Iron Gate dam to Indian Creek. (Source: Grove, 2002)

Tributary Reach (RM)	Percent of Total									
	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Iron Gate (190.1) to Cape Horn Ck (186.8)	24.2	38.9	39.1	40.9	45	55.1	60.9	37.5	25.8	31.9
Cape Horn Ck (186.8) to Shasta River (176.6)	2.1	11.1	15.6	10.6	14.2	16.1	11.7	12.5	12.4	13.5
Shasta River (176.6) to Humbug Ck (173.8)	2.7	1.1	1.9	0.8	1.1	3.3	3.5	8	3.6	3.4
Humbug Ck (173.8) to Vesa Ck (166.7)	7.9	3.4	4.9	3.3	4.3	3	0.9	5.1	7.2	5.9
Vesa Ck (166.7) to Little Humbug Ck (160.0)	7.9	2.7	4.9	4.2	2.3	4.3	3.3	3.6	6.7	5.4
Little Humbug Ck (160.0) to Kohl Ck (154.1)	2.4	4.2	1.2	2.4	0.9	0.4	1.2	2.1	4.2	4.2
Kohl Ck (154.1) to Kinsman Ck (147.3)	5.5	2.2	1.1	1.1	1.8	1.6	2.9	3.5	2.8	3.8
Kinsman Ck (147.3) to Kuntz Ck (141.2)	6.4	5.6	3.8	1.8	8.6	2.5	1.9	6.8	7.1	6.6
Kuntz Ck (141.2) to Walker Ck (134.8)	7.6	5.2	3.9	5.5	1		2.1	2.5	2.5	2.5
Walker Ck (134.8) to Portuguese Ck (129.0)	6.7	2.2	4.4	6	1.8	0.4	0.3	0.4	1.7	1.5
Portuguese Ck (129.0) to Shinar Ck (123.7)	12.4	7.1	6	10.7	6.5	4.7	3.6	7.5	9.7	5
Shinar Ck (123.7) to China Ck (119.3)	5.8	6.9	5.2	4.8	3.3	3	2.9	7.5	10.3	7.7
China Ck (119.3) to Ottley Gulch (114.2)	1.2	3.9	2.2	3.1	1.4	1.4	1.6	1.3	3.2	3.5
Ottley Gulch (114.2) to Indian Ck (108.0)	7.3	5.4	5.8	4.8	7.6	3.5	3	3.9	2.8	5.2

Coho salmon and steelhead spawn primarily in the tributaries, but they use the mainstem Klamath as a migration corridor, and may rear for a period in the mainstem river or in the estuary on their way to the ocean. The ability of the mainstem Klamath River to support the rearing and migration of anadromous salmonids is constrained by high water temperatures, poor water quality, and disease outbreaks, especially during the summer months. Temperature refugia provided by inflows from springs and from cooler tributaries are used extensively by rearing and migrating salmonids.

In recent years, substantial losses of juvenile salmonids have occurred during their migration through the lower Klamath River, and a major kill of adult salmon and steelhead occurred in September 2002. These losses have been primarily from disease, and losses observed during juvenile migration monitoring have been especially severe during periods of sustained high water temperatures (Scheiff et al., 2001). Section 3.3.3.1.2, *Anadromous Fish Species*, provides additional information on the thermal tolerance of Klamath River anadromous salmonids, and section 3.3.3.1.4, *Diseases Affecting Salmon and Steelhead*, provides information on losses associated with fish diseases and their relationship to water quality conditions.

Although information on the abundance of non-salmonid species downstream of Iron Gate dam is limited, some information is available from sampling conducted to monitor the outmigration of juvenile salmon and steelhead in the lower Klamath River. Klamath smallscale sucker, Pacific lamprey, and speckled dace were the most common of the non-target species that were collected during screw-trap sampling conducted between 1997 and 2000 in the Klamath River upstream of its confluence with the Trinity River (table 3-49). Sculpins, threespine stickleback, and green sturgeon were the next most abundant species collected.

Table 3-49. Non-target species (excluding Chinook salmon, coho salmon, and steelhead) collected during screw-trap sampling conducted at Big Bar (RM 49.7) on the Klamath River and at Willow Creek (RM 21.1) on the Trinity River, 1997-2000. (Source: Scheiff et al., 2001)

	Total Number Captured										
	Klamath					**Trinity**					
Common Name	**1997**	**1998**	**1999**	**2000**	**Total**	**1997**	**1998**	**1999**	**2000**	**Total**	**Species Total**
Klamath smallscale sucker	1,930	388	285	132	2,735	6,403	1,923	1,045	514	9,885	12,620
Pacific lamprey	1,085	1,444	2,121	815	5,465	1,281	1,140	387	28	2,836	8,301
Klamath speckled dace	618	147	167	130	1,062	950	385	476	519	2,330	3,392
Sculpin	186	24	42	14	266	123	13	58	31	231	497
Threespine stickleback	6	0	0	0	6	103	16	0	197	371	377
Green sturgeon	127	9	80	10	226	49	16	0	0	65	291
Golden shiner	3	49	196	20	228	3	4	7	8	22	290
Sockeye salmon	0	0	0	0	0	17	30	223	13	283	283
American shad	11	0	2	1	14	148	2	0	73	223	237
Brown bullhead	3	5	2	1	11	6	0	32	1	39	50
Brown trout	2	1	0	0	3	6	0	3	10	19	22
Fathead minnow	2	0	2	9	13	0	0	0	0	0	13
Green sunfish	0	1	2	0	3	5	1	1	0	7	10
Crappie	2	0	1	0	3	0	0	0	0	0	3
Largemouth bass	0	0	0	0	0	0	0	0	0	0	0
Season Total	**2,045**	**1,680**	**2,615**	**1,000**	**7,340**	**2,691**	**1,607**	**1,248**	**880**	**6,426**	**13,766**
Days Trapped	**126**	**96**	**116**	**93**		**231**	**206**	**191**	**143**		

Lower Klamath River Tributaries

The tributaries downstream of Iron Gate dam provide important spawning and rearing habitat for fall and spring Chinook salmon, coho salmon, and steelhead. This section describes historical and current use by anadromous fish and the condition of habitat in the four largest tributaries, the Shasta, Scott, Salmon, and Trinity rivers. Bogus Creek, a smaller tributary that enters the Klamath River 0.5 mile downstream of Iron Gate dam, also provides important spawning habitat for fall Chinook and coho salmon. Available information on the use of Bogus Creek and other smaller tributaries by anadromous fish is provided in section 3.3.3.1.2, *Anadromous Fish Species.*

<u>Shasta River</u>. The Shasta River enters the Klamath River at RM 176.6, 13.5 miles downstream from Iron Gate dam. The Shasta River currently provides approximately 35 miles of fall Chinook habitat, 38 miles of coho habitat, and 55 miles of steelhead habitat (Hardy and Addley, 2001). Dwinnell dam, constructed on the Shasta River at RM 37 in 1926, eliminated access to about 22 percent of the habitat that was historically available to salmon and steelhead in the Shasta River. The formerly large run of spring Chinook in the Shasta River was lost around the time that Dwinnell dam was constructed (NAS, 2004). Current anadromous fish production in the basin is thought to be limited by low flows and high water temperatures, stream diversions, and degraded spawning gravels (Hardy and Addley, 2001). Cumulative water withdrawals in conjunction with groundwater pumping during the agricultural season may restrict access by fall Chinook to the lower 10 to 15 miles of the river. Stream temperatures are adversely affected by reduced flows, agricultural return flows, and loss of riparian vegetation from overgrazing (Hardy and Addley, 2001).

The Shasta River is reported to have been one of the most productive salmon streams in California because of its combination of continuous flows of cold water from springs, low gradients, and naturally productive waters (NAS, 2004). Cal Fish & Game has operated a fish counting facility on the lower Shasta River since 1930, which provides the longest record of abundance trends of anadromous salmonids in the Klamath River Basin. Currently, the facility consists of a video fish counting weir. The facility is operated primarily during the fall Chinook migration, so counts of other species are not comprehensive but they do provide an indication of abundance trends over time. Based on weir counts and spawner surveys conducted in the Shasta River downstream of the fish counting facility, the number of fall Chinook that returned to the Shasta River exceeded 80,000 fish as recently as 1931, but runs of fall Chinook have generally been less than 10,000 fish since the mid 1940s. Fall Chinook salmon runs were generally less than 5,000 fish from 1983 through 1999, but rebounded to between 6,000 and 12,000 fish from 2000 through 2002 (figure 3-40). Counts of coho salmon at the Shasta fish counting facility have typically been less than 400 fish, and annual counts were 30 fish or less from 1985 through 2000 (figure 3-41). Counts of steelhead at the facility frequently exceeded 1,000 fish prior to 1943 and occasionally through the early 1980s, but since 1988 fewer than 20 steelhead have been counted in each year through 1996 (figure 3-42).

Cal Fish & Game monitored the outmigration of juvenile Chinook salmon, coho salmon, and steelhead in the Shasta River using a rotary screw trap from late February through early July 2002 (Chesney and Yokel, 2003). A total of 526,256 Chinook, 8,294 steelhead, and 747 coho salmon juveniles (fry, parr, and smolts) were captured. An estimated 3,135,902 Chinook salmon smolts migrated during a 14-week period with peak emigration in mid-March, and an estimated 6,657 steelhead migrated during a 7-week period with peaks in mid-April for smolts and early June for pre-smolts (parr). Too few coho salmon smolts (300) were captured to estimate total number of coho outmigrants, although peak catches occurred in late April and late May. Many steelhead and coho salmon outmigrants were age 0+ fish that moved from the Shasta to the Klamath as Shasta River flows declined (Chesney and Yokel, 2003).

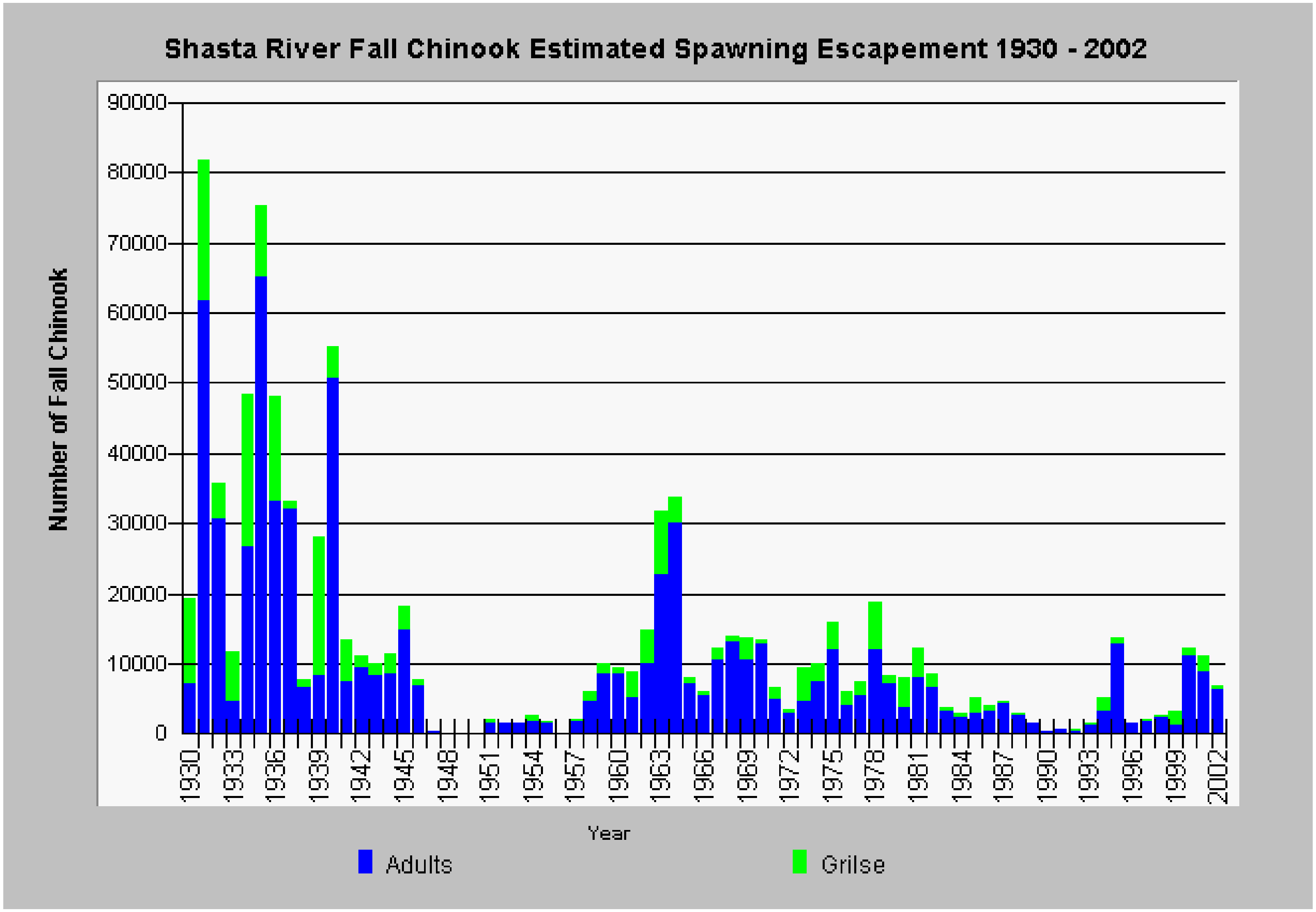


Figure 3-40. Shasta River estimated spawning escapement of grilse and adult fall Chinook salmon, 1930 to 2002. Note: Grilse (jacks) are precocious adult Chinook salmon males that have spent only one year in the ocean. (Source: Accessed from http://www.krisweb.com/krisklamathtrinity/krisdb/webbuilder/sh_c11.htm on August 27, 2006)

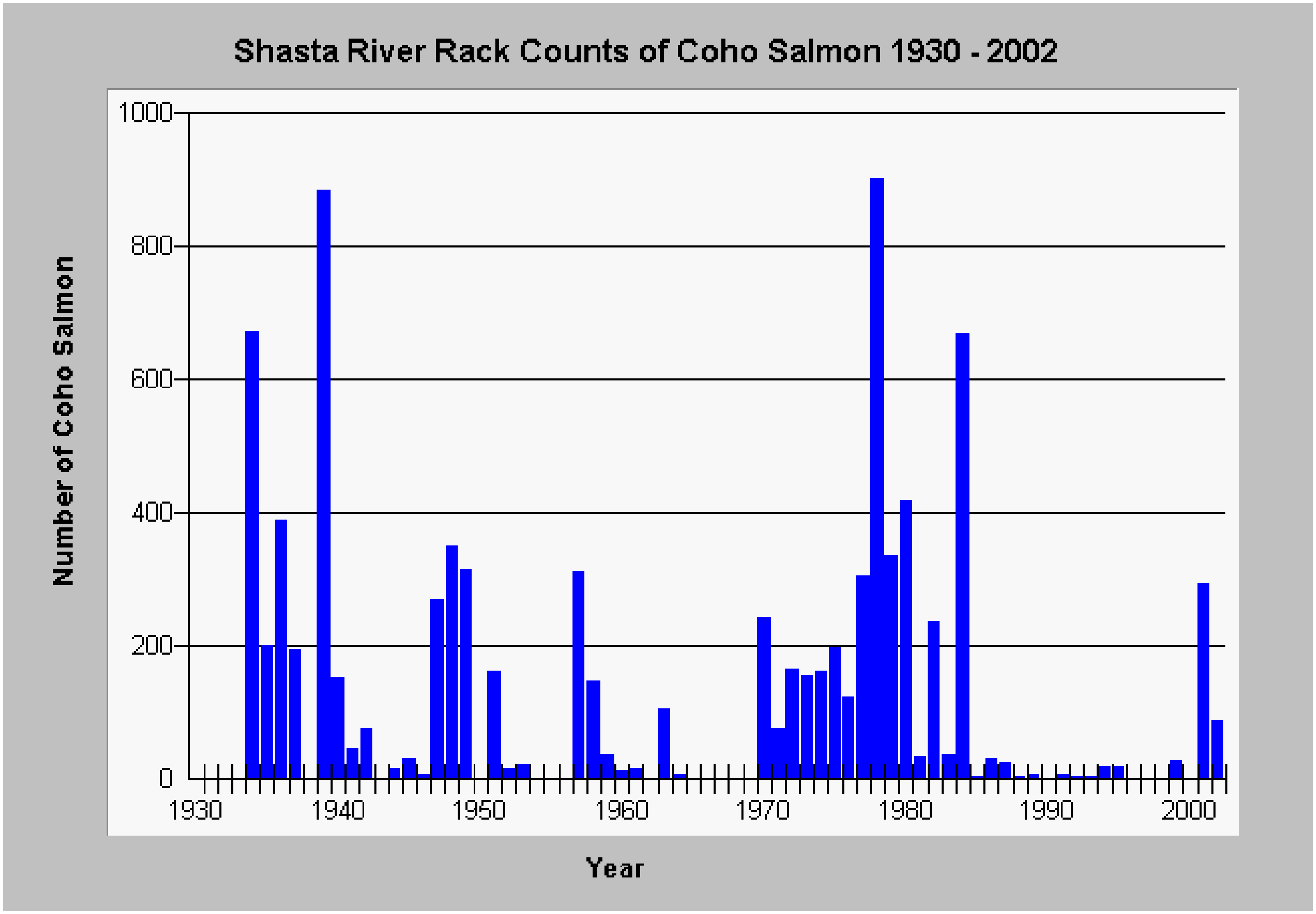


Figure 3-41. Shasta River weir counts of coho salmon, 1930 to 2002. (Source: Accessed from http://www.krisweb.com/krisklamathtrinity/krisdb/webbuilder/sh_c15.htm, on August 27, 2006)

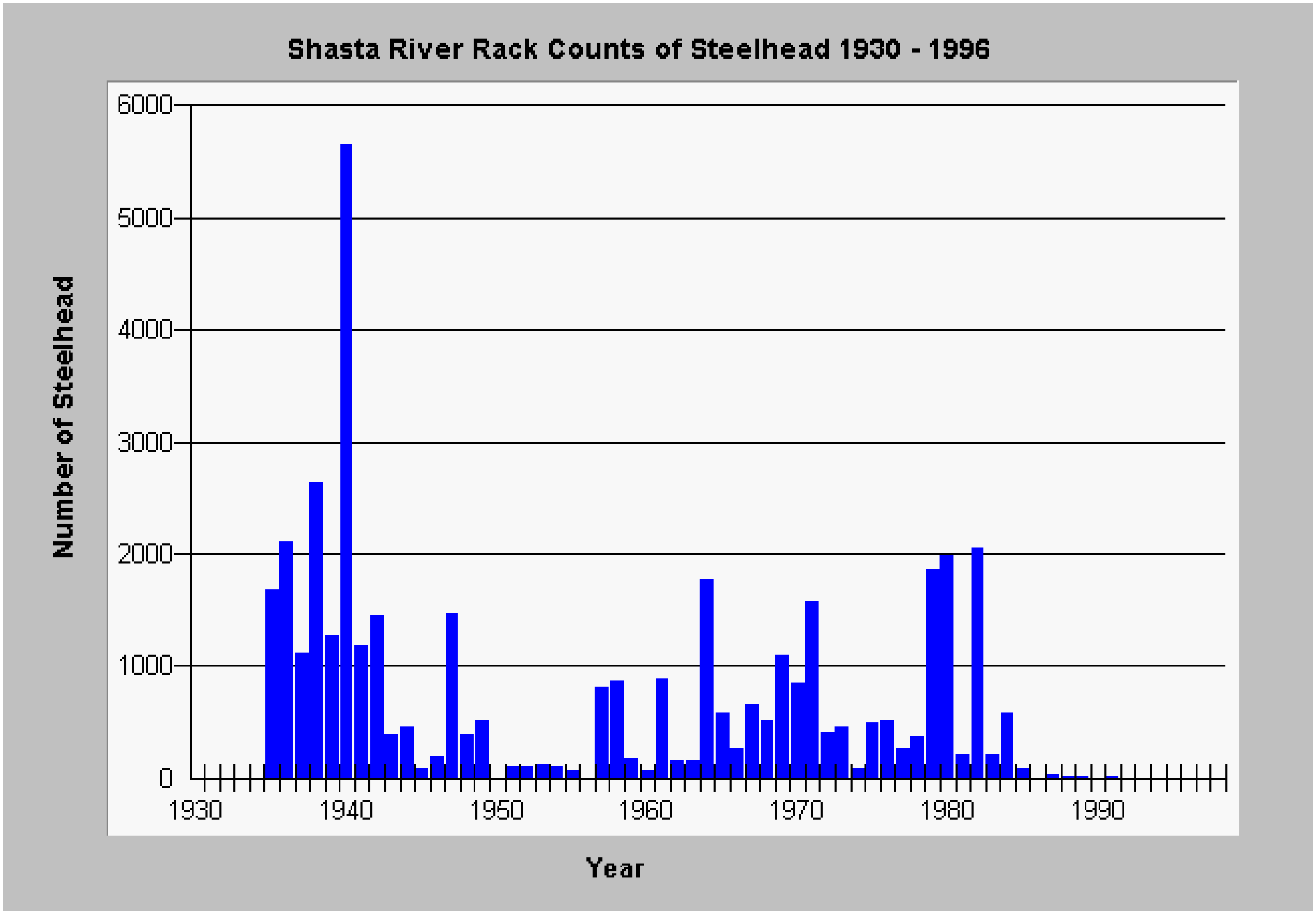


Figure 3-42. Shasta River weir counts of adult steelhead, 1930 to 1996. (Source: Accessed from: http://www.krisweb.com/krisklamathtrinity/krisdb/webbuilder/sh_c16.htm on August 27, 2006)

Scott River. The Scott River enters the Klamath River at RM 143, 33.6 miles downstream of the Shasta River. Including tributaries, the Scott River Basin presently has about 59 stream miles of habitat suitable for fall Chinook, 88 miles of habitat suitable for coho salmon, and 142 miles of habitat suitable for steelhead (Hardy and Addley, 2001). Anadromous fish production within the Scott River Basin is affected by reduced flows, degraded spawning habitat, high summer water temperatures, and several unscreened diversions. Cumulative water withdrawals in conjunction with groundwater pumping during the agricultural season currently limit upstream migration of fall Chinook to the lower 42 miles of the mainstem Scott River (Hardy and Addley, 2001). The mainstem channel of the Scott River has been extensively altered by placer and hydraulic mining, logging, grazing, elimination of wetlands, and flood-management or bank-stabilization efforts (NAS, 2004). However, locally driven efforts are under way in the Scott Valley to improve water quality and salmonid spawning and rearing habitat, and fish screens have been installed at many of the water diversions in the basin (NAS, 2004).

Between 1978 and 2002, estimated spawning escapement of fall Chinook salmon to the Scott River ranged from 1,615 fish in 1990 to 12,657 fish in 1995 (see table 3-47). Although quantitative estimates of steelhead and coho escapement are not available, a survey conducted in several of the tributaries to the Scott River during the 2001/2002 spawning season identified a total of 212 coho redds, 173 live coho, and 115 carcasses (Maurer, 2002). Cal Fish & Game monitored the outmigration of juvenile Chinook salmon, coho salmon, and steelhead in the Scott River using a rotary screw trap from late February through mid-July 2002 (Chesney and Yokel, 2003). A total of 11,793 Chinook, 11,918 steelhead, and 1,939 coho salmon juvenile (fry, parr and smolts combined) were captured. An estimated 319,286 Chinook salmon smolts migrated during an 8-week period and 5,088 steelhead smolts migrated during a 5-week period. Peak catches of both species occurred from late March to early April and again from late June to early July. Too few coho salmon smolts (6) were captured to estimate the total number of coho outmigrants, although peak catches occurred in mid- to late June (Chesney and Yokel, 2003).

Salmon River. The Salmon River enters the Klamath River at RM 66, 77 miles downstream of the Scott River. It is one of the most pristine watersheds within the Klamath River Basin, and a high percentage of the watershed is protected under a wilderness designation. Hardy and Addley (2001) estimate that the watershed currently has 81 stream miles of fall Chinook habitat and 85 miles of coho habitat, and the amount of steelhead habitat was considered to be similar to the amount for coho. NAS (2004) states that the watershed supports 140 miles of fall Chinook habitat and 100 miles of coho and steelhead habitat. Hardy and Addley (2001) indicate that there are no substantial impediments to anadromous fish production in the Salmon River Basin, although areas of unstable spawning gravels have been identified, and water temperatures can be higher than optimal for rearing salmonids at some times and locations. NAS (2004) states that logging roads, road crossings, and frequent fires in the basin contribute to high sediment yields, and that historical and continued placer mining has reduced riparian cover and disturbed spawning and holding habitat.

The Salmon River supports spring and fall Chinook salmon, coho salmon, steelhead, Pacific lamprey, and green sturgeon (Hardy and Addley, 2001). The estimated escapement of fall Chinook to the Salmon River Basin between 1978 and 2001 ranged from 780 fish in 1999 to 6,000 fish in 1997 (see table 3-47). Estimated escapement of spring Chinook to the Salmon River Basin between 1980 and 2002 ranged from 143 fish in 1983 to 1,443 fish in 1995 (figure 3-43). Estimated escapement of summer steelhead to the Salmon River Basin typically exceeded 300 fish between 1980 and 1988, decreased to less than 100 fish from 1995 through 2000, and rebounded to over 300 fish in 2001 and 2002 (figure 3-44). Green sturgeon counted during snorkel surveys conducted by the Yurok Tribe in 2002 peaked at 11 fish in late May and 14 fish in early June, but dropped to zero fish on June 11, suggesting that the sturgeon had likely spawned and moved downstream.[47]

[47]Information from http://www.krisweb.com/krisklamathtrinity/krisdb/webbuilder/sa_ct9.htm, accessed August 27, 2006.

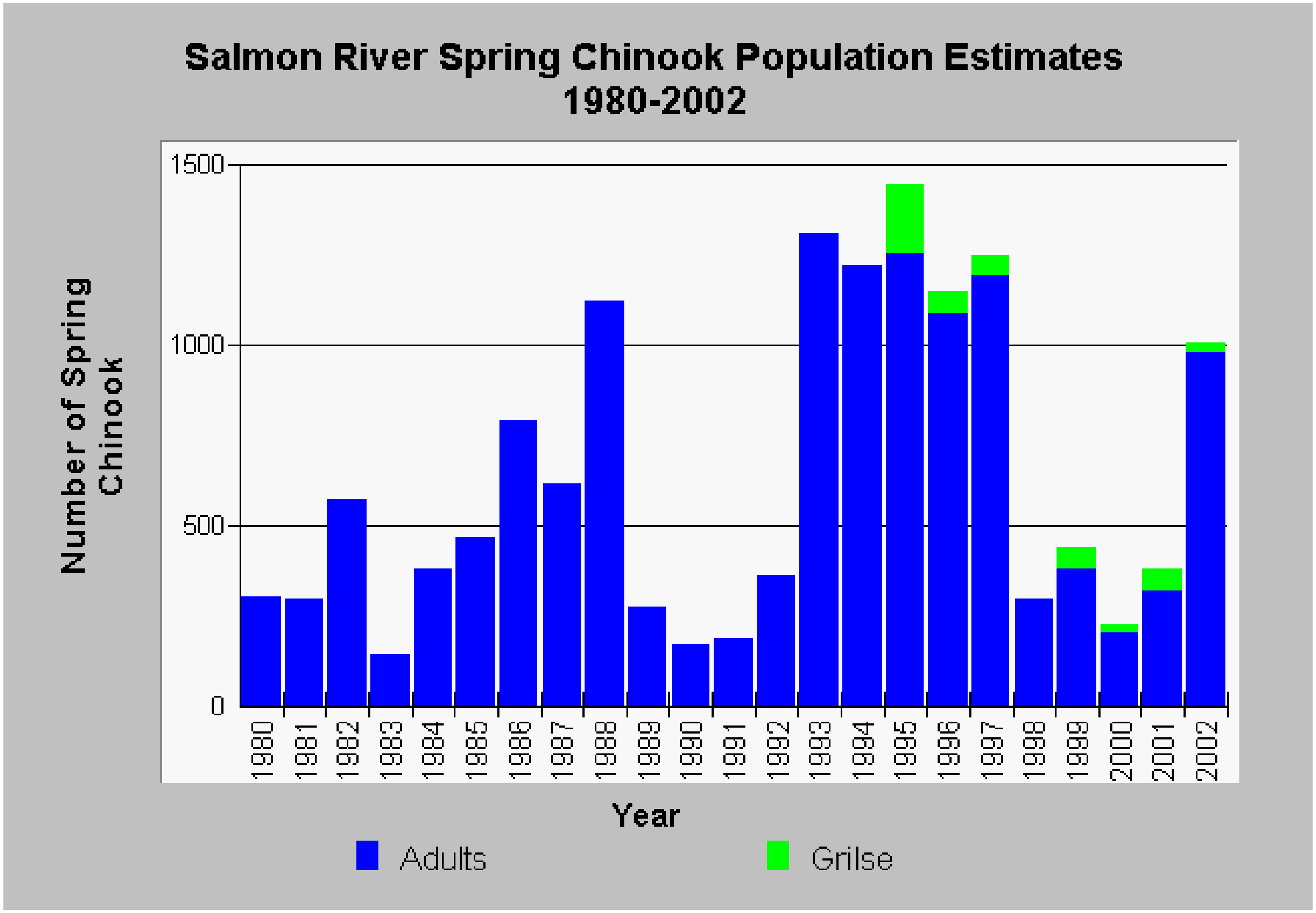


Figure 3-43. Salmon River estimated spawning escapement of grilse and adult spring Chinook salmon, 1980 to 2002. (Source: Accessed from http://www.krisweb.com/krisklamathtrinity/krisdb/webbuilder/sa_c8.htm on August 27, 2006)

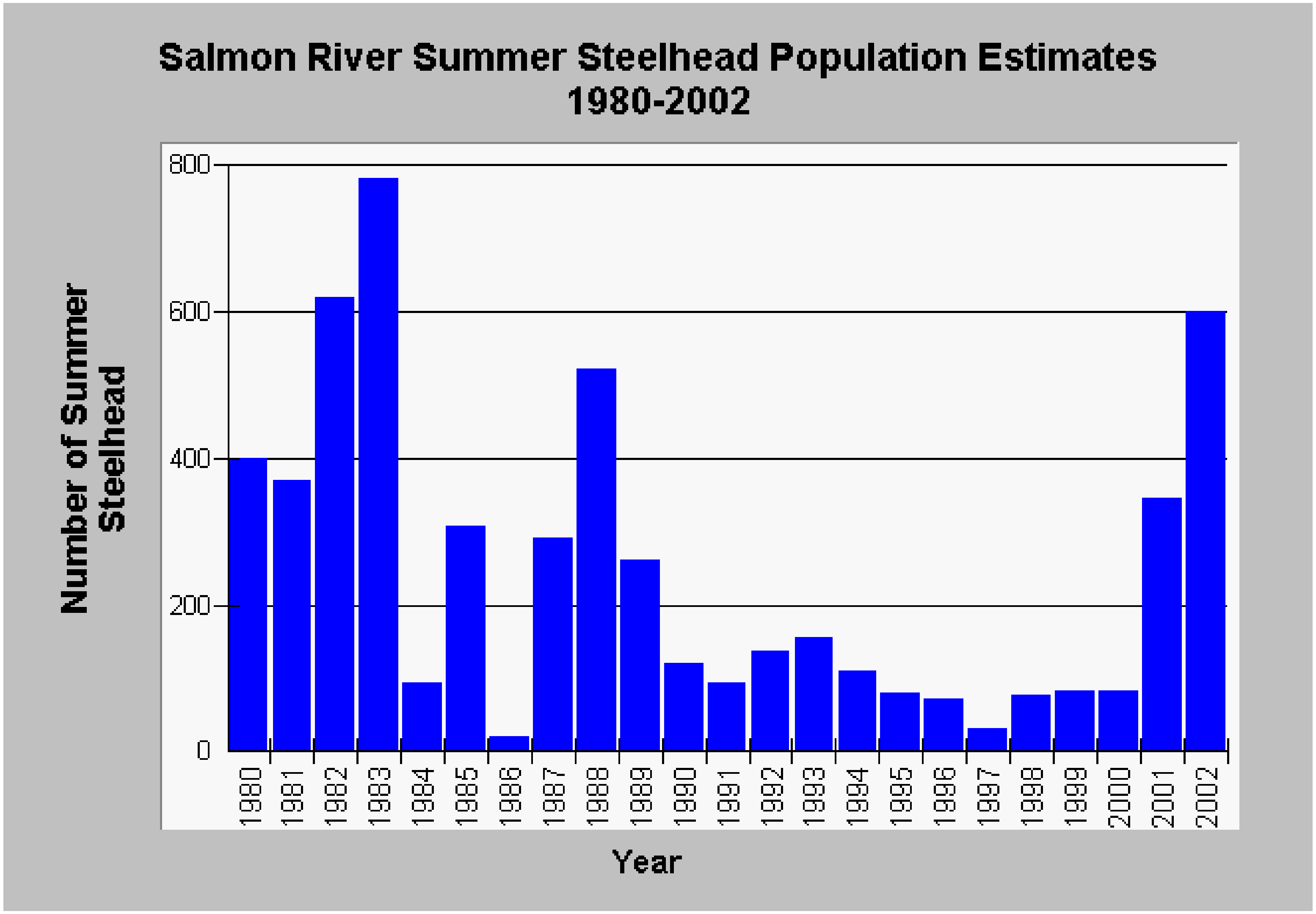


Figure 3-44. Salmon River estimated spawning escapement of steelhead, 1980 to 2002. (Source: Accessed from http://www.krisweb.com/krisklamathtrinity/krisdb/webbuilder/sa_c11.htm on August 27, 2006)

Trinity River. The Trinity River enters the Klamath River at RM 40, 26 miles downstream of the Salmon River. Prior to the construction of TRD of the Reclamation Central Valley Project in the early 1960s, the Trinity River accounted for close to one-third of the average total runoff from the Klamath River Basin. The TRD consists of Trinity dam (at RM 116), which has an impoundment capacity of 2.4 million acre-feet, and Lewiston dam (at RM 109), which diverts water to the Central Valley Project. Construction of the TRD eliminated access for anadromous fish to approximately 59 miles of Chinook spawning habitat and 109 miles of steelhead habitat (Hardy and Addley, 2001).

Following construction of the TRD, the flows below Lewiston dam were reduced by approximately 80 percent, and the contribution of the Trinity River to the total flow of the Klamath River declined from 32 to about 26 percent. As discussed in section 3.3.2, *Water Resources*, flows released into the Trinity River have recently been increased under the Trinity River ROD, which was implemented, in part, in 2001 and went into full effect in November 2004. Because the waters released from Trinity dam remain relatively cool throughout the summer and early fall months, increased flows required under the ROD have the potential to reduce water temperatures in the lower Trinity River and in the Klamath River downstream of its confluence with the Trinity.

Hardy and Addley (2001) state that the mid-Trinity River Basin (Lewiston dam to the confluence with the South Fork Trinity) has about 140 stream miles of habitat suitable for Chinook and coho salmon, and about 225 miles of steelhead habitat. They also estimate that the South Fork Trinity has 115 stream miles of habitat suitable for Chinook and coho salmon, and about 190 miles of steelhead habitat. They did not estimate the amount of salmonid habitat in the lower Trinity River Basin, but they state that the lower basin contains important habitat for spawning fall Chinook, spring Chinook, winter and fall steelhead, coho, green sturgeon, and Pacific lamprey.

Hardy and Addley (2001) consider the primary factors that limit anadromous fish production in the Trinity basin to be reduced flows and migration blockages from agricultural diversions, reduced water quality, sedimentation, riparian encroachment, and the effects of large flood events. In the South Fork subbasin, they state that fires, timber harvest, road construction and historic mining practices, and large flood events have played a role in the loss of anadromous fish production.

The estimated escapement of fall Chinook to the Trinity River Basin between 1977 and 2002 ranged from 7,936 fish in 1991 to 132,411 fish in 1986 (see table 3-47). The estimated escapement of spring Chinook to the basin between 1978 and 2002 ranged from 1,315 fish in 1983 to 53,852 fish in 1988 (figure 3-45). The estimated escapement of coho salmon to the basin between 1977 and 2002 ranged from 239 fish in 1994 to 51,826 fish in 1987 (figure 3-46). We have not located any estimates of steelhead escapement for the Trinity basin.

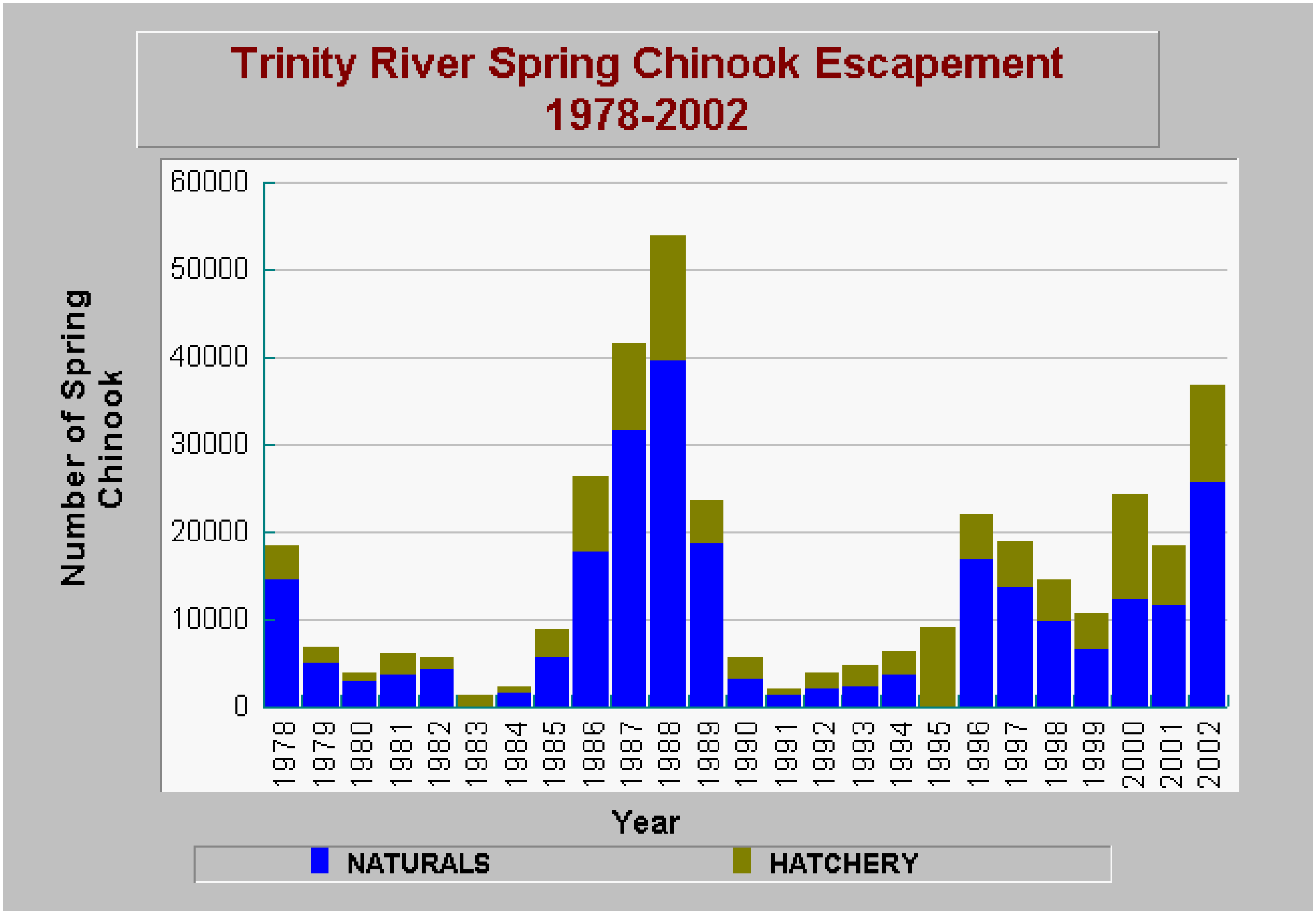


Figure 3-45. Trinity River estimated spawning escapement of naturally spawning and hatchery spawned spring Chinook salmon, 1978 to 2002. (Source: Accessed from http://www.krisweb.com/krisklamathtrinity/krisdb/webbuilder/mt_c10.htm on August 27, 2006)

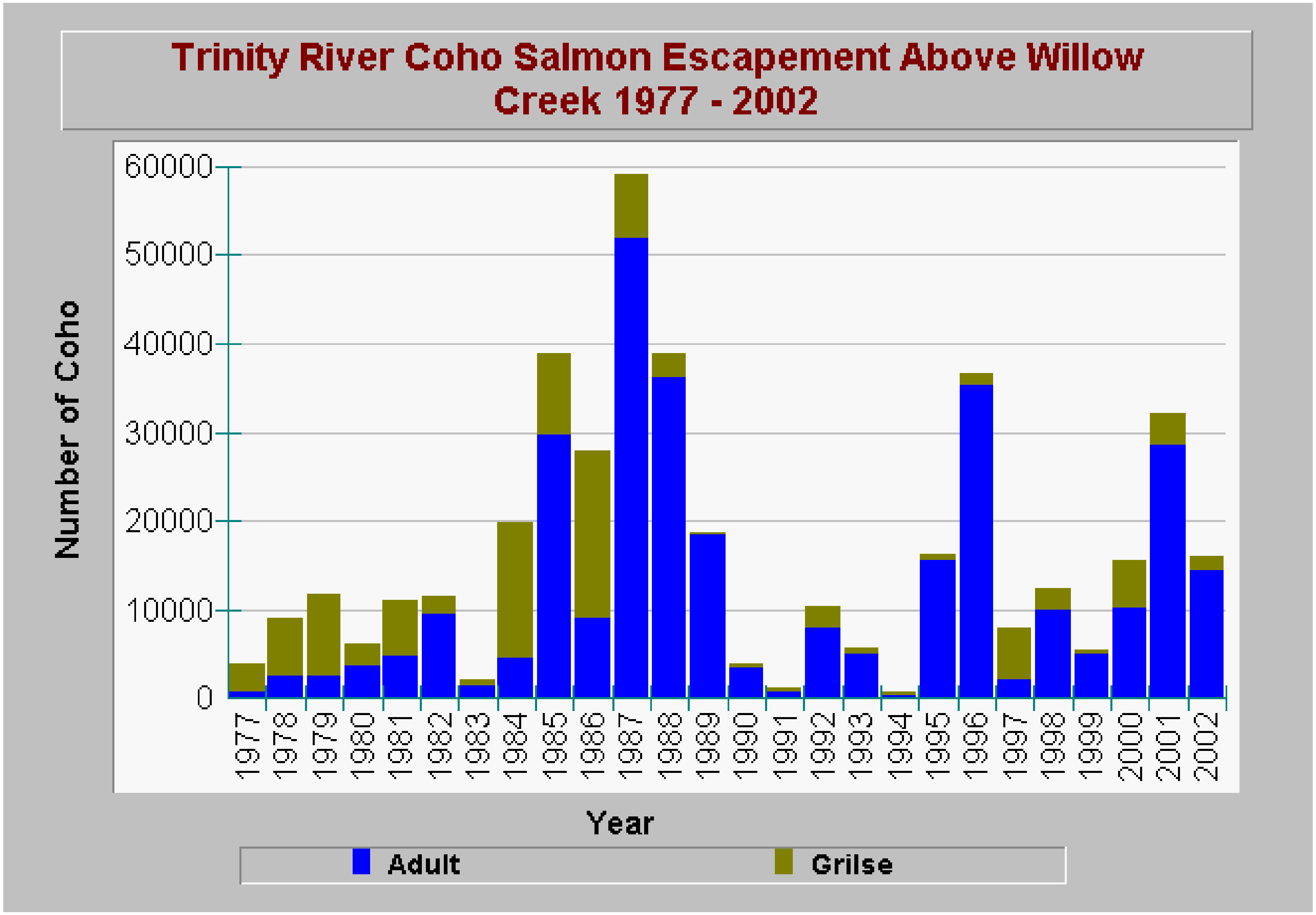


Figure 3-46. Trinity River estimated spawning escapement of grilse and adult coho salmon above Willow Creek, 1977 to 2002. (Source: Accessed from http://www.krisweb.com/krisklamathtrinity/krisdb/webbuilder/mt_c15.htm on December August 27, 2006)