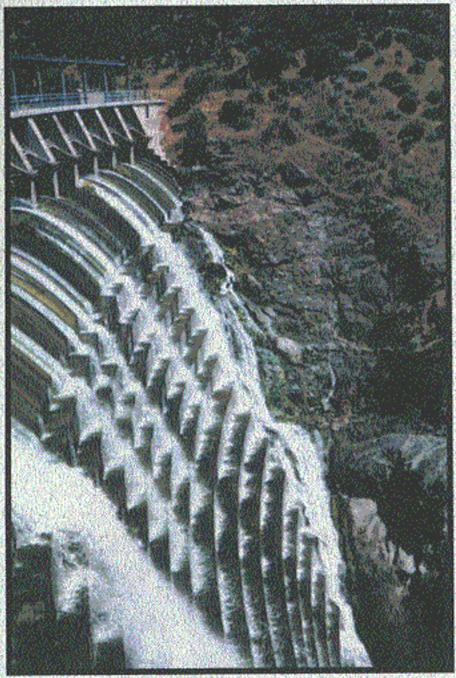
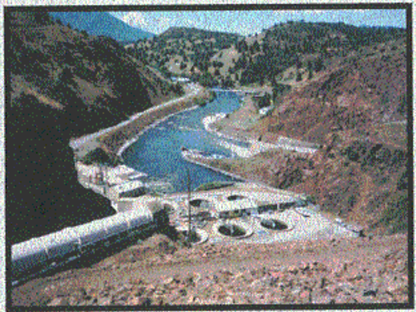
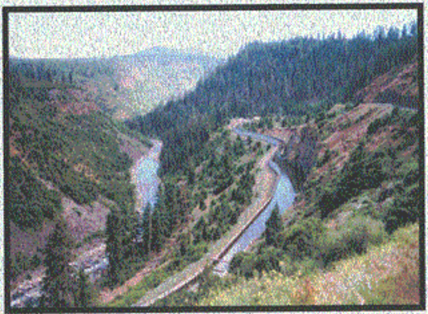
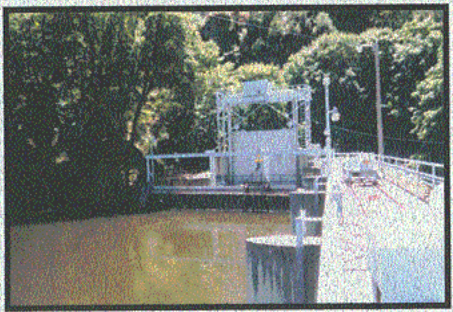
FISH PASSAGE CONDITIONS on the UPPER KLAMATH RIVER

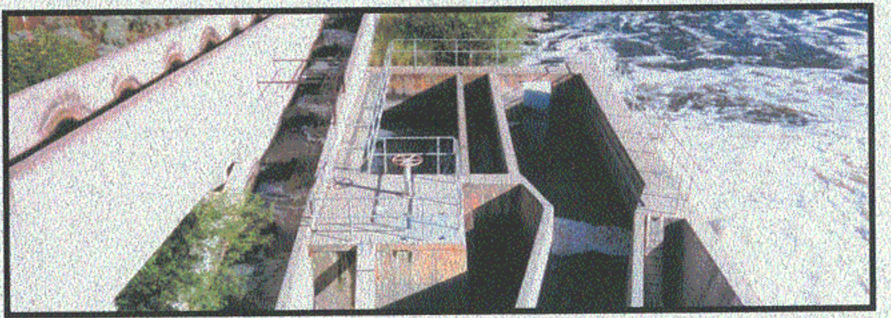
July 2000











Submitted to:

The Karuk Tribe
and
PacifiCorp

Submitted by:

FISHPRO

3780 SE Mile Hill Drive
Port Orchard, WA 98366
360-871-2727

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1.1 Background

The Klamath River Basin Conservation Area was established as a result of the 1986 Klamath Act adopted by Congress for the purpose of rebuilding the river's fish resources. The Act acknowledged that many activities associated with western settlement and development had significantly reduced the anadromous fish habitat of the Klamath-Trinity River system. In order to provide fishery resources necessary for Indian subsistence and ceremonial purposes, ocean commercial harvest, recreational fishing, and the economic health of many local communities, the Act authorized a 20-year fish restoration program to be implemented through the cooperative efforts of federal, state and local jurisdictions (KRBFTF 1991).

About 65% of the total Klamath River Basin Conservation Area is located in the Upper Klamath River subbasin. Along the mainstem Klamath River within this subbasin are six dams: Iron Gate, Copco 2, Copco 1, J.C. Boyle, Keno, and Link River. These physical structures as well as the environmental conditions in their vicinity are the subject of this report. All of these dams are operated by PacifiCorp for the purpose of power generation and/or flow regulation. The first five dams (Iron Gate to Keno) and the Westside and Eastside powerhouses comprise PacifiCorp's Klamath Project and will be the subject of a FERC relicensing application in the year 2006. Link River dam is owned by US Bureau of Reclamation and is therefore not part of the relicensing effort.

Published reports and personal interviews indicate that salmon, steelhead, lamprey and sucker populations were present and viable in the Upper Klamath River basin into the early 1900s. Then, during negotiations between the California Fish and Game Commission and the California Oregon Power Company regarding the construction of Copco 1 dam, a decision was made to construct a fish hatchery in lieu of a fishway over the dam. Upstream fish migration into the upper basin was subsequently blocked in 1910, when full-width racks were constructed for the Klamathon Mill. An egg-taking station was later added by the U.S. Bureau of Fisheries (Fortune et al. 1966). In 1925, the terminus for upstream fish migration moved downstream from Copco 1 by one-quarter mile with the construction of Copco 2 dam, and an egg collecting station was constructed at Fall Creek and conveyed to the State of California. "The Fall Creek hatchery was operated and maintained until 1948 when it was discontinued as uneconomical" (FERC 1963, Opinion No. 381). A new hatchery facility was constructed seven miles downstream in 1962 after the construction of Iron Gate dam.

In the mid-1960s, a Steering Committee comprised of the Oregon State Fish Commission, PacifiCorp, and other interested parties directed a study to examine the feasibility of re-establishing salmon and steelhead into the Upper Klamath basin. The study included field investigations to determine existing biological and environmental conditions in the Upper Klamath basin, as well as assessment of pertinent future plans for the area. The study also developed conceptual plans and associated costs for two fish passage alternatives, one involving fish ladders at all dams, and a second involving trapping and hauling of fish around Iron Gate and the Copco dams and fish ladders on the upper three dams (Fortune et al. 1966). The Steering Committee subsequently indicated that it appeared to be biologically feasible to re-establish spring chinook and steelhead in the Upper Klamath basin as far as the Upper Klamath Lake, since both species migrate at times when water quality conditions are satisfactory. The findings also stated that there was sufficient usable gravel to accommodate approximately 9,000 chinook spawners and 7,500 steelhead. Nonetheless, the Steering Committee decided against any sort of program to re-establish anadromous fish runs in the Upper Klamath basin, concluding that the combination of downstream losses, upstream losses, and difficulty of finding suitable stocks would prevent establishment of self-sustaining runs (Upper Klamath Basin Steering Committee 1966).

The passage of the Klamath Act in 1986 focused renewed interest in the fish passage issue. Two specific actions in the Klamath Act in carrying out the fisheries restoration program emphasized the need "to carry out such actions as are necessary to: (i) improve and restore Area habitats, and to promote access to blocked Area habitats, to support increased run sizes; (v) improve upstream and downstream migration by removal of obstacles to fish passage and the provision of facilities for avoiding obstacles" in order to restore, by year 2006, the biological productivity of the Klamath River basin (Klamath Act, 1986). Since the passage of the Klamath Act in 1986, fish populations have continued to decline. Chinook spawning escapements have fallen below the minimum acceptable population of 35,000 adult natural spawners, and Coho salmon have been listed under the Endangered Species Act as Threatened. Despite public and private efforts to understand or reverse this trend, the number of fish returning to the Klamath River system has continued to diminish. Current measures to protect and restore the anadromous fish runs of the Klamath River basin do not appear to be adequate. In order to restore anadromous fish to optimum levels, as prescribed in the Klamath Act, more progressive measures are needed to initiate both immediate and long term recovery.

A major goal of the Klamath Basin Tribes is the reintroduction of anadromous fish upstream of mainstem dams. In an effort to determine what meaningful measures are necessary to reintroduce anadromous fish beyond the dams into the upper Klamath River basin, the Karuk Tribe of California (Karuk Tribe) prepared a proposal for this first phase report. In recognition that PacifiCorp and the Karuk Tribe both have shared interests in resolving anadromous fishery problems associated with the management and operation of water management facilities on the Klamath River, PacifiCorp agreed to work together with the Karuk Tribe to conduct this first phase assessment of anadromous fish needs and dam and reservoir conditions.

1.2 Purpose

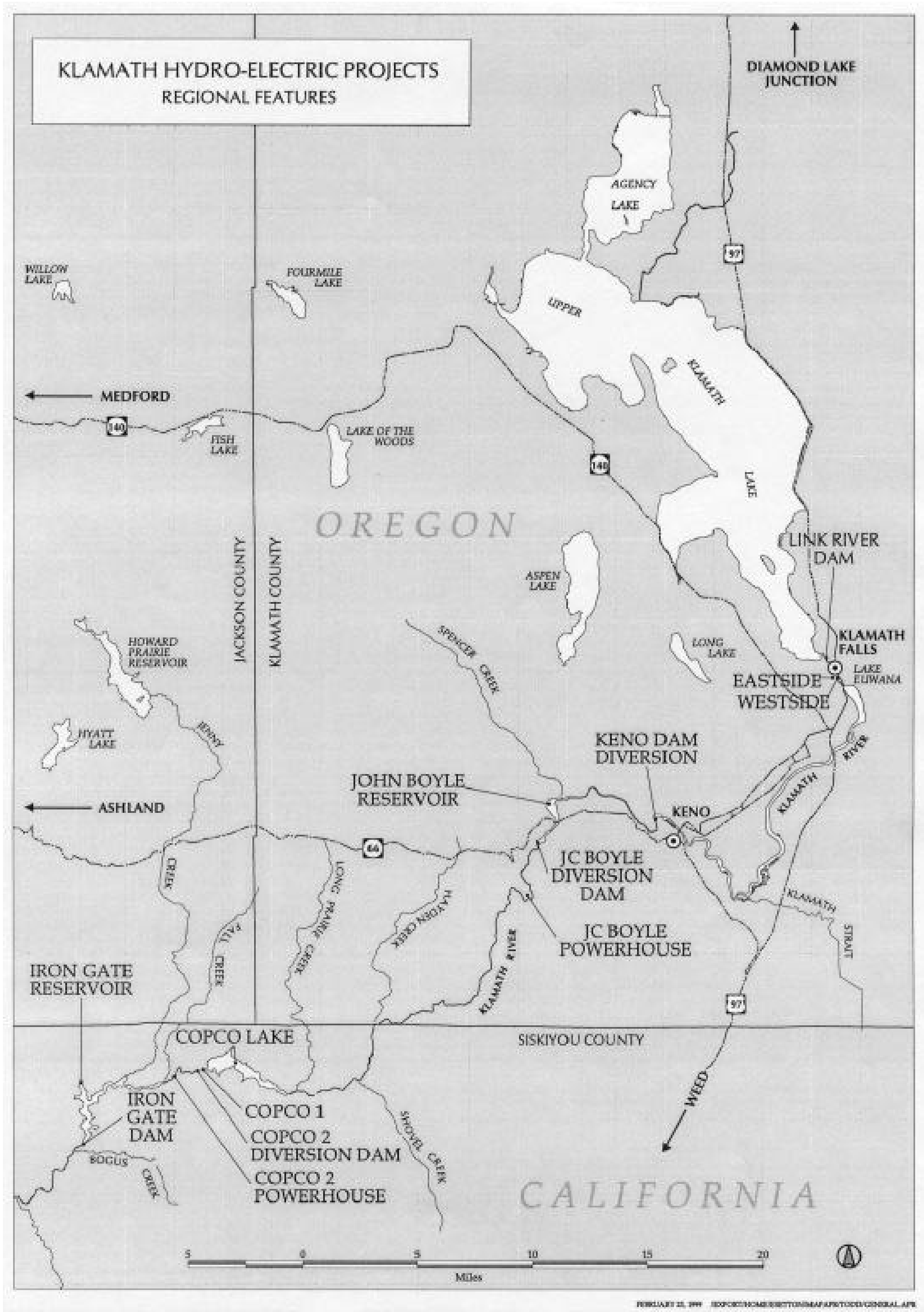
It is a major goal of the Klamath Basin Tribes to see that anadromous fish populations become reestablished in the Upper Klamath River basin. At the same time, the issue of fish passage is certain to be of concern to PacifiCorp as it begins the relicensing process for the Klamath Project. The purpose of this report is to conduct a first-level assessment to describe the current physical and environmental conditions present for both upstream and downstream fish passage through the Upper Klamath basin. The report will present a summary of issues, concerns and criteria that have been used for similar fish passage projects. It will also provide a consolidated source for information regarding the current status of physical structures and environmental conditions in the mainstem portion of the basin. Based on these materials, a general review of fish passage conditions will be made as to whether current conditions present a low, medium or critical impact to the potential success for fish passage.

1.3 Study Area

The Upper Klamath basin includes all of the area above Iron Gate dam, encompassing 5,301,700 acres or 65% of the total Klamath River Basin Conservation Area (KRBFTF 1995). Due to an emphasis on fish passage, this study focuses on conditions in the mainstem Upper Klamath River, from Iron Gate dam to Upper Klamath Lake. Included in this area are the six dams operated by PacifiCorp for power generation and/or flow regulation: Iron Gate, Copco 2, Copco 1, J.C. Boyle, Keno, and Link River (Figure 1-1). There is additional discussion regarding some of the major tributaries which drain to the mainstem Upper Klamath River, most notably Shovel Creek and Spencer Creek.

1.4 Target Species

This report will review fish passage requirements for the following species: spring chinook salmon, fall chinook salmon, coho salmon, steelhead trout, Pacific lamprey, and suckers. There is good evidence that chinook, coho and steelhead were historically present in the Upper Klamath River basin, and the remaining species, other than Pacific lamprey, are known to exist in the area today. Klamath River coho salmon were listed as a threatened species in 1997 under the Endangered Species Act, and a decision is scheduled to be made in 2002 regarding potential listing of Klamath River steelhead. The shortnose sucker and Lost River sucker were first listed as threatened by the State of California in 1974, and were federally listed as endangered in 1988.


KLAMATH HYDRO-ELECTRIC PROJECTS
REGIONAL FEATURES
DIAMOND LAKE JUNCTION
AGENCY LAKE
WILLOW LAKE
FOURMILE LAKE
UPPER KLAMATH LAKE
MEDFORD
FISH LAKE
LAKE OF THE WOODS
OREGON
JACKSON COUNTY
KLAMATH COUNTY
LINK RIVER DAM
ASPEN LAKE
SPENCER CREEK
LONG LAKE
KLAMATH FALLS
LAKE EWAUNA
HOWARD PRAIRIE RESERVOIR
EASTSIDE
WESTSIDE
HYATT LAKE
JENNY
KENO DAM DIVERSION
ASHLAND
JOHN BOYLE RESERVOIR
KENO
KLAMATH RIVER
JC BOYLE DIVERSION DAM
JC BOYLE POWERHOUSE
LONG PRAIRIE CREEK
HAYDEN CREEK
FALL CREEK
KLAMATH STRAIT
IRON GATE RESERVOIR
COPCO LAKE
SISKIYOU COUNTY
IRON GATE DAM
COPCO 1
COPCO 2 DIVERSION DAM
COPCO 2 POWERHOUSE
BOGUS CREEK
SHOVEL CREEK
WEED
CALIFORNIA
Miles

1.5 Report Organization

Subsequent sections in this report address the following topics:

Section 2 - Common Issues in Fish Passage - This section summarizes the current understanding of key issues that impact fish passage for both upstream migration and downstream immigration .

Section 3 - Fish Passage Requirements for Target Species - This section presents a brief life history description of the target species for this report with an emphasis placed on those life stages that involve migration and immigration. Summary tables denoting major characteristics and passage criteria are presented for both upstream migration and downstream immigration.

Section 4 - Structural Setting - This section summarizes the physical features and operational characteristics for each of the six mainstem facilities , with emphasis placed on those conditions that may effect fish passage.

Section 5 - Environmental Setting – This section presents information regarding environmental parameters that may have a significant effect on fish migration and habitat utilization. References are listed that relate to recent research on environmental conditions.

Section 6 - Review of Current Fish Passage Conditions - Based on information presented in Section 2 to 5, this section presents a general assessment of fish passage conditions in each segment of the Upper Klamath basin.

SECTION 2 - COMMON ISSUES IN FISH PASSAGE

In recent years there has been considerable progress made toward understanding the effectiveness of both upstream and downstream fish passage technologies. The following section provides a brief description of issues that commonly factor into each of the following four fish passage conditions:

- upstream dam passage
- downstream dam passage
- upstream reservoir passage
- downstream reservoir passage.

In addition, there is a brief discussion on habitat requirements because the successful reestablishment or enhancement of fish populations requires suitable habitat for spawning, egg incubation and early rearing. A review of each of these fish passage conditions in the project area is presented in Section 6.

2.1 Upstream Dam Passage

Upstream dam passage is critical in the migration of adult anadromous fish, if it is desired to use spawning and rearing habitat upstream of a dam. For the salmon and steelhead species, upstream dam passage requirements are generally considered well-developed and understood. At the same time, there is no single solution for designing upstream fishways and the technology is open to innovation. Effective fish passage systems can generally be developed if there is a thorough understanding of both the site characteristics and the swimming ability and migrational behavior of the target species. Upstream fish passage facilities can be designed to accommodate fishes that are bottom swimmers, surface swimmers or orifice swimmers; fishes that prefer plunging or streaming flow; and weak or strong swimmers. In some cases, it may be necessary to provide more than one fish passage system if there are multiple target species with diverse needs (Office of Technology Assessment 1995).

The three most common methods of upstream fish passage are fish ladders, fish elevators and locks, and trapping and trucking. While it is recognized that other methods of upstream fish passage may be applicable on the Klamath River, a review of these other less common methods was not in the scope of this report. Discussions in this document are limited to the three most common methods.

Fish ladders are the most common method of upstream fish passage, and include a variety of types that are distinguished by their hydraulic design and operability through a range of flows. Fish lifts allow the fish to be “passively” transported, can be automated, and are often the best solution for high head sites. Fish trapping and trucking can be especially effective when there are a number of upstream barriers that must be crossed.

The success of any method will require an understanding of the hydrological conditions both upstream and downstream of the passage site. The conditions that factor into the design of key elements for a fishway system include:

- adequate attraction flow at the fishway entrance
- good access to the entrance with regards to tailwater fluctuations, migration orientation, and other operational discharges
- adequate flow control in the fishway to accommodate swimming and endurance traits of the weakest target species
- structural design features that are in agreement with swimming characteristics
- proper siting of the fishway exit away from spillways and powerhouses to minimize fallback
- ability to minimize and remove accumulations of debris
- ability to provide good water quality conditions, especially at the fishway entrance.

The Office of Technology Assessment (1995) provides useful review and further detail on these upstream passage issues.

2.2 Downstream Dam Passage

The provision of downstream dam passage for fish at hydropower facilities is typically working toward three important goals: to allow transport of downstream migrants past a barrier; to prevent fish from being entrained in turbine intakes; and to minimize delay in migration. Methods for providing this protection will be impacted greatly by characteristics of the target fish, magnitude of the river system, and complexity of the hydropower system.

Physical barriers are the most widely used method for protection of downstream migrants, providing total physical exclusion from entrainment. Common designs for physical barriers include simple fixed screens, inclined plane screens, submersible travelling screens, and vertical travelling screens. In all cases, it is essential to provide enough screen area such that velocities through the screen are low enough to allow fish to swim away without impingement. The screens must be kept clear of debris that can accumulate and diminish the available flow-through area.

Physical barriers also require provision of a bypass route past the dam, to allow continued transport once fish are diverted away from the screen. The design of a bypass entrance has proven to be one of the most challenging aspects of downstream passage design, demanding a thorough understanding of the behavior of target species and their response to seeking a passage route under variable hydraulic conditions. Bypass outfalls are also critical in achieving safe downstream passage, with high potential for disorientation and predation.

Physical barriers can be very expensive to build and maintain, especially at large facilities that take the bulk of river flow. Alternatively, resource agencies may approve structural guidance devices such as angled trash racks or louvers that guide fish away from turbine intakes without providing total exclusion. Behavioral guidance devices such as light and sound continue to be explored, though their effectiveness appears to be very site and species specific. Other methods for providing downstream fish passage include turbine passage, spilling, pumps, or transportation.

For this report, each facility will be reviewed for the following conditions that effect fish passage :

- Potential injury through turbine passage: The type of turbine will influence passage effectiveness; for example, high-head Francis turbines typically result in higher mortality rates than low-head Kaplan turbines (Bell and DeLacy 1972). In addition, it will be noted whether there are alternate routes for downstream dam passage, since this will effect the percentage of the migrant population that pass through the turbines.
- Potential injury during spillway passage: frequency of spill, height of fall over the spillway, presence of energy dissipation devices all impact effectiveness.
- Potential injury during bypass conveyance: smooth interior surfaces, adequate width, absence of sharp bends or negative pressures, proper lighting, and appropriate hydraulic gradients all contribute to effectiveness of fish passage.
- Effective guidance to bypass entrance: the ability for fish to find the entrance would reduce both migration delay and potential for predation. Factors include entrance location relative to migrational traits (e.g. height in water column and orientation to bank), location relative to powerhouse and spillway flows, and quantity of bypass flow.
- Good passage hydraulics during all reservoir elevations: the downstream passage system should perform consistently throughout the year and during all modes of operation.

- Potential predator accumulation at exits: survival may be impacted by presence and abundance of predators, plus velocity of receiving water at outfall.

Additional details regarding downstream passage methods can be found in the review developed by the Office of Technology Assessment (1995).

2.3 Upstream Reservoir Passage

For this report, each facility will be reviewed for the following conditions that effect fish passage upstream through reservoirs:

- Potential delay due to loss of orientation: the size of a reservoir and the number and size of tributary embayments may impact the ability of a migrating adult to follow velocity and bank-line cues.
- Potential high water temperature during migration: high water temperatures during normal period of migration can cause delay in migration, increase susceptibility to disease, or result in lethal conditions.
- Potential low dissolved oxygen during migration: low dissolved oxygen during migration can cause increased stress or result in lethal conditions.
- Potential high pH during migration: high pH during migration can cause increased stress or result in lethal conditions.

2.4 Downstream Reservoir Passage

For this, report, each facility will be reviewed for the following conditions that effect fish passage downstream through reservoirs:

- Potential delay due to loss of orientation: the size of a reservoir may reduce velocities to the point where passive transport is no longer feasible; excessive delay may result in residualism.
- Potential exposure to predators: the presence and abundance of predators may impact survival, with additional factor given to transit time through reservoir.
- Potential high water temperature during migration: high water temperatures during normal period of migration can cause delay in migration, increase susceptibility to disease, or result in lethal conditions.
- Potential low dissolved oxygen during migration: low dissolved oxygen during migration can cause increased stress or result in lethal conditions.
- Potential high pH during migration: high pH during migration can cause increased stress or result in lethal conditions.

2.5 Spawning, Egg Incubation and Early Rearing

Even with provision of fish passage facilities, the reintroduction of salmon cannot be successful in any area without adequate habitat for spawning, egg incubation and early rearing. Though largely beyond the scope of this report, the following conditions that effect habitat for spawning, egg incubation and early rearing have been used to provide a very general review of the following habitat conditions at each area:

- Adequate spawning and incubation habitat: impact will be species-specific dependent on mainstem or tributary preferences, proportions of reservoir and mainstem reach, presence of perennial tributaries, and gravel availability.
- Acceptable water quality (water temperature, DO and pH) during spawning and incubation: conditions may become lethal during this period; the egg and emergent-fry life stages are usually more susceptible.
- Adequate rearing habitat: impact will be species-specific dependent on mainstem or tributary preferences, presence of perennial tributaries, and length of rearing period prior to emigration.
- Acceptable water quality (water temperature, DO and pH) during early rearing: conditions may become lethal during this period.

SECTION 3 - FISH PASSAGE REQUIREMENTS FOR TARGET SPECIES

The target species of this report have differing requirements for fish passage that are dependent on their physical characteristics, physiological stamina, and habitat use within the basin. This section identifies criteria that factor into the effectiveness of fish passage facilities. It includes a discussion of the general life history of the target species, water quality conditions necessary for sustained habitation, and typical design criteria for upstream and downstream fish passage facilities.

3.1 Life Histories

The six target species of this study (spring chinook, fall chinook, coho, steelhead, lamprey and suckers) have differences in the seasonal timing of adult migration, spawning, emergence and juvenile emigration. As a consequence, similar life stages of two species may encounter very different conditions in hydrology and water quality. The following subsections provide a brief description of the life history for each target species as a means to identify the periodicity of key life stages. While discussed in more detail below, a summary of life stage periodicity for all target species is presented in Table 3-1. In those cases where the species are not currently present in the Upper Klamath basin, best judgement was used as to what life stage periodicity characteristics would likely occur with successful re-establishment. This judgement included consideration of the following:

? For anadromous salmonids, it is most reasonable to draw comparison to existing fish populations in the vicinity of Iron Gate, rather than those of fish occupying the lower basin.

? Life history information reported by Shaw et al. (1977) is considered most germane to this study because of the project vicinity. Current data is considered to have greater relevance than historical data even where hatchery stocks are entailed, since current life history characteristics would likely prevail in those stocks if passage were made available. Where there were data gaps, information was obtained from Leidy and Leidy (1984).

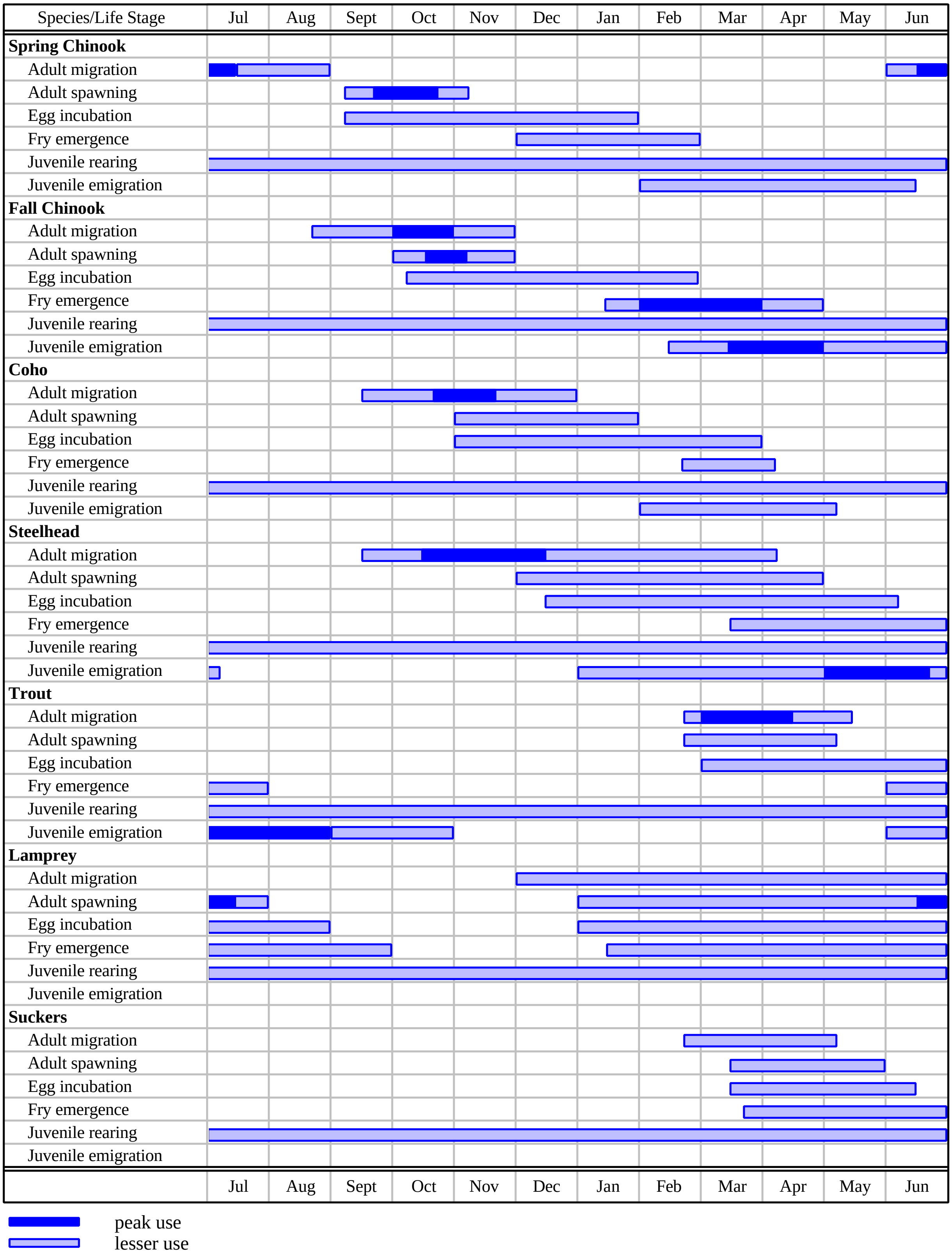
? Juvenile fish are likely to be present in the basin year round.

Periodicity information pertaining to specific species is discussed in each subsection.

a. Spring Chinook

Spring chinook salmon (*Oncorhynchus tshawytscha*.) along with other anadromous fish have been blocked from the Upper Klamath basin since the completion of Copco 1 dam in 1917. Fortune et al. (1966) summarized historical

Table 3-1. Life stage periodicity for target species in the Upper Klamath Basin. See text for list of assumptions.



information that pertained to the range and periodicity of spring chinook in the upper basin. Figure 3-1 illustrates the historic and current range of spring chinook in the entire Klamath River basin.

Spring chinook are anadromous fish, and the Klamath River stocks typically spend three to five years in the ocean before returning to their natal river. Snyder (1931) described a spring run that entered the mouth of the Klamath River from late March through mid-June. In the mid-1970s, spring chinook adults arrived at the Iron Gate Hatchery (at the downstream boundary of the Upper Klamath basin) throughout July and August (Shaw et al. 1997). Currently, there is limited spring chinook spawning in Klamath River tributaries between Iron Gate dam and Seiad Creek. It is believed that passage from the mainstem Klamath into these tributaries occurs in early June (Shaw et al. 1997).

Spring chinook spawning in Pacific Northwest stocks has been observed both in large tributaries and in mainstem rivers (Wydowski 1979). There is no evidence that spring chinook currently spawn in the mainstem Klamath River (Shaw et al. 1997). Spawning timing has been described by Leidy and Leidy (1984) to occur in October and November. Spring chinook utilize larger gravel and deeper water than other salmonids (Scott and Crossman 1973). Redds are constructed by the female with eggs being fertilized while deposited into the gravel (Hart 1973). Fecundity is approximately 5,000 eggs per female (Hart 1973), but is dependent on the size of the female (Wydowski and Whitney 1979). Adults will remain near the redd until death.

Hatching time is dependent upon water temperature (Wydowski and Whitney 1979), with eggs in warmer water developing at a faster rate (up to a limit). After hatching, fry reside for two to three weeks in the gravel (Scott 1973). Juvenile emergence occurs from December through February (Leidy and Leidy 1984). Emigration from the tributaries occurs soon after emergence, typically from February through Mid-June (Leidy and Leidy 1984). Juveniles may emigrate directly to the Klamath River estuary or remain in the mainstem and emigrate as yearlings (Shaw et al. 1997).

b. Fall Chinook

Fall chinook salmon (*Oncorhynchus tshawytscha*) are anadromous fish which have additionally been blocked from Upper Klamath basin with the completion of Copco 1 dam in 1917. Fortune et al. (1966) summarized historical information describing the use and periodicity of fall chinook in the upper basin. Figure 3-2 illustrates the historic and current range of fall chinook in the entire Klamath River basin.

Fall chinook salmon reside in the ocean from two to five years before returning to their native rivers to spawn. Upstream adult migration of fall chinook

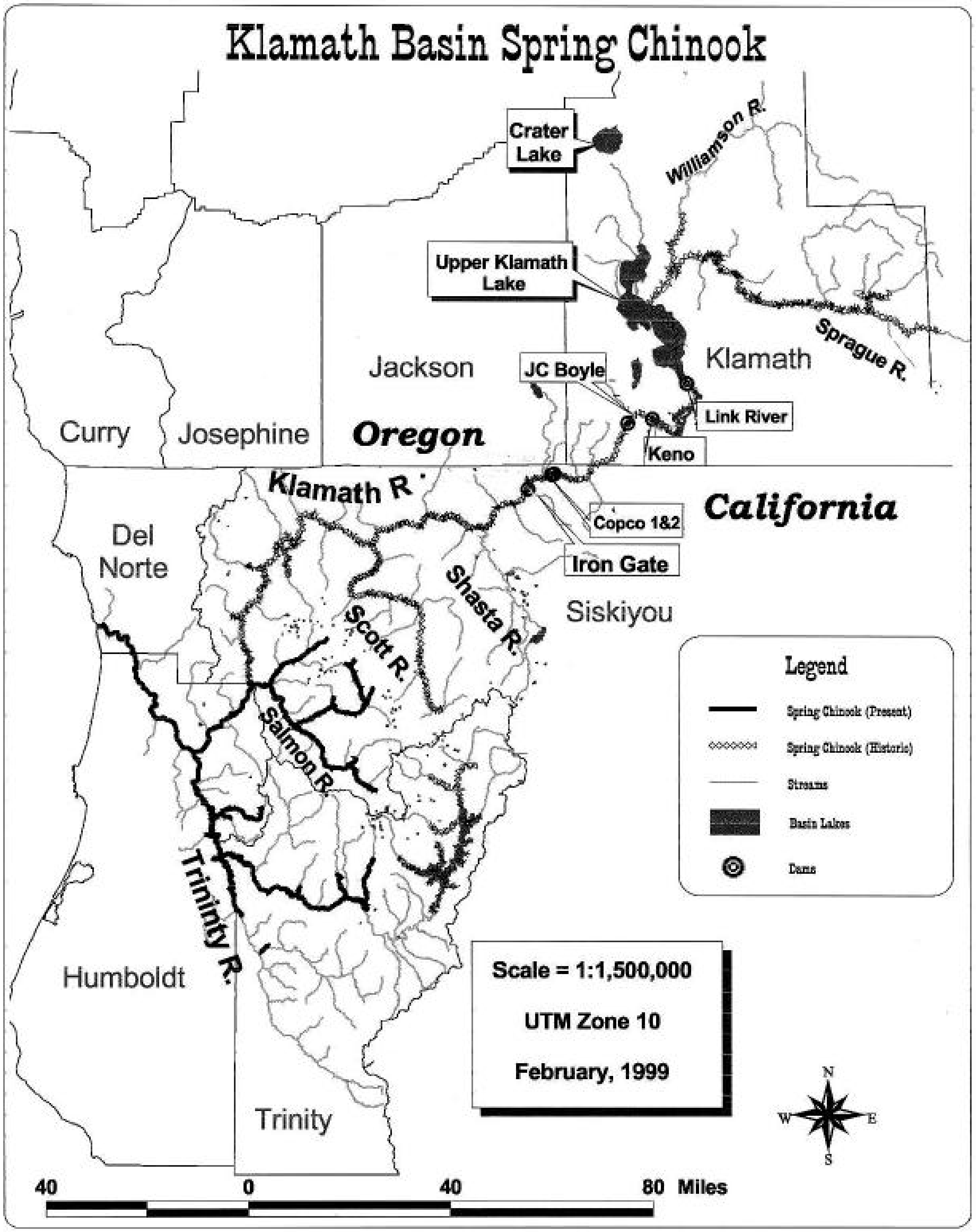


Figure 3-1. Present and historic range of Klamath Basin spring chinook. (Source: Karuk Tribe)

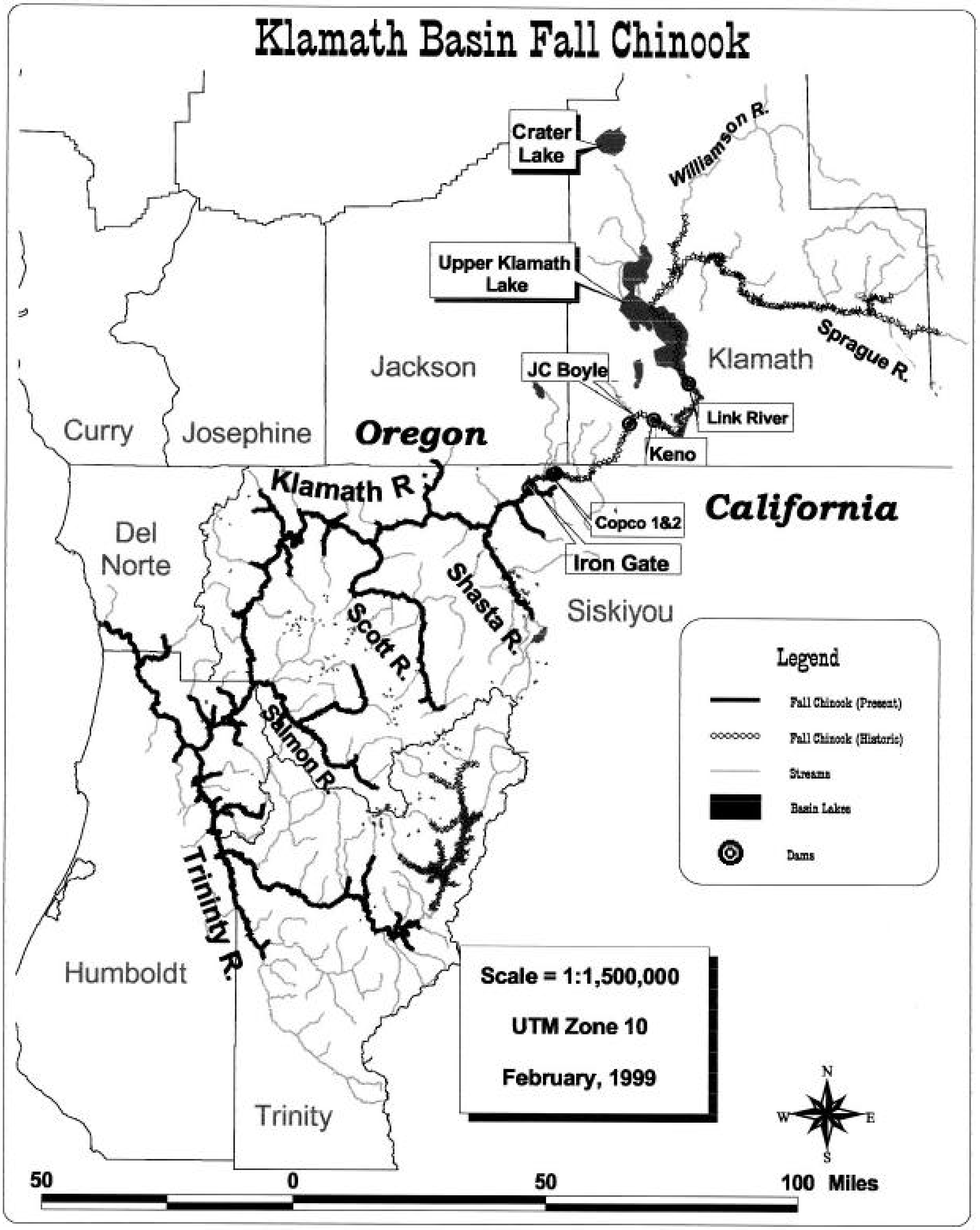


Figure 3-2. Present and historic range of Klamath Basin fall chinook. (Source: Karuk Tribe)

occurs between mid-August and December (Shaw et al. 1997). The migration rate may be effected by river water temperature (KRBFTF 1991).

Observation in recent years (1991-1995) at Iron Gate Fish Hatchery, Bogus Creek weir, Shasta River weir and Scott River weir show migration timing beginning in the second to third week of September with peak fish counts in mid-October (Shaw et al. 1997). This current peak timing appears to be one to four weeks later than historic runs prior to the construction of Iron Gate dam (Shaw et al. 1997).

Spawning may commence soon after reaching the spawning grounds. Fall chinook utilize larger tributaries or the mainstem river for spawning, where deeper water and larger gravel can be found (Scott et al. 1973). Redd construction and spawning behavior are consistent with spring chinook. Mainstem spawning from Iron Gate to Indian Creek has been surveyed in 1993 through 1996 (Shaw 1997). The first redds were observed in this reach the second week of October, with the peak occurring during the last week of October and spawning completed by the end of November (Shaw 1997).

Hatching and emergence are dependent on water temperature. Young remain in the gravel after hatching for two to three weeks (Wydowski and Whitney 1979). Shaw et al. present emergence timing for 1994 and 1995 mainstem spawning which depicted a one month shift in peak emergence due to water temperatures. Emergence timing for mainstem and tributary spawning can be expected to occur from mid-January through May (Shaw et al. 1997).

Three juvenile life histories have been identified in the Klamath River and described in Shaw et al. (1997). Type I juveniles rear in the river for only several months before migrating to the ocean in summer months. Type II juveniles reside in either tributaries or the main river for an extended period before migrating to the ocean from autumn to mid-winter. Type III life history fish migrate to the ocean as yearlings. They rear in fresh water from summer through winter before emigrating the following spring. With these various juvenile life history patterns, juvenile rearing can be expected to occur throughout the year. Some emigration may occur throughout the year, but the predominating out-migrating period occurs from mid February through June (Shaw et al. 1997).

c. Coho

Coho salmon (*Oncorhynchus kisutch*) reside in the ocean for approximately 18 months before returning to their natal rivers (Wydowski and Whitney 1979). The adults return primarily as three year olds from mid-September through December (Bell 1991). In-river beach seining and trapping activities show a peak migration timing occurring from mid-October to mid-November (Shaw et al. 1997). Figure 3-3 illustrates the present range of coho in the entire Klamath River basin.

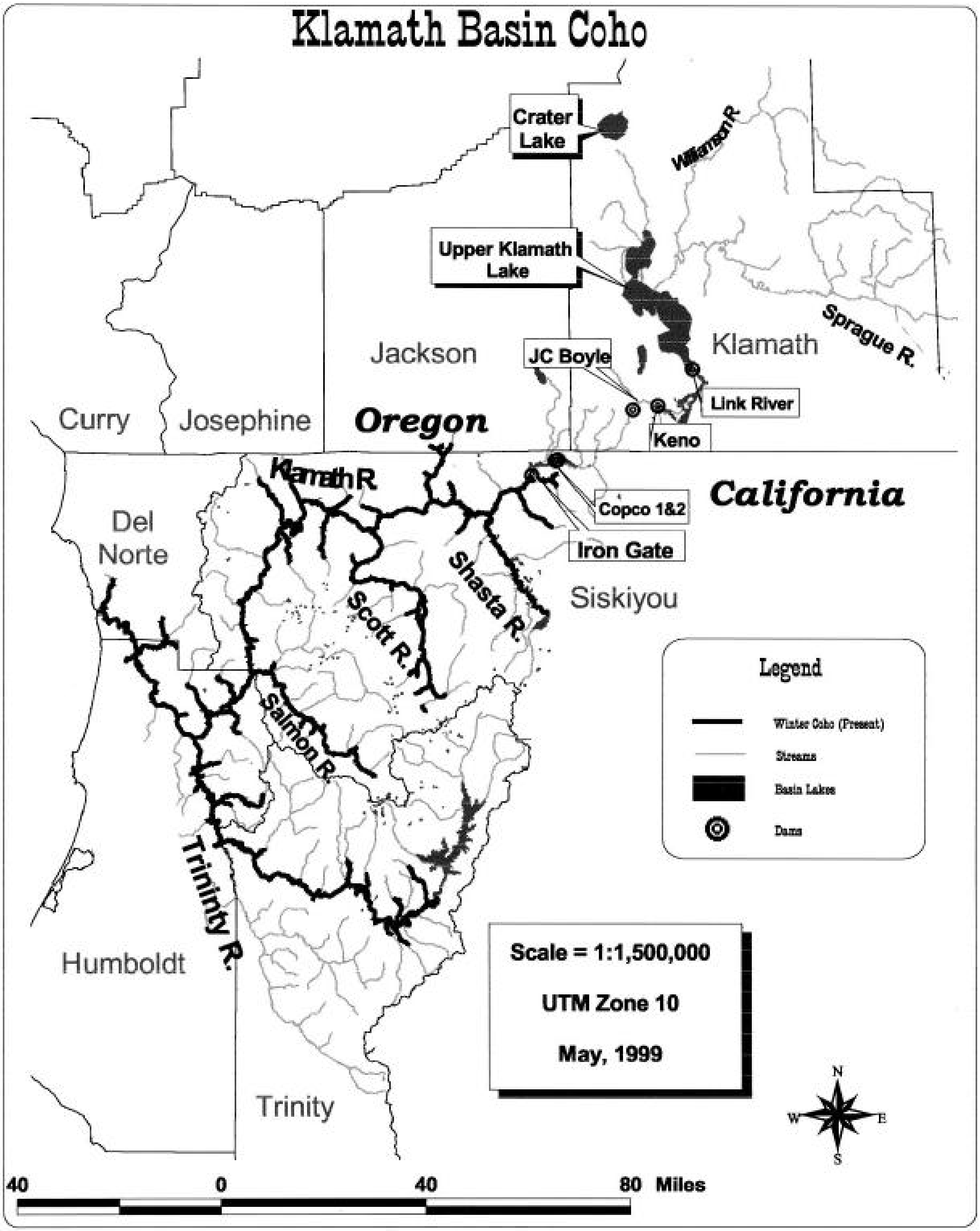


Figure 3-3. Present range of Klamath Basin coho.
(Source: Karuk Tribe)

Spawning can occur in the mainstem river, but the preferred habitat is the riffle area of small tributaries (Hart 1973). Little information is available on spawning in the Klamath River, but it is believed to occur from November through January (Shaw et al. 1997, Leidy and Leidy 1984).

Incubation and emergence are water temperature dependent, with incubation requiring one to three months (Leidy and Leidy 1984). Emergence data is very sparse for the mainstem Klamath, but trapping data from Bogus Creek and Shasta River suggest emergence from late February through mid-April (Shaw et al. 1997). Leidy and Leidy (1984) describe alevin emergence occurring in February through mid-May for the Klamath River system.

The juvenile coho fry will remain in fresh water for approximately one year. During this time they are quite aggressive and territorial, defending their position in the stream (Hart 1973). The survival of the fry is dependent on the maintenance of instream flows, especially during the summer (Hart 1973). Elevated mainstem river temperature may cause juveniles to seek cooler waters in tributaries. Emigration of juveniles from the basin occurs from February through early May.

d. Steelhead

Steelhead trout (*Oncorhynchus mykiss*) were also blocked from the upper Klamath River with the construction of Copco 1 dam. Figure 3-4 illustrates the present range of steelhead in the Klamath River basin. Three races of steelhead are recognized by fisheries management agencies: Spring / Summer, Fall and Winter. Each race has unique timing and life history strategy. Shaw et al. (1997) identified and described these three life histories. Summer run steelhead were historically present in the Klamath from March to June with spawning activity in tributaries from December to February. Fall run fish enter the river from July to November with tributary spawning activity in February through April. Limited information is available for the Winter race but migration timing is described as November through March with tributary spawning occurring in February through mid May.

An additional life history pattern recognized in the Klamath River is the “half-pounder” (Shaw et al. 1997). These steelhead return to the river after only three to four months of residence in salt water. The “half-pounders” return to the river in September and can comprise 22 to 95% of the life history pattern, dependent on race (Shaw et al. 1997). The life stage periodicity summary (Table 3-1) does not specifically reflect the “half-pounders” life history pattern but is generally represented within the juvenile rearing component which shows presence year-round to reflect the different life history types.

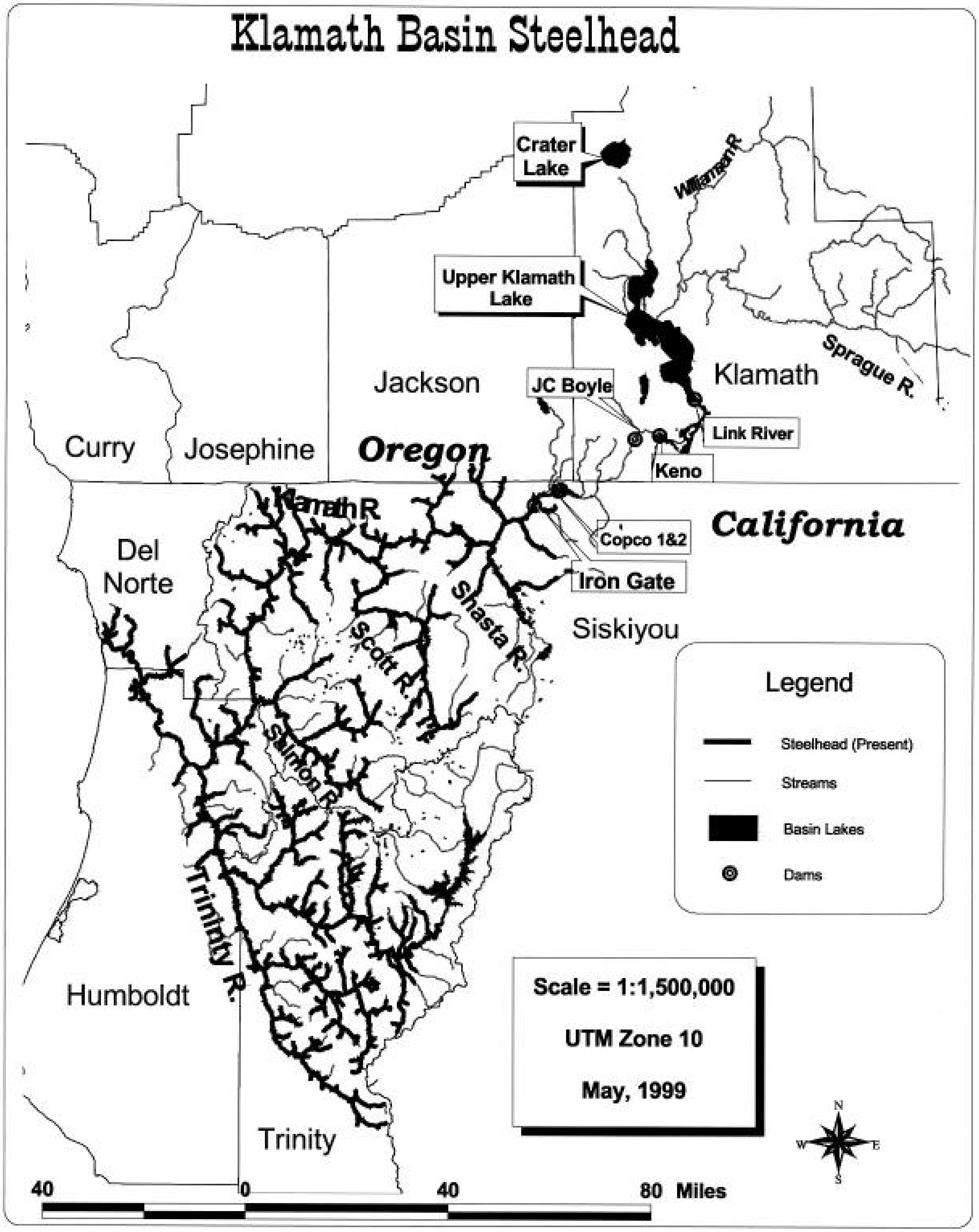


Figure 3-4. Present range of Klamath Basin steelhead.
(Source: Karuk Tribe)

Egg incubation occurs from the commencement of spawning and, depending on water temperature, continues through early June (Leidy and Leidy 1984). Fry emergence occurs from mid-March to June. Juvenile steelhead will rear in fresh water for two years prior to emigration (Leidy and Leidy 1984, Shaw et al. 1997). Shaw et al. (1997) present information from Bogus Creek and Shasta River indicating that large numbers of steelhead are entering the mainstem Klamath River as young of the year and yearlings; these juveniles may rear in the mainstream until emigration as two-year olds.

e. Pacific Lamprey

The Pacific lamprey (*Lampetra tridentata*) is an anadromous fish. Their life history in the ocean consists of a parasitic relationship with various species of fish (Wydowski and Whitney 1979). Maturing adults begin to re-enter freshwater as early as December (J. Boyce, Humboldt University, personal communication 6/30/00) and continue through June (KRBFTF 1991). They move upstream by swimming and using their suckerlike mouths to cling to rocks or walls of dams (Wydowski and Whitney 1979).

As illustrated in Figure 3-5, the present distribution of Pacific lamprey in the Klamath basin occurs from the ocean up to Iron Gate dam (S. Reid, US Fish and Wildlife Service, Klamath Falls, Oregon, personal communication 10/28/99). There are populations of lamprey that currently exist above Iron Gate dam, but ongoing genetic research by the US Fish and Wildlife Service indicates these lamprey are more closely related to one another than to Pacific lamprey and hence they are likely a separate species (S. Reid, US Fish and Wildlife Service, Klamath Falls, Oregon, personal communication 10/28/99). Due to the similarity of these lamprey species, information regarding the historic range and distribution of each specific species is uncertain. The historic presence of salmon runs in the upper basin suggests that Pacific lamprey could have migrated that far as well. However, there is no specific evidence that Pacific lamprey migrated into the upper Klamath basin past Keno in the recent past (S. Reid, US Fish and Wildlife Service, Klamath Falls, Oregon, personal communication 10/28/99).

Considerable variation exists in spawning timing for Pacific lamprey. Literature review places spawning timing from January through July (Wydowski and Whitney 1979, Chase 1998; J. Boyce, Humboldt University, personal communication 6/30/00). The average number of eggs per female reported is 34,000, with a range of 10,000 to 106,000 (Hart 1973). Adults die after spawning. The eggs will hatch in two to four weeks depending on water temperature (Hart 1973).

After two to three weeks larvae or ammocoetes leave their nest, passively move downstream and bury themselves in the mud (Hart 1973). At this stage they have no eyes or teeth and filter feed microscopic plants and animals from the water (Wydowski and Whitney 1979). At about five to six years the ammocoetes begin to

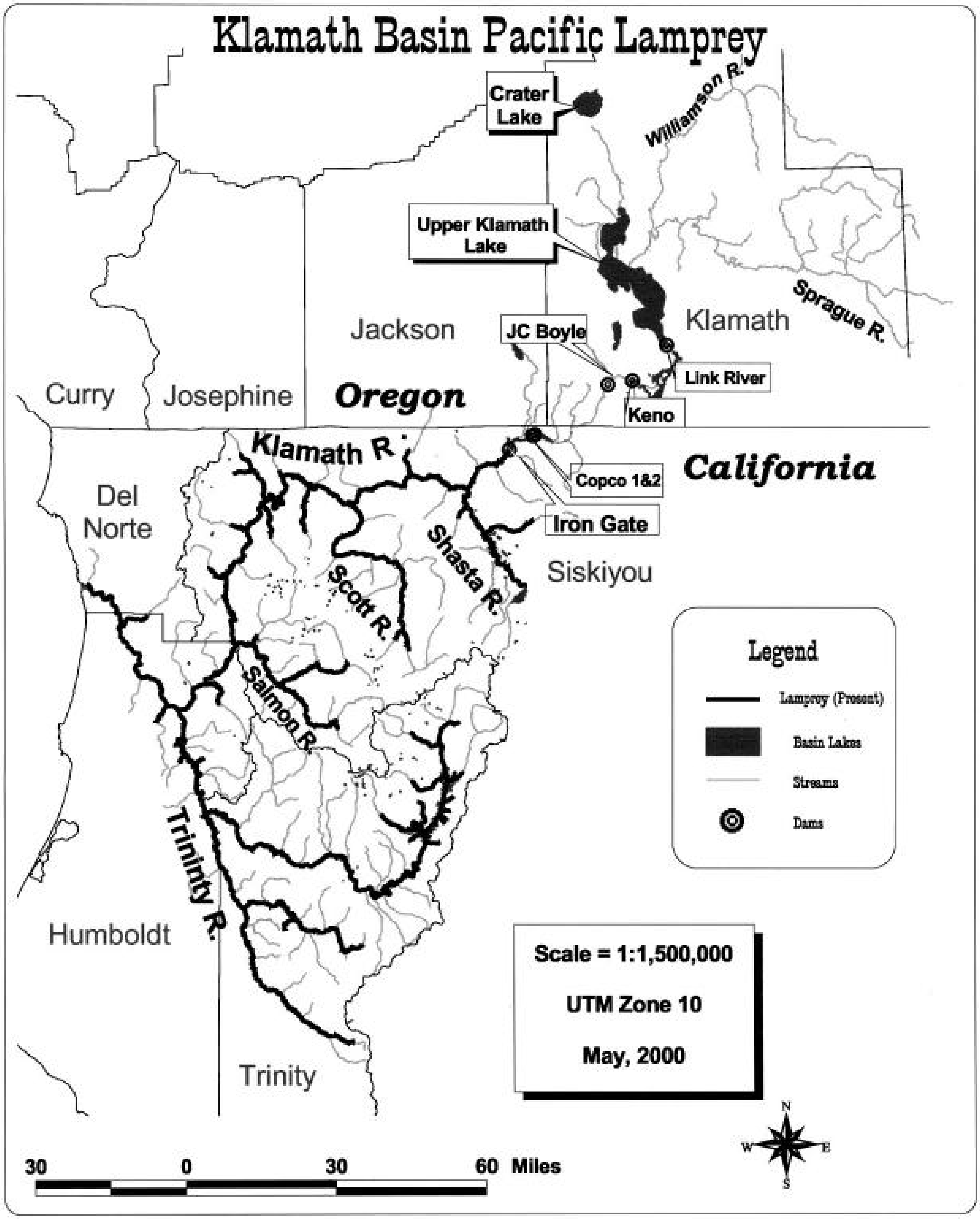


Figure 3-5. Present range of Klamath Basin Pacific lamprey.
(Source: Karuk Tribe)

transform into the adult stage and migrate to the ocean beginning in the spring. Table 3-1 presents the life stage periodicity for lamprey based on the work of Boyce (J. Boyce, Humboldt University, personal communication 6/30/00).

f. Suckers

Two species of suckers, the Lost River sucker (*Deltistes luxatus*) and the shortnose sucker (*Chasmistes brevirostris*) are endemic to the Upper Klamath basin. Populations of these two species are in decline and have been listed as endangered (Stubbs and White 1993). Lost River suckers are long lived and have been aged up to 43 years (Stubbs and White 1993). They become sexually mature between 6 to 14 years. Shortnose suckers have been aged up to 33 years and reach sexual maturity between 5 and 8 years (Stubbs and White 1993). These species reside in lakes until spawning when they migrate into tributaries or springs to spawn.

Stream spawning populations migrate in late February through April, depending on location within the basin (USFWS 1992). Spawning activity may begin as early as mid-March and continues through May (USFWS 1992). Spawning activity may be related to flow (Stubbs and White 1993). Suckers spawn near the bottom where gravel substrate is available. Once spawning is completed adults will migrate back to the lake to reside.

Sucker eggs hatch into larva, and shortly thereafter swim up out of the gravel and emigrate back to the lake. The majority of the larval emigration occurs in May and June, taking place at night between 2000 to 0700 hours (Stubbs and White 1993). Table 3-1 summarizes the life history periodicity for suckers in the Upper Klamath basin based on the Biological Opinion (USFWS 1992).

3.2 Water Quality Criteria

At the onset of this assessment, the Karuk Tribe and PacifiCorp agreed that water temperature, dissolved oxygen (DO) concentrations, and pH are the key water quality parameters that are likely to affect fish passage through the mainstem Upper Klamath River. The following subsection provides a discussion of criteria for these parameters that have been utilized by various authors. Recommended water quality criteria for this study are summarized in Table 3-2 located at the end of the section.

There is limited information specific to the target species in the Upper Klamath River. The salmonids and Pacific lamprey can be assumed to have very similar water quality preferences. However, it is likely that the lamprey would demonstrate a wider temperature and dissolved oxygen tolerance than the salmonids. Suckers would have the greatest water quality tolerance range for temperature, dissolved oxygen and pH. Limited data are available specific to the Lost River and shortnose suckers.

a. Temperature.

All fish are poikilothermic, meaning their body temperatures and resulting metabolism are driven by surrounding environmental conditions. As such, water temperature plays a critical role in the growth and survival of fish. Bartholow (1995) provides a concise review of available information relating to temperature requirements of anadromous salmonids. The following points are noted:

? The egg stage of almost all fish is more sensitive to temperature impact than are adults.

? For chinook salmon in the Trinity River, eggs and alevin exhibited a 100 percent mortality rate when the mean weekly temperature reached 18°C (64°F). Fry and pre-smolts exhibited a 100 percent mortality rate when the mean weekly temperature reached 21°C (70°F).

? Some mortality is likely to occur in chinook juveniles when the average temperature for a 7-day period exceeds 16°C (60°F).

? Adult chinook with chronic exposure to temperatures of 15 – 17°C (59 - 63°F) are likely to exhibit signs of increased infertility and embryonic development abnormalities.

? Information collected prior to construction of Iron Gate suggested Klamath River adult chinook do not move when water temperatures exceed 19°C (66°F).

The review also emphasizes that elevated temperatures likely cause considerable stress to the fish even if direct morality is not observed, through factors such as elevated disease incidence (Bartholow 1995). For the purpose of the scoping study, Bartholow (1995) chose two benchmark temperatures to gage the general health of the Klamath basin with respect to supporting anadromous salmon populations. A weekly mean water temperature of 15°C (59°F) was selected as the thermal threshold in computing chronic stress in salmonids, with the expectation that at least some lethal and sub-lethal effects will occur in the population. Likewise, a daily mean water temperature of 20°C (68°F) was selected as an indicator of acute stress in salmonids.

Generally, suckers are able to withstand higher temperatures than salmonids. Acute bioassay research conducted on juvenile Lost River and shortnose suckers found the 96 hour lethal concentration (LC-50) for high temperature to be in the range of 29.4°C (85°F) to 31.2°C (88°F) (Monda and Saiki 1993, Bellerud and Saiki 1995). Larval forms of these same species showed an even higher temperature tolerance, with 96 hour LC-50s ranging from 31.4°C (89°F) to 31.9°C (90°F) (Monda and Saiki 1994, Bellerud and Saiki 1995).

Specific data regarding thermal tolerance for Pacific lamprey were not found.

b. Dissolved Oxygen

In her report to determine impaired versus unimpaired water quality classifications for the Klamath basin surface waters, Campbell (1995) utilized DO criteria based on the EPA 1986 water quality criteria for salmonids, the most sensitive fish species described. For chronic exposure, the salmonid criteria is a minimum DO of 7 mg/L, while the salmonid criteria for acute exposure is a minimum DO of 5 mg/L. Fortune et al. (1966) used a 5.0 mg/L criteria for basic survival and migration of salmonids, and 7.0 mg/L during incubation.

A review of classic texts for the culture of salmonid species found an agreement that 5 mg/L was the minimum safe level for rearing (Leitritz and Lewis 1980; Piper et al. 1982; Bell 1990). Data relating to fish culture is not necessarily transferable to the wild, however. Most authors felt a minimum DO of 7 mg/l was preferable. For the purposes of this report, a minimum DO of 7 mg/L is used as the threshold for chronic exposure.

The sucker species demonstrate a slightly greater tolerance to low DO. Stubbs and White (1993) reported research that showed the presence of juvenile suckers occurred only where DO was greater than 4.5 mg/L, and adults were found only in waters with a DO greater than 6 mg/L. Results of acute bioassays for Lost River and shortnose suckers showed 96 hour LC-50s for low DO ranging from 1.2 mg/l to 2.3 mg/l (Monda and Saiki 1993, Monda and Saiki 1994, Bellerud and Saiki 1995). With the expectation that less extreme levels will produce chronic stress, it has been suggested that a low DO of 5.0 mg/l is an appropriate chronic threshold level for suckers (The Klamath Tribes Natural Resources Department 1996).

c. pH

For salmonids, Campbell (1995) recommended criteria that call for pH to be greater than 6 and less than 9, based on EPA water quality guidelines. For hatchery production of salmonids, pH values in the range of 6.5 to 9 are generally recommended (Piper et al. 1982).

For suckers, a maximum pH of 9.5 has been recommended as a threshold level for chronic stress (The Klamath Tribes Natural Resources Department 1996). Results of acute bioassays for Lost River and shortnose suckers showed 96 hour LC-50s for high pH ranging from 9.84 to 10.68 (Stubbs and White 1993, Monda and Saiki 1993, Monda and Saiki 1994, Bellerud and Saiki 1995). Minimum pH tolerances were not reported.

Data on pH tolerances for Pacific lamprey were unavailable.

3.3 Upstream Passage Criteria

Effective upstream fish passage systems can generally be developed if there is a thorough understanding of both 1) the site hydrology and 2) the swimming ability and migration behavior of target species. Most fisheries agencies have established design criteria for development of fishways for salmon and trout. However, these standards may be inappropriate for passage of suckers since they are generally weaker swimmers. A summary of swimming abilities and common upstream design criteria are presented in Table 3-2.

The effectiveness of Denil fishways in passing lamprey and suckers was examined by Slatick and Basham (1985). They found that Pacific lamprey were successful at passing through Denil fishways of all lengths and slopes used, with the longest being 66 feet with a slope of 27.3%. Suckers were observed passing a 50 foot Denil with a 28.7% slope, but they rejected the 66 foot ladder.

A four-year fish trapping study conducted by PacifiCorp (1997) detected sucker passage at the Link River dam fish ladder only in the one period during which substantial spill occurred. Sucker passage was noted at Keno dam fish ladder all four years of the study, but most of this passage (68%) occurred in the single year with highest spill. There were no suckers counted at the J.C. Boyle fish ladder, although more than 2,400 suckers were captured during a trapping study at the same location in 1959.

3.4 Downstream Passage Criteria

A range of methods exist for preventing entrainment and downstream passage, and some have met with more success than others. In Oregon and Washington, it is typical for agencies to require a conventional physical barrier method as opposed to an “alternative” method such as lights. A summary of common design criteria for juvenile fish screens is presented in Table 3-2.

There are no known criteria for protecting lamprey ammocoetes as they move passively downsteam. The ammocetes are quite fragile and prone to screen impingement.

Steelhead spawners (kelts) return to the ocean and repeat the migration cycle typically two or three times. Accordingly, downstream passage facilities where steelhead are present must be able to accommodate passage of adult fish in addition to the usual juveniles.

Table 3-2. Selected criteria for assessing fish passage conditions in the Upper Klamath Basin.

Parameter	Criteria	Relevant Species						Reference
		Spring Chinool	Fall Chinook	Coho	Steelhead	Lamprey	Suckers	
WATER QUALITY CRITERIA								
Water Temperature								
Chronic maximum (7 days)	15 °C	X	X	X	X			Bartholow 1995
	unknown					X	X	----
Acute maximum (1 day)	20 °C	X	X	X	X			Bartholow 1995
	unknown					X	X	----
Dissolved Oxygen								
Chronic minimum (7 days)	7 mg/L	X	X	X	X			Campbell 1995
	6 mg/L (ad)						X	Stubbs and White 1993
	4.5 mg/L (juv)						X	Stubbs and White 1993
	unknown					X		----
Acute minimum (1 day)	5 mg/L	X	X	X	X			Campbell 1995
	4 mg/L						X	Stubbs and White 1993
	unknown					X		----
pH								
Chronic maximum (7 days)	9.55						X	Stubbs and White 1993
	9	X	X	X	X			Campbell 1995
	unknown					X		----
Acute maximum (1 day)	10.5						X	Monda and Saiki 1992
	9.5	X	X	X	X			Campbell 1995
	unknown					X		----
Chronic minimum (7 days)	6	X	X	X	X			Campbell 1995
	unknown					X		----
							X	Stubbs and White 1993
UPSTREAM FISH PASSAGE CRITERIA								
Average Fish Size	13.5 lbs		X					Snyder 1931
	11 lbs	X						KPOP Draft
	8 lbs			X	X			Bell 1991
	76 cm					X		Wydowski and Whitney 1979
	< 1 m						X	Stubbs and White 1993
Upper Limit of Swimming Speeds for Adult Fish								
Sustained (no fatigue)	4.6 fps				X			Orsborn and Powers 1985
	3.4 fps	X	X	X				Orsborn and Powers 1985
	2 fps						X	Bell 1991
	1 fps					X		Bell 1991
Prolonged (up to 200 min)	13.7 fps				X			Orsborn and Powers 1985
	10.8 fps	X	X					Orsborn and Powers 1985
	10.6 fps			X				Orsborn and Powers 1985
	5 fps						X	Bell 1991
	3 fps					X		Bell 1991

Table 3-2. Selected criteria for assessing fish passage conditions in the Upper Klamath Basin. (Cont.)

Parameter	Criteria	Relevant Species: Spring Chinook	Fall Chinook	Coho	Steelhead	Lamprey	Suckers	Reference
UPSTREAM FISH PASSAGE CRITERIA (Cont.)								
Burst (up to 15 sec)	26.5 fps				X			Orsborn and Powers 1985
	22.4 fps	X	X					Orsborn and Powers 1985
	21.5 fps			X				Orsborn and Powers 1985
	10 fps						X	Bell 1991
	7 fps					X		Bell 1991
Fish Ladder Design Criteria								
Minimum water depth (ft)	0.8	X	X					ODFW 1991
	0.6			X	X			ODFW 1991
Maximum vertical jump (ft)	1.0	X	X	X	X			ODFW 1991
Jump pool min. depth (ft)	2.0	X	X	X	X			ODFW 1991
Max. flow, based on energy dissipation	4	X	X	X	X			Bell 1991
Maximum weir or orifice	8	X	X	X	X			Bell 1991
Maximum Denil velocity (fps)	5	X	X	X	X			Bell 1991
	< 5					X	X	Slatick and Basham 1985
Maximum resting pool	1	X	X	X	X			Bell 1991
Space in trapping or holding area	1.5 cf per 5 lbs fish	X	X	X	X			Bell 1991
Fish Lock Design Criteria								
Typical fish position (ft)	3 to 6 ft	X	X	X	X			Bell 1991
Space (cf) (< 8 hrs holding)	20 cf / fish	X	X	X	X			Bell 1991
Space (cf) (> 8 hrs holding)	30 cf / fish	X	X	X	X			Bell 1991
DOWNSTREAM FISH PASSAGE CRITERIA								
Juvenile Passage Design Criteria								
Minimum water depth (ft)	0.2	X	X	X	X	X	X	ODFW 1991
ODFW Fish Screen Design Criteria								
Maximum approach velocity (fps)								
Fry (to 59 mm)	0.4	X	X	X	X			ODFW 1991
Fingerling	0.8	X	X	X	X			ODFW 1991
Min. sweeping velocity (fps)	2	X	X	X	X			ODFW 1991
Minimum open area	40%	X	X	X	X			ODFW 1991
CDFG Fish Screen Design Criteria								
Maximum approach velocity (fps)								
Streams / rivers	0.33	X	X	X	X			CDFG 1997
Canals	0.4	X	X	X	X			CDFG 1997
Min. sweeping velocity (fps)								
Streams / rivers	2 x approach	X	X	X	X			CDFG 1997
Canals	2	X	X	X	X			CDFG 1997
Minimum open area	27%	X	X	X	X			CDFG 1997

SECTION 4 - STRUCTURAL SETTING

The Klamath River Hydroelectric Project has 6 facilities with considerable differences in their physical characteristics and operation. Section 4 summarizes the structural features of these facilities, with emphasis placed on those components that impact fish passage. The facilities are described sequentially in the 6 subsections below, working upstream from Iron Gate to the Link River facility. Summary tables of the key elements for all facilities have been developed for the structural components (Table 4-1) and reservoir features (Table 4-2).

4.1 Iron Gate Facility

The Iron Gate facility is located in Siskiyou County, California, 18 miles northeast of Yreka and approximately 5 miles from the California-Oregon border. Facility construction began in 1960 and was completed in 1962. Iron Gate functions include power generation and storage, but as the most downstream facility of the Klamath River Project, its main function is to provide reregulation of Klamath River flows. Facility components include a dam, spillway, powerhouse, diversion tunnel, and a reservoir that extends about 7 miles upstream from the dam. The Iron Gate Fish Hatchery is located within the boundary of this facility, but only those aspects of the hatchery that involve fish passage are within the scope of this report. Details in the following subsections regarding the facility components are derived primarily from dam safety inspection reports (Bechtel Corporation 1968b, Black & Veatch 1993b), with additional information supplied by PacifiCorp.

a. Dam

The Iron Gate dam is located at River Mile 190.1 of the Klamath River. It is a zoned earthfill embankment approximately 740 feet long and with a crest width of 20 feet (Figure 4-1). When originally constructed, the dam rose 184 feet from its rock foundation to the crest at the maximum section. In 1965 while repairing damage from a flood of the previous year, the height of the dam was increased by 5 feet. The Iron Gate dam now reaches a maximum height of 189 feet above the foundation and has a crest elevation of 2343.0.

The upstream face of the dam is protected by a 10 foot thick layer of riprap. There are two benches on the upstream face, located at Elevations 2205.0 and 2275.0. The slope varies from 3 to 1 at the base of the dam to 2 to 1 near the top of the dam (Figure 4-2).

The downstream face is protected by a 5 foot thick layer of riprap. There is a single bench located at Elevation 2275.0 and a broad berm constructed of random fill at

Elevation 2189.0. The slope of the downstream face varies from 2 to 1 at the base to 1.75 to 1 near the top.

Table 4-1. Structural features of Klamath River facilities.

Item	Iron Gate	Copco 2	Copco 1	J.C. Boyle	Keno	Link River
General Features						
Owner	PacifiCorp	PacifiCorp	PacifiCorp	PacifiCorp	PacifiCorp	USBR
Purpose	flow regulation, hydropower	hydropower	hydropower	hydropower	flow regulation	water supply, hydropower
Completion date	1962	1925	1918	1958	1967	1927
Dam location (river mile)	190.1	198.3	198.6	224.7	230.0	254.3
Powerhouse location (river mile)	190.0	196.4	198.5	220.4	none	253.7 Eastside 253.3 Westside
Generating Facilities						
Total generating capacity (MW)	18	27	20	80	none	3.2 (E), 0.6 (W)
Turbine quantity	1	2	2	2	0	1 (E), 1 (W)
Turbine type	vert. Francis	vert. Francis	hor. Francis	vert. Francis	Not applicable	vert. Francis (E) hor. Francis (W)
Unit turbine rating	25,000 HP	20,000 HP	18,000 HP	112,000 HP	Not applicable	unknown
Gross head (ft) at powerhouse	158	157	123	440	Not applicable	unknown
Normal full pool elevation (ft msl)	2328.0	2483.0	2606.0	3788.0	4085.0	4143.3
Power intake IE (ft msl)	2293.0	2455.0	2575.0	± 3778	Not applicable	4130.0
Spill Facilities						
Dam length (ft)	740	278	410	693	680	435
Spillway length (ft)	727	130	182	115	265	300
Spill gate quantity	0	5	13	3	6	31
Spill gate type	ungated	Taintor	Taintor	Taintor	Taintor	weirs
Spillway crest (ft msl)	2328.0	2573.0	2593.5	3781.5	4070.0	4143.3
Spillway apron (ft msl)	2164.0	2452.0	2483.0	3763.5	4052.0	4130.0
Gross head (ft) at spillway	164	21	111	18	18	13
Spillway energy dissipaters	Yes	No	Yes	No	No	No
Sluice gates						
Fish Passage and Protection Facilities						
Upstream fish passage ladders	No (note 1)	No	No	Yes	Yes	Yes
Juvenile bypass facilities	No	No	No	Yes	Not applicable	No

Notes:
1. Two existing fish ladders service the Iron Gate Fish Hatchery, but do not allow passage past the dam.
2. Spillway crest at Link River dam is adjustable with stoplogs; normal full pool elevation is shown.

Table 4-2. Reservoir features of Klamath River facilities.

Item	Iron Gate	Copco 2	Copco 1	J.C. Boyle	Keno	Link River
Reservoir common name	Iron Gate Reservoir	Copco 2 Reservoir	Copco Reservoir	J.C. Boyle Reservoir	Lake Ewauna	Upper Klamath Lake
Dam location (river mile)	190.1	198.3	198.6	224.7	230.3	254.3
Distance to next dam (miles)	8.2	0.3	26.1	5.6	24.0	---
Reservoir length (miles)	6.8	0.3	4.5	3.6	22.5	---
Surface area (acres) (Notes 1, 2)	944	40	1,000	420	NA	90,000
Maximum depth (ft)	167	28	108	53	NA	NA
Normal full pool elevation (ft msl)	2328.0	2483.0	2606.0	3793.0	4085.0	4143.3
Normal minimum pool elevation (ft msl)	2320.0	NA	2601.0	3788.0	NA	4137.0
Normal operating fluctuation (ft)	8.0	NA	5.0	5.0	NA	6.3
Total storage capacity (ac-ft) (Note 3)	58,794	73.5	45,390	3,495	18,500	523,700
Normal active storage capacity (ac-ft)	3,790	NA	4,758	1,507	NA	523,700
Average flow (cfs) (Note 4)	1,852	1,885	1,885	1,511	1,624	1,428
Retention time (days)						
• at average flow	16	0.020	12	1.2	6	185
• at 710 cfs	42	0.052	32	2.5	13	372
• at 1,500 cfs	20	0.025	15	1.2	6	176
• at 3,000 cfs	10	0.012	8	0.6	3	88
• at 10,000 cfs (extreme event)	3	0.004	2	0.2	1	26

Notes:
1. NA = Data Not Available
2. Pool elevations for these values are unknown.
3. Total storage capacity is at normal full pool.
4. Data for Keno from USGS Gage 11509500. All other data from PacifiCorp, showing averages of daily values for turbine flows plus spill flows for 1994 through 1997.

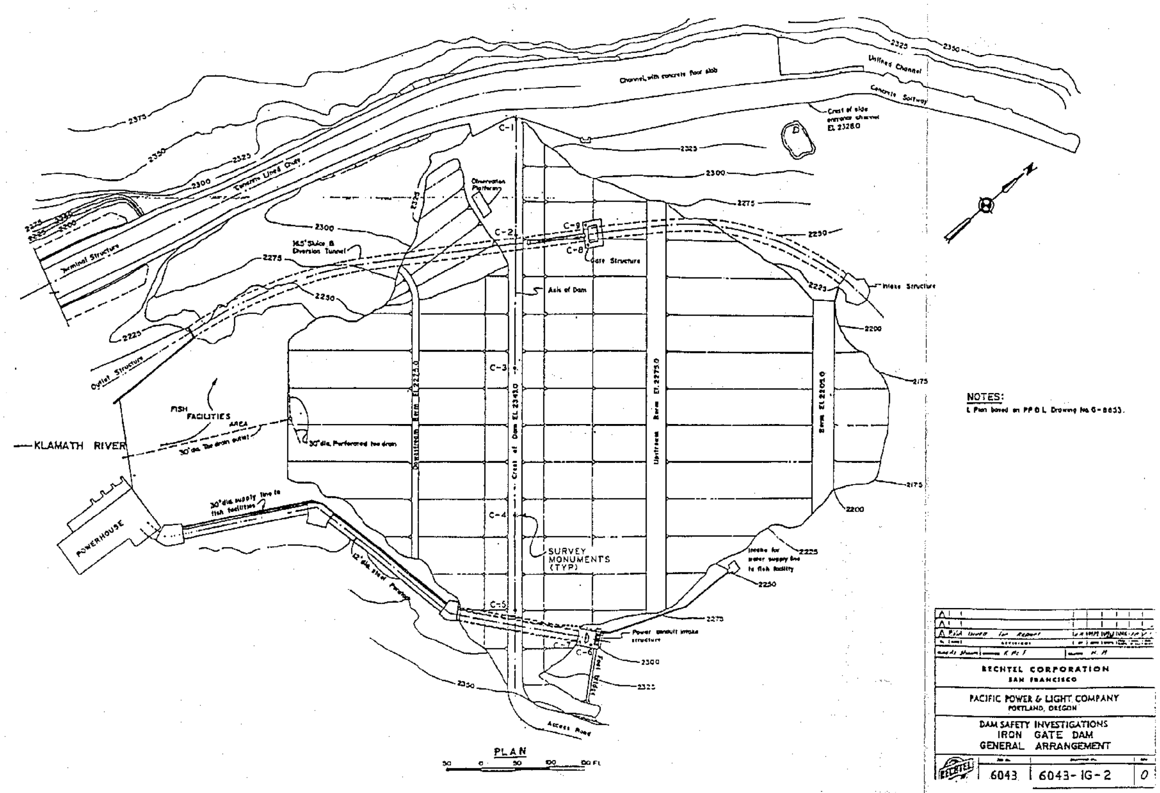


Figure 4-1. Iron Gate Dam General Arrangement. (Source: Black & Veatch 1993b)

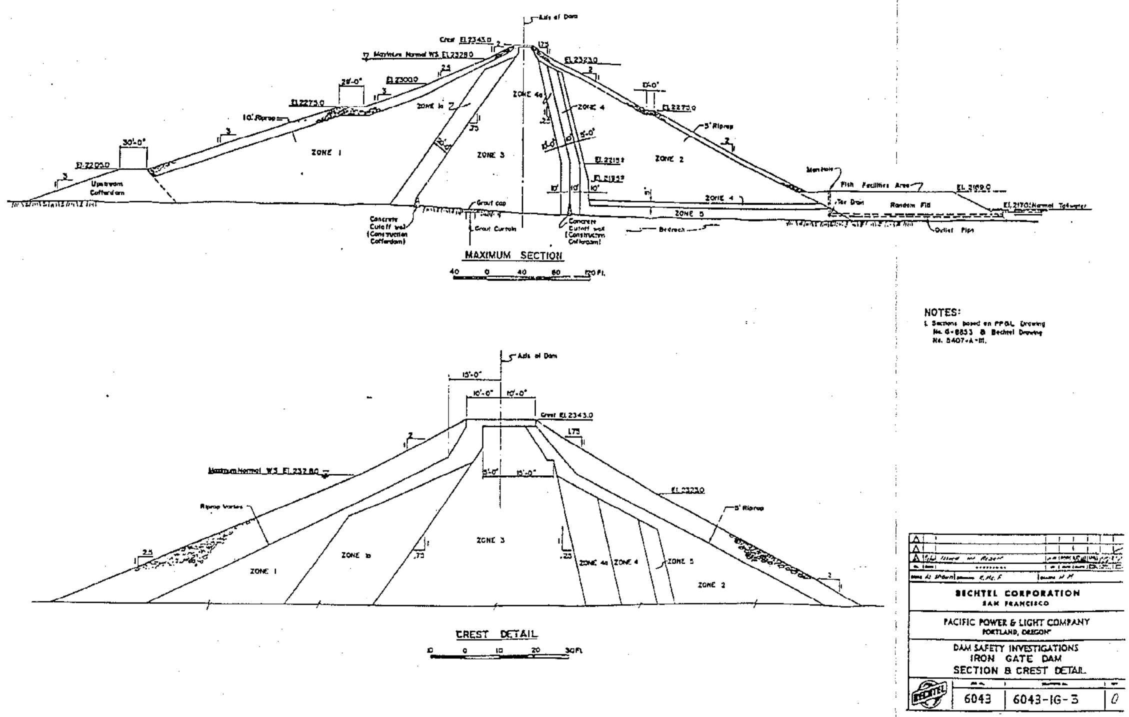


Figure 4-2. Iron Gate Section and Crest Detail. (Source: Black & Veatch 1993b)

b. Spillway

The Iron Gate spillway is located at the right abutment of the dam and is comprised of four sections: the side channel, the control section, the chute, and the terminal structure. The side channel extends 730 feet upstream from the face of the dam and includes a 3 foot wide slide-gated notch to provide small, controlled releases from the reservoir, plus a 727 foot long, ungated, concrete ogee weir that results in uncontrolled releases of any flow that rises above the spillway crest elevation of 2328.0. The side channel was excavated in the rock at the right abutment, and while the left bank (or weir side) of the channel has been lined with concrete, the right bank and portions of the floor are unlined.

The control section of the spillway is a concrete lined chute that spans 95 feet close to the dam axis. The section is dimensioned to limit flows through the chute to about 100,000 cfs.

The chute portion of the spillway is concrete lined and covers a length of 555 feet. It has a variable width, and a floor slab that drops about 130 feet in height, ending at Elevation 2164.0.

The terminal structure is a concrete basin 47 feet wide by 178 feet long, bringing the spillway to the streambed about 250 feet downstream from the toe of the dam. The terminal structure acts as a jump basin for rising spillway flows up to about 20,000 cfs, and beyond this flow it acts as a flip bucket. As the spillway flow recedes, it will act as a flip bucket down to about 12,000 cfs before reverting back to a jump basin mode.

c. Power Generating Facilities

The Iron Gate powerhouse is located on the left bank of the river at the downstream toe of the dam. The powerhouse is an open structure housing one vertical shaft Francis turbine unit rated at 25,000 HP, providing a generating capacity of 18 megawatts at a normal diversion of 1,550 cfs and 154 feet net head. The maximum hydraulic capacity of the powerhouse is 1,710 cfs. To insure that minimum flows can be maintained in the river at all times, the powerhouse is equipped with a synchronous 66 inch Howell-Bunger type bypass valve around the turbine.

The intake for the powerhouse penstock is located in a free-standing 45 foot high concrete tower accessed by a foot bridge at the left abutment. The intake is about 35 feet below the reservoir surface, with an invert at Elevation 2293.0. The intake structure incorporates a trash rack, a 14 by 17 foot slide gate, and transition section that ties into the 12 foot diameter penstock. The penstock extends 681 feet to the powerhouse.

d. Reservoir

The reservoir formed by the Iron Gate dam is about seven miles long. At its normal full pool elevation of 2328.0, it is estimated to have a depth of 167 feet, a surface area of 944 acres and a storage capacity of 58,794 acre-feet.

e. Fish Passage Facilities

The Iron Gate facility has two fish ladders that are operated to collect adults for the Iron Gate Fish Hatchery program. The entrance to one ladder is adjacent to the powerhouse, with the ladder terminating at the hatchery's trapping holding, and spawning facilities at the base of the dam. The second ladder is located at the confluence with Bogus Creek, about 0.5 mile downstream of the dam. The Bogus Creek ladder includes sorting facilities that allow fish to be returned directly to the river or placed in a truck for the short haul to the hatchery's holding and spawning area.

Both Iron Gate ladders are a pool and weir design typical for collection of salmonids. They have been effective at collecting chinook, coho and steelhead for the Iron Gate Fish Hatchery program. However, these ladders are not capable of providing passive fish passage past the dam to Iron Gate reservoir, which has a normal water surface more than 130 feet above the hatchery facilities. The ladders do provide the Iron Gate facility with strong potential to develop trap and haul operations for upstream passage.

f. Additional Outlets

Two intakes provide a water supply of up to 60 cfs for the hatchery facilities. The high level intake is located at the tower structure for the penstock intake, with an invert at Elevation 2309, about 17 feet below the surface. This intake is not used during summer months since the surface waters are too warm for use in the hatchery. The low level intake is located about 220 feet upstream from the tower structure, with an invert elevation of 2253 and a depth about 75 feet below the surface. Water drawn from this depth remains cool even through summer, but it has very low levels of dissolved oxygen and requires aeration before use in the hatchery.

During construction of Iron Gate dam, the river flow was diverted through a tunnel which was bored through bedrock in the right abutment, parts of which were lined with a 16.5 foot high concrete horseshoe section. The tunnel intake is a 33 foot high concrete structure equipped with trash racks located on the floor of the reservoir about 380 feet upstream from the dam axis. With an invert at Elevation 2175.0, the tunnel intake is normally about 150 feet below the surface. Control of flow through the tunnel is provided by a hydraulically operated slide gate located 112 feet upstream of the dam axis, housed in a concrete tower structure that is accessible by bridge. The tunnel terminates in a reinforced concrete outlet structure at the downstream toe of the dam. The diversion tunnel is opened only to supplement releases during extraordinarily high flows.

4.2 Copco 2 Facility

The Copco 2 facility is located in Siskiyou County, California, at RM 198.3 of the Klamath River. Construction was completed in 1925, making it the second oldest of the Klamath River facilities. The main function of the Copco 2 facility is power generation, and components include a dam, spillway, a powerhouse downstream supplied by a mile-long system of tunnels, pipe and steel penstocks , and a reservoir that extends 0.3 miles upstream to the base of Copco 1 dam (Figure 4-3). The information below has been derived primarily from FERC application drawings.

a. Dam

Copco 2 dam was constructed as a concrete gravity dam with an earth wing. The total length of the dam is 278 feet, with the concrete portion of the dam comprising 148 feet connecting to the left bank, and the earth wing being the 130 feet connecting to the right bank (Figure 4-4). The working deck over the concrete dam and the crest of the earth wing are both at Elevation 2493.0. The construction required excavation to Elevation 2441.0 to provide a firm foundation, resulting in a structure height of 52 feet. The original grade of the site was at Elevation 2460.0, placing the top of the dam 33 feet above the streambed.

b. Spillway

The spillway at Copco 2 is comprised of five spillbays, each 26 feet wide, equally spaced across the concrete portion of the dam. Flow over the spillway is controlled by five Taintor gates, with their inverts at the spillway crest elevation of 2573.0, and their tops at Elevation 2484.0. The normal maximum water surface is at Elevation 2483.0.

c. Power Generating Facilities

The Copco 2 powerhouse is located on the left bank, about one mile downstream of the dam at RM 196.9. The powerhouse has a total rating of 27 megawatts at approximately 2,535 cfs under 152 feet net head (Raytheon 1995). Generating facilities consist of two vertical shaft Francis turbine units. The centerline of the turbine scroll case is at Elevation 2338, above a normal tailwater at Elevation 2326.

The intake structure for the powerhouse is located at the left bank of Copco 2 dam. The structure holds an angled screen about 50 feet wide and 32 feet high that rests on the reservoir floor at Elevation 2455.0. Flow into the intake is controlled by a caterpillar gate behind the screen. The structure provides a

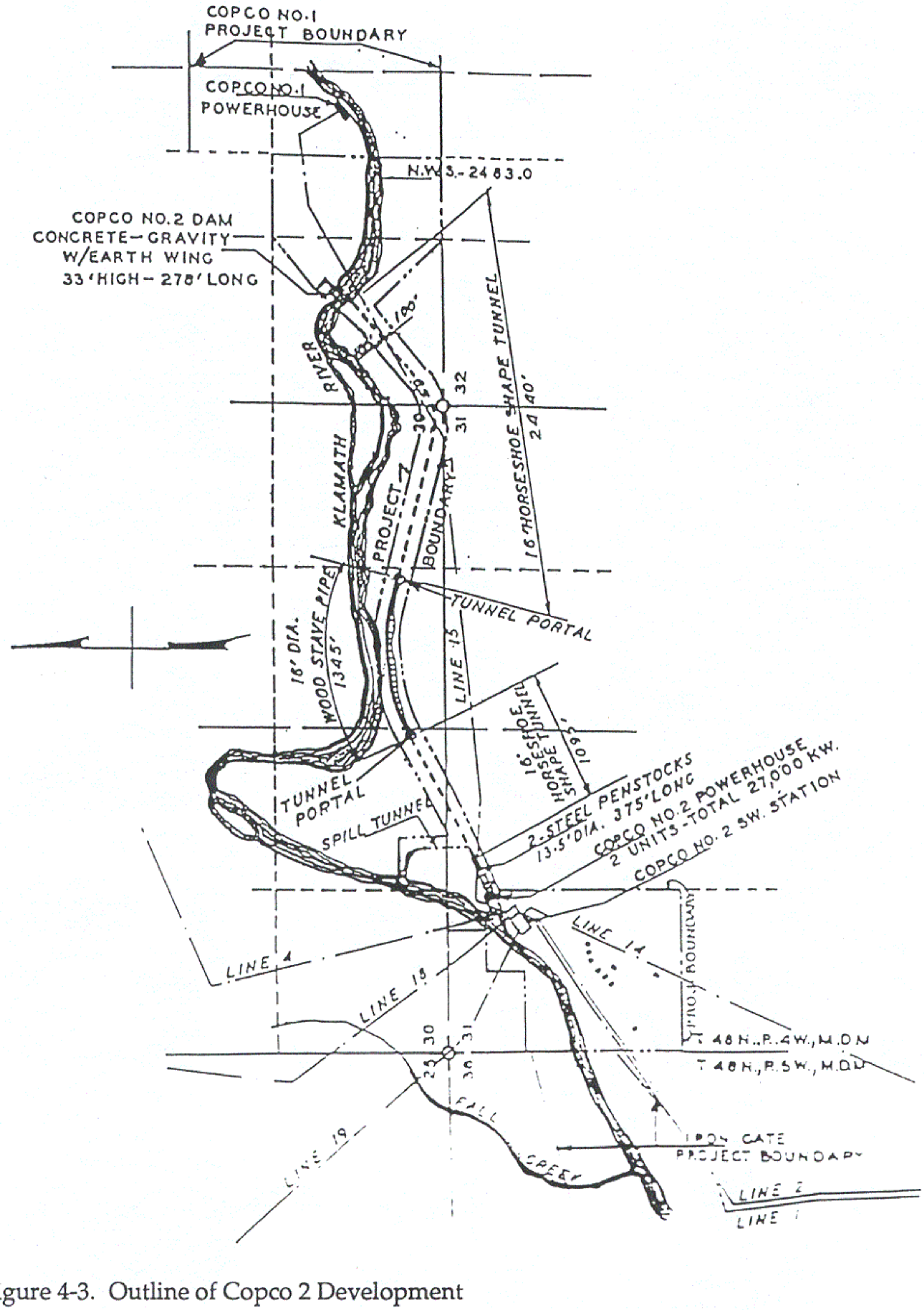


Figure 4-3. Outline of Copco 2 Development

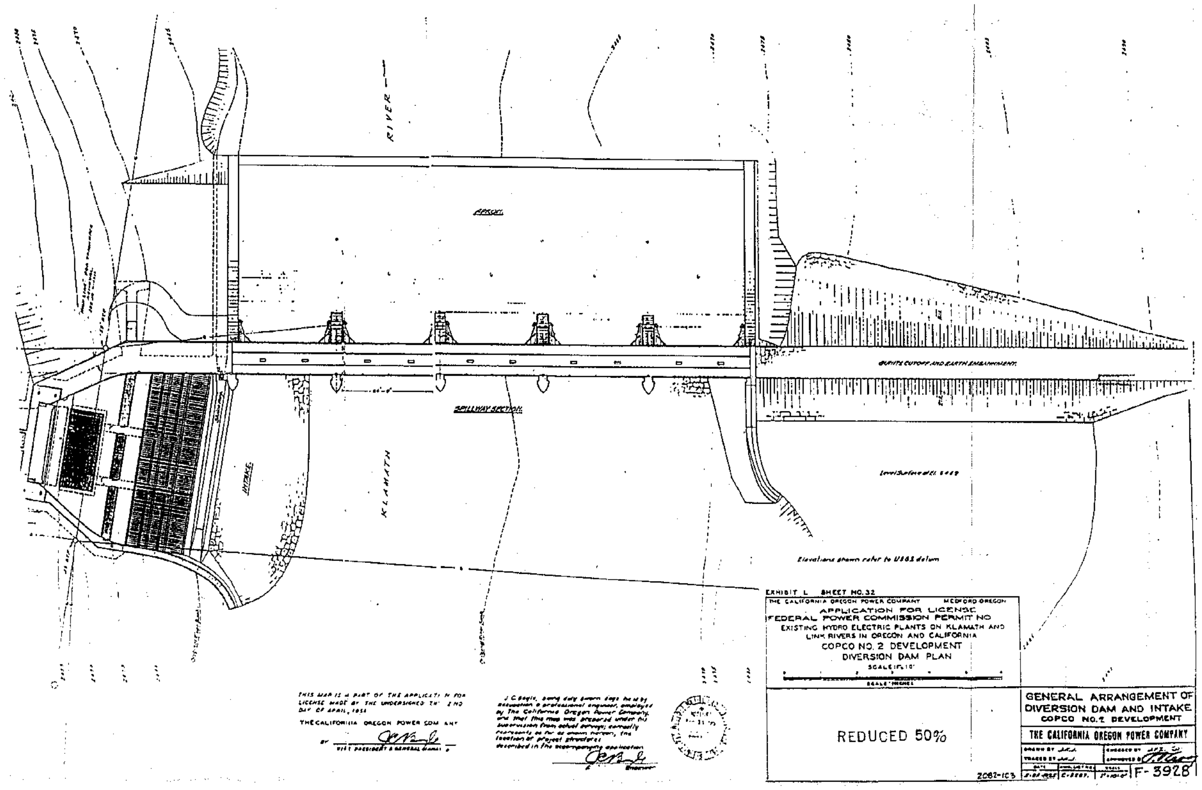


Figure 4-4. Copco 2 Dam General Arrangement

transition to the entrance of an extended conveyance route consisting of the following:

16 foot high horseshoe shape tunnel	2,440 feet
16 foot diameter wood stave pipe	1345 feet
16 foot high horseshoe shape tunnel	1095 feet
2 – 13.5 foot diameter steel penstocks	375 feet
Total length	5265 feet

d. Reservoir

The reservoir created by Copco 2 dam extends 0.3 mile upstream to the base of Copco 1 dam. It has a normal full pool elevation of 2483.0, and a maximum depth of 28 feet occurring at the intake structure entrance. The reservoir has a surface area of 40 acres and a storage capacity of 73.5 acre-feet.

e. Fish Passage Facilities

Copco 2 is not equipped with fish passage facilities to aid in upstream or downstream movement past the dam. However, to enhance fish habitat conditions in the bypass reach between the Copco 2 dam and powerhouse, PacifiCorp has added a flume at the left bank of the dam to maintain a minimum flow (approximately 10 cfs) into the reach.

4.3 Copco 1 Facility

Copco 1 facility is located in Siskiyou County, California, at River Mile 200.3 of the Klamath River. It is the oldest facility on the mainstem Klamath River, with construction starting in 1911 and dam closure occurring in 1917. The main function of the Copco 1 facility is power generation, and components include a dam, spillway, a powerhouse located at the base of the dam, and a reservoir that extends about 4.5 miles upstream from the dam. Details in the following subsections regarding these components are derived primarily from dam safety inspection reports (Bechtel Corporation 1968a, Black & Veatch 1993a).

a. Dam

Copco 1 dam is located in a steep-sided, narrow gorge of the Klamath River. In order to make the best use of the rock abutments at the site, the dam was constructed as a concrete gravity dam with a large-diameter curve at the upstream face. The crest length between rock abutments is about 410 feet. The upstream face of Copco 1 dam is basically vertical, while the downstream face has a stairstep appearance, with the height of each riser being about 6 feet (Figure 4-5).

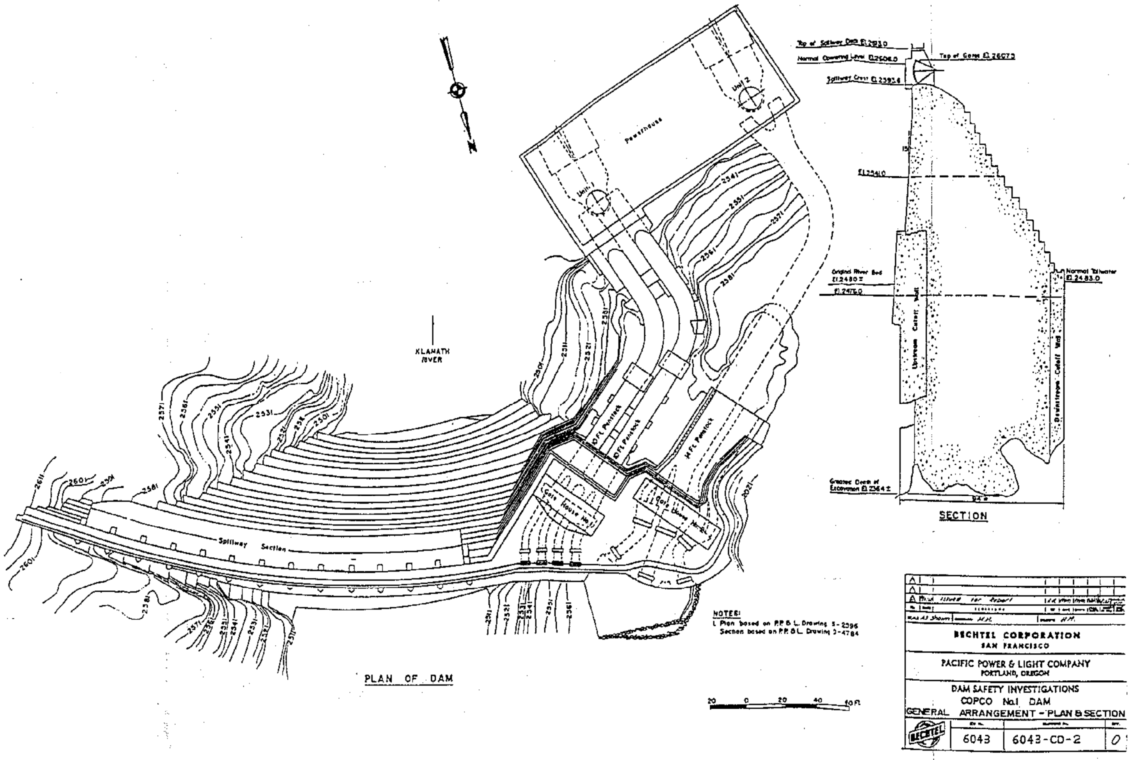


Figure 4-5. Copco 1 Dam Plan and Section. (Source: Black & Veatch 1993a)

The operating deck of the dam is located at Elevation 2613, about 133 feet higher than the pre-project river bed elevation. Excavation of gravel and boulders beneath the river bed extended much deeper than was expected during planning stages of construction. When finally completed, the total height of the concrete dam as measured from the lowest depth of excavation was 230 feet.

In order to carry out the sub-river excavation, an upstream cutoff wall was constructed with a maximum thickness of about 20 feet, along with a downstream cutoff wall about 8 feet thick. Both of these cutoff walls were incorporated into the final dam structure. At the original river level, the width of the dam is about 98 feet.

b. Spillway

Copco 1 dam has a gated, controlled spillway located in the center of the dam. The spillway contains 13 bays each 14.0 feet wide, controlled by Taintor gates 14.0 feet high. The spillway crest is at Elevation 2593.5, and the top of the gates is at Elevation 2607.5, which also represents the normal high water level and facility boundary.

The spillway gates are operated by three movable electric hoists mounted on rails on the spillway deck. The hoists are operated locally, though one can be operated remotely from the Copco 1 powerhouse or the Klamath Falls Dispatch Center. One hoist can be operated by hand or by an auxiliary gasoline engine in the event of an emergency situation during an electric power failure.

When water is spilled through the gates, excess energy is dissipated as it flows down the stepped face of the dam.

c. Power Generating Facilities

The Copco 1 powerhouse is located on the right bank about 250 feet downstream of the dam. The powerhouse has a total rating of 20 megawatts at approximately 2,360 cfs under 125 feet net head. Generating facilities consist of two double-runner horizontal Francis turbine units, identical except that Unit 1 is an overshot arrangement, while Unit 2 is undershot. The nameplate rating of each turbine is 18,000 hp at 125 feet net head and 200 rpm.

There are four gated intakes for Unit 1. Each pair of intake pipes joins together, forming two 10-foot diameter penstocks that directly feed Unit 1. In similar fashion, two gated intake pipes for Unit 2 join to form one 14-foot diameter penstock. There are provisions for a third unit which has never been installed. The controlling invert elevation of the operable power conduits is about Elevation 2575, such that Copco Reservoir cannot be drawn down below this level.

d. Reservoir

The impoundment created by Copco 1 dam is commonly referred to as Copco Reservoir. It has an operating range of 5 feet, with the normal maximum pool at Elevation 2606.0 and the normal minimum pool at Elevation 2601.0. Extending about 4.5 miles upstream from the dam, the reservoir has a surface area of 1,000 acres. The maximum depth is 108 feet, and the total storage capacity is 45,390 acre-feet..

e. Fish Passage Facilities

Copco 1 is not equipped with any facilities for upstream or downstream fish passage past the dam.

f. Additional Outlets

There are no additional outlets to Copco 1 dam. During construction of the dam, the river flow was diverted through a tunnel on the left abutment, with a typical cross section of 16 feet by 18 feet. This tunnel has been permanently closed off with a concrete plug, and there is currently no controlled discharge through the tunnel.

4.4 J.C. Boyle Facility

The J. C. Boyle facility is located in Klamath County, Oregon, about 15 miles southwest of the city of Klamath Falls. The dam is located at River Mile 224.7 of the Klamath River and was constructed from 1957 to 1958. The main function of the J.C. Boyle facility is power generation, with principal components consisting of a dam and spillway, a powerhouse 4 miles downstream with an associated diversion canal, and a reservoir that extends about 3.6 miles upstream from the dam (Figure 4-6). Details regarding these components are derived primarily from the 1993 dam safety inspection report (Black & Veatch 1993c), with additional information supplied by PacifiCorp.

a. Dam

J.C. Boyle dam has a total length of 693 feet, comprised of a 297 foot concrete dam section and a 414 foot earth embankment. The embankment is an earthfill dam with a maximum height of 68 feet above the original stream bed. Its crest is 15 feet wide at Elevation 3800.0, which is 7 feet above the normal maximum reservoir water level. The embankment, which was constructed entirely on rock in the river channel, has a central vertical core supported by upstream and downstream shells of sand and gravel (Figure 4-7).

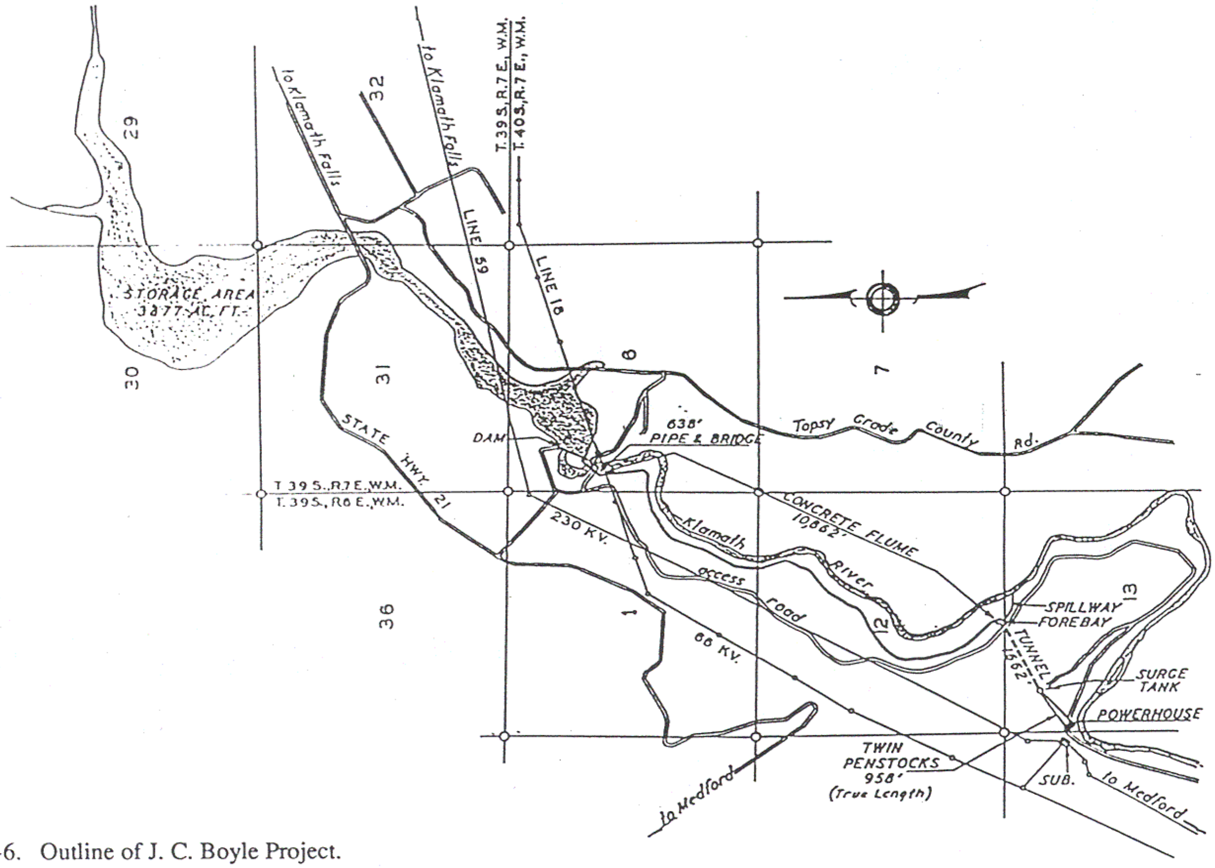


Figure 4-6. Outline of J. C. Boyle Project.

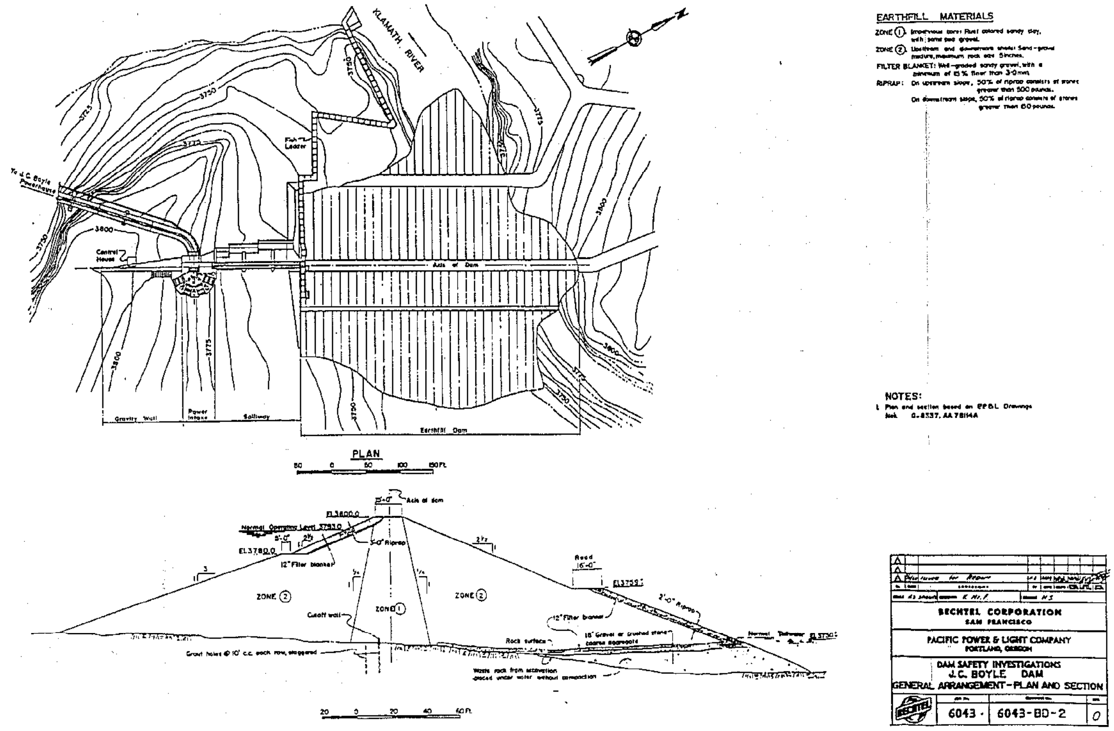


Figure 4-7. J. C. Boyle Dam General Arrangement. (Source: Black & Veatch 1993c)

The upstream face of the embankment has a 3 to 1 slope at the base, and a 2.5 to 1 slope in the highest 20 feet that is protected by a 3-foot thick layer of riprap. The downstream face has a constant slope of 2.5 to 1 except for a 16 foot access road at Elevation 3759. A 2-foot thick layer of riprap is at the toe of the downstream face to protect against backwater erosion from the spillway discharge channel.

The left end of the embankment abuts on a concrete gravity wall that contains the fish ladder. The maximum height of the wall is 31 feet.

The concrete portion of the dam includes a spillway about 115 feet long and an intake structure about 64 feet long. The remainder of the concrete dam is a gravity wall with a maximum height of 28 feet that extends from the intake block to the left abutment.

b. Spillway

The J.C. Boyle spillway is a concrete gravity ogee overflow section with three 36-foot by 12-foot Tainter gates operated by an electrically powered traveling hoist. The spillway crest is at Elevation 3781.5 and the top of the gates are at Elevation 3793.5. Each spillway bay discharges onto a 13-foot wide concrete apron, with the apron slabs stepping up from Elevation 3763.5 to 3768.82 to 3774.0, respectively, progressing toward the left bank. Below the apron is a vertical drop of 15 feet maximum height to the discharge channel which was excavated in rock. The discharge channel is unlined except where erosion damage has been repaired by dental concrete treatment. The channel is approximately 300 feet long with a bottom width of 30 feet and a design slope of 7%. A concrete wall was added in 1966 to further protect the fish ladder from erosion.

c. Power Generating Facilities

The power generating facilities, including diversion intake, water ways and the powerhouse, extend approximately 3 miles downstream from the point of diversion. The diversion intake structure, located to the left of the spillway, is a 40-foot high concrete tower having four openings to the reservoir. Each opening is 11.5 feet wide and equipped with vertical traveling screens. Past these openings, the intake transitions to a single 14 foot diameter steel conduit which extends approximately 638 feet to span the Klamath River and discharge into and open concrete walled canal. Flow into the conduit is controlled by a 14-foot by 14-foot fixed wheel gate operated by an electrically powered hoist.

The diversion canal is 2 miles long and is either double or single walled depending on the terrain. It terminates in a forebay and is provided with appropriate overflow structures at the upstream and downstream ends that direct overflow back to the river via the spillway following load rejection.

Water for power generation is drawn from the forebay through a 15.5-foot diameter concrete lined horseshoe section tunnel which is 1,644 feet long. During the last 57 feet of the tunnel, there is a steel lining that bifurcates into two 10.5-foot diameter steel penstocks. In their descent to the powerhouse, the penstocks reduce in two steps to 9 feet in diameter. Each penstock is 956 feet in length and supported above ground.

The power plant consists of two General Electric vertical generators with a total nameplate rating of 79,990 kilowatts. The two turbines from the Baldwin, Lima, Hamilton Corporation are rated at 56,000 hp each. The normal net effective head is 440 feet, and the total hydraulic capacity is approximately 2,500 cfs. Generation capacity is rated at 80 MW through the two units, one at40MW and the other at 40 MW.

d. Reservoir

The reservoir capacity is 3,495 acre-feet, 1,507 acre-feet of which is usable pondage. The normal water surface elevation is 3793.0 feet with a normal low water surface of 3788.0 feet. The reservoir extends upstream for a distance of approximately 3.6 miles.

e. Fish Passage Facilities

The J.C. Boyle dam is equipped with a pool and weir fish ladder, built in 1958during the dam construction. The ladder allows fish to rise about 67 feet in elevation through 57 pools. The entrance to the ladder is located on the left bank approximately 200 feet downstream from the toe of the dam, and after about 569 feet in length the ladder exits about 50 feet upstream from the dam axis. In general, the pools have a width of 6.0 feet, a length of 8.0 feet and side walls extending 6 feet above the bottom of the pool. The weirs between pools are 3.5 feet in height and have a 4 inch by 4 inch orifice centered at the bottom of the weir. An automated gate maintains a constant flow into the ladder, and an auxiliary water supply system assures that a total of 80 cfs is provided as attraction flow at the entrance.

Downstream passage facilities are also provided at the J.C. Boyle dam. Each of the four entrances at the intake structure is equipped with Rex vertical travelling screens to prevent entrainment of fish into the power canal. High pressure spray systems keep the screens clean and free of debris buildup. In 1988, the fish screen housings were modified to allow full year continuous operation (F. Shrier, PacifiCorp, personal communication 6/24/98). In 1992, new fiberglass screens with 1/8 mesh replaced the previous metal screens (PacifiCorp 1997). The bypass route is a pipe that has its entrance at the south end of the intake structure and its exit at the discharge channel below the spillway apron. A constant bypass flow of 20 cfs is used to convey fish through the bypass entrance.

f. Additional Outlets

There are no additional outlets from the J.C. Boyle dam. Two culverts lie under the spillway with invert elevations of 3751.5 which were used for river diversion during construction, Each of these culverts have a width of 9.5 feet and a height of 10.0 feet. After construction the culverts were backfilled with concrete and hence can no longer be used to discharge from the reservoir.

4.5 Keno Facility

The Keno facility is located in Klamath County, Oregon, with a dam at River Mile 230.3 of the Klamath River. Construction completion occurred in 1967 to replace the original crib dam which was destroyed in the December 1964 flood. The Keno facility has no power generating facilities, with a main function of controlling water elevations in Lake Ewauna and regulating flow to downstream facilities. Components of the facility include a dam and spillway, a fish ladder, and a reservoir upstream of the dam. No documents were available that summarize Keno facilities and operation. The details described below have been derived from construction drawings and notes from a site visit conducted in June 1998.

a. Dam

The Keno dam has a length of approximately 680 feet, consisting of a 145 foot long earth embankment on the right bank, and a 535 foot long concrete portion that extends to the left abutment. With a crest elevation of 4091.0, the dam rises about 25 feet above the original streambed centerline elevation of 4066. Excavation of 2 to 8 feet below the original grade was required to provide firm foundation (Figure 4-8).

The earth embankment is comprised of a core zone with transition zones on either side and outer shell zones. The embankment crest is at Elevation 4091.0 and has a width of 25 feet. The upstream face has a slope of 2.5 to 1 and is protected with a layer of riprap from top to base. The downstream face has a 2 to 1 slope and a riprap layer only at the toe below Elevation 4072.0.

The concrete portion of the dam includes a 110 foot long non-overflow section that adjoins the embankment at the right, a spillway section in the center that is 265 feet in length, and a final non-overflow section 160 feet long that extends to the left abutment. The left section includes a sluiceway and the fish ladder facilities. The working deck is at Elevation 4091.0, consisting of an access road that runs the full length of the dam. The upstream face of the concrete dam is basically vertical. The downstream face of the non-overflow section broadens out with a slope of 0.6 to 1.

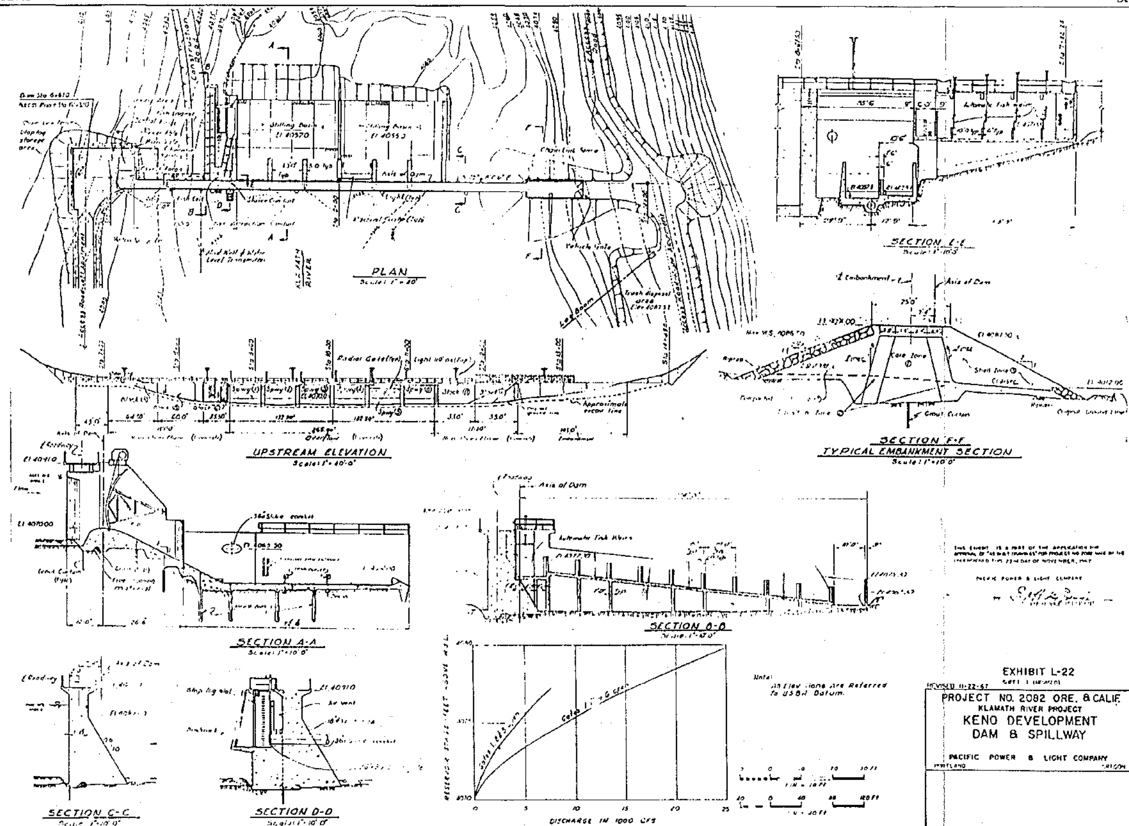


Figure 4-8. Keno Dam Plan and Sections.

b. Spillway

Keno dam has a gated, controlled spillway on the left segment of the dam. There are 6 spillbays each housing radial gates 40.0 feet wide by 14.0 feet high. The spillway has a crest is at Elevation 4070.0 and subsequently slopes down at a 2 to 1 slope to one of two stilling basin slabs. The two basins have different slab elevations: Elevation 4052.0 at the left basin and Elevation 4056.0 at the right basin. Both basins extend approximately 60 feet beyond the toe of the spillway. Flow over the spillway and discharge beyond the apron are both oriented normal to the flow of the river.

c. Power Generating Facilities

The Keno facility has no power generating facilities.

d. Reservoir

The reservoir formed by the Keno dam is commonly referred to as Lake Ewauna. It has a normal full pool elevation at 4085.0 and a total storage capacity of 18,500 acre feet. The maximum allowed water surface at the facility is Elevation 4086.5.

e. Fish Passage Facilities

The original construction of Keno dam included fish ladder facilities in the left portion of the dam. It is a pool and weir ladder that has 24 pools to provide 19 feet of vertical passage. The ladder has two vertical slot entrances: one facing downstream and one facing across the spillway apron. The ladder continues approximately 330 feet to exit at the face of the dam. Each pool is 6 feet wide by 10 feet long, divided by weirs that are 5 foot high with a 3 foot by 1 foot rectangular notch at the sidewall. Each weir also has an orifice at the bottom measuring 1.25 feet high and 10 inches wide. There are four automatic weirs located in the 40 foot long exit pool that are used to maintain a flow of 15 cfs into the ladder and adjust to fluctuating levels in the reservoir. Additional attraction flow for the ladder is supplied through a conduit with its intake at the face of the dam, discharging into a diffusion chamber that feeds the entrance pool through a grating 5 feet high (Figure 4-9). The Keno fish ladder is operated year round.

Because there is no power generation at Keno, it is not necessary to provide facilities for protecting downstream migrants from turbine entrainment. A minimum flow of 250 cfs is routed through the ladder or over the spillway, allowing downstream passage past the dam to occur year-round.

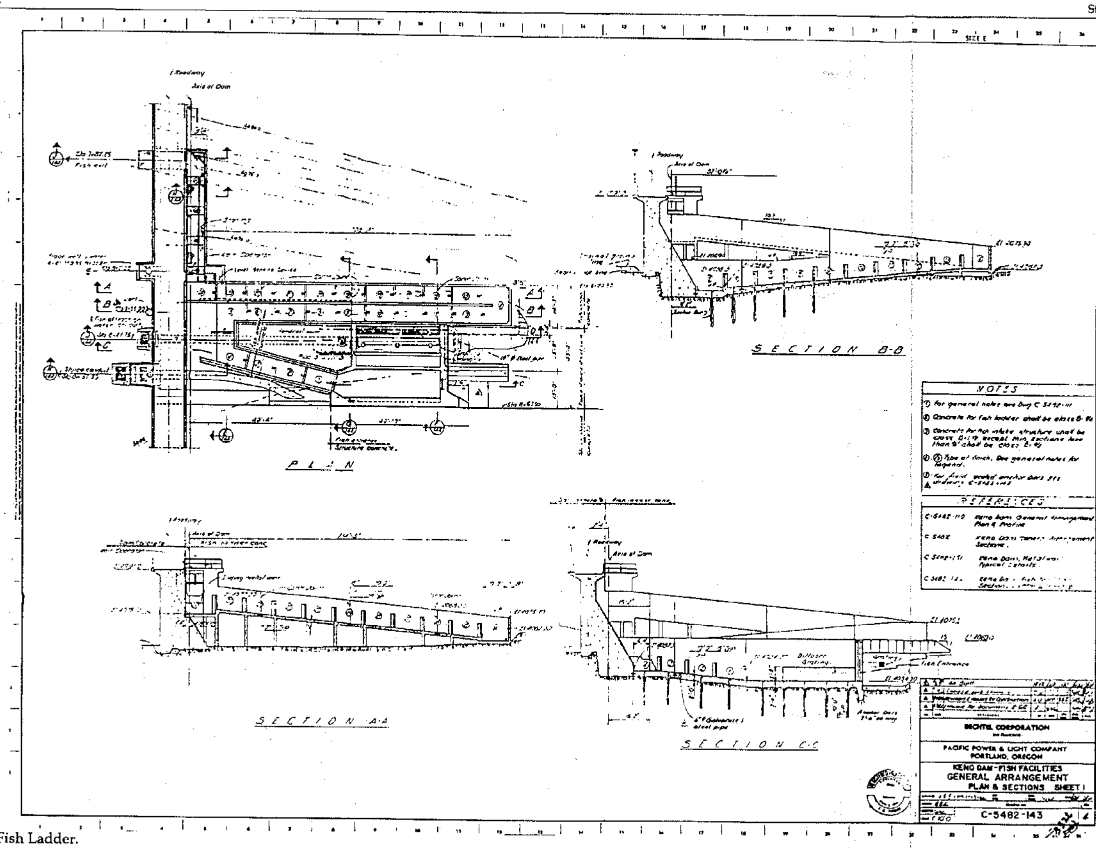


Figure 4-9. Keno Dam Fish Ladder.

f. Additional Outlets

Keno dam has a sluice facility located in the left portion of the dam. The sluice entrance is a vertical slot protected by a trash rack with its invert at approximately Elevation 4065. Sluice flow is controlled with stoplogs. Flow enters a 36 inch conduit that has its discharge port in the wall to the left of the spillway apron.

4.6 Link River Facility

The Link River facility is located in Klamath County, Oregon, within the city limits of Klamath Falls. Two entities own different components of the Link River facility. The Link River dam is owned by the US Bureau of Reclamation (USBR) and operated by PacifiCorp. The generating facilities, consisting of the Westside powerhouse and the Eastside powerhouse, are both owned and operated by PacifiCorp. The generating facilities were built prior to construction of the dam and operated off the original level of Upper Klamath Lake. The Westside powerhouse was constructed in 1908, and the Eastside powerhouse followed in 1924.

Located at River Mile 254.3 of the Klamath River, the Link River dam is the uppermost in the series of six dams on the mainstem Klamath River. .The Link River dam was constructed in 1927 as part of the USBR's Klamath Irrigation Project. It is operated pursuant to a contract between PacifiCorp and the USBR, functioning to provide regulation of Upper Klamath Lake levels, divert water into the Eastside and Westside powerhouses, and maintain a minimum flow in the Link River reach between the dam and the Eastside powerhouse. The details described below that summarize the Link River facilities and operation have been derived from construction drawings, notes from a site visit conducted in June 1998, and the fish trapping study conducted by PacifiCorp (1997).

a. Dam

The Link River dam has a total length of 435.5 feet between abutments. The dam is comprised of many segments, including the 48 foot long intake structure for the Eastside powerhouse at the left bank; a 260 foot long section containing stoplog overflow weirs; a 40 foot section containing the main discharge control gates; and a 40 foot section holding the intake facilities for the Westside powerhouse (Figure 4-10).

The top of the dam is at Elevation 4145.0, 15 feet above the minimum streambed grade at Elevation 4130. There is minimal concrete in the dam, consisting primarily of a sill and vertical piers to support stoplogs and gates. It is unknown how deep the footing extends beneath the streambed to support the dam.

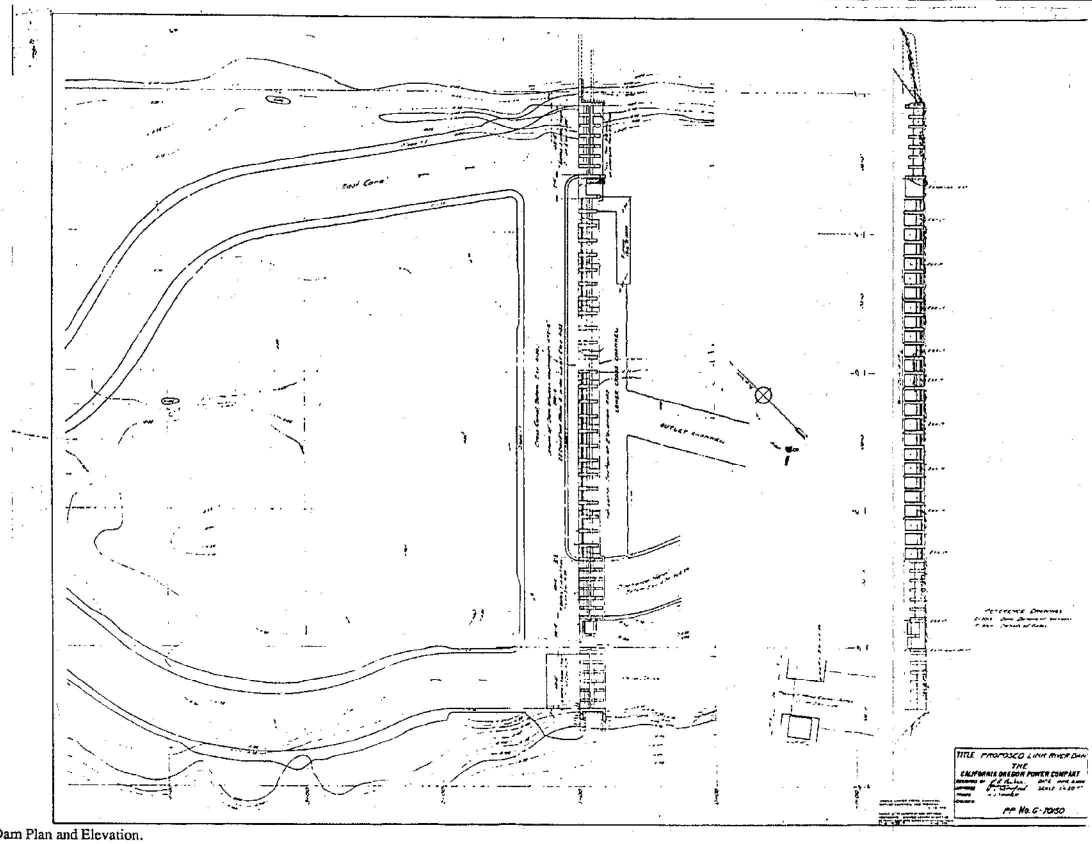


Figure 4-10. Link River Dam Plan and Elevation.

b. Spillway

The main regulating gates for Link River dam are located in a 40 foot section near the right bank. There are 6 gates total, each 5 feet wide and 7 feet high. The sill for the main gates is at Elevation 4130, even with the grade of the downstream river channel.

Additional regulation can be provided by removing stoplogs from the weirs within the 260 foot long overflow section. There are 25 weirs that comprise the overflow section, each 8 foot wide. Stoplogs in the 10 weirs closest to the main gates were retrofitted in 1974 to provide a single stoplog assembly that can be lifted with the aid of a movable gantry crane and overhead hoist (Figure 4-11). The overflow weir closest to the left bank also serves as the entry into the fish ladder. The sill for the overflow section is at Elevation 4135.

c. Power Generating Facilities

Two power generating facilities owned by PacifiCorp are associated with the Link River facility. The Eastside Powerhouse is located on the left bank at River Mile 253.7, with a 3.2 MW generating capacity. The Westside Powerhouse is located on the right bank at River Mile 253.3 and has a 0.6 MW capacity. Typical diversions are 1,200 cfs and 250 cfs to the Eastside and Westside powerhouses, respectively. The Westside Powerhouse is operated only when the Eastside facility is at maximum capacity and additional releases are needed to control the water levels in either Upper Klamath Lake or Lake Ewauna.

The intake for the Eastside diversion is located in a 48 foot long section at the left abutment. The intake holds 7 control gates, each 5 feet wide and 7 feet high. The sill for the gates is located at Elevation 4130. The conveyance route to the powerhouse begins with the Eastside Canal, 670 feet long, 50 to 60 feet wide at the water surface and 15 feet deep. The conveyance route then transitions to a wood stave pipe 12 feet in diameter and 1,729 feet long, followed by a steel pipe 12 feet in diameter and 1,321 feet long, and finally a steel penstock 12 feet in diameter and 40 feet long. There is one turbine unit in the Eastside powerhouse.

The Westside powerhouse intake is located in a 40 foot long section at the right abutment. The intake holds 6 control gates, each 5 feet wide and 7 feet high. The sill for the gates is located at Elevation 4129. The power canal supplying the Westside is called Keno Canal and is approximately one mile long. No additional details are known regarding the Westside facilities.

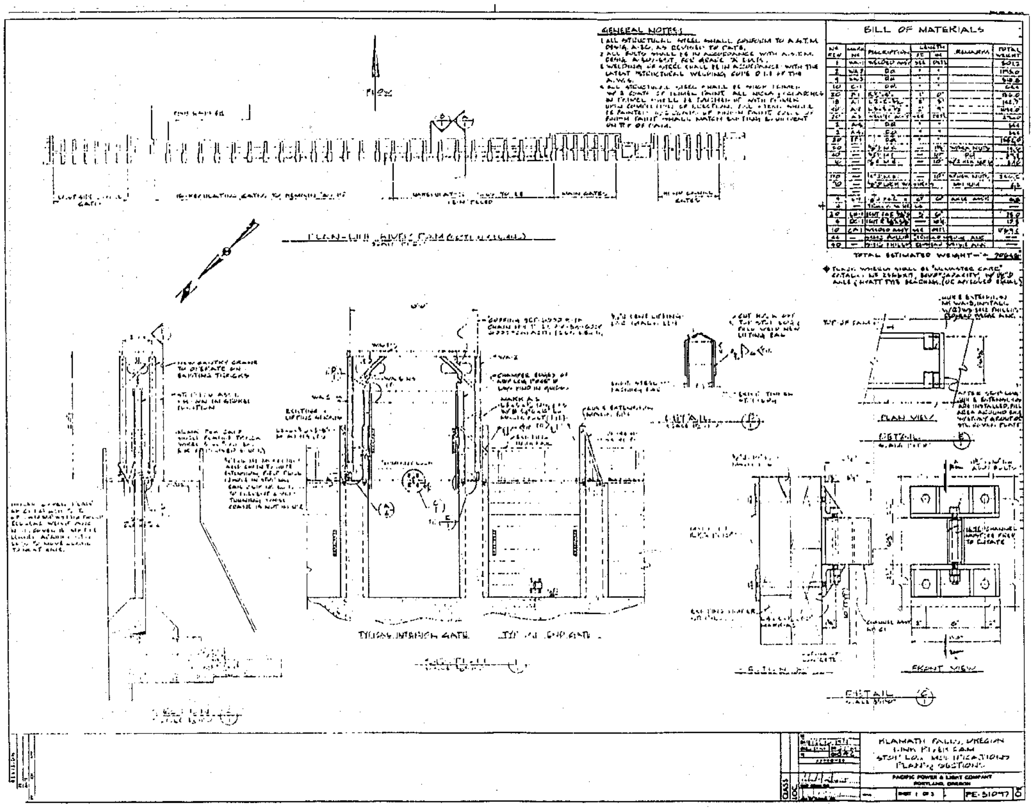


Figure 4-11. Link River Dam Spillway Details.

d. Reservoir

The reservoir created by the Link River dam is known as Upper Klamath Lake. The lake existed prior to dam construction but was modified in 1927 to create additional irrigation storage capacity. At the full pool elevation of 4143.3, Upper Klamath Lake has a surface area of 90,000 acres and a total storage capacity at approximately 523,700 acre-feet. The reservoir is managed by the USBR and operated by PacifiCorp.

e. Fish Passage Facilities

A pool and weir type fish ladder was constructed along with the Link River dam in 1927 and modified with a vertical slot entrance pool in 1988. Plans for a new ladder to replace the existing facility are currently under development by the USBR.

The existing ladder entrance is located about 12 feet downstream from the toe of the dam, oriented toward the center of the channel. The ladder exit is located at the overflow weir closest to the left bank.

The ladder consists of 11 pools, is approximately 105 feet long, and provides for approximately 13 feet in vertical gain. Each pool is 8.5 feet wide by 8.0 feet long with a level floor slab at Elevation 4132.5. The concrete weir that separates each pool contains a notch in the center that is 4 feet wide and of varying height. The invert of the sill increases from one foot above the floor at the lowest weir to 2.5 feet above the floor at the highest weir.

Flow into the ladder is dependent on the elevation of Upper Klamath Lake. PacifiCorp operators will periodically adjust the flow manually using stoplogs at the overflow weir.

SECTION 5 - ENVIRONMENTAL SETTING

The environmental setting of the Upper Klamath River exhibits diverse conditions resulting from both distinct geological features and man-made alterations. In this section, information is presented regarding environmental parameters that have significant effect on fish migration and habitat utilization. The information is presented by reach.

5.1 Basin-wide Characteristics

The average annual precipitation in the Upper Klamath Basin is about 13 inches, most of it in the form of snowfall. Because of the porous nature of the volcanic rocks prevalent in the basin, much of the snowmelt filters through the ground to emerge as springs or to recharge groundwater (KRBFTF 1995). Surface water diversions in the basin are predominantly for agricultural purposes, with about 840,000 acre-feet per year, or about 93% of total water use, being diverted for irrigation in Klamath County (Forbes and Elswick 1995). The Oregon Department of Environmental Quality states that, with respect to water resources, the Klamath Basin is the most intensely managed basin in Oregon (Cude, date unknown).

These man-made alterations have impacted streamflow conditions in the basin. As compared to conditions prior to 1960, there is an average of 103,000 acre-feet less water that passes Keno gage in the summer months and 29,000 acre-feet more flow in February (USNBS 1995). These values represent changes on the order of 9% to 16% of the mean annual flow. However, natural variation in precipitation can result in changes as great as 71% from the mean annual flow. The impact of drought and the resulting decrease in flow is more significant than changes brought about by man (USNBS 1995). As an indicator of the frequency of these climatic events, Figure 5-1 illustrates the annual average discharge for the Klamath River near Keno for Water Years (WY) 1961-97, overlain with the water year type.

Three of the reservoirs formed by the PacifiCorp dams are deep enough to result in stratification during the summer months: Iron Gate reservoir, Copco reservoir (located above Copco 1 dam), and J.C. Boyle reservoir. During stratification, the natural density differences between warm and cool water produce a distinct upper layer of warm water that prevents wind-generated aeration from mixing with the cooler lower layer. As the summer progresses, oxygen depletion in the lower layer is usually worsened due to additional photosynthetic and decomposition factors. The net effect is that typically only a relatively narrow zone between the upper and lower layers has both the temperature and oxygen conditions that are within the criteria range suitable for fish. More discussion on reservoir stratification and its implication on downstream conditions is presented within each relevant subsection.

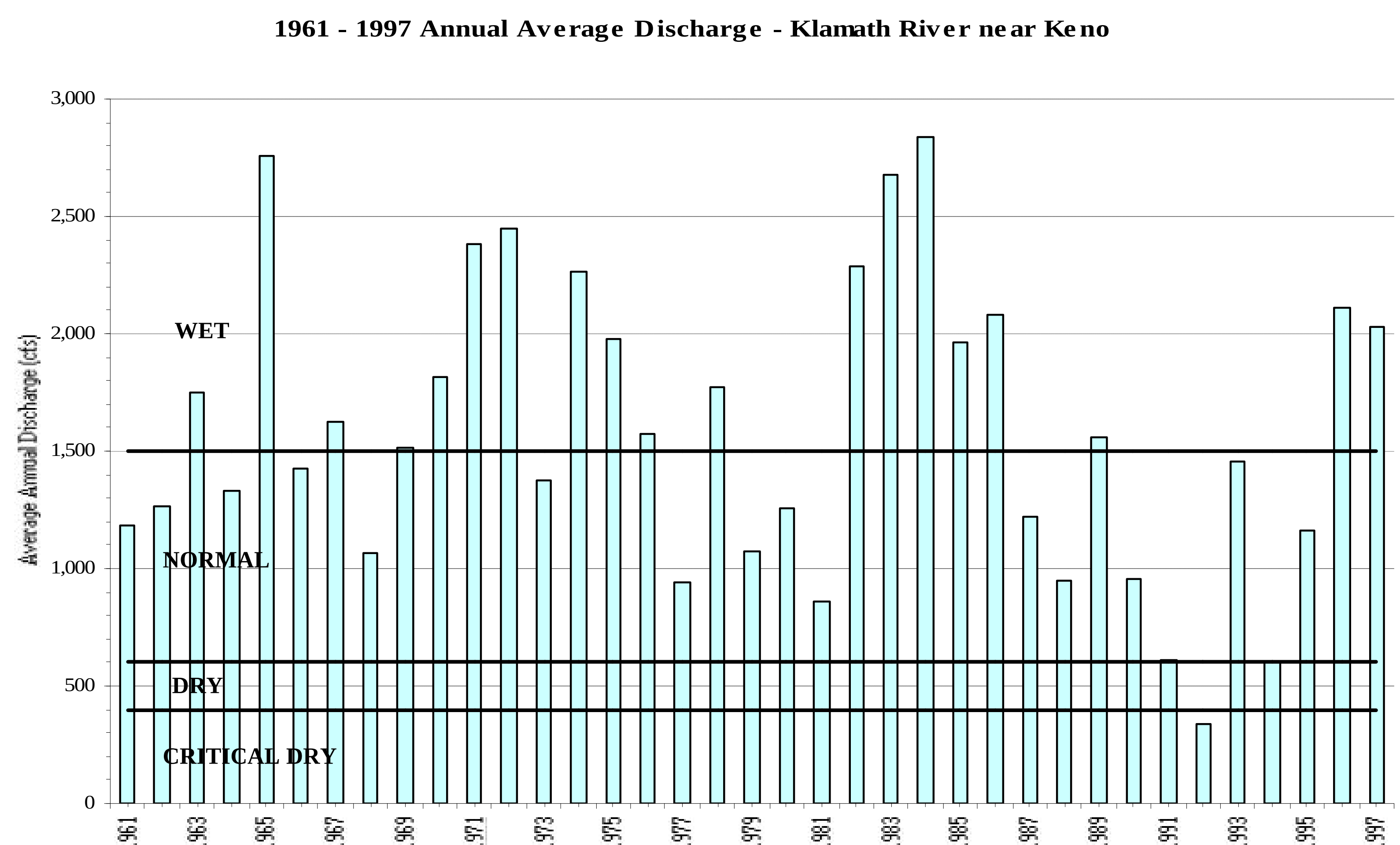


Figure 5-1. 1961 - 1997 Annual Average Discharge -- Klamath River near Keno

5.2 Iron Gate to Copco 2

a. General Characteristics

This reach of the Klamath River spans 8.2 miles, from Iron Gate dam located at River Mile (RM) 190.1 upstream to Copco 2 dam at RM 198.3. Iron Gate reservoir forms the bulk of the reach, extending 6.8 miles above the dam, covering 944 surface acres and encroaching on the tailrace of the Copco 2 powerhouse located at RM 196.9. The uppermost 1.4 miles of the reach is a steep-gradient, free-flowing bypass reach between the Copco 2 dam and powerhouse, carrying a flow of approximately 10 cfs plus any additional flow not routed through the Copco 2 powerhouse. Two tributaries enter the Klamath River in this reach: Jenny Creek at approximately RM 194.0, and Fall Creek at approximately RM 196.3.

Environmental conditions for this reach have been monitored by multiple sources. A USGS water-stage recorder (#11516530) is located 0.6 mile below Iron Gate dam, on the left bank just downstream from Bogus Creek. The gage has been maintained from October 1960 through the present, with chemical data available for WY 1962-81, and water temperature data available from WY 1963-80. More recently, in 1996 and 1997, the USGS and PacifiCorp conducted water quality sampling using a continuous-monitoring Hydrolab recorder located just below Iron Gate dam at the access bridge. The North Coast Regional Water Quality Control Board (NCRWQCB) has worked in conjunction with PacifiCorp and UC Davis to collect water temperature and water quality data in Iron Gate reservoir. Operational data on turbine flow, spill flow, diversions to Iron Gate Hatchery and reservoir elevation are maintained by PacifiCorp.

b. Discharge

The WY 1962-97 period of record for the USGS gage below Iron Gate dam exhibits a mean annual Klamath River flow of 2,068 cfs. The extremes for this same period are a maximum discharge of 29,400 cfs on 12/22/64 and a minimum discharge of 389 cfs on 8/25-28/92 (USGS 1999). Measurements from this gage include flow from Bogus Creek, which has a mean flow estimated at 15 to 20 cfs.

Discharge from Iron Gate can occur at four locations: through the turbine penstock located about 35 feet below the reservoir surface; at the spillway located at the reservoir surface; or through one of two intakes feeding the Iron Gate Hatchery supply, located 19 feet and 75 feet below the normal full pool elevation (Deas and Orlob 1998). Releases to the hatchery supply system are limited to 50 cfs, representing about 2.5% of the mean annual flow.

Iron Gate dam is operated to reregulate Klamath River flows affected by hydropower generation at J.C. Boyle, Copco 1 and Copco 2. Additional operational constraints are set by provisions in PacifiCorp's Klamath River Project FERC license and the current NMFS Biological Opinion for BOR's Klamath Project operations (NMFS 1999). The FERC license stipulates a minimum release from Iron Gate of 710 cfs during June and July, 1,000 cfs during May and August, and 1,300 cfs for the remaining months (FPC. 1961). However, since June 1996, PacifiCorp operates Iron Gate flows according to the BOR operations' plans, rather than according to FERC minimum flows. BOR flows are typically much higher than FERC flows.

Daily average discharge values for turbine releases and spill at Iron Gate dam have been supplied by PacifiCorp for this report for the period January 1994 through May 1998 (PacifiCorp 1998). Daily average discharges for 1996 are presented in Figure 5-2 to illustrate both the day to day variation and the seasonal patterns that typically occur. Data indicate that during the wet winter months, the river flow exceeded the capacity of the powerhouse, and the turbine discharged relatively constantly around 1,750 cfs (turbine capacity) with surplus flow passing over the spillway. From June through late September 1996, the flow was low enough to route all releases through the turbine with no spill. Minimum discharge during this period was around 1,000 cfs, conforming with FERC minimum releases. Nominal amounts of spill occurred from late September through November 1996.

These same patterns can be seen in monthly average discharge data derived from the entire 1994 to 1998 record (Figure 5-3a). Spill typically occurs in conjunction with near-capacity turbine discharge during December through May, while June through November is characterized by little if any spill and reduced turbine discharge.

The dramatic variation in climatic conditions that can occur within the basin is also evidenced in the 1994 to 1998 discharge data. Under the system of classification used by BOR for its Klamath Project, 1994 was considered a critical dry year while 1995, 1996 and 1997 were all wet years. During 1994 the annual average discharge at Iron Gate dam was only 774 cfs, and all flow was routed through the powerhouse with no spill (Figure 5-3b). In sharp contrast, the annual average discharge in 1996 was 2,969 cfs (3.8 times the 1994 value), and the average annual value for spill was 1,545 cfs. The average discharge from Iron Gate dam for 1994 through 1997 was calculated to be 1,852 cfs, with 1,189 cfs passing through the powerhouse and 663 cfs passing over the spillway. The daily minimum discharge for the period was 542 cfs occurring in 1994, and the daily maximum discharge of 13,600 cfs occurred in 1996.

c. Reservoir Retention and Elevation

The total storage capacity of Iron Gate reservoir was noted in Section 4 to be nearly 59,000 acre-feet (and active / usable storage is 3,790 acre-feet). At the annual average flow rate of 1,852 cfs identified above, the average retention rate in the reservoir is 16 days. Between extreme flow events of 710 cfs for a minimum and 10,000 cfs as a maximum, the retention time would range from 42 days down to 3 days.

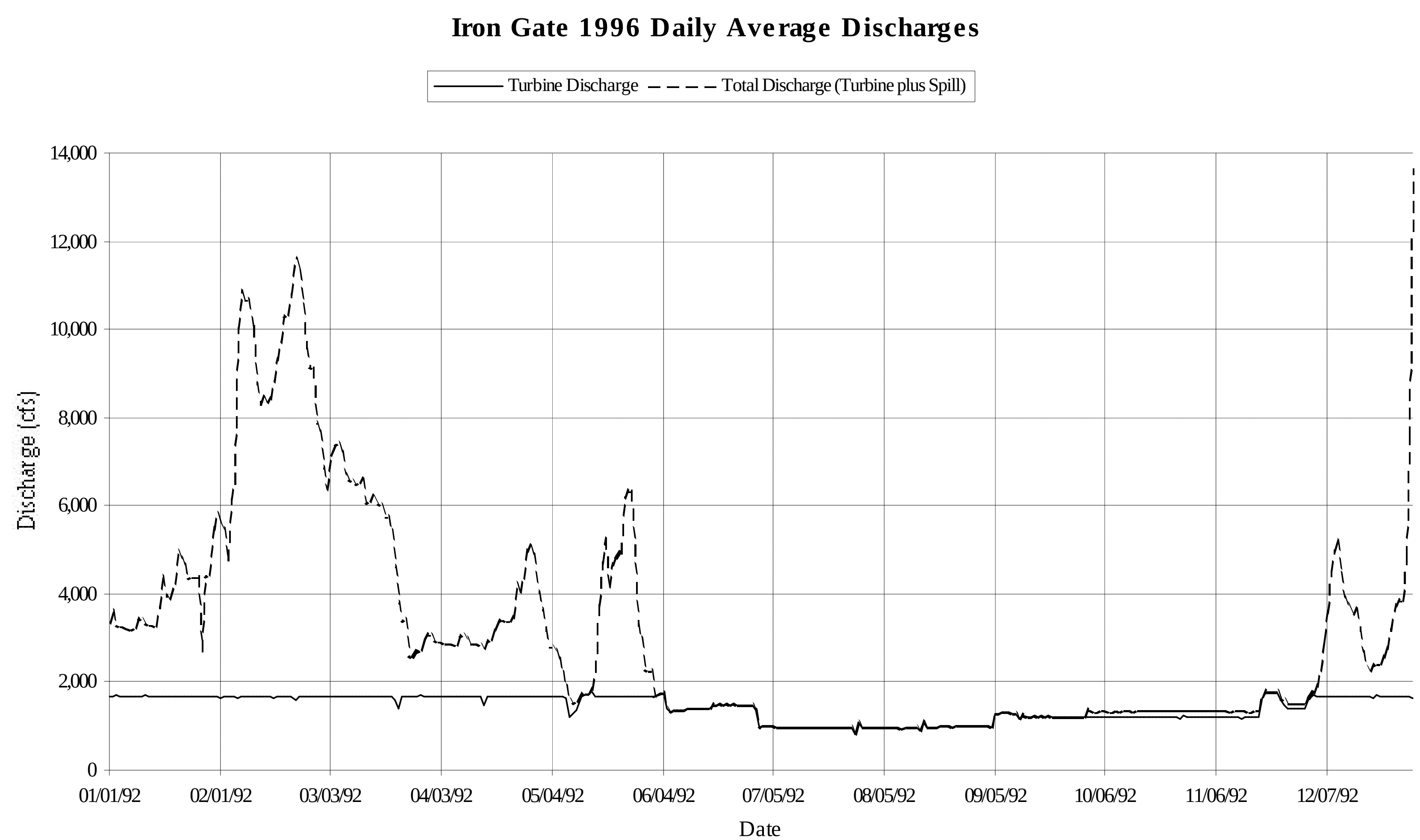
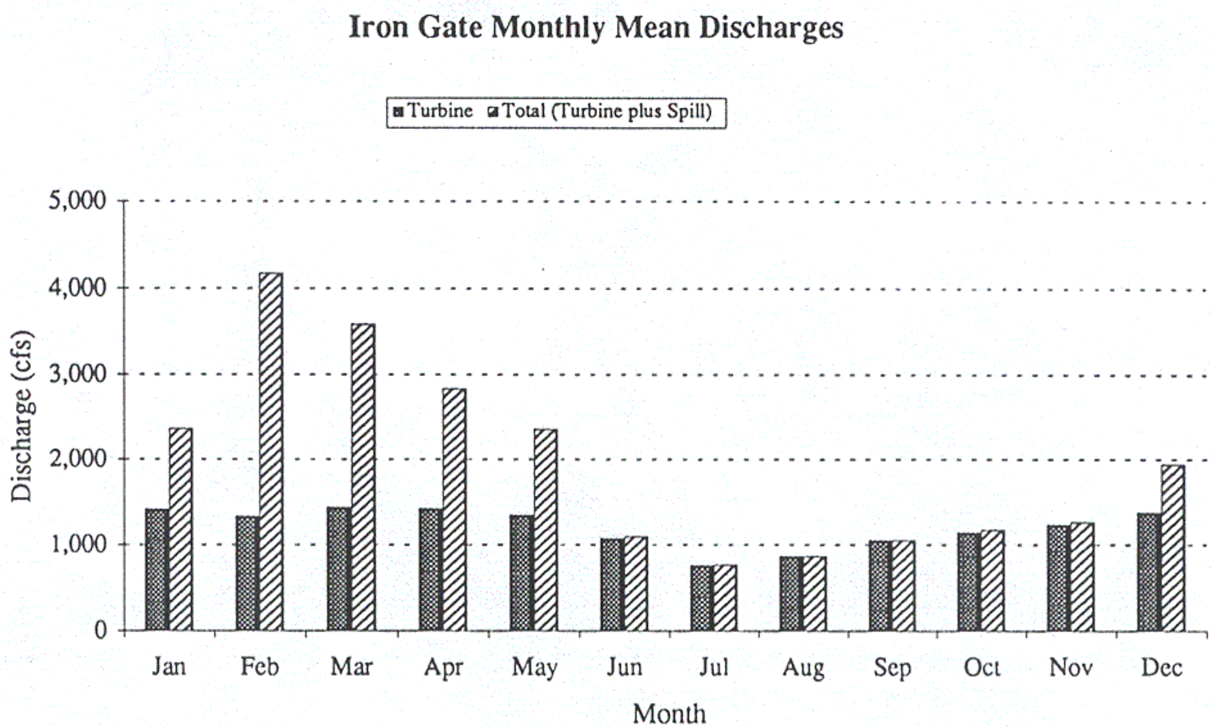


Figure 5-2. Iron Gate 1996 Daily Average Discharges



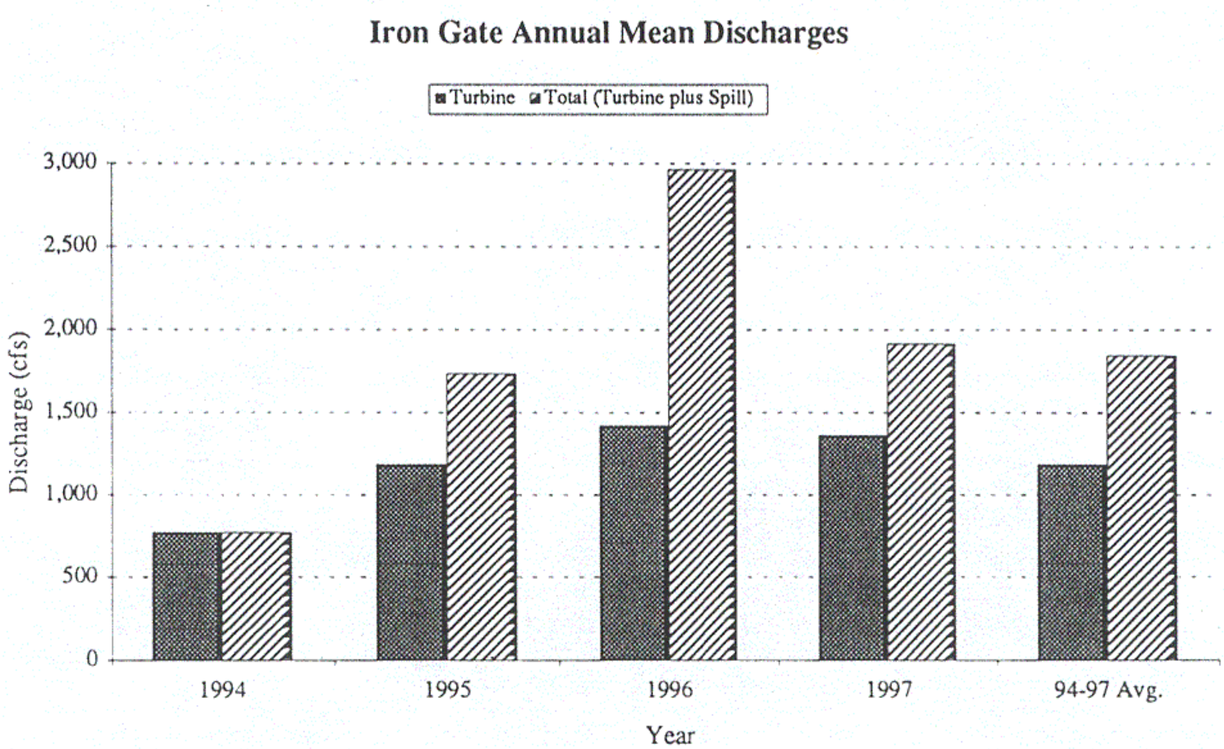


Figure 5-3. Iron Gate discharges, January 1994 to May 1998. a) Monthly mean discharges.
b) Annual mean discharges.

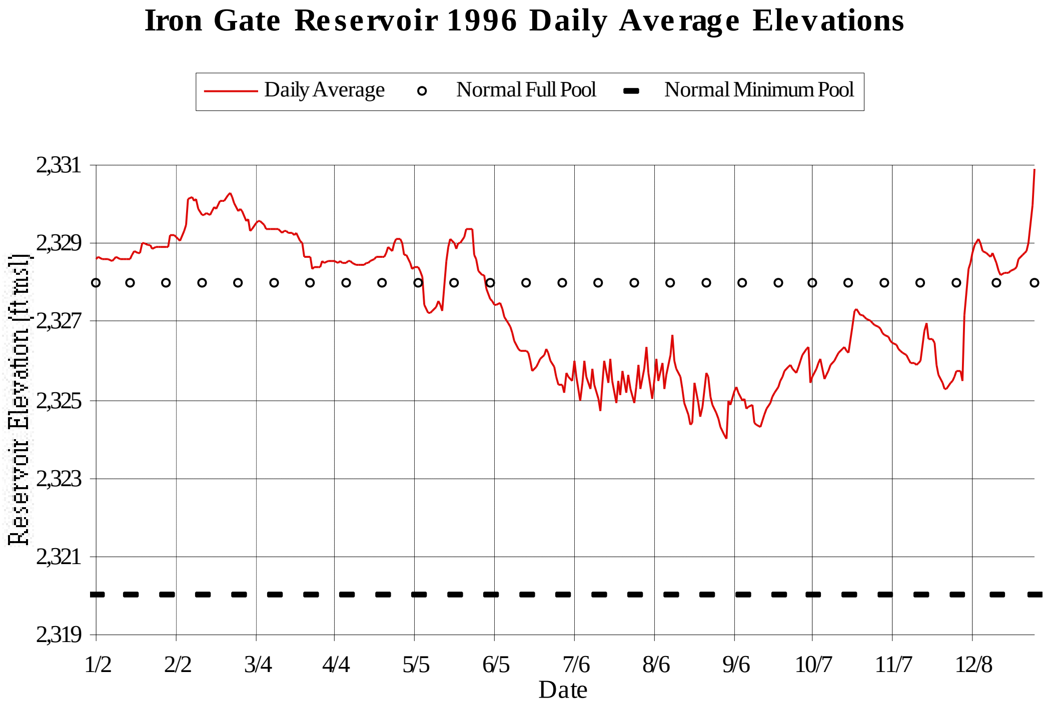
Normal operating conditions for Iron Gate dam provide for a four foot reservoir fluctuation, with the normal full pool elevation at 2,328 ft msl (the spillway crest) and the normal minimum pool elevation at 2,320 ft msl. Daily average values for Iron Gate reservoir elevation for the period of January 1994 through May 1998 were provided by PacifiCorp (1998). Figure 5-4 illustrates the daily average reservoir elevation for each day of 1996 and gives evidence of the flood conditions experienced in the basin during the winters of both 1995-96 and 1996-97. Monthly average elevations for the 1994-98 data set indicate that the reservoir is typically near full pool elevation during the winter months with a gradual lowering in elevation from June through November (Figure 5-4). The average elevation for Iron Gate reservoir from 1994 through 1997 was 2,326.4 ft msl, with an extreme minimum of 2.323.2 in March 1994 and an extreme maximum of 2,330.9 ft msl in December 1996.

d. Water Temperature

Iron Gate reservoir becomes stratified during the summer. To better characterize the water temperature profile, PacifiCorp and UC Davis deployed water temperature loggers at seven depths ranging from 7 to 118 feet during 1996 and 1997. Information regarding data reliability and coverage is noted in Deas and Orlob (1998), though a completed analysis of the data is not known to exist at present. Earlier data relating to stratification is presented in City of Klamath Falls (1986), showing stratification in Iron Gate reservoir as early as April and continuing through late October. The data show reservoir surface temperatures in the range of 16 to 27°C during stratification, with a differential between surface and bottom temperatures ranging from 8 to 19°C. During winter months when the reservoir is not stratified, the data infer that Iron Gate reservoir water temperature is in the general vicinity of 10°C throughout the water column.

As mentioned previously, releases from Iron Gate can occur through the turbine penstock, at the spillway, or through the two hatchery supply intakes. The water temperature of the combined releases from Iron Gate will consequently be dependent on the proportion of flow and localized water temperature through each release point.

Water temperature data were collected by USGS and PacifiCorp during 1996 and 1997 using a continuous-monitoring Hydrolab recorder located just below Iron Gate dam at the access bridge. Data for 1996 were reduced to daily average values and are subsequently displayed in Figure 5-5. In general, water temperature rose above 15°C (the chronic threshold level for salmonid fish) in late May and did not drop back down to this level until mid-October. Temperatures were above the salmonid acute threshold of 20°C during July and August. Comparing this temperature data to the 1996 discharge data at Iron Gate (see Figure 5-2), it is worth noting that the rise in temperature occurs simultaneously with the dramatic



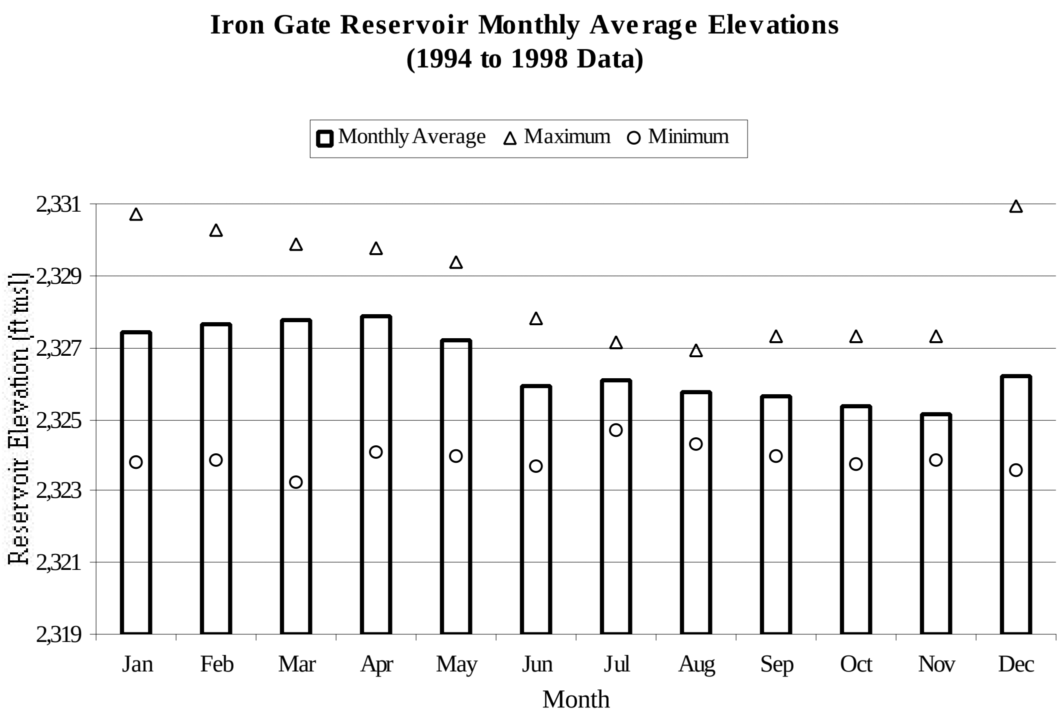


Figure 5-4. Iron Gate Reservoir elevations. a) Daily average elevations for 1996. b) Monthly average elevations for January 1994 to May 1998, also showing range of daily average values.

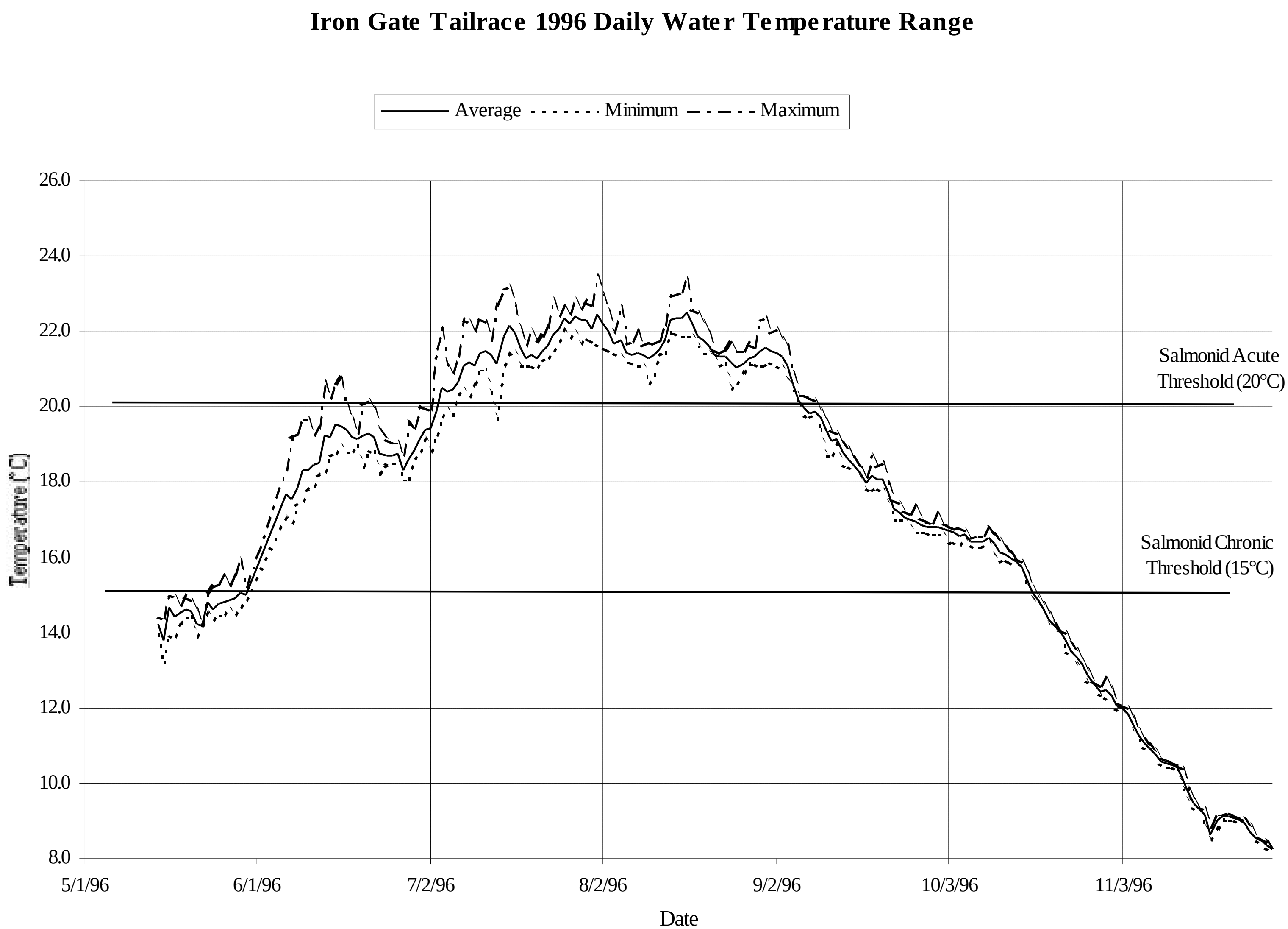


Figure 5-5. Iron Gate Tailrace 1996 Daily Water Temperature Range

decrease in flow following spring runoff and the concomitant increase in travel time through the basin. It is also interesting to note that since no spill occurred at Iron Gate from June through September and since the high level hatchery intake is closed during the summer, these warm waters were drawn predominantly from the penstock intake located about 35 feet below the reservoir surface. This would suggest that the metalimnetic layer within the stratified reservoir that is cool enough to meet fish habitat criteria lies deeper than the penstock intake. This also suggests there is less cool water in the reservoir than postulated by Fortune et al. (1966), who suggested that the metalimnetic layer might lie 10 to 20 feet below the surface. An investigation into the amount of cooler water (≤55°F) in the reservoir found it to be limited to a mean volume of 9,402 acre-feet in August, 6,059 acre-feet in September and 2,650 acre-feet in October (PacifiCorp, 1995). To put these values in perspective, 2,650 acre-feet would be discharged in less than 2 days at the minimum flow rate of 710 cfs.

Water temperatures in the part of the reach above Iron Gate reservoir are reflected in measurements taken at Copco 2 tailrace from 1994 to 1997 (PacifiCorp 1996; Deas and Orlob 1998). Generally, water temperature rose above the chronic threshold level for salmonid fish (15°C) between early May to mid-June and did not return below this level until mid- to late-October. Temperatures rose above the acute threshold of 20°C during July and August of 1994, 1996 and 1997. (Temperature sampling for 1995 began on August 18 with a recorded value around 20°C; it is likely that temperatures were above 20°C for this year as well.) Low temperatures in the vicinity of 2 to 3°C were observed in late December and January.

e. Dissolved Oxygen

The same continuous-recording Hydrolabs noted above for water temperature were also used to monitor dissolved oxygen in the Klamath River just below Iron Gate dam during 1996 and 1997. Data for 1996 were reduced to daily average values and are subsequently displayed in Figure 5-6. Generally, DO does not drop to the acute level of 5.0 mg/L, but the chronic criteria level of 7 mg/L is exceeded intermittently between mid-June and mid-September, and again in late October.

As is typical of deeper lakes and reservoirs, the dissolved oxygen concentration in Iron Gate reservoir is not uniform from top to bottom once stratification occurs. Deas and Orlob (1998) reference data collected by the North Coast Water Quality Control Board (NCWQCB) in May 1996 and May 1997 that shows a roughly inverse relationship between DO and depth, with surface DO concentrations around 10 mg/l and bottom concentrations less than 1 mg/l. Earlier studies (City of Klamath Falls 1986) describe anoxic bottom waters and fully saturated surface waters throughout summer and early fall.

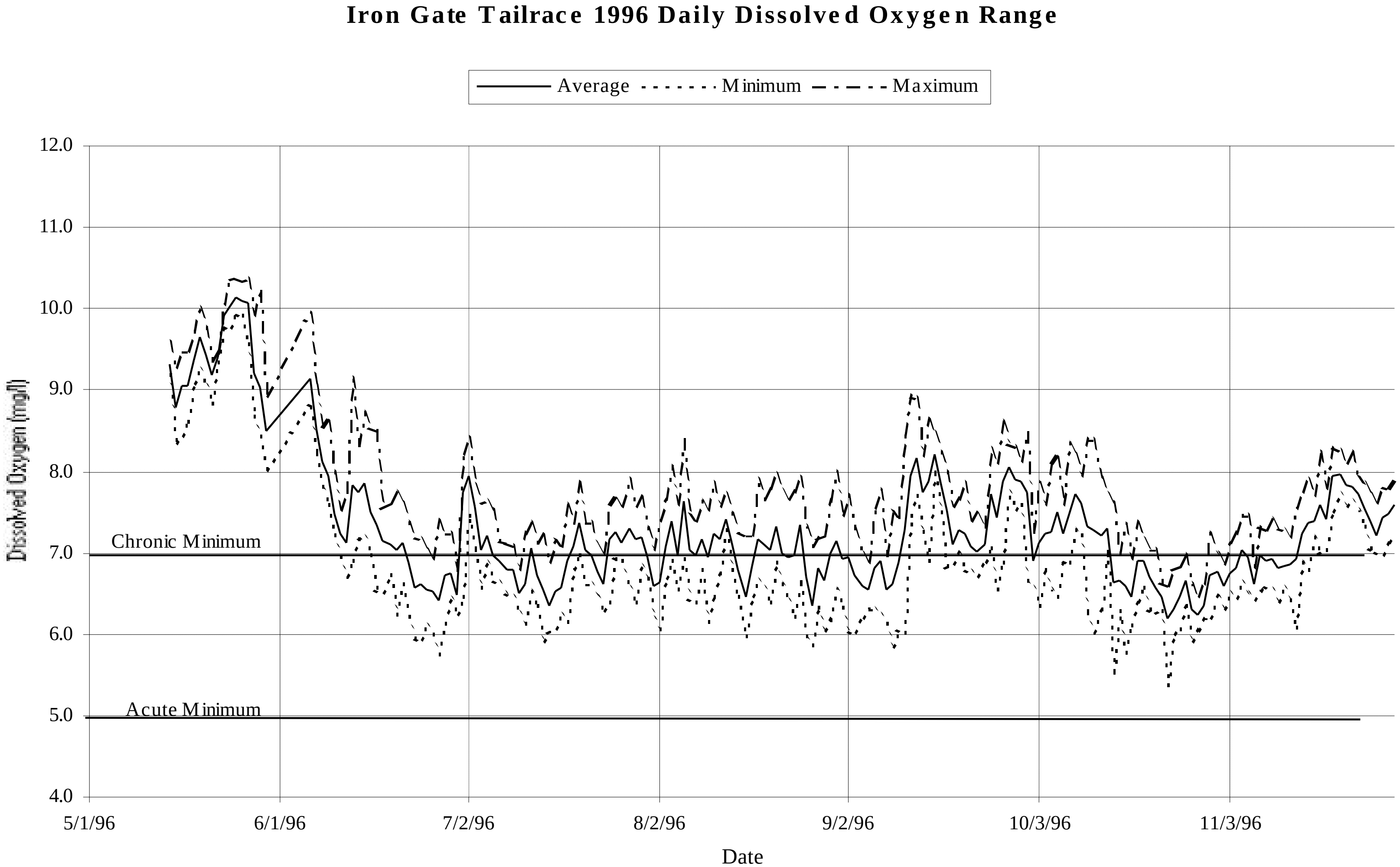


Figure 5-6. Iron Gate Tailrace 1996 Daily dissolved Oxygen Range

For the free-flowing upper portion of this reach (between the Copco 2 powerhouse and diversion dam), Deas and Orlob (1998) estimated that DO concentrations would be directly related to Copco dam release conditions measured by NCWQCB in 1997. Generally, they estimated DO to be near or slightly below DO saturation values during winter and early spring, with levels decreasing to about 3 mg/l below saturation during summer and into early fall. However, given the 1.5 mile length of this upper stretch, it is anticipated that natural aeration may bring the water to near-saturation levels by the time it reaches the head end of Iron Gate reservoir.

f. pH

The continuous-recording Hydrolabs noted above for water temperature were also used to monitor pH in the Klamath River just below Iron Gate dam during 1996 and 1997. Data for 1996 were reduced to daily average values and are displayed in Figure 5-7. There are no pH occurrences outside the desired range of 6 to 9.

g. Predators

The presence of predators can impact juvenile survival during downstream migration, especially if there is significant delay caused during reservoir navigation. During 1998 and 1999, PacifiCorp and OSU sampled fish in Iron Gate reservoir as part of a study to determine status of endangered suckers in Klamath River mainstem reservoirs. Preliminary data show the presence of several fish species, with the introduced yellow bullhead showing the highest catch per unit effort (CPUE) at 18, and the native Tui chub being second with a CPUE of 5.5 (PacifiCorp 1999). The predominant species found during earlier fish surveys were yellow perch, largemouth bass, Tui chub, pumkinseed, golden shiner and brown bullheads (CDFG 1990, CDFG 1992). It was noted that many of these species feed on aquatic insects and plankton when small and then feed on fish species as they grow. As a result, in addition to there being a predatory issue, there is also an issue of interspecies competion with juvenile salmonids and suckers for feeding and habitat.

5.3 Copco 2 to Copco 1

a. General Characteristics

This reach of the Klamath River spans 0.3 miles, from Copco 2 dam located at RM 198.3 upstream to Copco 1 dam at RM 198.6. The reach is comprised entirely of the small Copco 2 reservoir, having a surface area of 40 acres and a total storage capacity of 74 acre-feet. Copco 2 powerhouse is operated as a slave to Copco 1, such that the two powerhouses have the same hydraulic flow rate at any one time, thereby eliminating any need for water storage at Copco 2. The banks of Copco 2

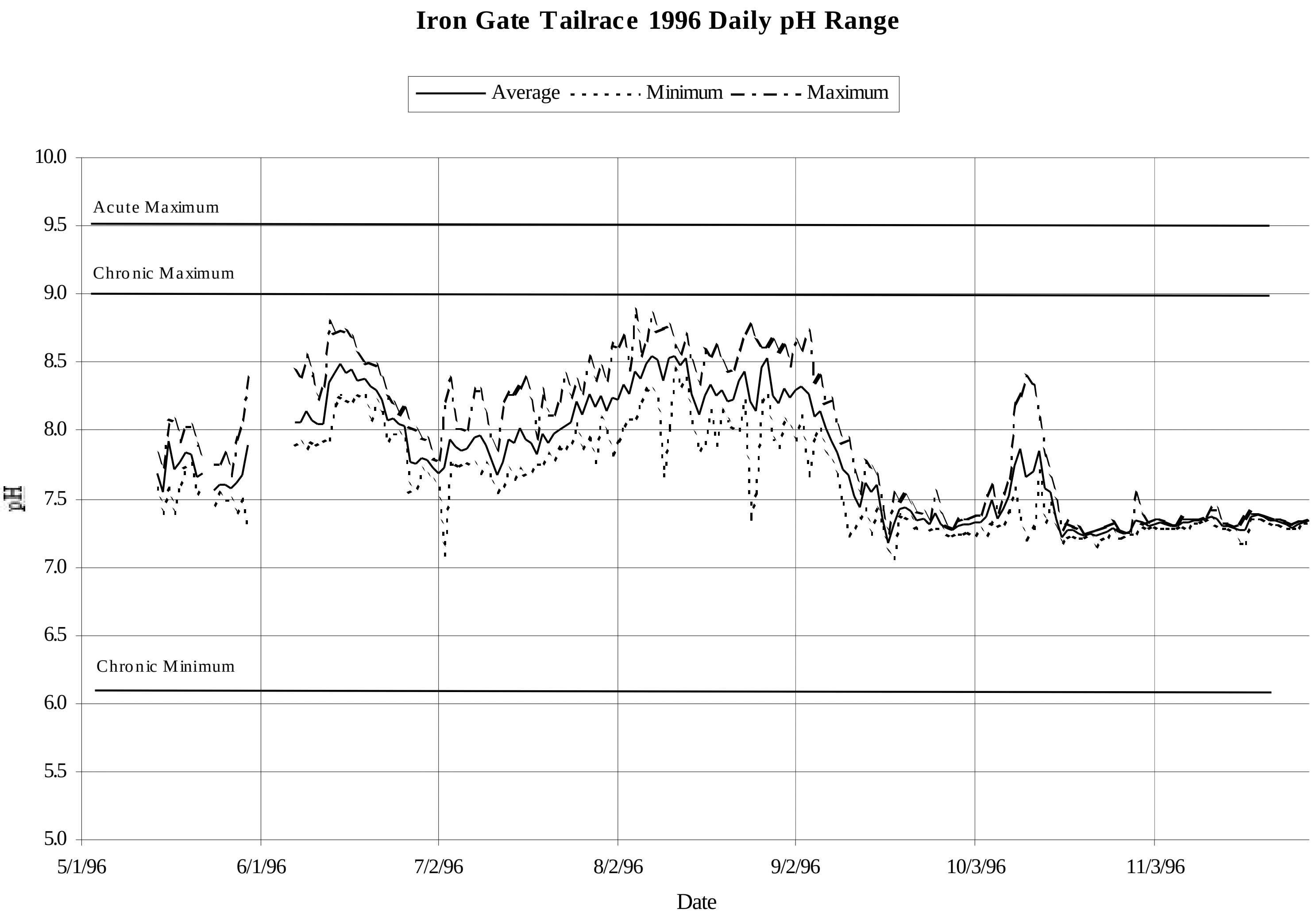


Figure 5-7. Iron Gate Tailrace 1996 Daily pH Range

reservoir are quite steep, resulting in a small watershed area and insignificant tributary inflow for this reach.

There is very limited data on environmental conditions for this reach, most likely due to its limited size. Because of the integrated manner in which Copco 1 and Copco 2 are operated, turbine flow at either site can be represented by measurements recorded by PacifiCorp at Copco 2 powerhouse. Similarly, spill flow for both Copco 1 and 2 can be represented by measurements recorded by PacifiCorp at Copco 1 dam.

b. Discharge

Discharge from Copco 2 can occur at three locations: through the penstock intake located at the left bank of the dam; at the spillway; or through a short flume (also located at the left bank) that provides a flow of about 10 cfs to the bypass reach below Copco 2 dam.

Daily average discharge values for turbine releases at Copco 2 and spill releases at Copco 1 have been supplied by PacifiCorp for this report for the period January 1994 through May 1998 (PacifiCorp 1998). Daily average discharges for 1996 are presented in Figure 5-8 to illustrate day-to-day variations that can occur. Turbine flows were relatively constant around 2,800 cfs from January through mid-April and generally around 1,400 cfs for the rest of the year. Exceptions to this occurred in the low-flow months of July and August, when turbines were generally run at around 1,200 cfs or 700 cfs. Spill occurred in the months of January through May and again in December, showing periods where storm and snowmelt runoff could vary the total Klamath River flow by more than 1,000 cfs in a day or nearly 5,000 cfs in a week. Peak discharge in 1996 occurred on February 22 with a turbine flow of 2,787 cfs and 9,377 cfs of spill.

Seasonal flow patterns can be seen in monthly average discharge data derived from the entire 1994 to 1998 record (Figure 5-9a). Spill typically occurs during December through May, while June through November are characterized by little if any spill and reduced turbine discharge. The month having the highest total flow was February, while the lowest flow conditions occurred in July.

The dramatic variation in climatic conditions that can occur within the basin is also evidenced in the 1994 to 1998 discharge data. During 1994 the annual average discharge at Copco was only 669 cfs, and all flow was routed through the powerhouse with no spill (Figure 5-9b). In sharp contrast, the annual average discharge in 1996 was 2,754 cfs (4.1 times the 1994 value), and the average annual value for spill was 1,089 cfs. The average discharge from Copco for 1994 through 1997 was calculated to be 1,885 cfs, with 1,290 cfs passing through the powerhouse and 595 cfs passing over the spillway.

The daily minimum discharge for the period was 0 cfs following a turbine trip and plant outage occurrence in 1994.

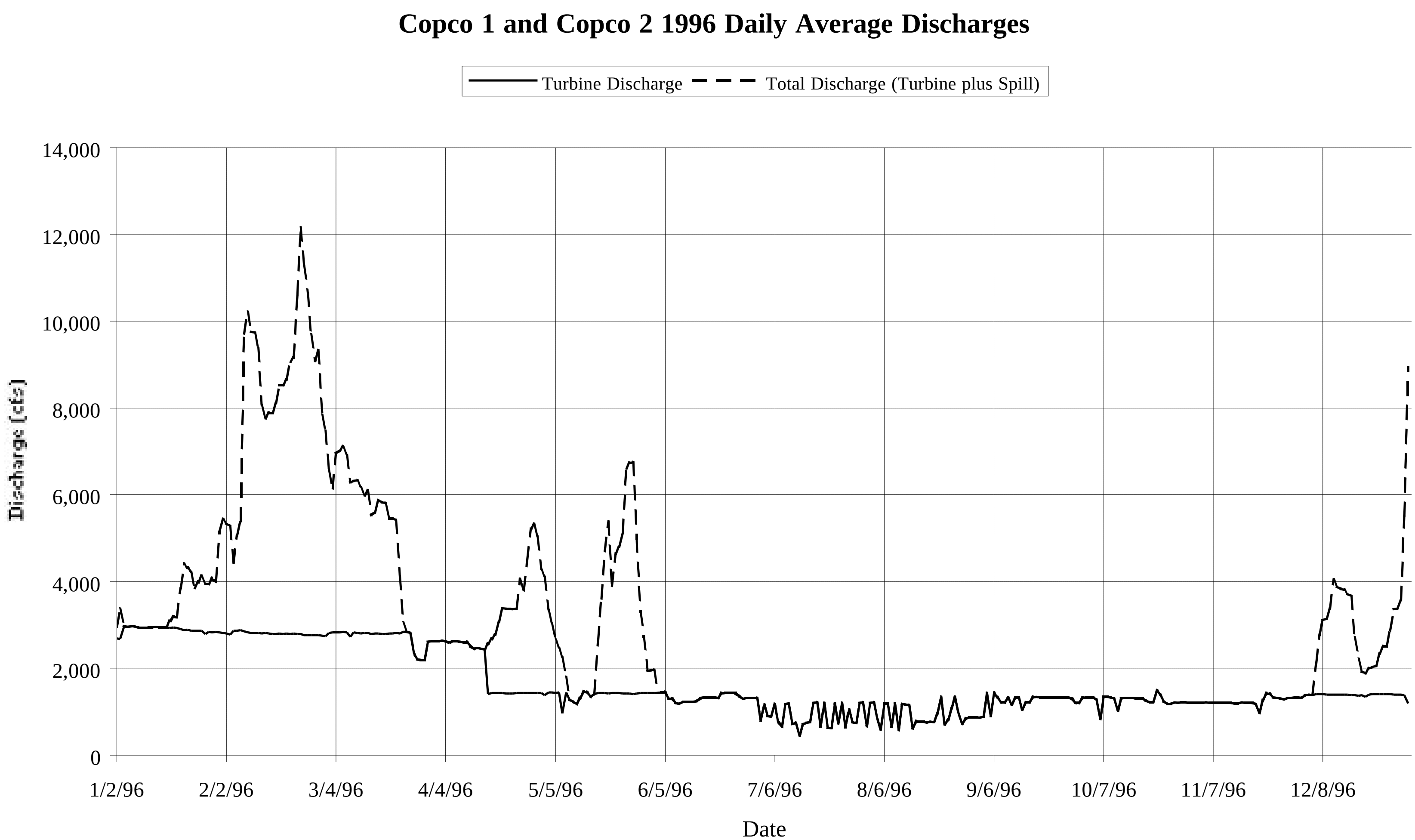
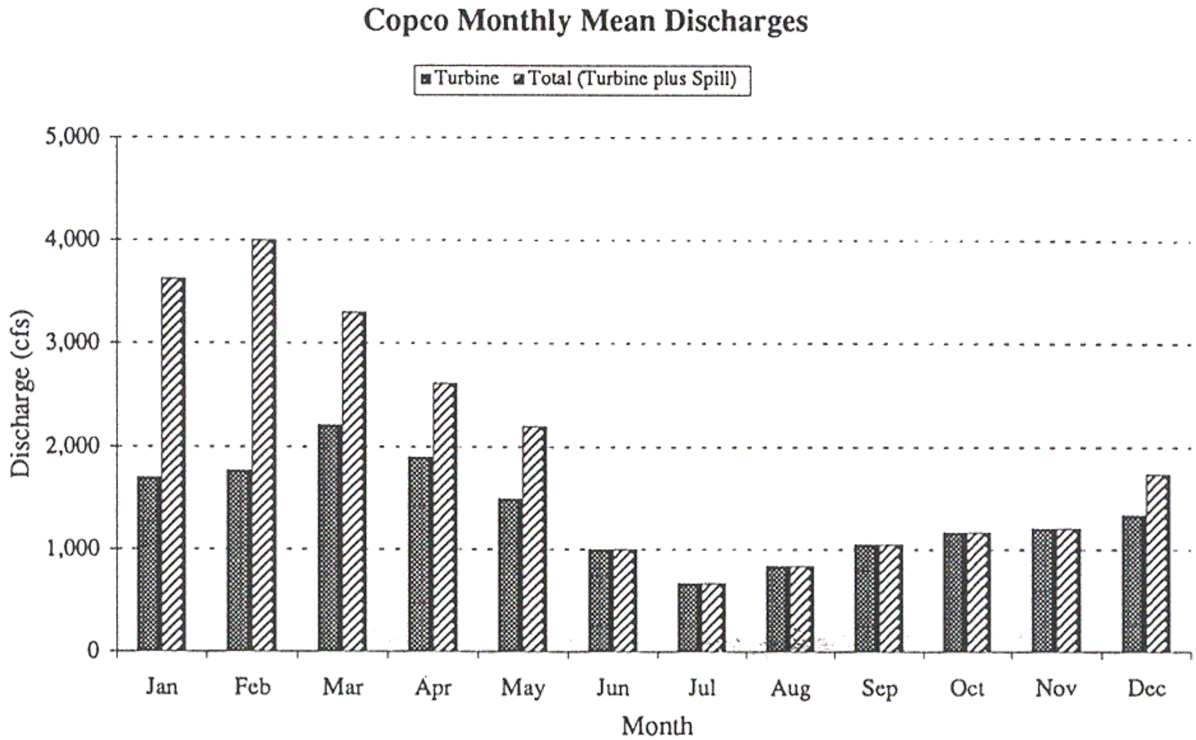


Figure 5-8. Copco 1 and Copco 2 1996 Daily Average Discharges



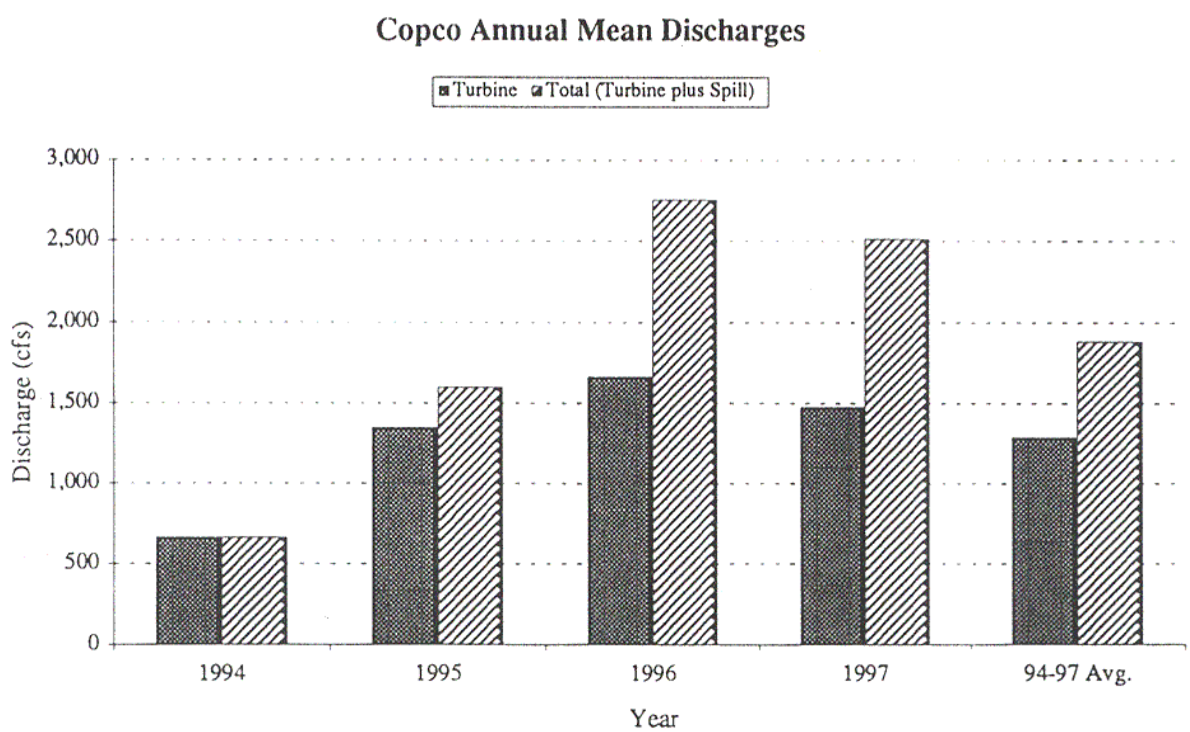


Figure 5-9. Copco discharges, January 1994 to May 1998. a) Monthly mean discharges. b) Annual mean discarges.

The daily maximum discharge of 13,044 cfs occurred in 1997.

c. Reservoir Retpention and Elevation

The total storage capacity of Copco 2 reservoir was noted in Section 4 to be 73.5 acre-feet. At the annual average flow rate of 1,885 cfs identified above, the average retention rate in the reservoir is .02 days, or 0.5 hour. Between extreme flow events of 710 cfs for a minimum and 10,000 cfs as a maximum, the retention time would range from 1.2 hour down to 0.1 hour.

Copco 2 dam is typically operated at the normal full pool elevation of 2,483.0 ft msl (the spillway crest). Reservoir surface elevations are not routinely measured at Copco 2. It is anticipated that elevations are quite stable since Copco 2 operates in conjunction with Copco 1.

d. Water Temperature

There are no known studies that monitor water temperatures specifically within this reach. However, because of the shallow depths and short retention time within Copco 2 reservoir, it is expected that water temperatures are relatively constant with depth throughout the year. With no strong stratification, water temperatures should be similar for releases through the penstock, spillway or bypass flume. As a consequence, temperatures measured at the tailrace of Copco 2 powerhouse should be representative of temperatures within Copco 2 reservoir. These results were described previously in Section 5.2.d for the discussion of conditions in the reach above Iron Gate reservoir. If applied generally to this reach, it can be expected that water temperatures rise above the chronic threshold level for salmonid fish (15°C) around May and do not return below this level until mid- to late-October. Temperatures may rise above the acute threshold of 20°C during July and August. In December and January, temperatures in the vicinity of 2 to 3°C can be expected.

e. Dissolved Oxygen

Deas and Orlob (1998) estimated monthly DO concentrations for releases from Copco 1 dam using grab sample measurements collected by NCWQCB and USGS in 1996 and 1997. Generally, they estimated DO to be near or slightly below DO saturation values from January into July, with levels decreasing to 2 or 3 mg/l below saturation during August through December. Their estimates place the DO level near or below the chronic threshold of 7 mg/l in July and August.

Direct measurements of DO at the Copco 1 tailrace were collected by PacifiCorp (1996) on several dates during 1994, 1995 and 1996. DO levels were generally in the range of 10 to 12 mg/l in the spring with a gradual decrease towards 6 to 8 mg/l in the summer. All measurements were above the salmonid acute minimum threshold of 5.0 mg/l, but measurements collected during July through October 1996 were below the chronic minimum threshold of 7.0 mg/l .

f. pH

PacifiCorp (1996) measured pH levels at the Copco 1 tailrace on several occasions during 1994, 1995 and 1996. Generally, pH values ranged between 7.5 and 8.5 with higher values tending towards the summer months. All measurements were within the criteria range of 6 to 9 considered as acceptable pH for salmonid fish.

g. Predators

There are no known studies that have surveyed fish populations or abundance within this specific reach.

5.4 Copco 1 to J.C. Boyle

a. General Characteristics

This reach of the Klamath River spans 26.1 miles, from Copco 1 dam located at RM 198.6 upstream to J.C. Boyle dam at RM 224.7. The reach has three characteristic regions: Copco reservoir in the lower part of the reach, a free-flowing and steep-gradient river in the middle portion, and an upper portion consisting of the bypass reach between the J.C. Boyle Powerhouse and Dam. The principal tributaries entering the Klamath River in this reach are Rock Creek (RM 213.9), Shovel Creek (RM 206.5) and Long Prairie Creek (RM 203.3). The state boundary between California and Oregon occurs within this reach at RM 209.3. The eleven mile stretch from the state line upstream to the J.C. Boyle Powerhouse was designated an Oregon State Scenic Waterway in 1988 and a Federal Wild and Scenic River in 1994 (Forbes and Elswick 1995).

Copco reservoir is about 4.5 miles long and has a surface area of 1,000 acres. The water depth just upstream of the dam is estimated to be 125 feet deep based on a normal full pool water surface elevation of 2,606 ft msl and an original river channel elevation of 2,481 ft msl. With a total storage capacity of 45,390 acre-feet, Copco reservoir is about three-quarters the size of Iron Gate reservoir.

From the head end of Copco reservoir, the river extends about 17.3 miles to the tailrace of the J.C. Boyle Powerhouse at RM 220.4. This stretch has a fairly steep gradient with an average drop of 42 feet per mile. The J.C. Boyle Powerhouse typically operates during the summer and fall as a “peaking” facility, resulting in greater discharges during the daytime hours of high electrical demand and lower discharges at night.

The upper 4.3 miles of this reach is a bypass area between J.C. Boyle Powerhouse and dam. Flows of about 100 cfs are released into this reach at the dam, and an additional 250 to 300 cfs is supplied by perennial springs located in the vicinity of RM 224. The bypass reach has a very steep gradient of about 100 ft per mile which factors into the limited amount of gravel available for spawning habitat (ODFW 1997).

Environmental conditions for the Copco-J.C. Boyle reach are currently monitored by multiple sources. A USGS water-stage recorder (#11510700) is located on the right bank 0.7 mile downstream of J.C. Boyle Powerhouse. The gage has been maintained from January 1959 through the present. In 1996 and 1997, the USGS and PacifiCorp conducted water quality sampling using continuous-monitoring Hydrolab recorders at two locations within this reach: one near the state line, about 0.25 mile downstream of the California border near Shovel Creek; and a second downstream of the J.C. Boyle Powerhouse at the beginning of the canyon section. Operational data on turbine flow, spill flow, and reservoir elevation for Copco and J.C. Boyle are maintained by PacifiCorp.

b. Discharge

The WY 1960-95 period of record for the USGS gage below John C. Boyle Powerhouse exhibits a mean annual Klamath River flow of 1,764 cfs. The extremes for this same period are a maximum discharge of 11,000 cfs on 3/5/72 and a minimum discharge of 283 cfs on 2/17/68 (USGS 1999). Tributary flows from Rock Creek, Shovel Creek and Long Prairie Creek add to the Klamath River flow downstream from this gage and before reaching Copco dam.

Discharge from Copco dam can occur at two general locations: through the penstock intakes located at the right bank of the dam, or at the spillway. The intakes are located about 32 feet below the normal reservoir water surface.

Copco 1 and Copco 2 are operated in a “slave” mode such that turbine and spill releases are the same at each location. From 1994 through 1997, the average discharges from the Copco facilities were calculated to be 1,885 cfs, with 1,290 cfs passing through each powerhouse and 595 cfs passing over the spillways. A more detailed description of the Copco discharges is provided in Section 5.3.b.

c. Reservoir Retention and Elevation

The total storage capacity of Copco reservoir was noted in Section 4 to be 45,390 acre-feet. At the annual average flow rate of 1,885 cfs identified above, the average retention rate in the reservoir is 12 days. Between extreme flow events of 710 cfs for a minimum and 10,000 cfs as a maximum, the retention time would range from 32 days down to 2 days.

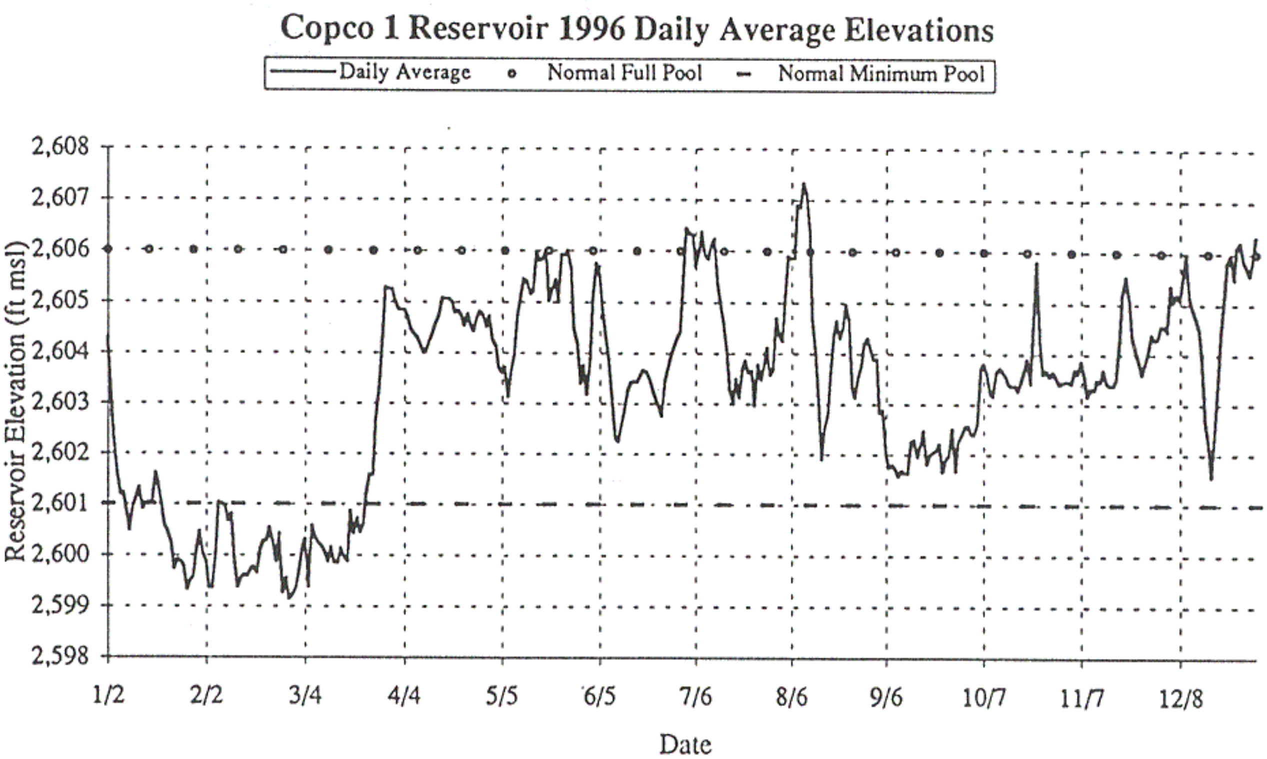
Normal operating conditions for Copco 1 dam provide for a five foot reservoir fluctuation, with the normal full pool elevation at 2,606 ft msl and the normal minimum pool elevation at 2,601 ft msl. Daily average values for Copco reservoir elevation for the period of January 1994 through May 1998 were provided by PacifiCorp (1998). Figure 5-10a illustrates the daily average reservoir elevation for each day of 1996. Monthly average elevations for the 1994-98 data set indicate that the reservoir is generally near full pool elevation during the summer months and near minimum pool elevation in winter (Figure 5-10b). The average elevation for Copco reservoir from 1994 through 1997 was 2,604.1 ft msl, with an extreme minimum of 2.598.5 in September 1997 and an extreme maximum of 2,607.4 ft msl occurring in summer of both 1995 and 1997.

d. Water Temperature

Copco reservoir becomes stratified during the summer. Data relating to stratification is presented in City of Klamath Falls (1986), showing stratification conditions that are generally less extreme and shorter in duration than those seen in Iron Gate reservoir. Copco reservoir temperature differentials were above 5°C during June through September, peaking around 14°C in July. Water temperatures at the reservoir surface during this period were in the range of 16 to 24°C. During winter months when the reservoir is not stratified, the data infer that Copco reservoir water temperature is in the general vicinity of 6°C throughout the water column.

Upstream from the reservoir, there are two locations for which continuous water temperature data were collected by USGS and PacifiCorp during 1996 and 1997 (USGS 1998). Data for 1996 were reduced to daily average values and are subsequently displayed in Figure 5-11 for the State Line site and in Figure 5-12 for the J.C. Boyle Powerhouse tailrace site. At the State Line, water temperatures generally rose above 15°C (the chronic threshold level for salmonid fish) in May and did not drop back down to this level until early October. Daily average temperatures at this site were above the salmonid acute threshold of 20°C during July. By late October, however, the daily average temperature was in the vicinity of 7°C.

Further upstream near the J.C. Boyle Powerhouse, the average and minimum water temperatures in summer were generally 2 to 4°C cooler than those at State Line, with the average temperature rising above the acute threshold of 20°C on only a few occasions (Figure 5-12). The average fall temperature at J.C. Boyle was around 8°C, or about 1°C warmer than at State Line. These conditions reflect the influence of springs located upstream of the powerhouse in the bypass reach, with a year-round contribution of about 250 cfs of 7 to 12°C groundwater (ODFW 1997). The cooler minimum temperatures at J.C. Boyle can be attributed to normal powerhouse peaking operations, whereby the total flow at the bottom of the bypass reach can be as little as 25% reservoir releases, with the rest comprised of cool spring flow (PacifiCorp 1996). By the time this water reaches the State Line, however, it has



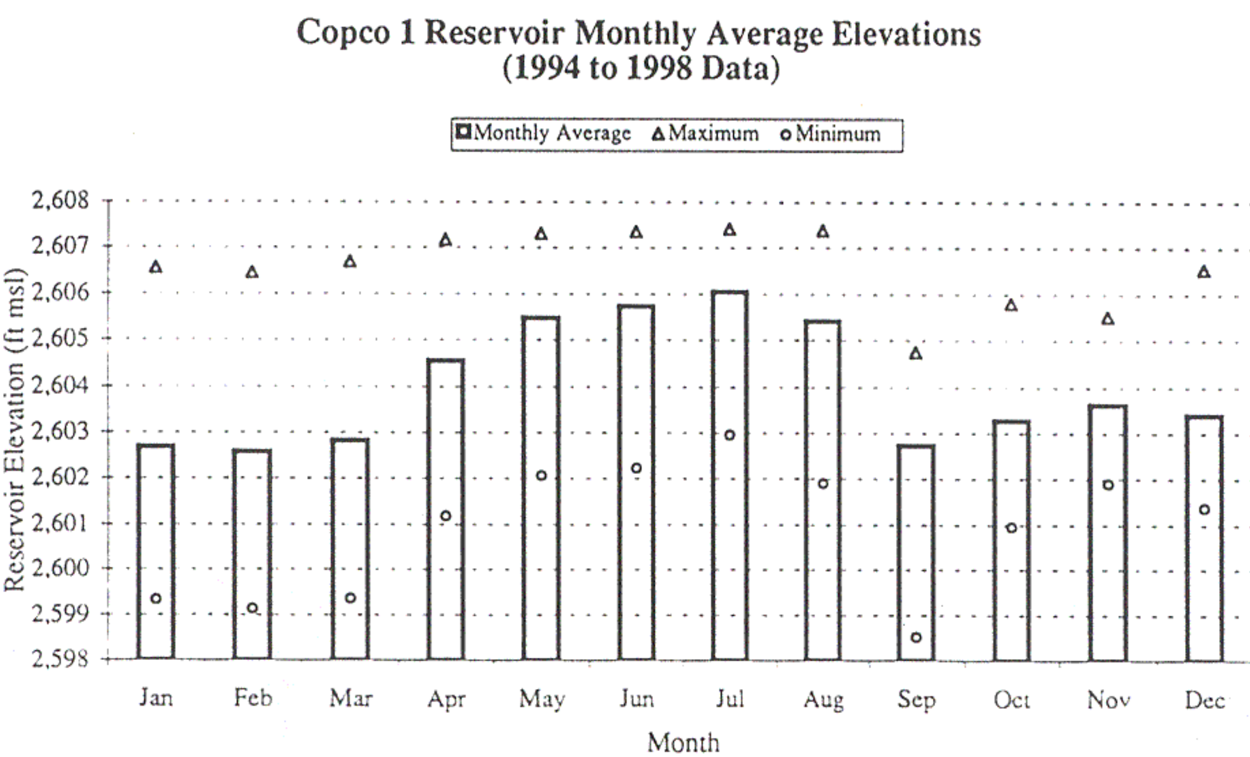


Figure 5-10. Copco 1 Reservoir elevations. a) Daily average elevations for 1996. b) Monthly average elevations for January 1994 to May 1998, also showing range of daily average values.

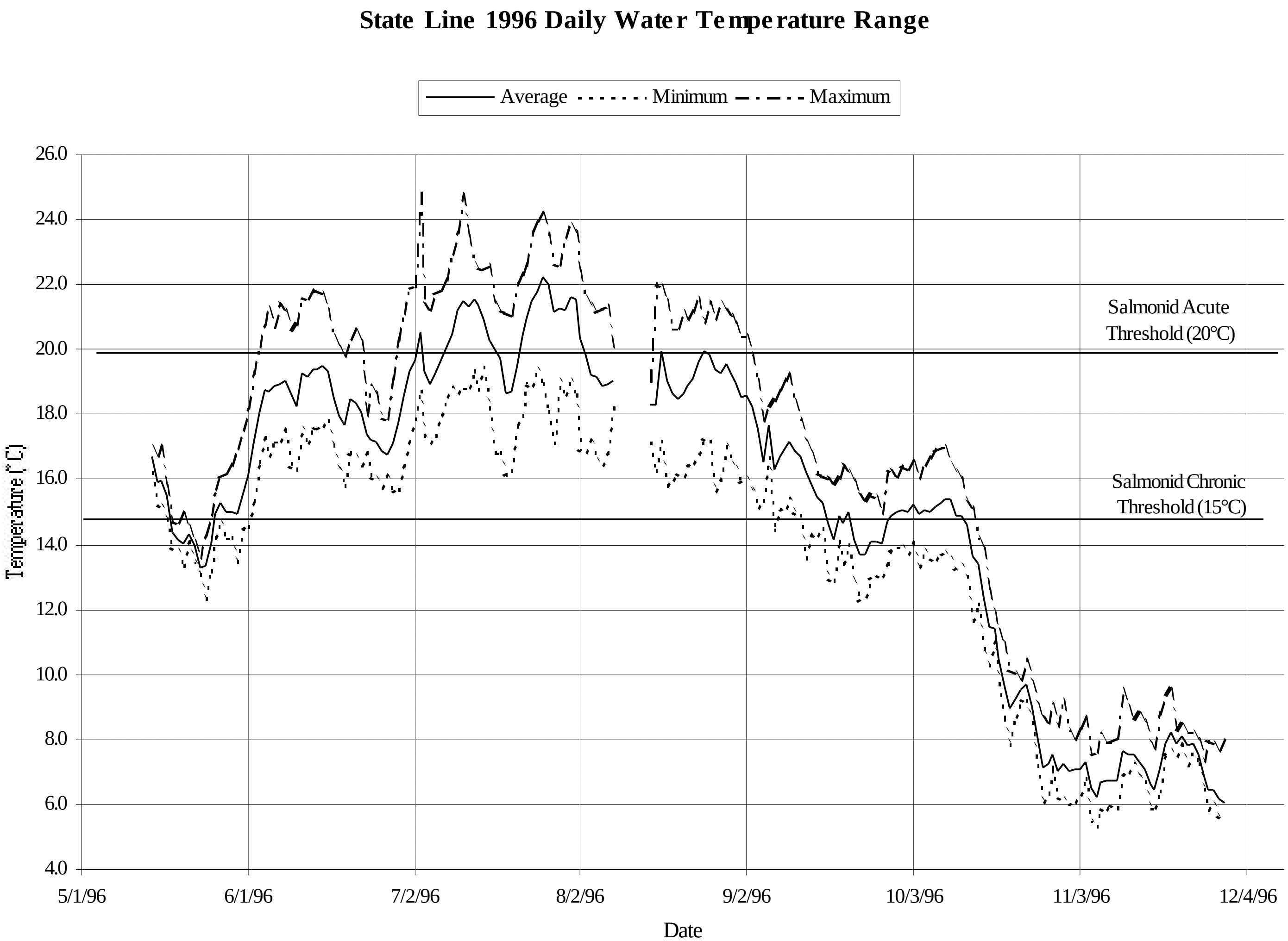


Figure 5-11. State Line 1996 Daily Water Temperature Range

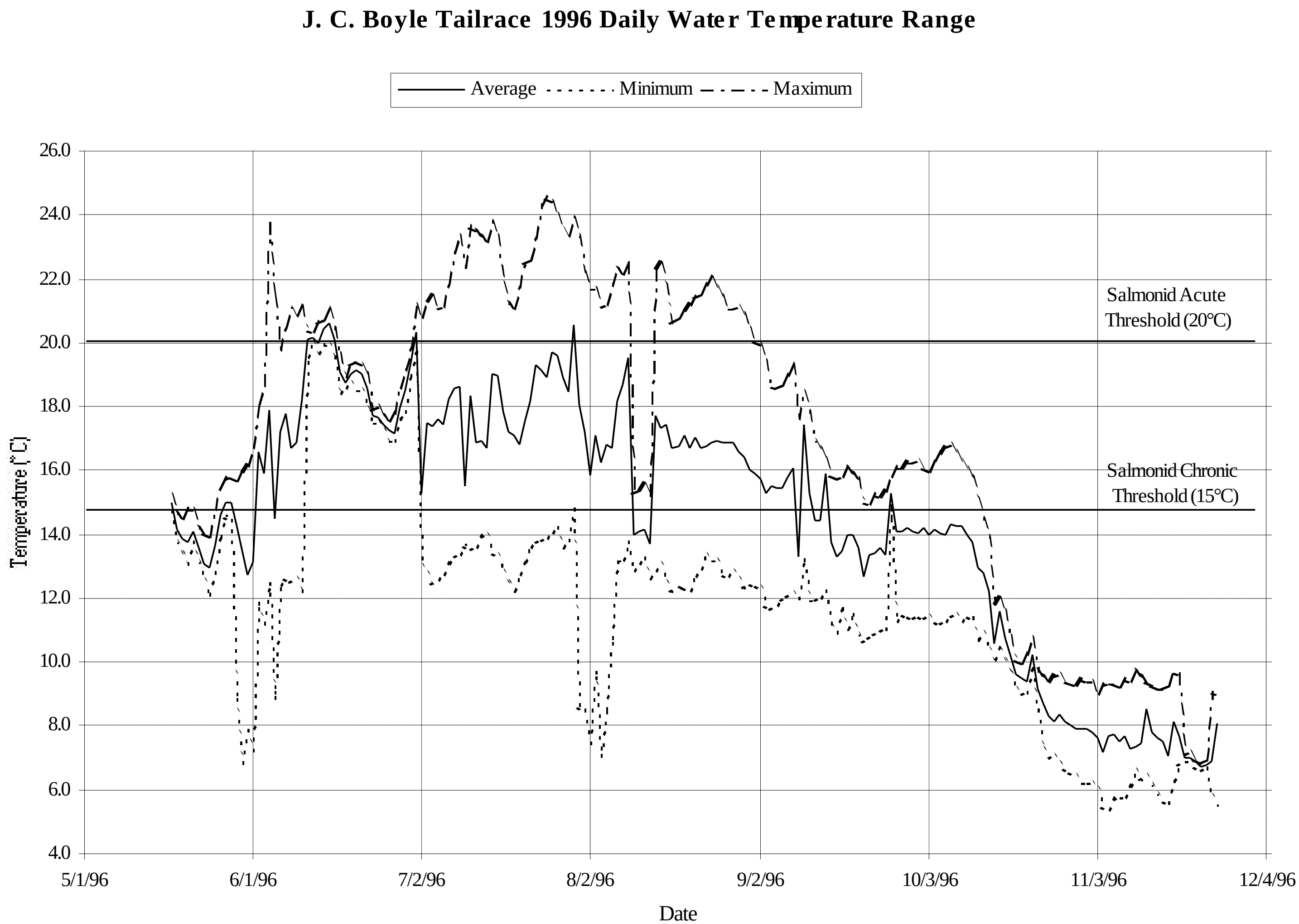


Figure 5-12. J.C. Boyle Tailrace 1996 Daily Water Temperature Range

equilibrated with air temperatures to develop a temperature range more typical of diurnal variations elsewhere in the basin.

Additional water temperature measurements were collected by PacifiCorp throughout this reach from 1994 to 1996 (PacifiCorp 1996). Measurements taken at the top of the J.C. Boyle bypass reach during 1994, 1995 and 1996 showed temperatures ranging from less than 3°C in the winter to the mid-20's in the summer. At the bottom of the bypass reach, there was a narrower temperature range of about 5 to 16°C, again showing the year-round influence of the springs. In 1996, water temperatures were measured in the Shovel Creek tributary. Daily maximum water temperatures went slightly above the chronic salmonid threshold of 15°C during June through August, peaking around 17°C. Daily minimum temperatures, however, remained below 13°C.

e. Dissolved Oxygen

The same continuous water quality sampling noted above for water temperature was also used to monitor dissolved oxygen at the State Line and J.C. Boyle Powerhouse sites during 1996 and 1997 (USGS 1998). Data for 1996 were reduced to daily average values and are subsequently displayed in Figures 5-13 and 5-14 for State Line and J.C. Boyle, respectively. On two occasions at J.C. Boyle, the daily minimum DO came near the acute level of 5 mg/L. More generally, however, the daily average and minimum DO exceed the chronic criteria level of 7 mg/L intermittently from June through mid- October.

From 1994 through 1996, PacifiCorp collected five to eight DO samples each year at five other sites in this reach: Copco reservoir inflow, J.C. Boyle tailrace, the bottom of the bypass reach, the top of the bypass reach, plus the tributary of Shovel Creek (PacifiCorp 1996). In a few samples at the J.C. Boyle tailrace and the top of the bypass reach, DO levels were below the chronic threshold of 7 mg/L. In Shovel Creek, DO never went below 9 mg/L.

As is typical of deeper lakes and reservoirs, the dissolved oxygen concentration in Copco reservoir is not uniform from top to bottom once stratification occurs. Earlier studies (City of Klamath Falls 1986) describe anoxic bottom waters and fully saturated surface waters throughout summer and early fall.

f. pH

The same continuous water quality sampling noted above for water temperature was also used to monitor pH at the State Line and J.C. Boyle tailrace sites during 1996 and 1997 (USGS 1998). Data for 1996 were reduced to daily average values and are subsequently displayed in Figures 5-15 and 5-16 for State Line and J.C. Boyle, respectively. Generally, pH values at both sites varied between 7.0 and 9.0, with a daily range of about 0.5 pH unit. All measurements were within the criteria range of 6 to 9 considered acceptable for salmonid fish.

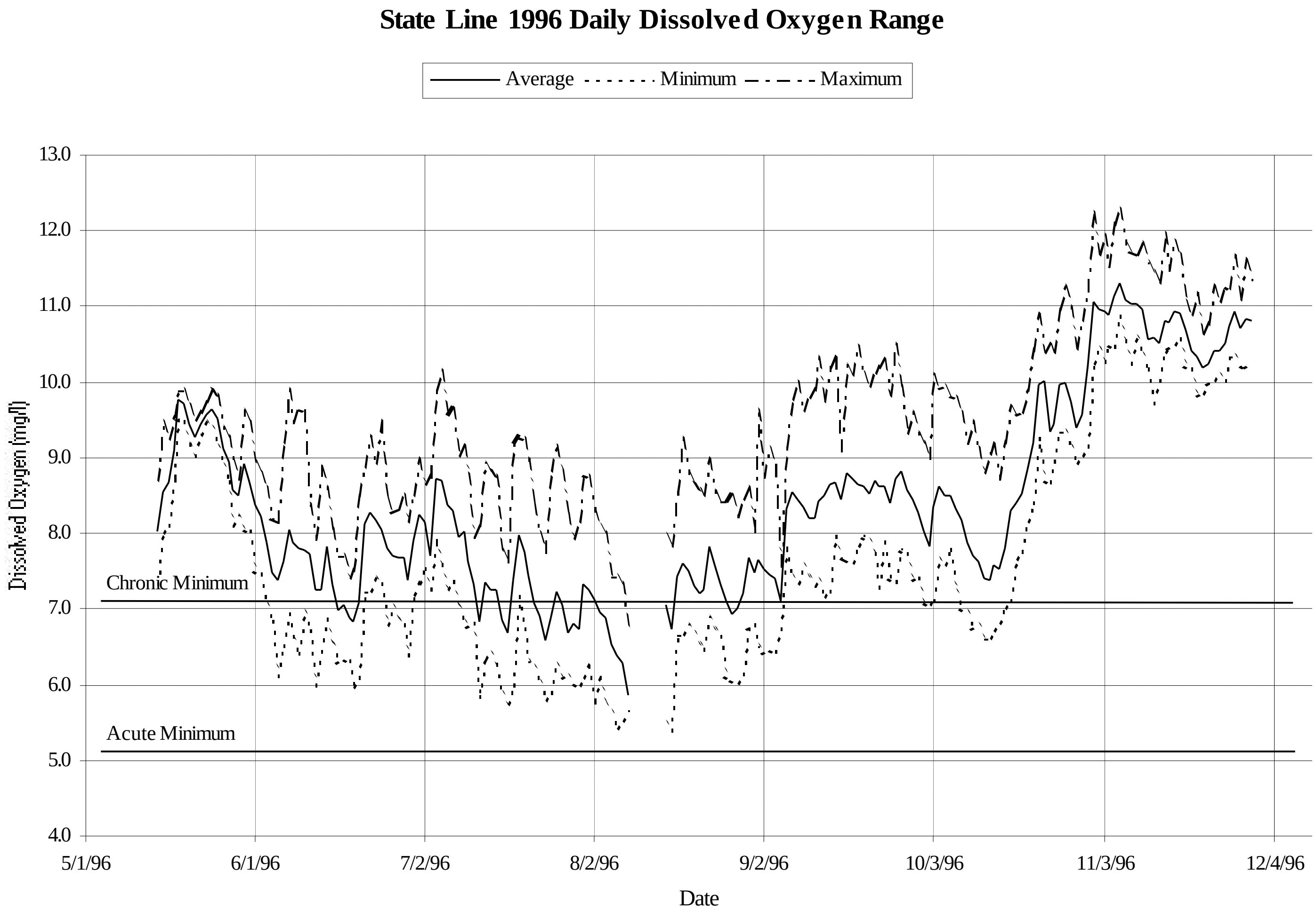


Figure 5-13. State Line 1996 Daily Dissolved Oxygen Range

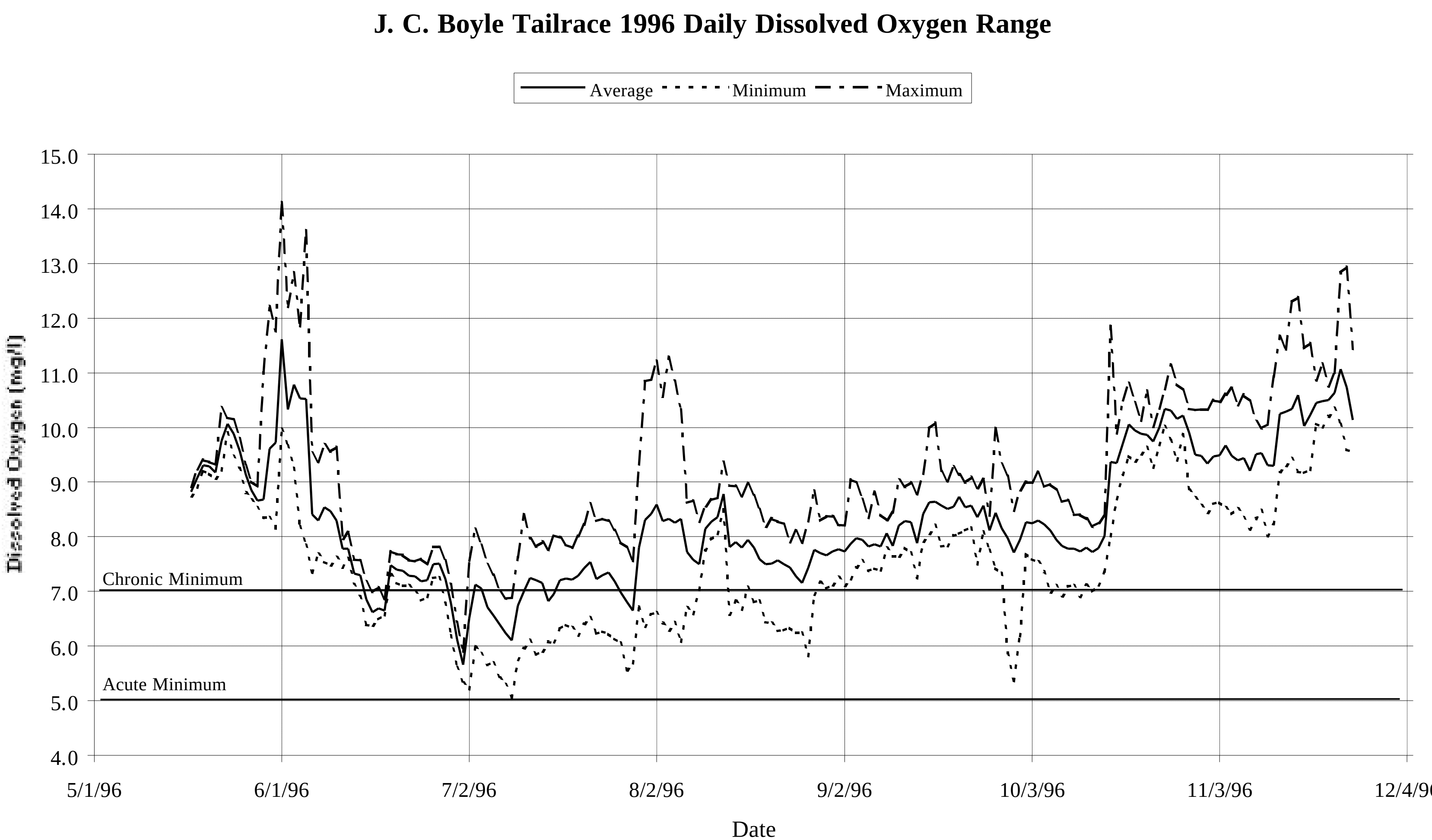


Figure 5-14. J.C. Boyle Tailrace 1996 Daily Dissolved Oxygen Range

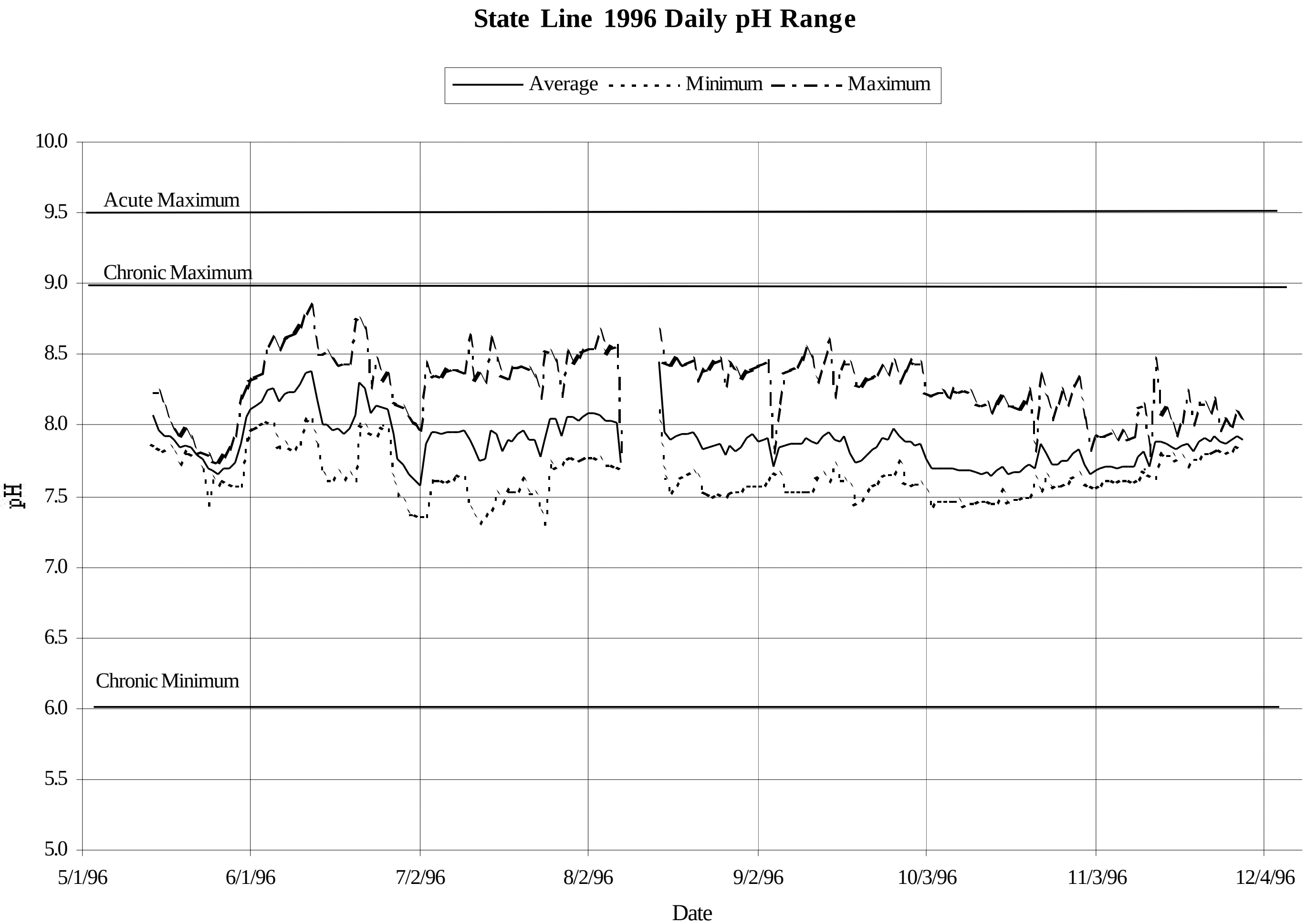


Figure 5-15. State Line 1996 Daily pH Range

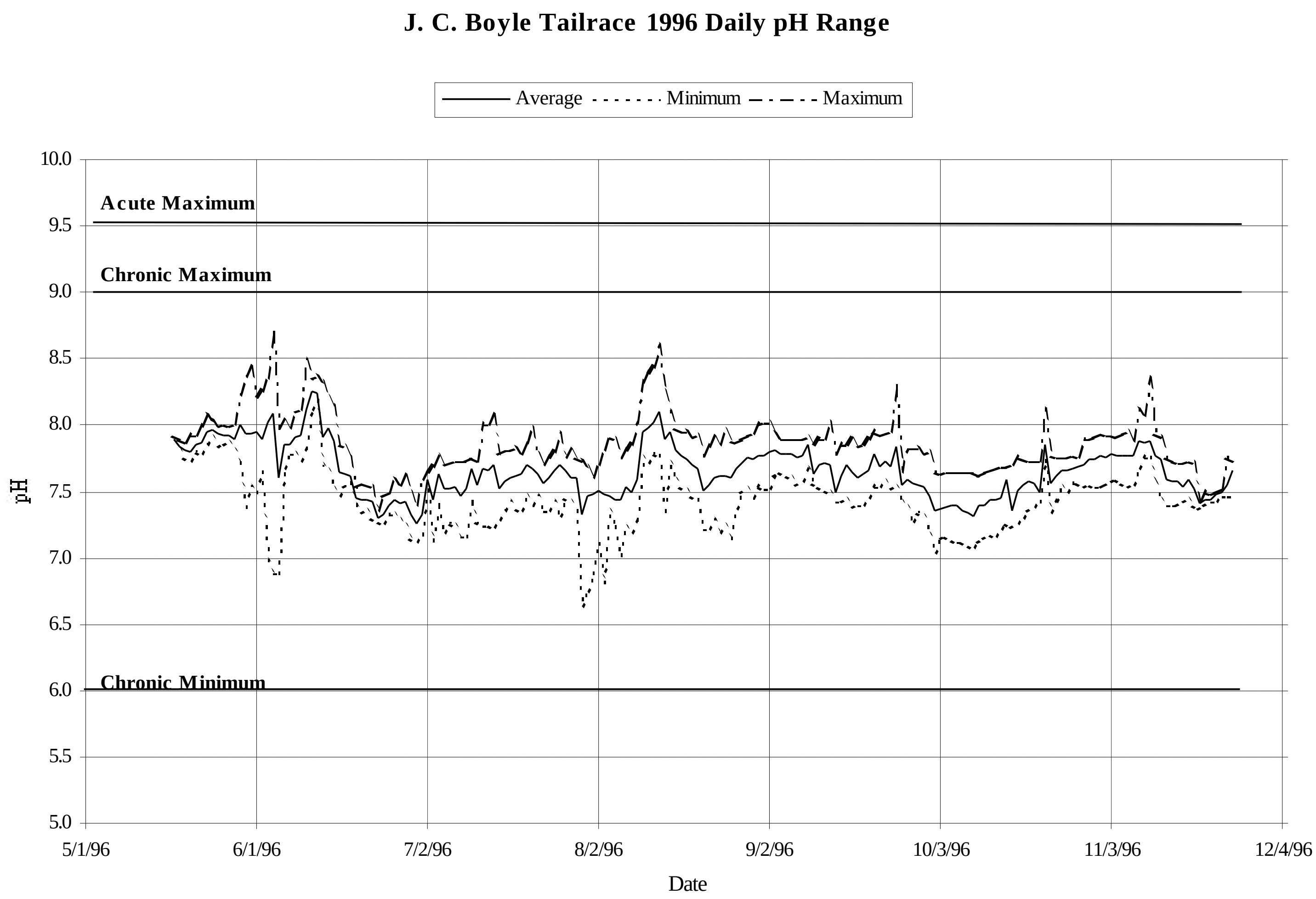


Figure 5-16. J.C. Boyle Tailrace 1996 Daily pH Range

PacifiCorp (1996) measured pH levels at five sites in the reach on several occasions during 1994, 1995 and 1996. While the graphic illustrations do not indicate any pH events above 9, the text reports that a pH of 9.31 was recorded at the Copco reservoir inflow site in 1995.

g. Predators

During 1998 and 1999, PacifiCorp and OSU sampled fish in Copco reservoir as part of a study to determine status of endangered suckers in Klamath River mainstem reservoirs. Preliminary data show the presence of several fish species, with the introduced yellow perch showing the highest catch per unit effort (CPUE) at 75, and the introduced golden shiner being second with a CPUE of 15 (PacifiCorp 1999).

Additional surveys to determine species composition and size in Copco reservoir have been conducted by CDFG and USBOR (CDFG 1988-1992, USBOR 1993). The predominate species encountered were yellow perch, golden shiner, largemouth bass, pumpkinseed and brown bullhead. Mean length demonstrated fish of sufficient size to be predators to juvenile salmonid species. It was noted that many of the sampled species juveniles feed on aquatic insects and plankton and then become piscavores as they grow. As a result, in addition to there being a predatory issue, there is also an issue of competition with juvenile salmonids and suckers for aquatic insects and habitat space.

5.5 J.C. Boyle to Keno

a. General Characteristics

This reach of the Klamath River spans 5.6 miles, from J.C. Boyle dam located at RM 224.7 upstream to Keno dam at RM 230.3. The reach has two characteristic regions: J.C. Boyle reservoir in the lower part of the reach, and a mainstem portion from the reservoir to the tailrace of Keno dam known as the Keno Reach. Spencer Creek is a substantial tributary that enters the Klamath River in this reach at RM 227.6.

J.C. Boyle reservoir is about 3.6 miles long and has a surface area of 420 acres. Its maximum water depth is 45 feet, while the average depth is only 11 feet (ODFW 1997). Typical operations can result in a reservoir surface fluctuation of 5 feet. With a total storage capacity of 3,495 acre-feet J.C. Boyle reservoir is less than six percent the size of Iron Gate reservoir. The active / usable storage of J.C. Boyle reservoir is 1,507 acre-feet.

From the head end of J.C. Boyle reservoir, the river extends through the canyon of the Keno Reach about 2.0 miles before reaching the tailrace of Keno dam. This stretch has a moderate gradient with an average drop of 50 feet per mile. The channel is generally broad rapids, riffles and "pocket water" among large rubble and boulders (ODFW 1997). The reach ends at Keno dam, a non-hydroelectric reregulating facility operated by PacifiCorp to control Lake Ewauna levels.

The Spencer Creek tributary is 18 miles long, with a majority of its flow coming from springs in the Buck Lake area. The lower 8 miles have a gentle gradient with a combination of gravel bars and beaver-dammed pools. ODFW (1997) states that Spencer Creek provides the majority of spawning habitat for trout residing in the Klamath River between Keno dam and the state line although there is no supporting evidence.

Environmental conditions for the J.C. Boyle-Keno reach are currently monitored by multiple sources. A USGS water-stage recorder (#11509500) is located on the left bank 0.9 mile downstream of Keno dam. The gage has been maintained from June 1904 to December 1913 and from October 1929 through the present. In 1996 and 1997, the USGS and PacifiCorp conducted water quality sampling using a continuous-monitoring Hydrolab recorder located downstream of Keno dam. Operational data on turbine flow, spill flow, and reservoir elevation for J.C. Boyle are maintained by PacifiCorp.

b. Discharge

The 75-year period of record for the USGS gage at Keno exhibits a mean annual Klamath River flow of 1,624 cfs. The extremes for this same period are a maximum discharge of 10,300 cfs on 2/28/86 and a minimum discharge of 26 cfs on 9/23/56 (USGS 1999). Normally, PacifiCorp operates Keno dam to maintain at least 250 cfs in the river downstream, except in special circumstances such as extreme drought conditions (ODFW 1997). Flow exiting the reach at J.C. Boyle dam includes tributary flow from Spencer Creek not accounted for in the USGS gage at Keno.

Discharge from J.C. Boyle dam can occur at four locations. Up to 3,000 cfs can be diverted through the screened, power canal intakes located at the left bank of the dam. A constant flow of 20 cfs is used to direct fish away from the screens and through a pipe discharging to the head end of the bypass reach. An additional 80 cfs is directed to the bypass reach through the fish ladder. Any excess flow not handled through these three routes is passed over the spillway.

Daily average discharge values for turbine and spill releases at J.C. Boyle have been supplied by PacifiCorp for the period January 1994 through May 1998 (PacifiCorp 1998). Daily average discharges for 1996 are presented in Figure 5-17 to illustrate day-to-day variations that can occur. Turbine flows were relatively constant around 2,400 cfs from January through mid-May and generally around 1,000 cfs for the rest of the year. Spill occurred in the months of January through May and again in

December, showing periods where storm and snowmelt runoff could vary the total Klamath River flow by more than 4,000 cfs in a few days. Peak

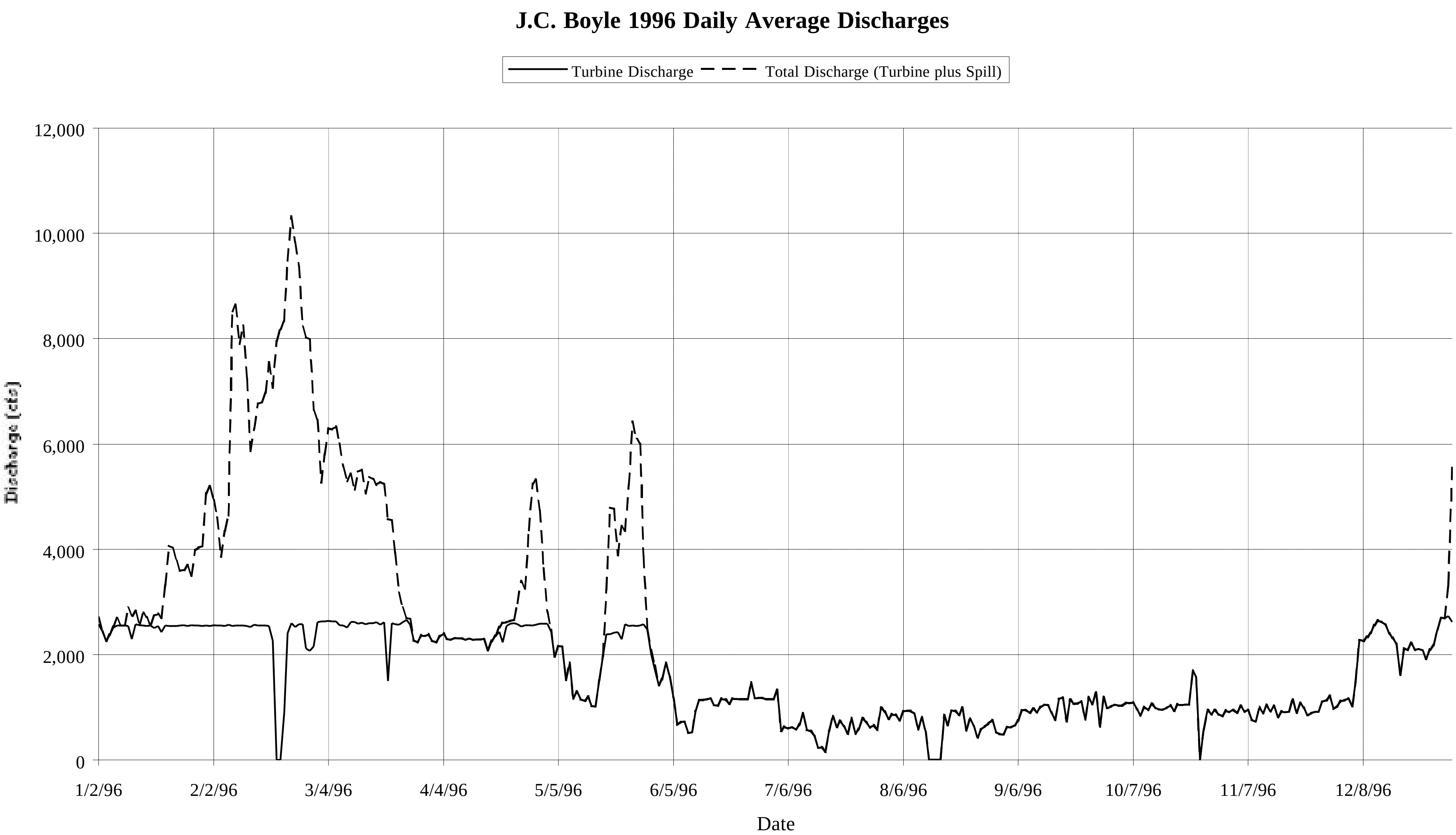


Figure 5-17. J.C. Boyle 1996 Daily Average Discharges

discharge in 1996 occurred on February 22 with a turbine flow of 2,597 cfs and 7,722 cfs of spill.

Seasonal flow patterns can be seen in monthly average discharge data derived from the entire 1994 to 1998 record (Figure 5-18a). Spill typically occurs during December through May, while June through November are characterized by little if any spill and reduced turbine discharge. The month having the highest total flow was February, while the lowest flow conditions occurred in July.

The dramatic variation in climatic conditions that can occur within the basin is also evidenced in the 1994 to 1998 discharge data. During 1994 the annual average discharge at J.C. Boyle was only 456 cfs, and all but a small amount was routed through the powerhouse (Figure 5-18b). In sharp contrast, the annual average discharge in 1996 was 2,324 cfs (5.1 times the 1994 value), and the average annual value for spill was 740 cfs. The average discharge from J.C. Boyle for 1994 through 1997 was calculated to be 1,511 cfs, with 1,101 cfs passing through the powerhouse and 410 cfs passing over the spillway. A daily minimum discharge of 0 cfs occurred in all years following plant outages, and the daily maximum discharge of 10,319 cfs occurred in 1996.

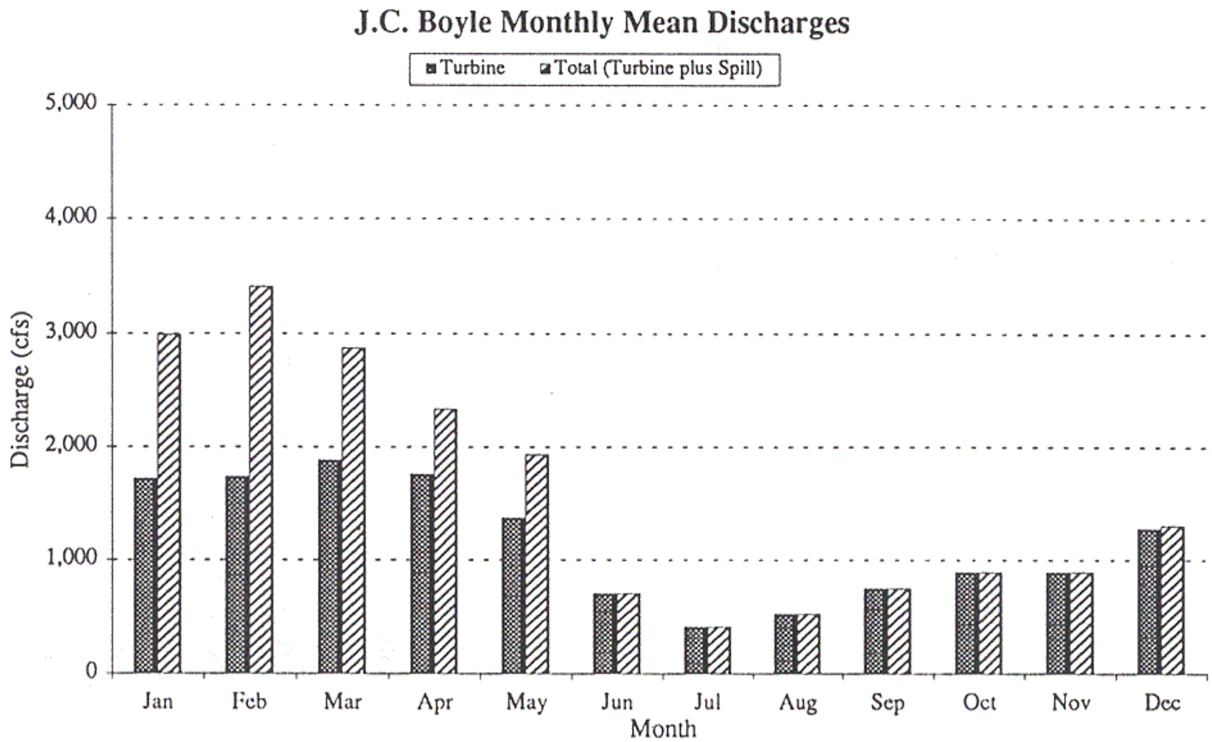
c. Reservoir Retention and Elevation

The total storage capacity of J.C. Boyle reservoir was noted in Section 4 to be 3,495 acre-feet. At the annual average flow rate of 1,511 cfs identified above, the average retention rate in the reservoir is 1.2 days. Between extreme flow events of 710 cfs for a minimum and 10,000 cfs as a maximum, the retention time would range from 2.5 days down to 0.2 days.

Normal operating conditions for J.C. Boyle dam provide for a five foot reservoir fluctuation, with the normal full pool elevation at 3,793 ft msl and the normal minimum pool elevation at 3,788 ft msl. Daily average values for J.C. Boyle reservoir elevation for the period of January 1994 through May 1998 were provided by PacifiCorp (1998). Figure 5-19a illustrates the daily average reservoir elevation for each day of 1996 and indicates that the reservoir was nearly always within the top three feet of the pool. Monthly average elevations for the 1994-98 data set indicate that the reservoir is generally kept within a one foot range throughout the year (Figure 5-19b). The average elevation for J.C. Boyle reservoir from 1994 through 1997 was 3,791.7 ft msl, with an extreme minimum of 3,788.4 ft msl in November 1997 and an extreme maximum of 3,793.3 ft msl occurring in June 1997.

d. Water Temperature

J.C. Boyle reservoir becomes somewhat stratified during the summer, but the relative shallowness of this reservoir results in more uniform conditions than seen at deeper reservoirs like Iron Gate or Copco. Data relating to stratification is presented in City of Klamath Falls (1986), showing temperature differentials that



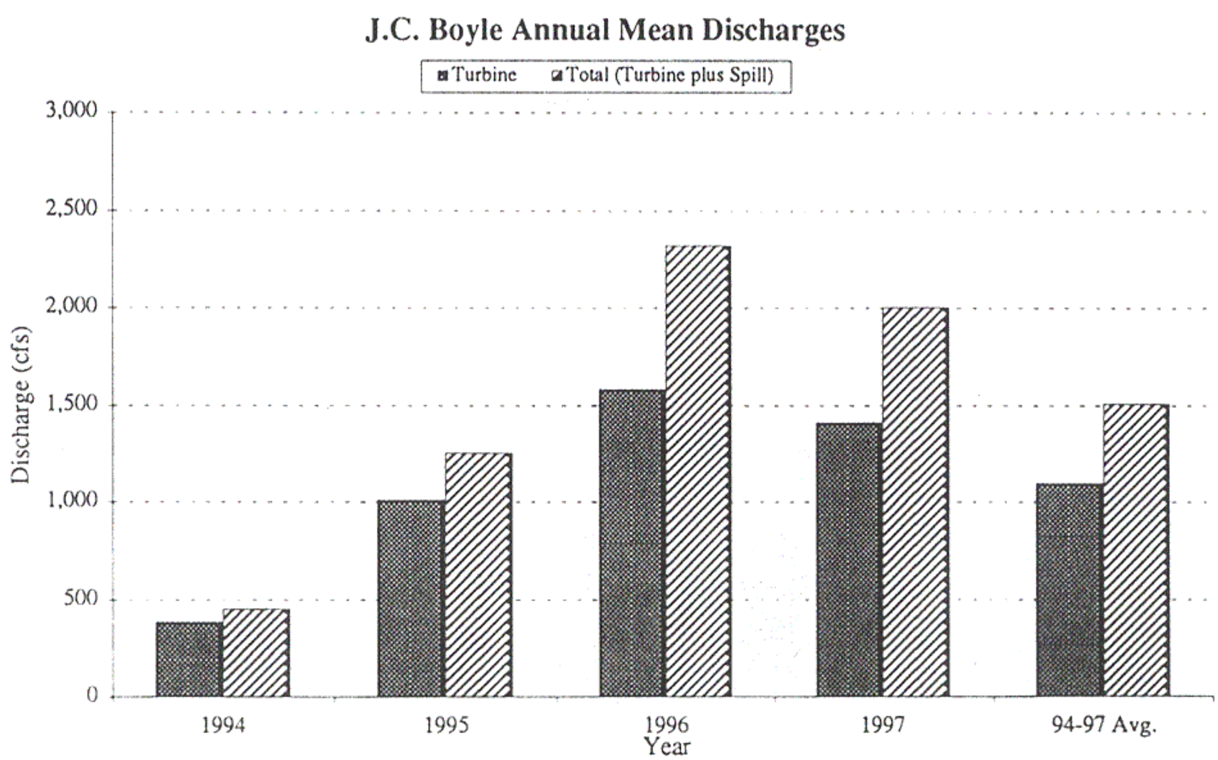
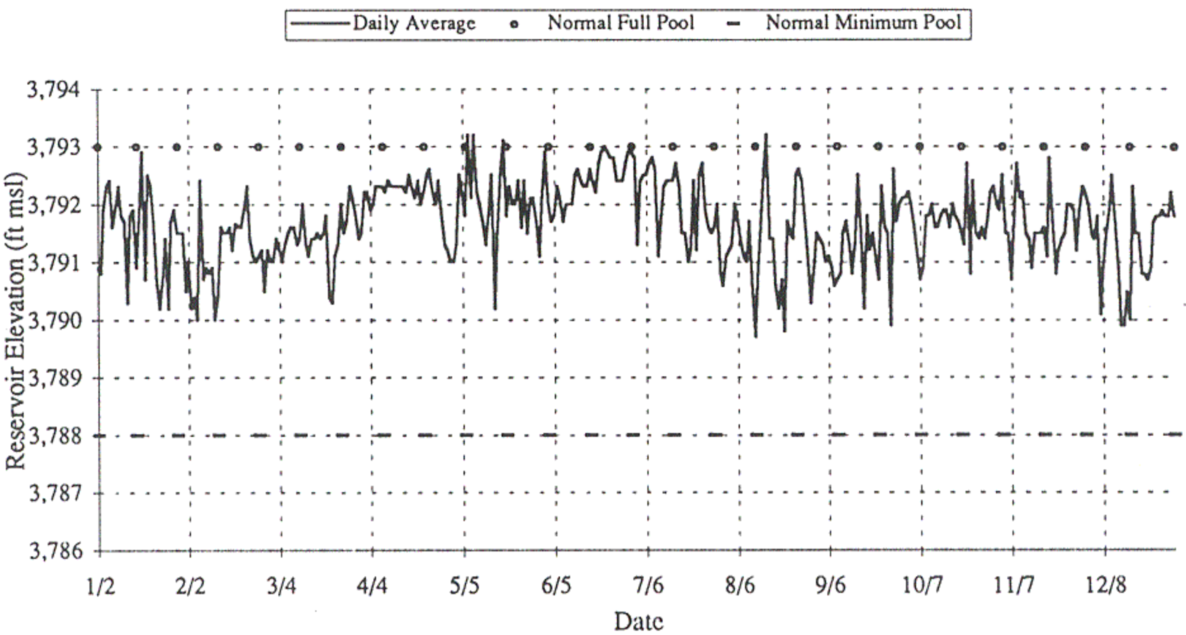


Figure 5-18. J.C. Boyle discharges, Jan. 1994 to May1998. a) Monthly mean discharges. b) Annual mean discharges.

J.C. Boyle Reservoir 1996 Daily Average Elevations



J.C. Boyle Reservoir Monthly Average Elevations

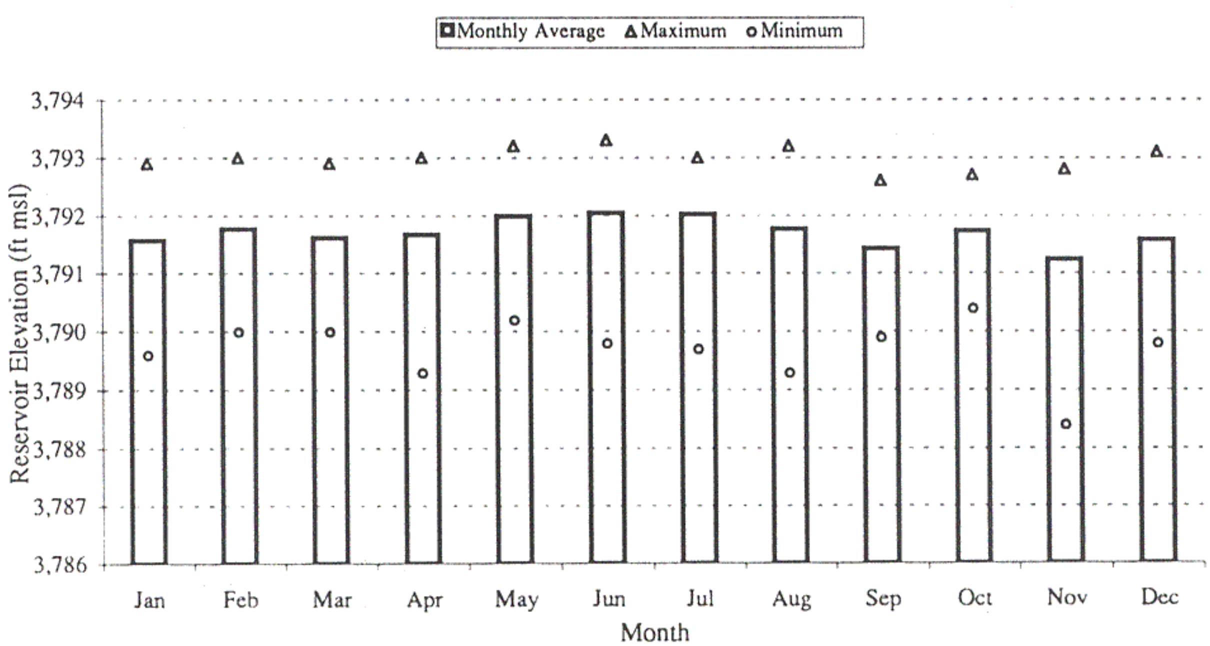


Figure 5-19. J.C. Boyle Reservoir elevations. a) Daily average elevations for 1996. b) Monthly average elevations for January 1994 to May 1998, also showing range of daily average values.

typically peak around 5°C in July and early August, but are back down around 2°C by the end of August. At the same time, water temperatures at the reservoir surface were above 20°C for more than two months straight. These data suggest that the entire reservoir is warmer than 15°C in the summer, with no deeper areas to provide cold water refugia.

Upstream from the reservoir at the Keno dam tailrace, the USGS and PacifiCorp collected continuous data for water temperature during 1996 and 1997 (USGS 1998). Data for 1996 were reduced to daily average values and are subsequently displayed in Figure 5-20. In early May when sampling began, water temperatures were already above 15°C (the chronic threshold level for salmonid fish), and except for a brief respite in late May, they remained above this level until mid-October. Daily average temperatures at this site were above the salmonid acute threshold of 20°C throughout July and August. By late October, however, the daily average temperature was in the vicinity of 7°C.

A similar pattern can be observed in water temperature measurements collected by PacifiCorp at the Keno dam tailrace from 1994 to 1996 (PacifiCorp 1996). In all three years, water temperatures went above the chronic salmonid threshold of 15°C during May and did not drop below the threshold until October. The acute salmonid threshold of 20°C was exceeded a minimum of eight weeks each year, typically spanning all of July and August.

e. Dissolved Oxygen

The same continuous water quality sampling noted above for water temperature was also used to monitor dissolved oxygen at the Keno dam tailrace during 1996 and 1997 (USGS 1998). Data for 1996 were reduced to daily average values and are displayed in Figures 5-21. The results indicate that DO levels are a critical issue at this site, with concentrations in the range of 0 to 5 mg/L nearly note: ?continuously from July through mid- October. The chronic DO threshold of 7 mg/L was not steadily surpassed until mid-November.

From 1994 through 1996, PacifiCorp collected five to eight DO samples each year at the Keno dam tailrace, and in 1994 four DO samples were collected at the head end of J.C. Boyle reservoir (PacifiCorp 1996). DO levels in these samples were not as low as the results showing in the USGS program, with only one sample reading below the chronic threshold of 7 mg/L. Several factors could contribute to the differences in these results, including time of day of the sampling, duration of sampling, depth of sampling, and frequency of instrument maintenance (i.e. the sensor can fail if left too long, especially in the Klamath River).

Dissolved oxygen concentrations in J.C. Boyle reservoir show variations that relate to the degree of stratification. Earlier studies (City of Klamath Falls 1986) indicate a DO profile that is generally well mixed, even in summer. It was noted.

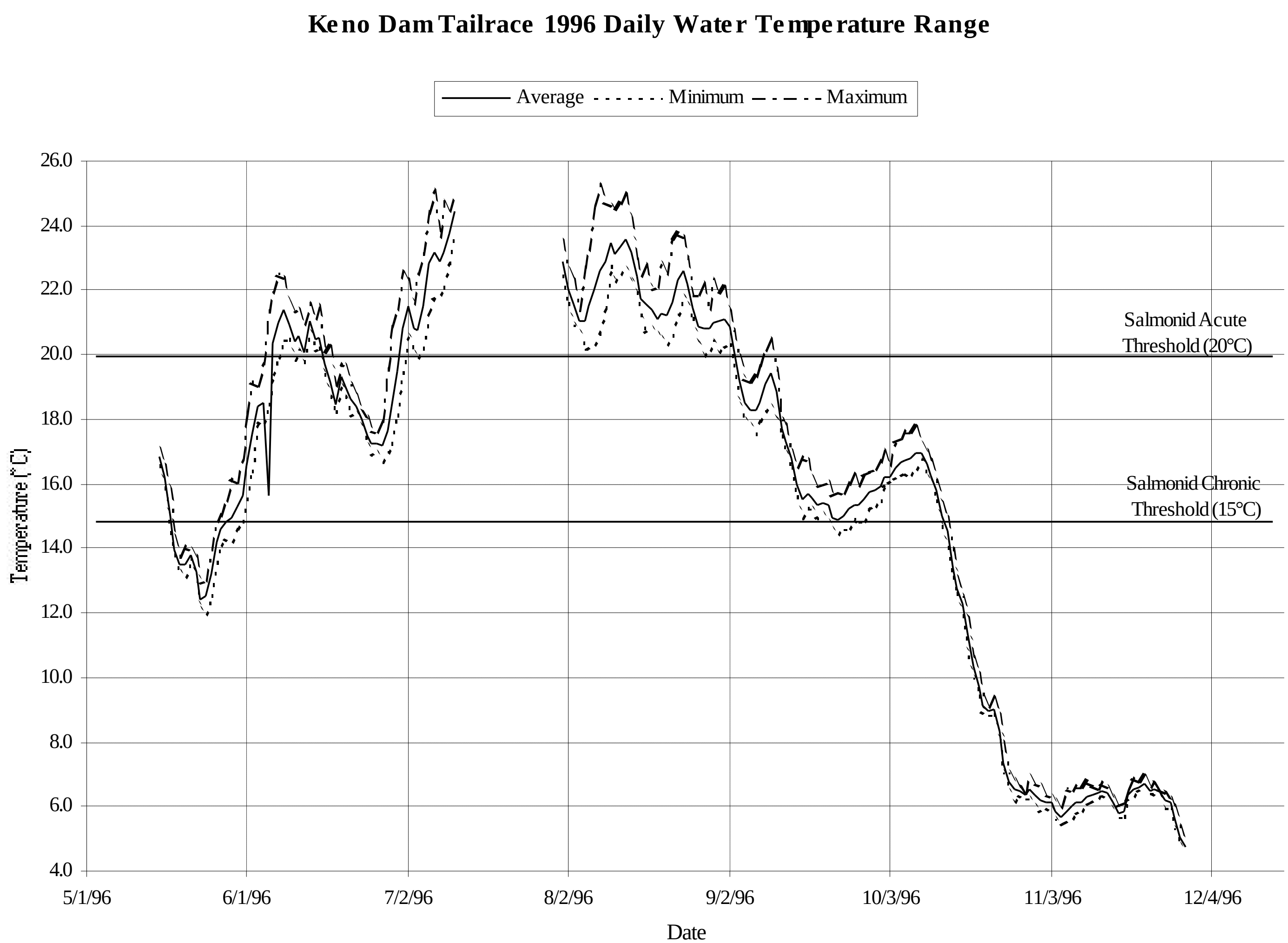


Figure 5-20. Keno Dam Tailrace 1996 Daily Water Temperature Range

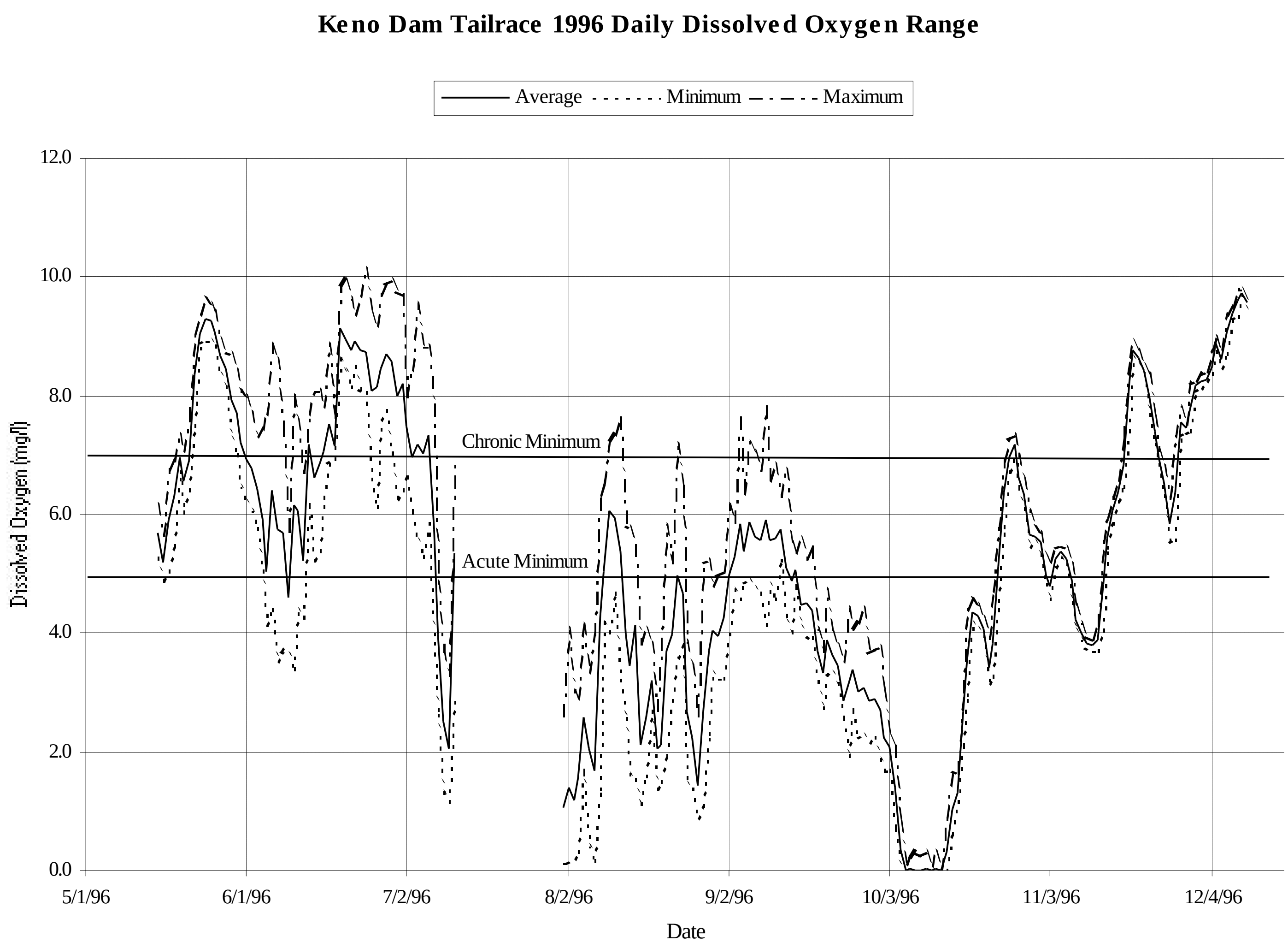


Figure 5-21. Keno Dam Tailrace 1996 Dissolved Oxygen Range

that stratification, and an associated DO differential, occurred only during a brief period when reservoir releases were at a minimum due to maintenance.

f. pH

The same continuous water quality sampling noted above for water temperature was also used to monitor pH at the Keno dam tailrace sites during 1996 and 1997 (USGS 1998). Data for 1996 were reduced to daily average values and are subsequently displayed in Figure 5-22. Generally, pH values varied between 7.0 and 9.0, with a daily fluctuation of about 0.5 pH unit occurring in the summertime. During a few day period in late June, the daily maximum and daily average pH values exceeded the chronic maximum pH threshold of 9 considered acceptable for salmonid fish, peaking at 9.3.

PacifiCorp (1996) measured pH levels at Keno dam tailrace on several occasions during 1994, 1995 and 1996, and in 1994 it measured pH at the head end of J.C. Boyle reservoir. Sample results were all in the range of 7 to 9, except for the 7/11/94 sample at Keno dam tailrace which measured 9.07.

g. Predators

During 1998 and 1999, PacifiCorp and OSU sampled fish in J.C. Boyle reservoir as part of a study to determine status of endangered suckers in Klamath River mainstem reservoirs. Preliminary data show the presence of several fish species, with the introduced Sacramento perch showing the highest catch per unit effort (CPUE) at 9.1, and the introduced pumkinseed being second with a CPUE of 8.5 (PacifiCorp 1999).

The ODFW Fish Management Plan for the Klamath River (ODFW 1997) notes the presence of the following warmwater gamefish in J.C. Boyle reservoir: largemouth bass, white and black crappie, Sacramento perch, pumpkinseed sunfish, yellow perch, and brown bullhead. Several species of non-game fish have also been sampled, including the endangered Lost River and shortnose suckers, speckled dace, blue and Tui chub, marbled sculpin, Pacific and Klamath lamprey, and fathead minnow. The management direction implemented by ODFW for J.C. Boyle reservoir is for natural production of redband trout. It notes that further work should be done to determine the level of predation on redband trout by spiney-rayed fishes in the reservoir.

5.6 Keno to Link River Dam

a. General Characteristics

This reach of the Klamath River spans 24.0 miles, from Keno dam located at RM 230.3 upstream to Link River dam at RM 254.3. The reach has two

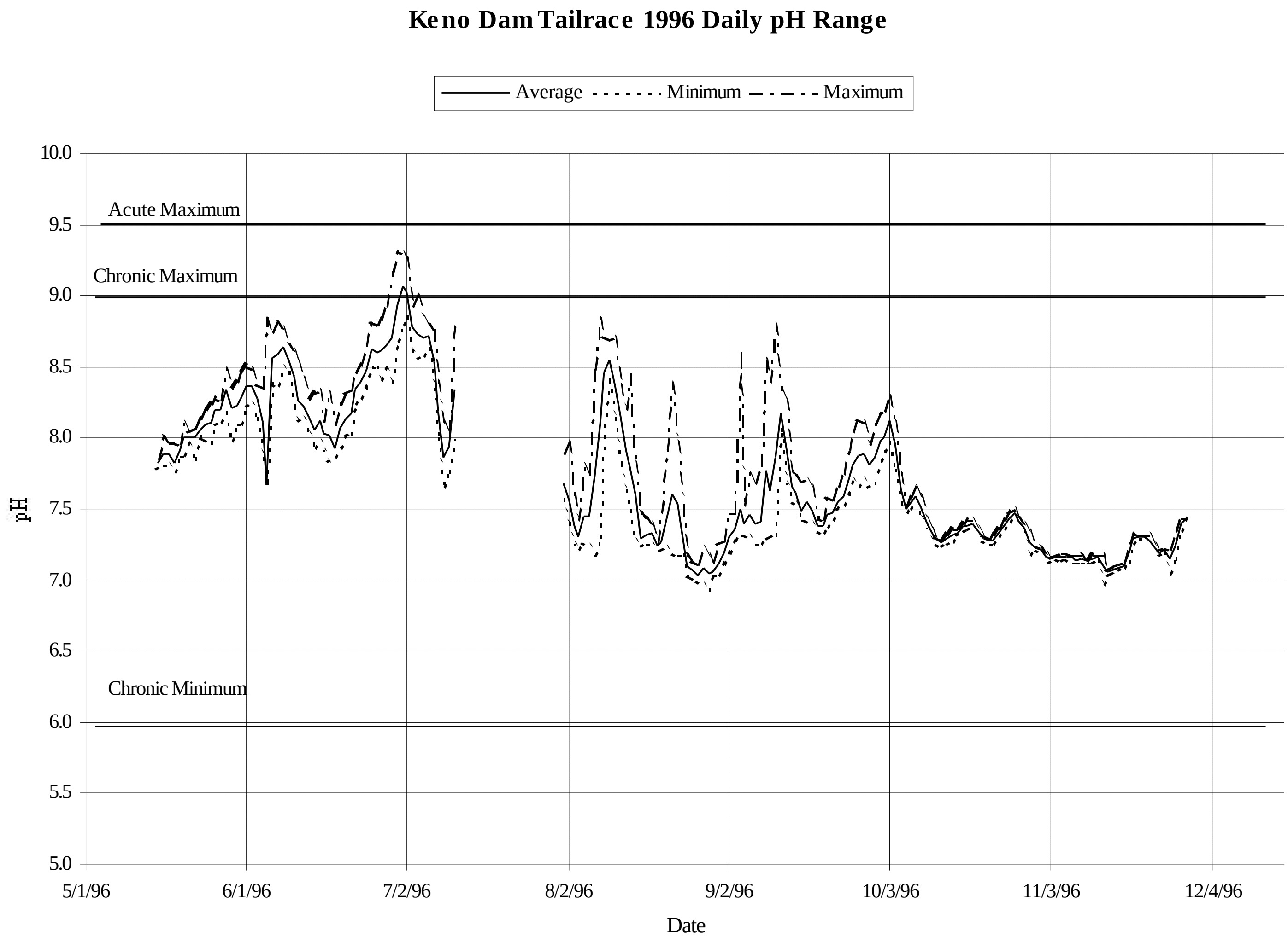


Figure 5-22. Keno Dam Tailrace 1996 Daily pH Range

characteristic regions: the mainstem Klamath River and Lake Ewauna in the lower part of the reach, and the Link River at the upper end.

The lower part of the reach is about 22.8 miles long, extending from Keno dam up to the outlet of the Link River at RM 253.1. This stretch is commonly referred to as Lake Ewauna, especially in the uppermost portion. It is in essence a widened portion of the head of the Klamath River, created by the impoundment of water at Keno dam. Water levels and flow rate are regulated at Keno dam in order to maintain near-constant conditions for irrigation facilities that drain into or pump from Lake Ewauna. Key facilities include the Klamath Straits Drain at RM 239, which has a capacity of 600 cfs and typically functions as an irrigation return for Lower Klamath Lake area; and the Lost River Diversion Channel at RM 249.6, which has a 3,000 cfs capacity and serves as an irrigation return for Upper Klamath Lake and Lost River irrigation lands or to supply additional water to the Tule Lake area.

The Link River "linked" Upper Klamath Lake to the original Lake Ewauna, as shown in Figure 1-1. It spans 1.2 miles. At the upstream end of the reach is Link River dam, owned by the BOR and operated by PacifiCorp to control Upper Klamath Lake elevations, divert water into the Eastside and Westside powerhouses, and maintain minimum flows in the reach between the dam and the Eastside powerhouse.

Environmental conditions in the Keno-Link River reach have been widely investigated in recent years in response to growing concern over poor water quality. Since 1986, the Oregon Department of Environmental Quality (ODEQ) has conducted numerous water quality surveys and coordinated with local water user groups and agencies to develop a Total Maximum Daily Load (TMDL) for nutrients in the basin. Flow is monitored by a USGS has a water-stage recorder (#11507500) is located on the right bank of the Link River, 600 feet upstream from the outlet of the Keno Canal (i.e. the Westside powerhouse tailrace). The gage has been maintained from May 1904 through the present, though records since 1983 differ from earlier records by not including flow in Keno Canal. From 1994 through 1996, PacifiCorp conducted water quality sampling in the Link River at the tailraces of the Eastside and Westside powerhouses.

b. Discharge

The 79-year period of record (WY 1905-83) for the USGS gage at Link River exhibits a mean annual flow of 1,593 cfs. The extremes for this same period are a maximum discharge of 9,400 cfs on 5/12/04 and a minimum discharge of 17 cfs on 12/13/37 (USGS 1999). These flows are reported to be adjusted to include flow exiting the Keno Canal, 600 feet downstream of the gage. (Discharge data from the USGS Link River gage should be similar to discharges reported by PacifiCorp's operational data for Link River dam, discussed in Section 5.7.b).

There are no significant tributaries that enter this reach. However, especially in the fall, there are substantial inflows of irrigation return water originally diverted from Upper Klamath Lake upstream of the Link River gage. This inflow is reflected by an increase in discharge at the USGS gage at Keno, with a mean annual flow of 1,624 cfs (see Section 5.5.b).

Discharge from Keno dam can occur at four locations: the fish ladder exit, the attraction flow pipe, the sluice pipe, and the spillway. A constant flow of 15 cfs is sent through the fish ladder,and remaining flow typically passes over the dam spillway. PacifiCorp releases a flow of 200 cfs at the dam. To assure this flow is almost always met, the facility is operated using a minimum release of 250 cfs. During periods of extreme drought, it may be necessary to reduce the minimum flow, as occurred in 1992 when under drought conditions the BOR requested reduction in flow to 150 cfs (Frank Shrier, personal communication 6/23/98).

c. Reservoir Retention and Elevation

The total storage capacity of Lake Ewauna was noted in Section 4 to be 18,500 acre-feet. At the annual average flow rate of 1, 624 cfs identified above, the average retention rate in the reservoir is 6 days. Between extreme flow events of 710 cfs for a minimum and 10,000 cfs as a maximum, the retention time would range from 13 days down to 1 day.

The operative normal range in elevation for Keno dam is between 4085.0 and 4086.0 ft msl. The dam is operated to maintain consistent water levels in Lake Ewauna for the benefit of irrigation project pumps. To enhance this function, PacifiCorp tries to maintain a more refined range between 4085.3 and 4085.6 ft msl.

d. Water Temperature

Water temperatures were measured in the Keno dam fish ladder at least three times a week from February 1988 to September 1991 as part of a trout movement study (PacifiCorp 1997). The results show a consistent seasonal pattern with summer temperatures peaking between 76 to 79°F (24 to 26°C) in July or August, and dropping to just above freezing in January.

Strong seasonal variation was also apparent in water temperature measurements collected by PacifiCorp at the Westside tailrace from 1994 to 1996 (PacifiCorp 1996). Water temperatures routinely went above the chronic salmonid threshold of 15°C during May and rarely dropped below the threshold before October. The acute salmonid threshold of 20°C was typically exceeded through July and August.

e. Dissolved Oxygen

Analysis of dissolved oxygen data collected by ODEQ since 1969 showed that dissolved oxygen generally decreased between the Link River below Link River dam and Klamath River at Keno Bridge (Sorenson and Schwarzbach 1991). While the median DO concentration measured at Keno Bridge was about 8 mg/L, there were instances of extremely low DO, with 25% of the samples in the range of 1 to 6 mg/L. It was noted that the decrease in DO between the two sites was probably related to Keno being downstream from the main irrigation return at Klamath Straits Drain.

From 1994 through 1996, PacifiCorp collected DO samples at the Eastside and Westside tailraces and at Link River dam (PacifiCorp 1996). DO concentrations were below the chronic threshold of 7 mg/L for all samples collected in August 1994 and August 1996.

f. pH

The same trout movement study noted above for water temperature also collected pH data at the Keno dam fish ladder (PacifiCorp 1997). Generally, pH values varied between 7.0 and 9.0. However, there were several episodes each summer during three out of the four years in which pH values exceeded 9, reaching as high as 9.9.

PacifiCorp (1996) measured pH levels at the Eastside and Westside tailraces and Link River dam on several occasions between March and November of 1994, 1995 and 1996. Measured pH was above 9.0 in 14% of the samples during 1994, 58% of the samples in 1995, and 33% in 1996.

g. Predators

The fish trapping study conducted at Keno dam fish ladder found Tui chubs and fathead minnows to be the most numerous species captured (PacifiCorp 1997).

ODFW (1997) notes the presence of the following warmwater gamefish in Lake Ewauna: largemouth bass; white and black crappie; Sacramento perch; bluegill, pumpkinseed and green sunfish; yellow perch; and brown bullhead. Several species of non-game fish have also been sampled, including the endangered Lost River and shortnose suckers, Klamath largescale suckers, speckled dace, blue and Tui chub, marbled sculpin, Pacific lamprey, and fathead minnow. The management direction implemented by ODFW for Lake Ewauna and Link River is for natural production of redband trout. It notes that further work should be done to determine the level of predation on redband trout by spiney-rayed fishes in the reservoir.

5.7 Above Link River Dam

a. General Characteristics

The outlet of Upper Klamath Lake into the Link River originally consisted of a series of small natural falls (i.e. Klamath Falls). In 1908, a power generating facility was constructed by PacifiCorp (then Copco) on the west side of the Link River to utilize this resource, drawing water from the lake through a canal and discharging it through a turbine to the river below the falls. Recognizing a potential to develop the resource more fully, an agreement was made between Copco and the US Bureau of Reclamation (BOR) in 1917 to encourage multiple uses of the Link River. In the decade following the agreement, the dike system around Upper Klamath Lake was expanded and a second powerhouse was constructed on the east side of the Link River. The Link River dam was completed by BOR in 1927, raising the level of Upper Klamath Lake six feet and providing storage for the BOR Klamath Irrigation Project. Portions of the natural falls are still visible about 350 feet downstream of the dam.

Today, the Link River dam is operated by PacifiCorp under the direction of BOR to maximize beneficial water use for endangered species (suckers), irrigation, hydropower generation, domestic use, municipal use, and water fowl conservation in wildlife refuges. Since there is very little storage in the mainstem Klamath reservoirs, and hence little operational flexibility in the entire system, the dam must also be operated in a manner that allows the BOR-specified instream flows below Iron Gate dam.

The characteristics of the Klamath River Basin above Link River dam are considerably different than those seen from Iron Gate to Link River. Upper Klamath Lake is the collection point for the majority of the Klamath Basin drainage and has a surface area more than 95 times the size of Iron Gate reservoir. The lake has very high levels of nutrients that can lead to massive blooms of blue-green algae during the summer, accompanied by wide fluctuations in dissolved oxygen and pH.

Environmental conditions in Upper Klamath Lake and the upper basin have made it the focus of numerous water quality investigations, with considerable coordination provided by ODEQ. The BOR has also conducted substantial monitoring programs, and in 1996 BOR and PacifiCorp conducted water quality sampling using a continuous-monitoring Hydrolab recorder located in the entrance to the Bureau's A Canal, just upstream of Link River dam. Operational data on turbine flow, spill flow, and reservoir elevation for the Link River facilities are maintained by PacifiCorp for power planning purposes.

b. Discharge

Daily average discharge values for turbine and spill releases for the Link River facilities have been supplied by PacifiCorp for the period January 1994 through May 1998 (PacifiCorp 1998). Daily average discharges for 1996 are presented in Figure 5-23 to illustrate day-to-day variations that can occur. Turbine flows from the Westside powerhouse were nearly constant at 230 cfs from mid-November through August and were not operating otherwise. Flow from the Eastside powerhouse generally flowed around 1,000 cfs during winter months when water was plentiful, but fluctuated repeatedly in the range of 200 to 1,200 cfs from late March to December. Spill occurred during all months, reflecting PacifiCorp's commitment to maintain minimum flows of at least 90 cfs in the reach between the dam and the Eastside powerhouse tailrace. Peak discharge in 1996 occurred on February 26 with a turbine flow of 1,002 cfs from the Eastside, 230 cfs from the Westside, and 5,044 cfs of spill.

Seasonal flow patterns can be seen in monthly average discharge data derived from the entire 1994 to 1998 record (Figure 5-24a). Significant spill flows occur from December through June, with only nominal spill amounts in summer and fall. Turbine discharge rates, on the other hand, remain relatively constant throughout the year. The month having the highest total flow was February, while the lowest flow conditions occurred in September and November.

The variation in climatic conditions that can occur within the basin is also evidenced in the 1994 to 1998 discharge data. During 1994 the annual average discharge at Link River dam was only 672 cfs, and there was no recorded spill the entire year (Figure 5-24b). In sharp contrast, the annual average discharge in 1996 was 1,902 cfs (2.8 times the 1994 value), and the average annual value for spill was 871 cfs. The average discharge from the Link River facilities for 1994 through 1997 was calculated to be 1,428 cfs, with 708 cfs passing through the Eastside powerhouse, 123 cfs passing through the Westside powerhouse and 596 cfs passing over the spillway. A daily minimum discharge of 15 cfs occurred in 1994, and the daily maximum discharge of 7,216 cfs occurred in 1997.

Discharge from Link River dam can occur at four general locations: through the Eastside power canal, the Westside power canal (also called the Keno Canal) through the fish ladder, or at the spillway. The minimum flow that is maintained downstream of the dam is supplied by discharge through the ladder plus leakage from the dam. Just upstream of the dam is the entrance to the Klamath Irrigation Project A Canal, which has a capacity of 1,150 cfs.

c. Reservoir Retention and Elevation

The total storage capacity of Upper Klamath Lake was noted in Section 4 to be 523,700 acre-feet. At the annual average flow rate of 1,428 cfs identified above, the average retention rate in the lake is 185 days. Between extreme flow events of 710 cfs for a minimum and 10,000 cfs as a maximum, the retention time would range from 372 days down to 26 days.

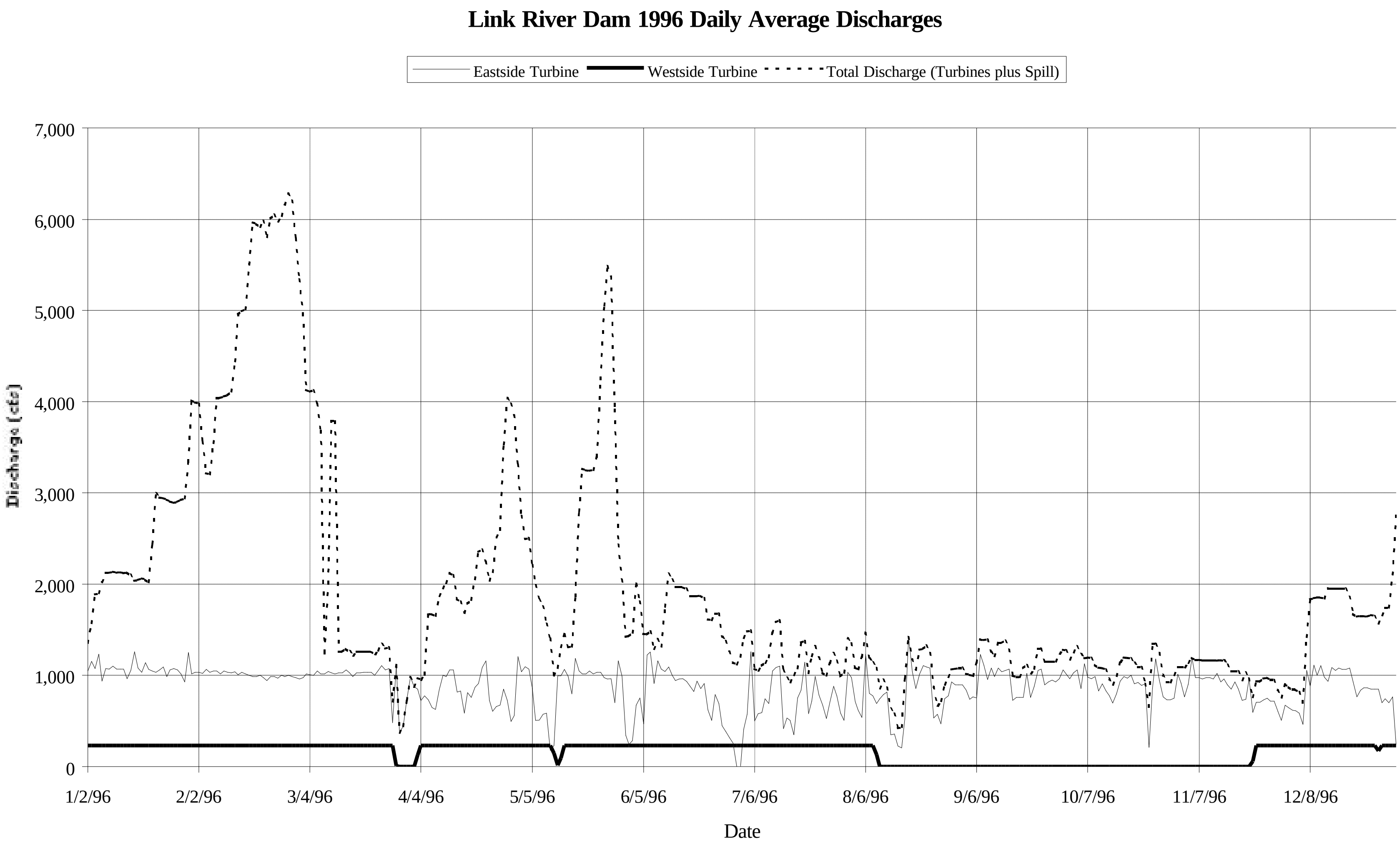
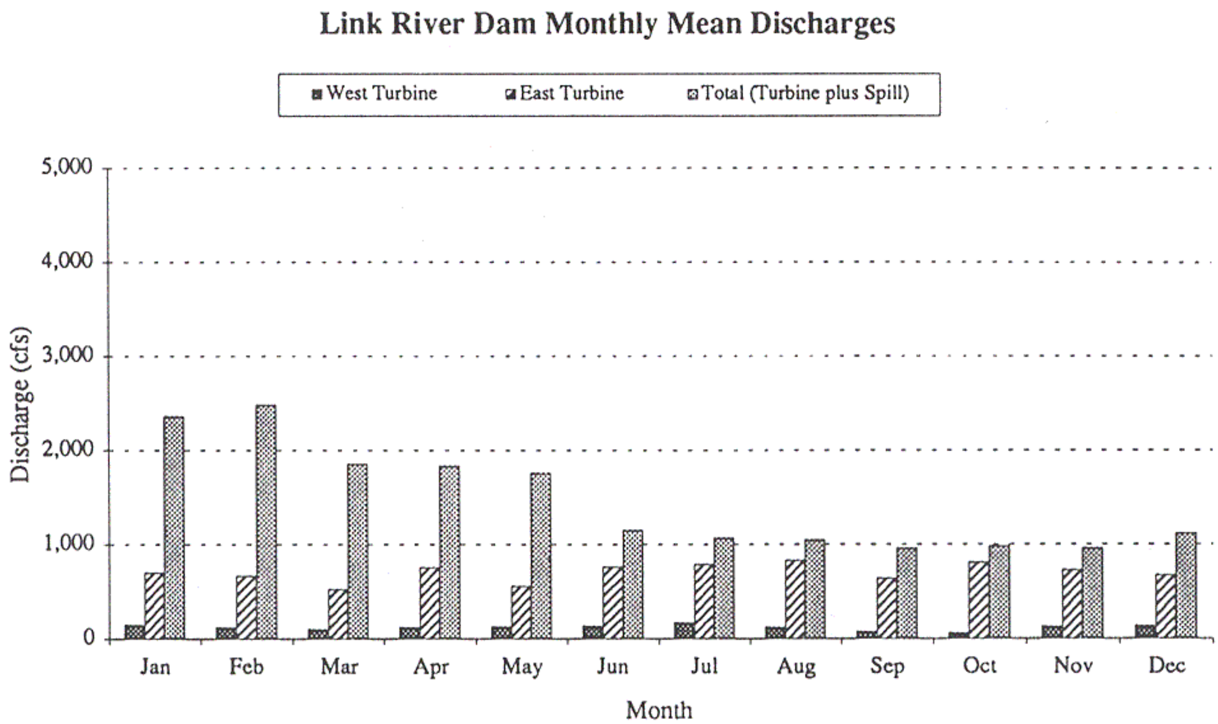


Figure 5-23. Link River Dam 1996 Daily Average Discharges



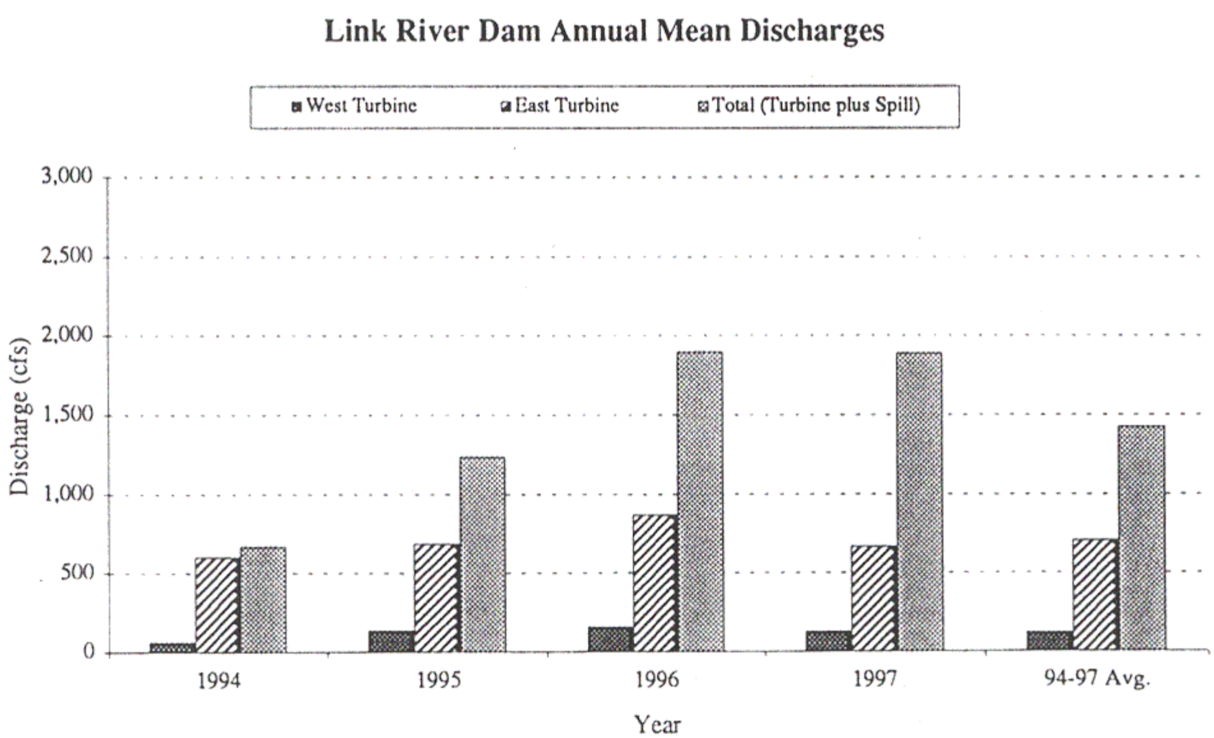


Figure 5-24. Link River Dam discharges, Jan. 1994 to May1998. a) Monthly mean discharges. b) Annual mean discharges.

Normal operating conditions for Link River dam provide for a 6.3 foot reservoir fluctuation, with the normal full pool elevation at 4143.3 ft msl and the normal minimum pool elevation at 4137.0 ft msl. However, lake elevations are dictated by the 1996 Biological Opinion. Daily average values for Upper Klamath Lake elevation for the period of January 1994 through May 1998 were provided by PacifiCorp (1998). Figure 5-25a illustrates the daily average reservoir elevation for each day of 1996, showing an increase to full pool elevation just before the onset of the irrigation season in May followed by a gradual drawdown till the end of the season in mid-October. Monthly average elevations for the 1994-98 data set show the same pattern (Figure 5-25b). The average elevation for Upper Klamath Lake from 1994 through 1997 was 4141.0 ft msl, with an extreme minimum of 4136.8 ft msl in September and October 1994 and an extreme maximum of 4143.3 ft msl occurring in May and June 1996.

d. Water Temperature

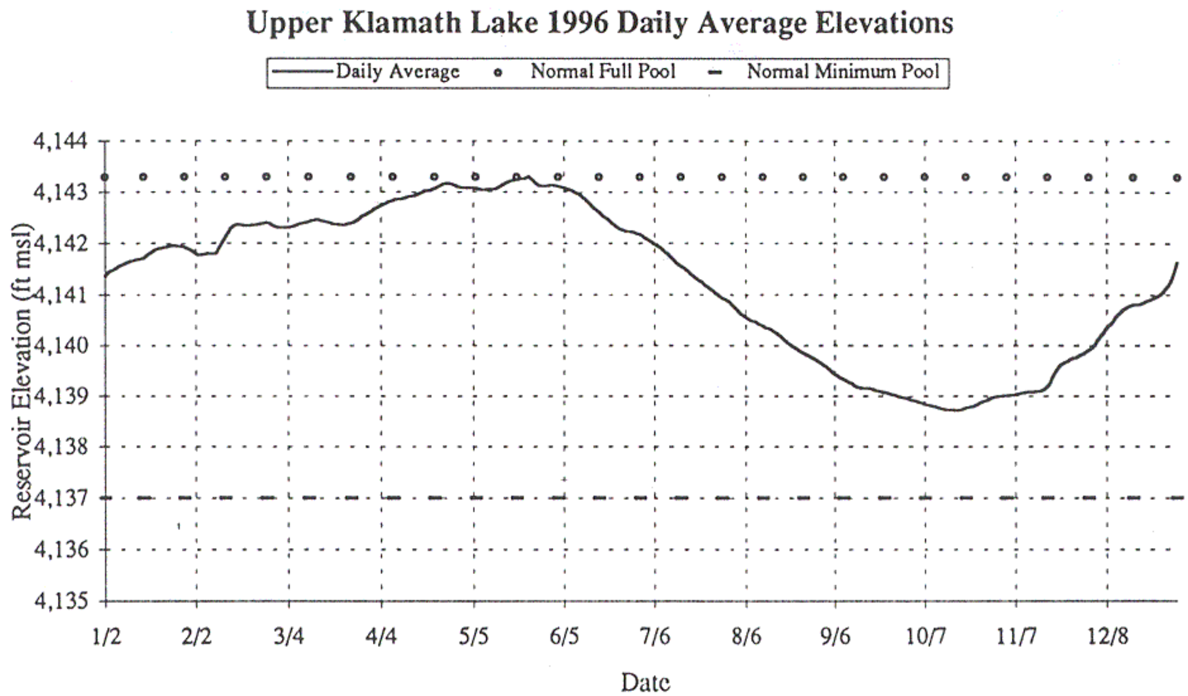
The BOR and PacifiCorp collected continuous data for water temperature during 1996 and 1997 upstream from Link River dam at the entrance to the A Canal (USBOR 1998). Data for 1996 were reduced to daily average values and are subsequently displayed in Figure 5-26. Samples collected between mid-June and early October were all above 15°C (the chronic threshold level for salmonid fish) except for a brief respite in mid-September. Daily average temperatures were above the salmonid acute threshold of 20°C in samples collected late June/early July and almost all of August. Samples from early March and late October showed daily average temperature in the vicinity of 5 to 8°C.

Water temperatures were measured in the Link River dam fish ladder at least three times a week from February 1988 to September 1991 as part of a trout movement study (PacifiCorp 1997). The results show a consistent seasonal pattern with summer temperatures peaking between 74 to 78°F (23 to 26°C) in July or August, and dropping to just above freezing in January.

e. Dissolved Oxygen

The same continuous water quality sampling noted above for water temperature was also used to monitor dissolved oxygen above Link River dam during 1996 and 1997 (USBOR 1998). Data for 1996 were reduced to daily average values and are displayed in Figures 5-27. The results show widely fluctuating DO levels with an extended period in August below the acute threshold of 5 mg/L. DO levels were below the chronic threshold of 7 mg/L during most of August and late October.

The entrance to the A Canal was a site included in a Klamath Project assessment coordinated by the USGS during 1991 and 1992 (Dileanis et al. 1996). While showing a median DO around 7.8, the data also give indication of sporadic fluctuations with a DO range from 3 to 12. Three periods of continuous monitoring



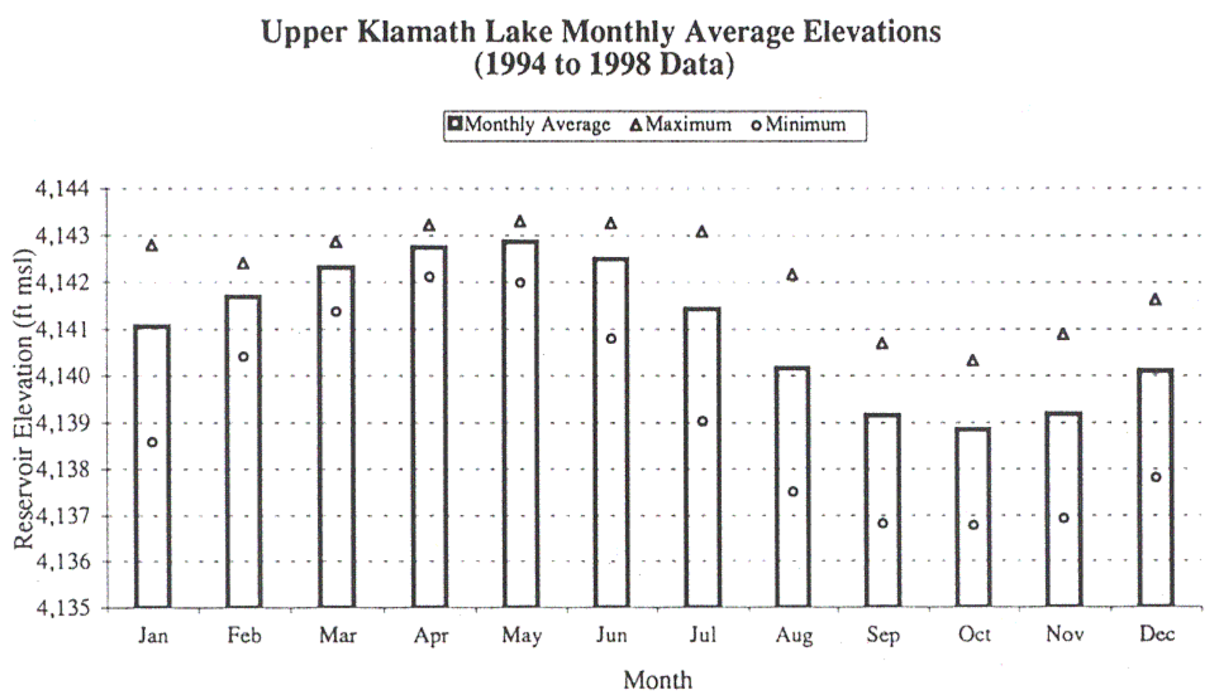


Figure 5-25. Upper Klamath Lake elevations. a) Daily average elevations for 1996. b) Monthly average elevations for January 1994 to May 1998, also showing range of daily average values.

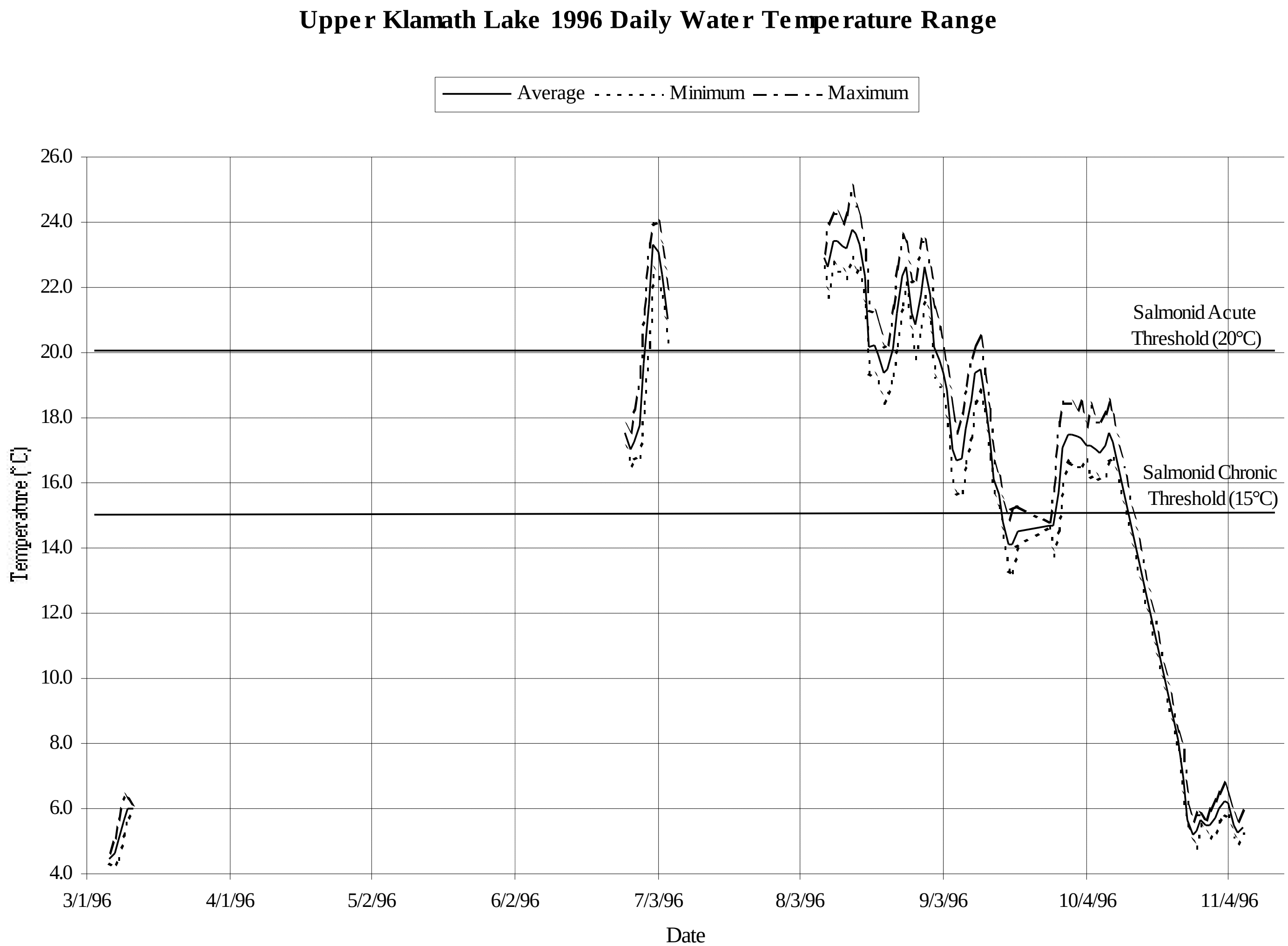


Figure 5-26. Upper Klamath Lake 1996 Daily Water Temperature Range

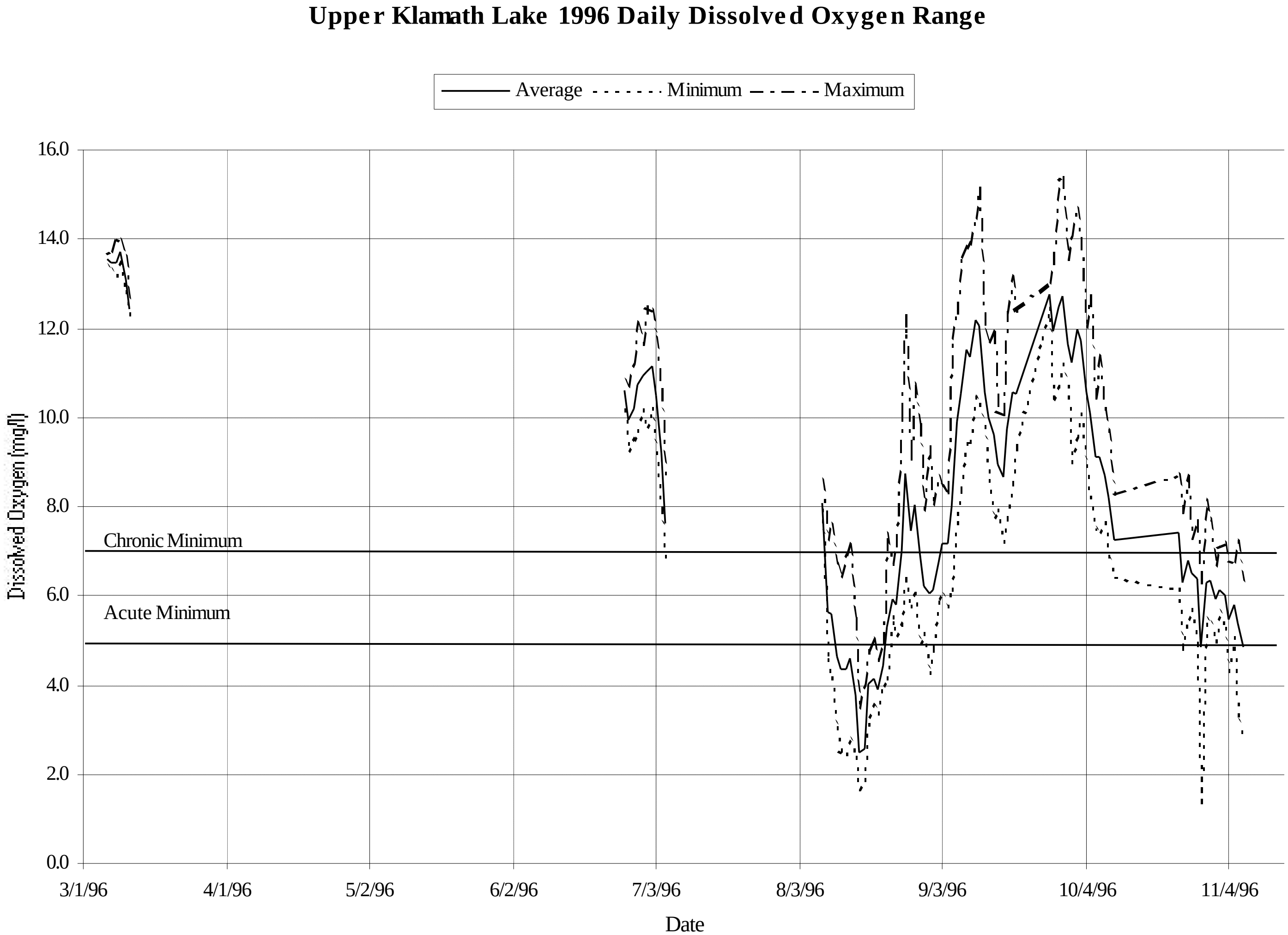


Figure 5-27. Upper Klamath Lake 1996 Daily Dissolved Oxygen Range

were conducted during July and August 1992; the percent of time DO levels were below 5.0 mg/L during these periods was 0%, 1% and 12%.

f. pH

The same continuous water quality sampling noted above for water temperature was also used to monitor pH above Link River dam during 1996 and 1997 (USBOR 1998). Data for 1996 were reduced to daily average values and are subsequently displayed in Figure 5-28. Generally, pH values varied between 7.0 and 9.0. Episodes in which the pH values exceeded 9 occurred in March, June, and a four week period beginning in early September.

The USGS study found that the entrance to the A Canal had one of the highest median pH values of all the Klamath Project sampling points (Dileanis et al. 1996). The pH criterion of 9.0 was exceeded in 55.6% of periodic measurements. During three periods of continuous monitoring conducted during July and August 1992, the pH criterion was exceeded 100% of time during two periods and 88% of the time in the third.

The same trout movement study noted above for water temperature also collected pH data at the Link River dam fish ladder (PacifiCorp 1997). Generally, there were numerous episodes each summer during which pH values exceeded 9, reaching as high as 10.2. However, these periods were not necessarily seasonal, as the pH could rapidly and intermittently return to pH levels as much as 2 pH units lower. These fluctuations are probably in response to changing biomass and respiration conditions caused by algal blooms in the lake and are related to the time of day the sample was taken.

g. Predators

ODFW (1997) notes the presence of the following warmwater gamefish in Upper Klamath Lake: largemouth bass; white and black crappie; Sacramento perch; bluegill, pumpkinseed and green sunfish; yellow perch; and brown bullhead. Several species of non-game fish have also been sampled, including the endangered Lost River and shortnose suckers, Klamath largescale and smallscale suckers, speckled dace, blue and Tui chub, marbled sculpin, Pacific and Klamath lamprey, and fathead minnow. The management direction implemented by ODFW for Upper Klamath Lake is for natural and hatchery production; with trophy, basic yield and intensive use management options. For all waters of the Klamath River Basin, there are directives to 1) manage bull trout for natural production consistent with Wild Fish Management Options; 2) manage Lost River and shortnose suckers accor-ding to the adopted Recovery Plan; 3) manage non-game fish for natural production; 4) manage warmwater game fish for natural production and stocked fish under Basic Yield Management

Option, except where there are subbasin policies; and 5) manage crayfish and introduced bullfrogs for natural production only.

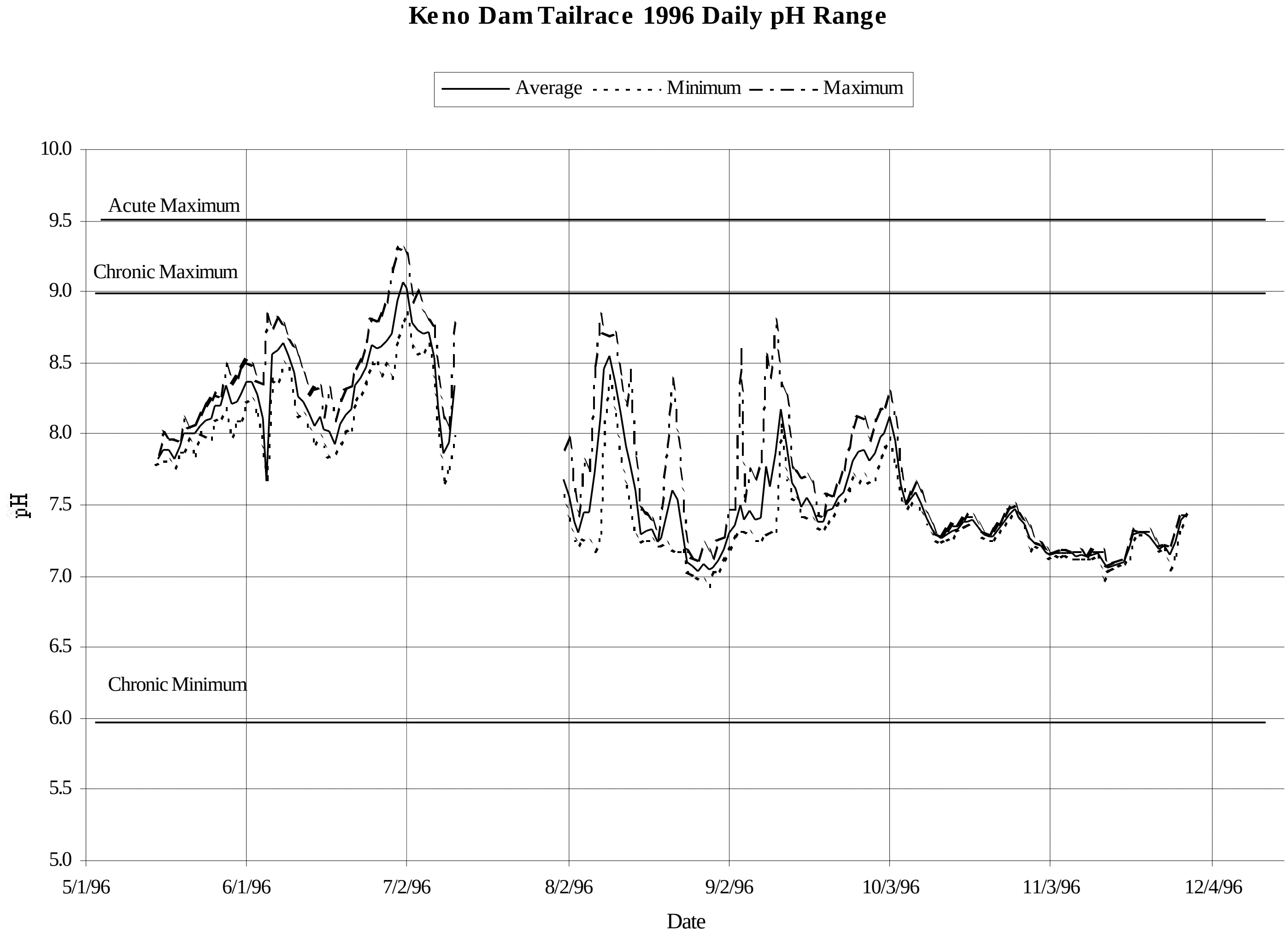


Figure 5-28. Upper Klamath Lake 1996 Daily pH Range

SECTION 6 – REVIEW OF CURRENT FISH PASSAGE CONDITIONS

In the previous sections, information was compiled for three general categories: target species life stage timing, the physical structures encountered in each reach, and the current environmental conditions. Section 6 integrates the temporal and linear aspects of this information to review how fish passage conditions may vary for different species and at different reaches. This review of fish passage conditions is intended to identify potential constraints and opportunities related to the reintroduction and enhancement of fish populations in the Upper Klamath River. For each reach, this review examines passage hydraulics and potential opportunities or impediments (water quality, delay, and predation) during migration for both upstream and downstream passage. In addition, the potential spawning, incubation, and rearing habitats are discussed. A summary of the parameters identified is presented in Table 6-1.

In most of the reaches there are several common parameters that will impede anadromous fish reintroduction. These include: reservoir size, which may delay migration, and lack of fish passage facilities. Various water quality parameters are severely limiting for at least two life stages in all reaches; water temperatures are frequently above the chronic threshold of 15°C and are above the acute threshold of 20°C during July and August. Also, marginal DO conditions (below 3mg/l) and high pH (9 and above) occur during the late summer. There is also a high risk of exposure to predators to target species migrating downstream. These predators can include yellow bullheads, native Tui chub, yellow perch, largemouth bass, pumpkinseed, golden shiner, brown bullheads, and fathead minnows, among others.

In the subsections below, the general condition of each reach is described followed by a review of current fish passage conditions listed in Table 6-1. Where information exists, other parameters that may influence target species is listed under Additional Information.

6.1 Iron Gate to Copco 2

Two tributaries enter the Klamath River in this reach: Jenny Creek at approximately RM 194.0, and Fall Creek at approximately RM 196.3, which may provide additional habitat. Migration of spring and fall chinook may be hindered under current water quality conditions. This reach may be able to function as a migration corridor for coho, steelhead, lamprey, and sucker.

a. Upstream Dam Passage

- There is an existing fish ladder that terminates at Iron Gate dam. This ladder is used for Iron Gate Hatchery operations that could be readily adapted for trap and haul operations. Past performance indicates that

Table 6-1. Review of fish passage conditions at Klamath River facilities.

Issue or Concern	Iron Gate						Copco 2						Copco 1					
	Spring chinook	Fall chinook	Coho	Steelhead	Lamprey	Suckers	Spring chinook	Fall chinook	Coho	Steelhead	Lamprey	Suckers	Spring chinook	Fall chinook	Coho	Steelhead	Lamprey	Suckers
Upstream Dam Passage																		
Adequate attraction flow	○	○	○	○	○	■	X	X	X	X	X	X	X	X	X	X	X	X
Good access to entrance	○	○	○	○	○	■	X	X	X	X	X	X	X	X	X	X	X	X
Adequate flow control	○	○	○	○	○	■	X	X	X	X	X	X	X	X	X	X	X	X
Suitable to swimming characteristics	○	○	○	○	○	■	X	X	X	X	X	X	X	X	X	X	X	X
Exit sited to minimize fallback	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Delay due to high water temperature	■	□	○	○	○	○	■	□	○	○	○	○	■	□	○	○	○	○
Upstream Reservoir Migration																		
Delay due to loss of orientation	■	■	■	■	■	■	□	□	□	□	□	□	■	■	■	■	■	■
High water temperature during migration	■	□	○	○	○	○	■	□	○	○	○	○	■	□	○	○	○	○
Low dissolved oxygen during migration	■	□	○	○	○	○	■	○	○	○	○	○	■	○	○	○	○	○
High pH during migration	○	○	○	○	○	○	■	○	○	○	○	○	■	□	○	○	○	○
Spawning / Egg Incubation / Early Rearing																		
Adequate spawning/incubation habitat	■	■	■	□	□	□	■	■	■	■	■	■	○	○	○	○	○	○
Temp. / DO / pH during spawning/incubation	■	■	□	○	○	□	■	■	□	○	○	□	□	□	□	□	■	□
Adequate rearing habitat	■	■	□	■	■	■	■	■	■	■	■	■	○	○	○	○	■	■
Temp. / DO / pH during rearing	■	■	■	■	□	□	■	■	■	■	□	□	□	□	□	□	■	□
Downstream Reservoir Passage																		
Delay due to loss of orientation	□	□	□	□	□	UK	○	○	○	○	○	UK	□	□	□	□	□	UK
Exposure to predators	■	■	■	■	■	UK	○	○	○	○	○	UK	■	■	■	■	■	UK
High water temperature during migration	○	○	○	○	○	UK	○	○	○	○	UK	UK	○	○	○	○	UK	UK
Low dissolved oxygen during migration	○	○	○	○	○	UK	○	○	○	○	UK	UK	○	○	○	○	UK	UK
High pH during migration	○	○	○	○	○	UK	○	○	○	○	UK	UK	○	○	○	○	UK	UK
Downstream Dam Passage																		
Injury during turbine passage	■	■	■	■	■	■	□	□	□	□	□	□	■	■	■	■	■	■
Injury during spillway passage	□	□	□	□	□	□	○	○	○	○	○	○	■	■	■	■	■	■
Injury during bypass conveyance	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Effective guidance to bypass entrance	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Good passage hydraulics for all reservoir elevations	■	■	■	■	■	■	○	○	○	○	○	○	■	■	■	■	■	■
Predator accumulation at exit(s)	■	■	■	■	■	■	○	○	○	○	○	○	■	■	■	■	■	■

Issue or Concern	JC Boyle						Keno						Link River					
	Spring chinook	Fall chinook	Coho	Steelhead	Lamprey	Suckers	Spring chinook	Fall chinook	Coho	Steelhead	Lamprey	Suckers	Spring chinook	Fall chinook	Coho	Steelhead	Lamprey	Suckers
Upstream Dam Passage																		
Adequate attraction flow	□	□	□	□	□	□	○	○	○	○	○	○	■	■	■	■	■	■
Good access to entrance	□	□	□	□	□	□	○	○	○	○	○	○	■	■	■	■	■	■
Adequate flow control	○	○	○	○	○	○	○	○	○	○	○	○	■	■	■	■	■	■
Suitable to swimming characteristics	□	□	○	○	□	○	○	○	○	○	○	○	■	■	■	■	■	■
Exit sited to minimize fallback	○	○	○	○	○	○	○	○	○	○	○	○	□	□	□	□	□	□
Delay due to high water temperature	□	□	○	○	○	○	□	□	○	○	○	○	□	□	○	○	○	○
Upstream Reservoir Migration																		
Delay due to loss of orientation	□	□	□	□	□	□	■	■	■	■	■	■	■	■	■	■	■	■
High water temperature during migration	□	□	○	○	○	○	□	□	○	○	○	○	□	□	○	○	○	○
Low dissolved oxygen during migration	■	■	○	○	○	○	■	■	○	○	○	○	■	■	○	○	○	○
High pH during migration	■	■	○	○	○	○	■	■	○	○	○	○	■	■	○	○	○	○
Spawning / Egg Incubation / Early Rearing																		
Adequate spawning/incubation habitat	□	□	□	□	○	○	■	■	■	■	■	■	○	○	□	□	○	○
Temp. / DO / pH during spawning/incubation	□	□	■	□	■	□	■	■	■	■	■	■	■	■	■	■	■	■
Adequate rearing habitat	□	□	□	□	■	■	□	□	■	■	■	■	○	○	■	□	■	■
Temp. / DO / pH during rearing	□	□	■	□	■	□	■	■	■	■	■	■	■	■	■	■	■	■
Downstream Reservoir Passage																		
Delay due to loss of orientation	□	□	□	□	□	UK	■	■	■	■	■	UK	■	■	■	■	■	UK
Exposure to predators	■	■	■	■	■	UK	■	■	■	■	■	UK	■	■	■	■	■	UK
High water temperature during migration	○	○	○	○	UK	UK	○	○	○	○	UK	UK	○	○	○	○	UK	UK
Low dissolved oxygen during migration	○	○	○	○	UK	UK	○	○	○	○	UK	UK	○	○	○	○	UK	UK
High pH during migration	○	○	○	○	UK	UK	○	○	○	○	UK	UK	○	○	○	○	UK	UK
Downstream Dam Passage																		
Injury during turbine passage	■	■	■	■	■	■	NA	NA	NA	NA	NA	NA	□	□	□	□	□	□
Injury during spillway passage	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Injury during bypass conveyance	□	□	□	□	□	□	X	X	X	X	X	X	X	X	X	X	X	X
Effective guidance to bypass entrance	□	□	□	□	□	□	X	X	X	X	X	X	X	X	X	X	X	X
Good passage hydraulics for all reservoir elevations	□	□	□	□	□	□	■	■	■	■	■	■	■	■	■	■	■	■
Predator accumulation at exit(s)	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Legend: ○ = Low impact □ = Medium impact ■ = High impact X = Structure Not Available NA = Not Applicable UK = Unknown the ladder is suitable for salmonids. The existing ladder may not be suitable for suckers due to their weaker swimming capabilities.

- High water temperatures may cause delay for spring and fall chinook migration.
- Good access and adequate attraction flow for most target species.

b. Upstream Reservoir Migration

- Delay due to loss of orientation for all species.
- Poor water quality conditions currently exist for spring chinook.

c. Spawning / Egg Incubation / Early Rearing

- Lack of spawning, incubation, and rearing habitat.
- Poor water quality conditions currently exist for most of the target species.

d. Downstream Reservoir Passage

- The large size of Iron Gate Reservoir is likely to cause some disorientation for all species.
- Exposure to predators.

e. Downstream Dam Passage

- Poor downstream passage hydraulics for all reservoir elevations.
- A majority of Iron Gate dam flow (not screened) passes through the turbines resulting in injury during turbine passage.
- Iron Gate's long ungated spillway provides good entrance conditions for downstream passage, but the flip bucket feature may be disruptive or harmful.
- A high potential for predator accumulation below the dam.

f. Additional Information

- Reservoir elevations show frequent to moderate fluctuations which would likely be detrimental to near-shore fish use.
- Spill occurs frequently from December through April, coinciding well with the peak in juvenile emigration for target species. The retention time, (between minimum and maximum flow events) in the reservoir can range from 42 to 3 days, impeding downstream passage.

6.2 Copco 2 to Copco 1

This small reach exhibits many of the same characteristics as Iron Gate; e.g. poor water quality conditions. The reach could serve as a migration corridor for most target species. The lack of tributary flows limits the potential for additional habitat.

a. Upstream Dam Passage

- Copco 2 does not have an upstream fish passage structure.
- High water temperatures may cause delay for spring and fall chinook migration.

b. Upstream Reservoir Migration

- Water quality conditions are currently poor for spring and fall chinook.
- Delay due to loss of orientation for all target species.

c. Spawning / Egg Incubation / Early Rearing

- Lack of adequate spawning, rearing and incubation habitat.
- Water quality conditions are currently poor in July and August, which negatively impact most of the target species.

d. Downstream Reservoir Passage

- Due to the small size of this reservoir, impacts are expected to be minor.

e. Downstream Dam Passage

- A majority of the flow passes unscreened through the turbines.

f. Additional Information

- Spill flows are common in the spring; however, the smaller head differentials at both the turbines and spillway would reduce mortality in comparison to Iron Gate.

6.3 Copco 1 to J. C. Boyle

Conditions in the reach above Copco 1 dam are very similar to those seen at Iron Gate, including the detrimental aspects of a large reservoir (i.e., potential increase in loss of orientation and predation). Shovel Creek is a perennial stream with potential spawning and rearing habitat. However, target species could compete with the current management for native trout. Water quality conditions for adult migrating spring and fall chinook are currently poor but may be more suitable for the other target species.

a. Upstream Dam Passage

- Copco 1 does not have an upstream fish passage structure.
- High water temperatures may cause delay for spring and fall chinook migration

b. Upstream Reservoir Migration

- Delay due to loss of orientation for all target species.
- Poor water quality conditions currently exist during spring chinook upstream migration.

c. Spawning / Egg Incubation / Early Rearing

- Poor water quality conditions currently exist during spawning egg incubation and early rearing.
- Inadequate rearing habitat for lampreys and suckers.

d. Downstream Reservoir Passage

- Delay due to loss of orientation for all target species due to reservoir size.
- Exposure to predators is high.

e. Downstream Dam Passage

- Injury during downstream passage; the stair-step design of the Copco 1 spillway may cause high mortality and the flow thorough the turbines is not screened.
- Downstream passage hydraulics is poor for all reservoir elevations.
- Predators can accumulate below the dam.

f. Additional Information

- Daily reservoir fluctuation is potentially detrimental to fish rearing in nearshore habitat.
- The retention time at Copco 1 would range from 32 to 2 days, which could delay migration through the reservoir

6.4 J. C. Boyle to Keno

This reach differs from the other reaches discussed in several ways. First, a pool and weir fish ladder is present and successful at passing fish upstream. However, PacifiCorp's fish trapping study (1997) did not record any passage of suckers even though there are historical accounts of high sucker usage. The configuration of the ladder entrance is not ideal due to its orientation with the spillway apron. The concern has been raised that attraction to the ladder is greatly diminished when spill flows exceed about 300 cfs. Secondly, Spencer Creek is located in this reach, providing an increased habitat for spawning and early rearing; the presence of trout suggests that the area could accommodate target species. However, ODFW has stated that target species would compete with the current management objective for Wild Trout (ODFW 1997). Lastly, the power canal intake is equipped with vertical travelling screens and a bypass system, greatly reducing the number of fish that are exposed to the turbines.

a. Upstream Dam Passage

- Adequacy of fish ladder attraction flow and entrance access for all target species.
- Passage facilities may not be suitable to the swimming characteristics of spring and fall chinook, and lamprey.
- High water temperatures may cause delay for spring and fall chinook migration.

b. Upstream Reservoir Migration

- Delay due to loss of orientation.
- Poor water quality conditions for spring and fall chinook.

c. Spawning / Egg Incubation / Early Rearing

- Poor water uality conditions currently exist during spawning egg incubation and early rearing.
- Lack of adequate spawning, incubation, and rearing habitat.

d. Downstream Reservoir Passage

- Delay due to loss of orientation.
- Exposure to predators during downstream passage.

e. Downstream Dam Passage

- For the target species that are not successfully bypassed, the potential injury during turbine passage is high.
- Poor downstream passage hydraulics for all reservoir elevations.
- The potential for predators to accumulate at the bypass exit is high.

f. Additional Information

- Normal operating conditions provide for frequent reservoir fluctuations. This is potentially detrimental to fish rearing in nearshore habitat.

6.5 Keno to Link River Dam

The physical structures in this reach are more conducive to fish passage due to the lack of power generating facilities and availability of a well-designed fish ladder. However, irrigation return waters and slow turnover worsen water quality conditions. This reach has limited spawning and rearing habitat but can provide access to better habitat above Upper Klamath Lake (via the Link River dam fish ladder).

a. Upstream Dam Passage

- The attraction flow is adequate at the existing facility for most target species.
- High water temperatures may cause delay for spring and fall chinook migration.

b. Upstream Reservoir Migration

- Delay due to loss of orientation.
- Poor water quality conditions currently exist for spring and fall chinook.

c. Spawning / Egg Incubation / Early Rearing

- Lack of adequate spawning, incubation, and rearing habitat.
- Poor water quality conditions during spawning egg incubation and early rearing.

d. Downstream Reservoir Passage

- Exposure to predators.
- Delay due to loss of orientation.

e. Downstream Dam Passage

- Poor downstream passage hydraulics for all reservoir elevations.
- Potential predators below dam.

f. Additional Information

- Water levels and flow rates are regulated at Keno dam to maintain near-constant conditions for irrigation facilities that drain or pump from Lake Ewauna.

- In the fall there are substantial inflows of irrigation return water entering the Klamath River in this reach.

6.6 Above Link River Dam

This reach has several distinct characteristics from the others. Water diversions for hydroelectric power are less than at other sites; however, there are no screens or bypass facilities for downstream migrants. There is a fish ladder present but, passage appears to be affected by flow through the ladder. There is inadequate control to maintain good ladder hydraulics and the response to spill events suggests that passage is better at higher flows. The Bureau of Reclamation is developing plans to improve the ladder. Lastly, Upper Klamath Lake exhibits frequent episodes of poor water quality, forcing fish into tributaries for refuge.

a. Upstream Dam Passage:

- Adequacy of fish ladder attraction flow, entrance access, flow control suitable to swimming characteristics, and fallback is questionable for all target species.
- High water temperatures may cause delay for spring and fall chinook migration.

b. Upstream Reservoir Migration

- Delay due to loss of orientation.
- Poor water quality conditions for spring and fall chinook.

c. Spawning / Egg Incubation / Early Rearing

- Poor water quality conditions during spawning, egg incubation, and rearing.
- Concern for adequate spawning and rearing habitat for most of the target species.

d. Downstream Reservoir Passage

- Delay due to loss of orientation.
- Exposure to predators.

e. Downstream Dam Passage

- Injury during turbine passage.
- Poor downstream passage hydraulics for all reservoir elevations.
- Predator accumulation below dam.

f. Additional Information

- Upstream of the dam is the entrance to the Klamath Irrigation Project A Canal which has a capacity of 1,150 cfs.
- Upper Klamath Lake has a surface area more than 95 times the size of Iron Gate Reservoir.
- Reservoir fluctuates on a seasonal basis.