2. Existing Hydrology Conditions

Several studies of the hydrology were conducted and detailed reports were generated for each study. The following reports are attached as appendices to this report:

1. Current Flood Hydrology of the Klamath River – Appendix A: Analyzes the historical flow duration and flood frequency data of the Klamath River from Keno Dam to the Pacific Ocean.

2. Hydrologic Data Development and Management – Appendix E: Describes development of naturalized flows from historic data, an overview of synthetic hydrology, and an overview of data management system.

3. Upper Klamath Biological Opinion Operations – Appendix E: Describes how the 2010 Biological Operational criteria were implemented into the Klamath Project Simulation Model (KPSIM) without adjustments for the Klamath Dam Removal (KDR) study. These are the operations assumed under No Action Alternative.

4. Upper Klamath KBRA operations – Appendix E: Describes how the KBRA operation criteria were implemented into KPSIM without adjustments for the Dam Removal Study. These are the operations assumed under the Dam Removal Alternative.

5. Hydrology Operations – Appendix E: KBRA operation criteria and implementation in KPSIM without KDR adjustments. These are the operations assumed under the Dam Removal Alternative.

6. Forecast Generation and Demand Representation in Upstream Operation Models – Appendix E: Detailed description of forecast generation for synthetic hydrology for UKL operations and KBRA demand computations

7. Climate Change hydrology development – Appendix E: Describes development of Climate Change Hydrology

A brief summary on the current conditions of the Klamath basin hydrology is given in this chapter.

2.1. Rainfall and Temperature

Monthly average temperature and precipitation at Klamath Falls, OR and Yreka, CA are giving in Figure 2-1 and Figure 2-2, respectively. The months with the most precipitation are November to March. The least precipitation falls during the months of July through September.

The annual precipitation at Klamath Falls and at Copco 1 Dam is given in Figure 2-3 and Figure 2-4, respectively. The annual precipitation for the period from 1907 to 1997 at Klamath Falls is 13.4 inches and the annual precipitation from 1959 to 2009 at Copco 1 is about 20 inches. Additional statistics on monthly rainfall at Keno and Copco 1 are given Figure 2-5 and Figure 2-6.

The annual mean temperature and total precipitation for Jackson, Klamath, and Siskiyou Counties from 1900 to 2009 was reported in Reclamation (2011c) and their figure is reproduced in Figure 2-7. The 25-year moving average of the mean annual temperature has been increasing since the 1970s and is approximately 1° F higher now than in the 1930s to 1960s. The total precipitation is quite variable year to year and does not show a consistent trend since the 1950s.

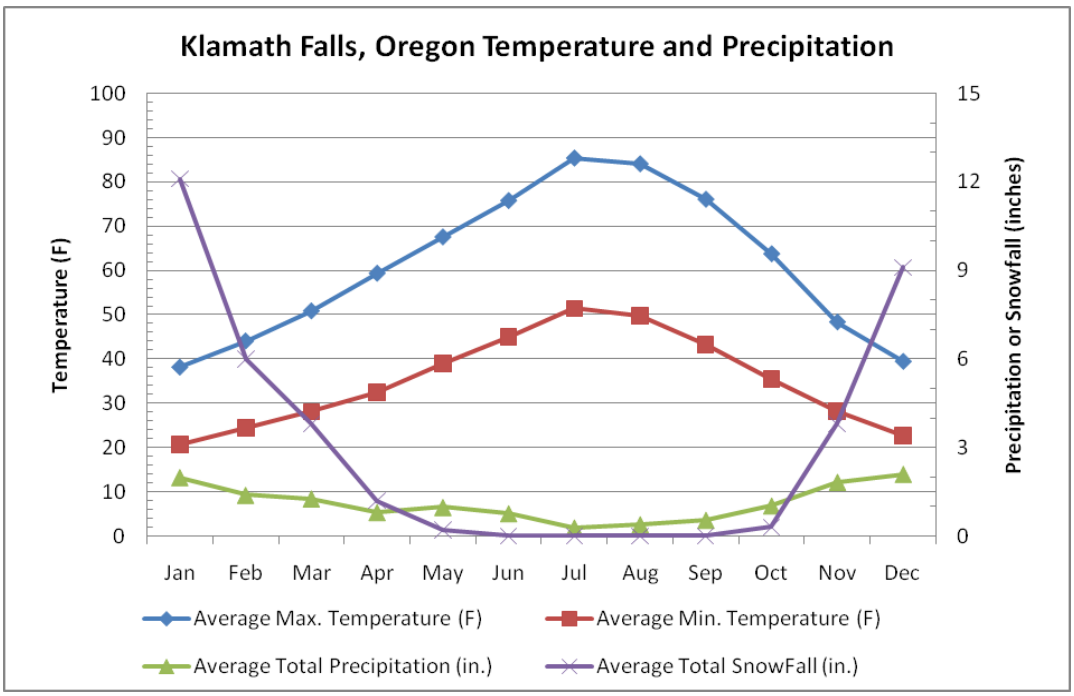

Figure 2-1. Average monthly temperatures and precipitation at Klamath Falls. (gage # 354506 at 41.97972 N, 1222.33778 W). Period of record is from 5/11/1887 to 5/31/2001. Data obtained from Western Regional Climate Center (http://www.wrcc.dri.edu/).

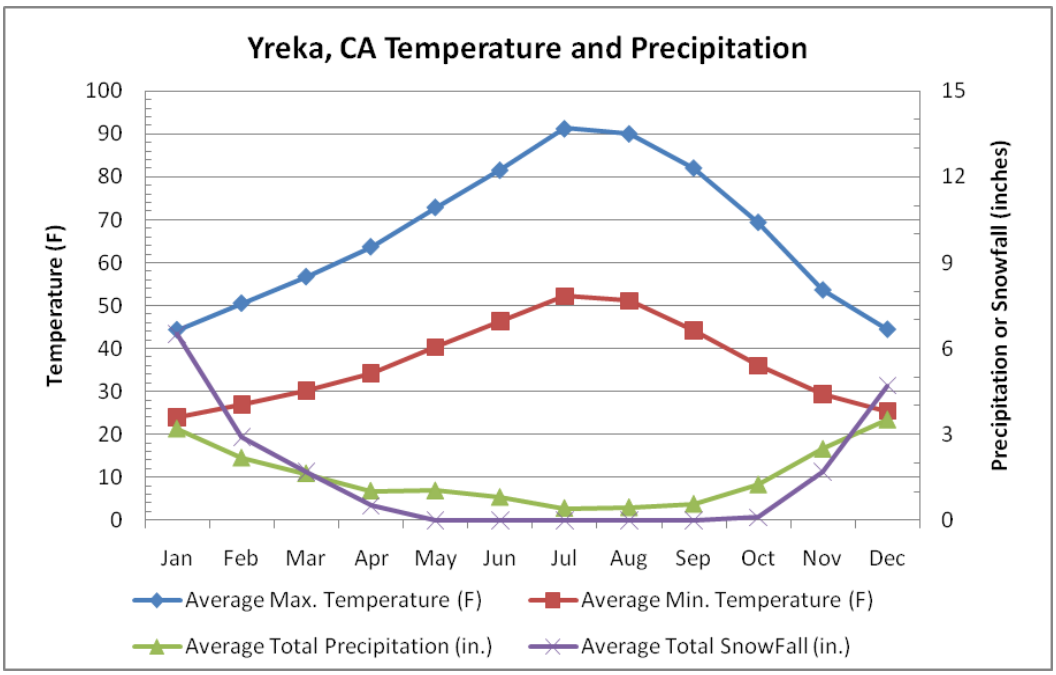

Figure 2-2. Average monthly temperatures and precipitation at Yreka, CA (gage # 049866). Period of record is from 2/ 1/1893 to 4/30/2010. Data obtained from Western Regional Climate Center (http://www.wrcc.dri.edu/).

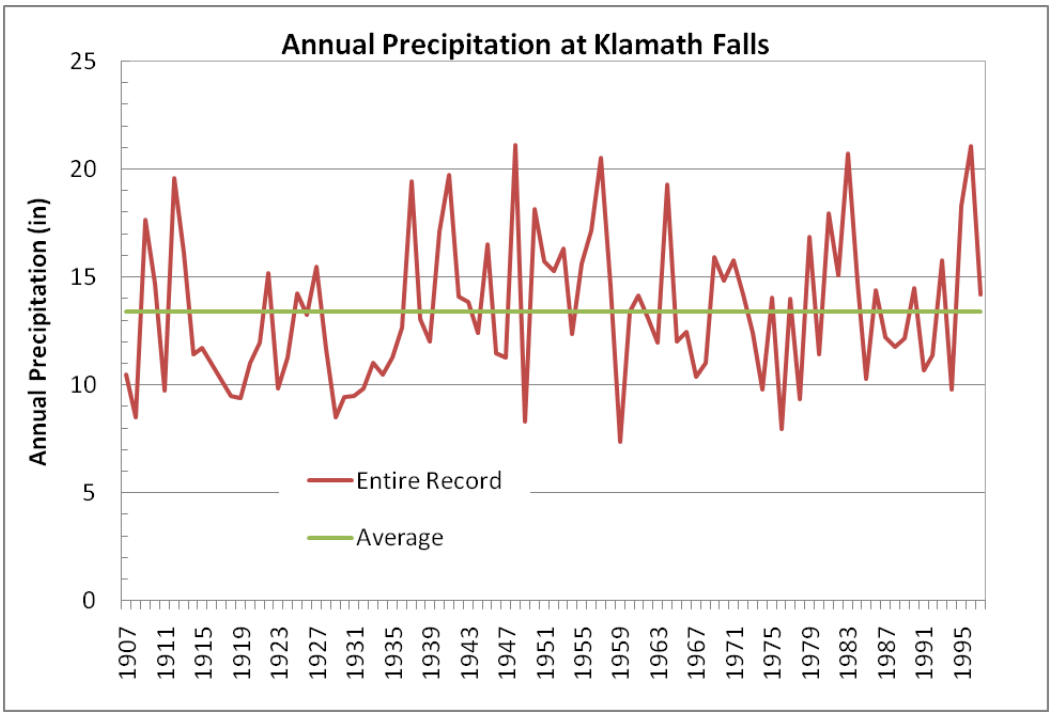

Figure 2-3. Annual precipitation at Klamath Falls. (gage # 041990 at 41.97972 N, 1222.33778 W). Data obtained from Western Regional Climate Center (http://www.wrcc.dri.edu/).

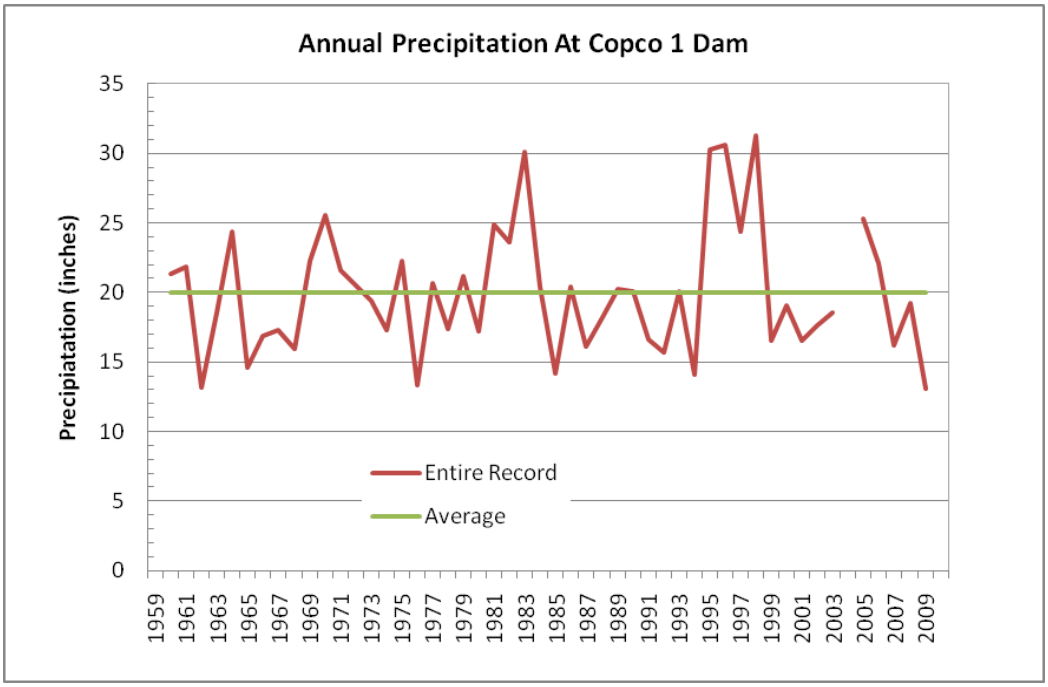

Figure 2-4. Annual precipitation at Copco 1 Dam (gage # 041990 at 41.97972 N, 1222.33778 W). Data obtained from Western Regional Climate Center (http://www.wrcc.dri.edu/).

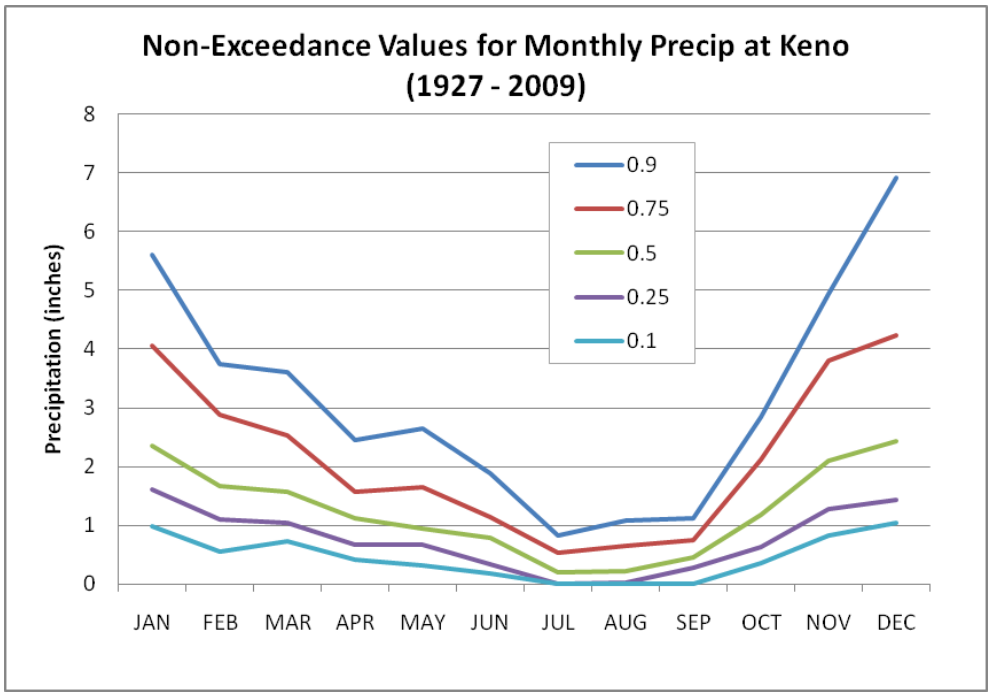

Figure 2-5. Rainfall statistics for rain gage located near Keno Dam (gage # 354403 at 42.12639 N, 121.93083 W). Data obtained from Western Regional Climate Center (http://www.wrcc.dri.edu/)

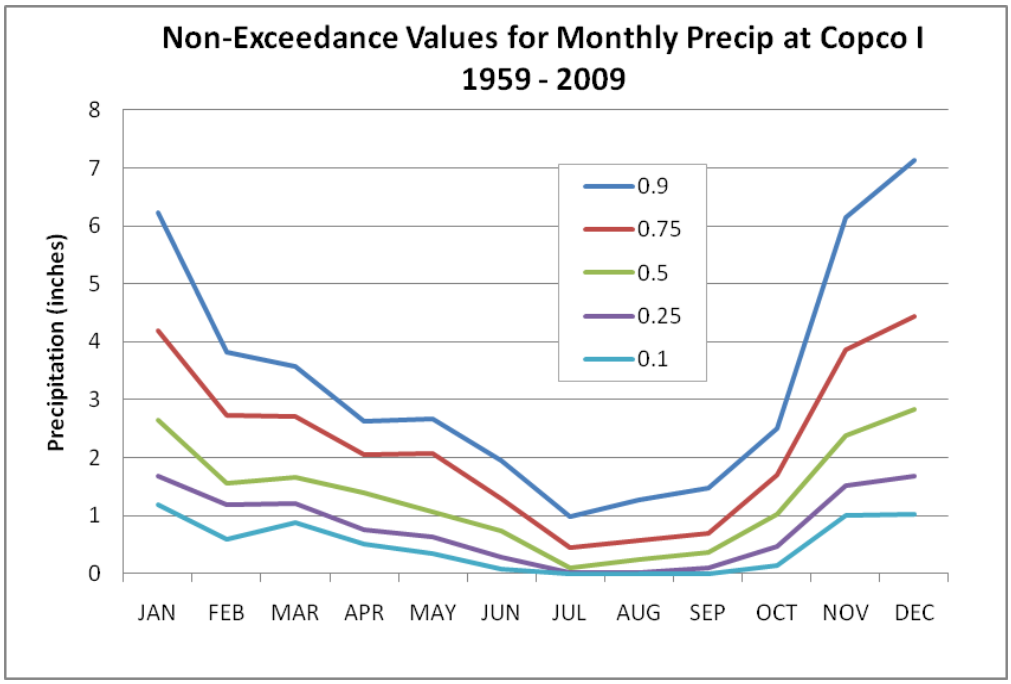

Figure 2-6. Rainfall statistics for rain gage located near Copco 1 Dam (gage # 041990 at 41.97972 N, 1222.33778 W). Data obtained from Western Regional Climate Center (http://www.wrcc.dri.edu/).

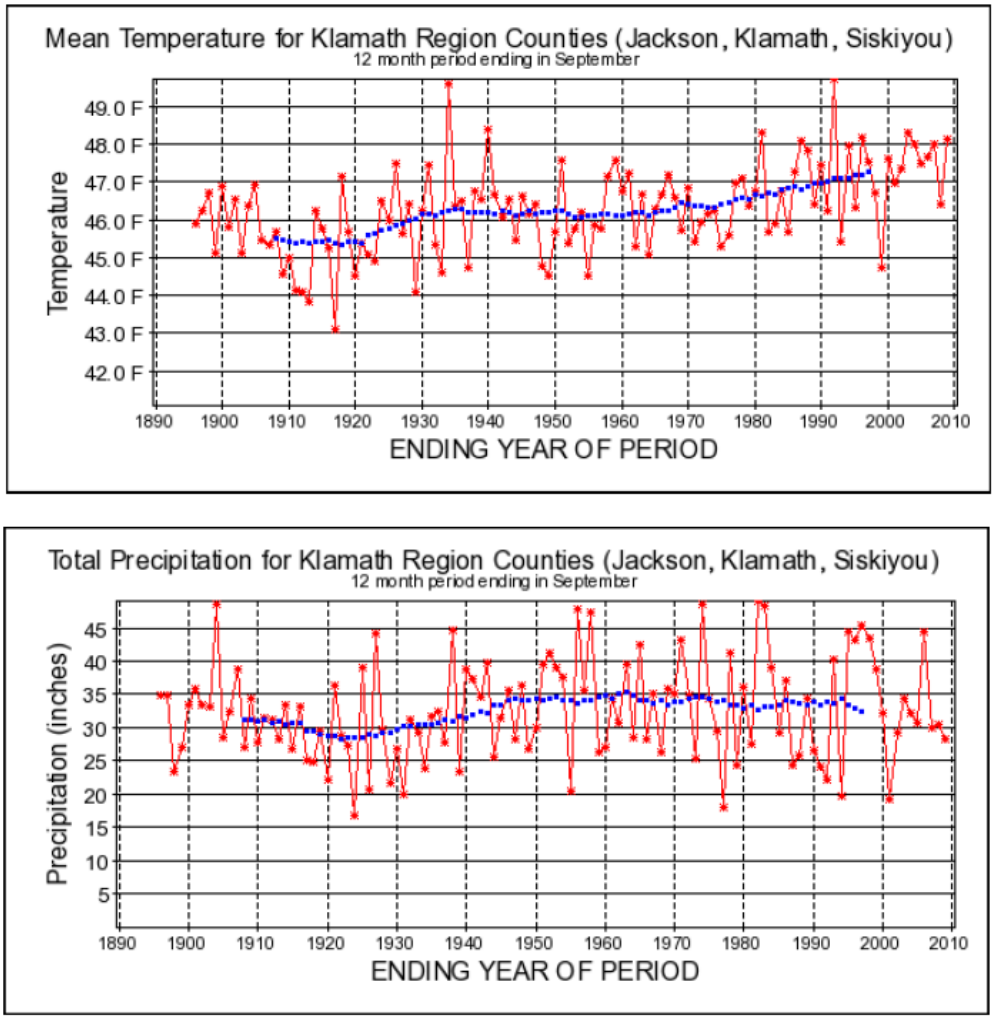

Figure 22. Observed annual (red) and moving-mean annual (blue) temperature and precipitation, averaged over the Klamath River Region.

Source: Western Climate Mapping Initiative (WestMap) available at: http://www.cefa.dri.edu/ Westmap/. Red line indicates annual time series for the given geographic region. Blue line indicates 25-year moving annual mean values, where each value is plotted on the center year of its respective 25-year period. WestMap data are derived from the PRISM climate mapping system (Daly et al. 2004; Gibson et al. 2002).

Figure 2-7. Historic annual mean temperature and total annual precipitation for Klamath Regional Counties from Reclamation, 2011c.

2.2. Dams, Water Diversion, and Hydropower Facilities

The storage capacities and details of the dams located on the Klamath River are given in Table 2-1 from PacifiCorp (2004a). Some of the details of their facilities are reproduced in this document. Upper Klamath Lake controlled by Link Dam has approximately 83% of the storage on the Klamath River, while the four PacifiCorp dams being analyzed for removal have 14% of the storage. These four dams are operated for hydropower and most often are operated as run-of-the-river facilities, whereas, Link Dam is operated primarily for water storage.

A flow schematic of the operations from Link Dam to Iron Gate is shown Figure 2-8 and a flow schematic of the Klamath Basin above Keno Dam is shown in Figure 2-9. A schematic of the Klamath Irrigation Project is shown in Figure 2-10.

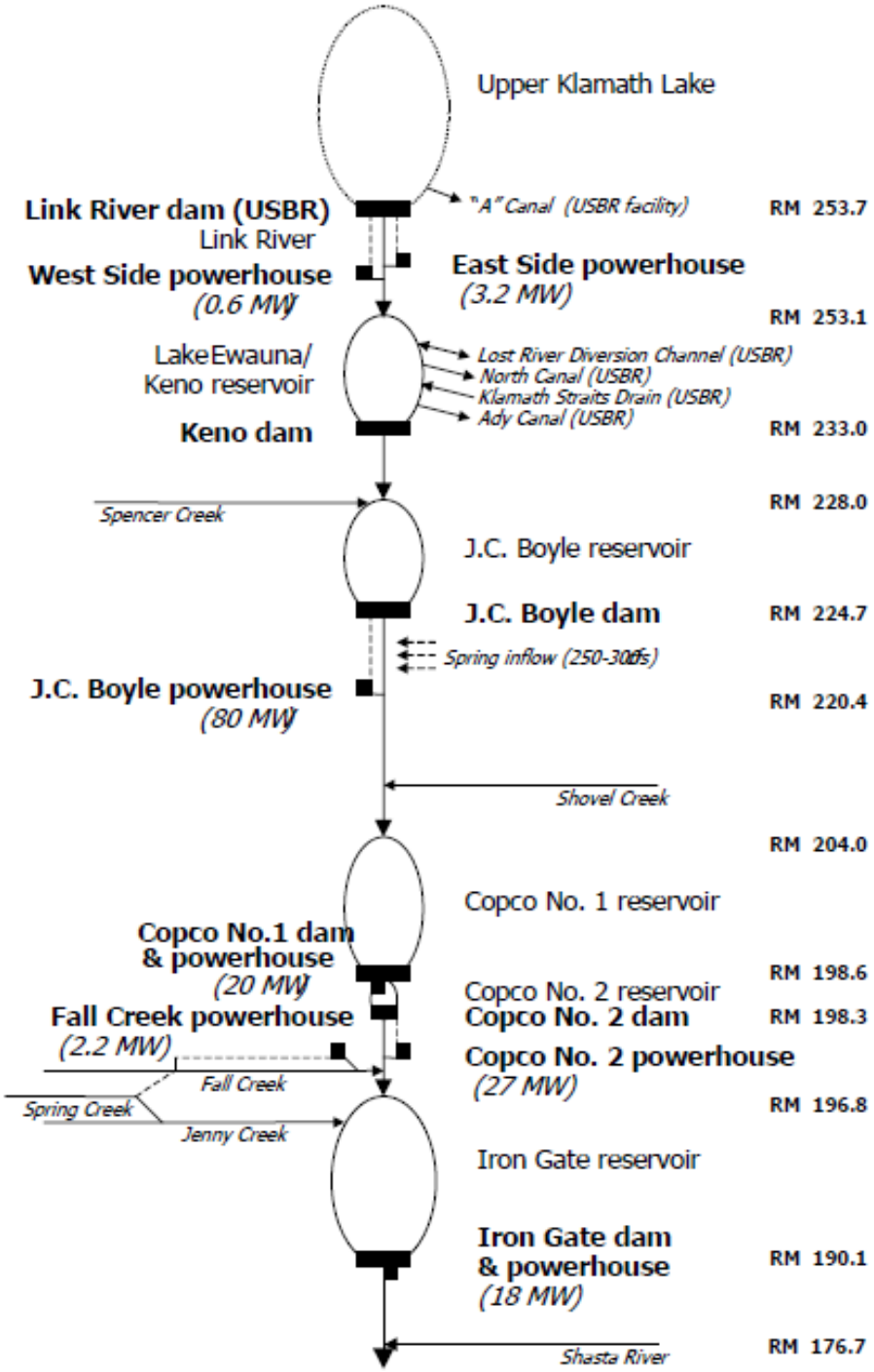

Figure 2-8. Schematic of Flow Operations in Klamath Basin (used by permission from PacifiCorp, Exhibit B, 2004).

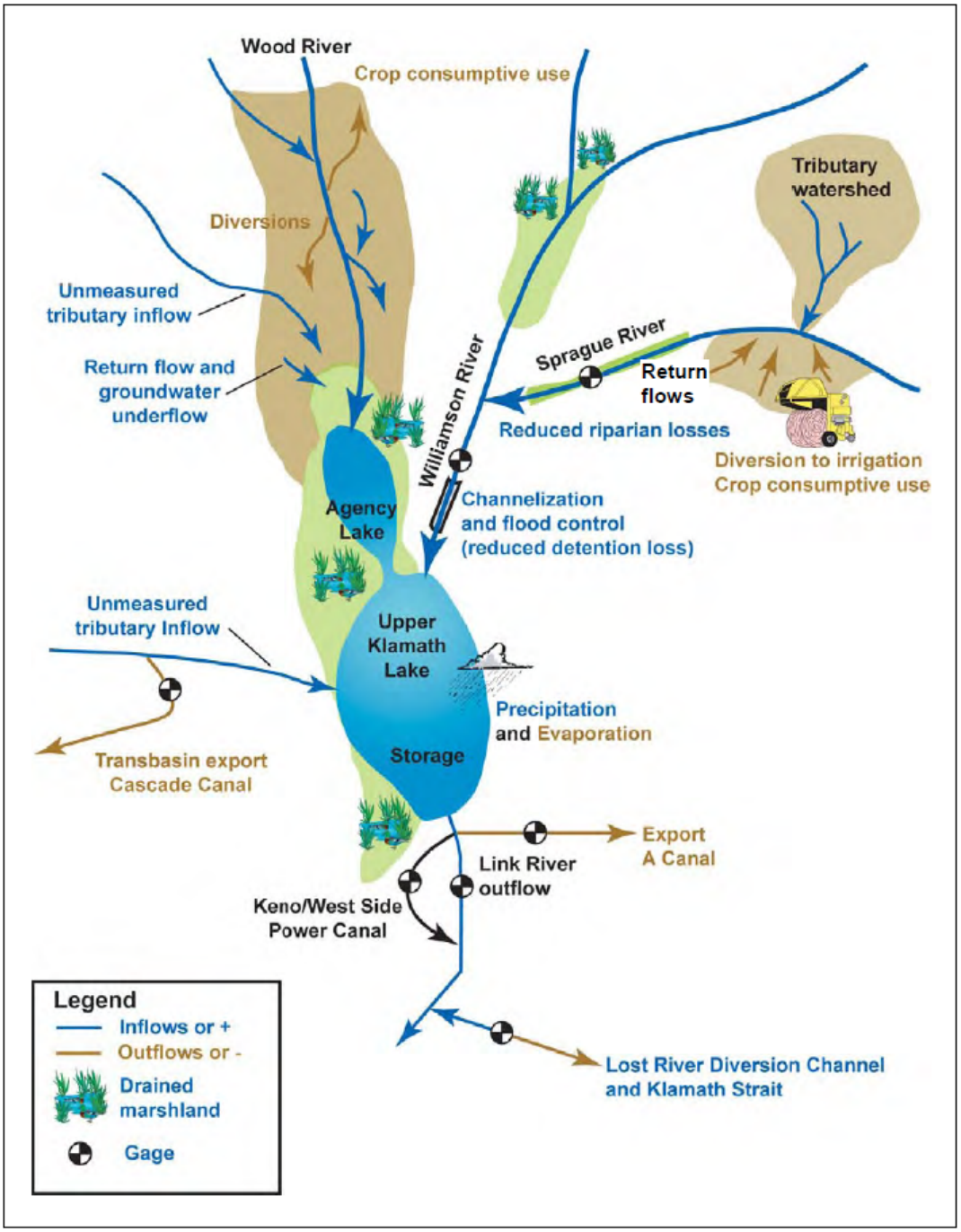

Figure 2-9. Upper Klamath Lake and Keno flow schematic (from Reclamation 2005).

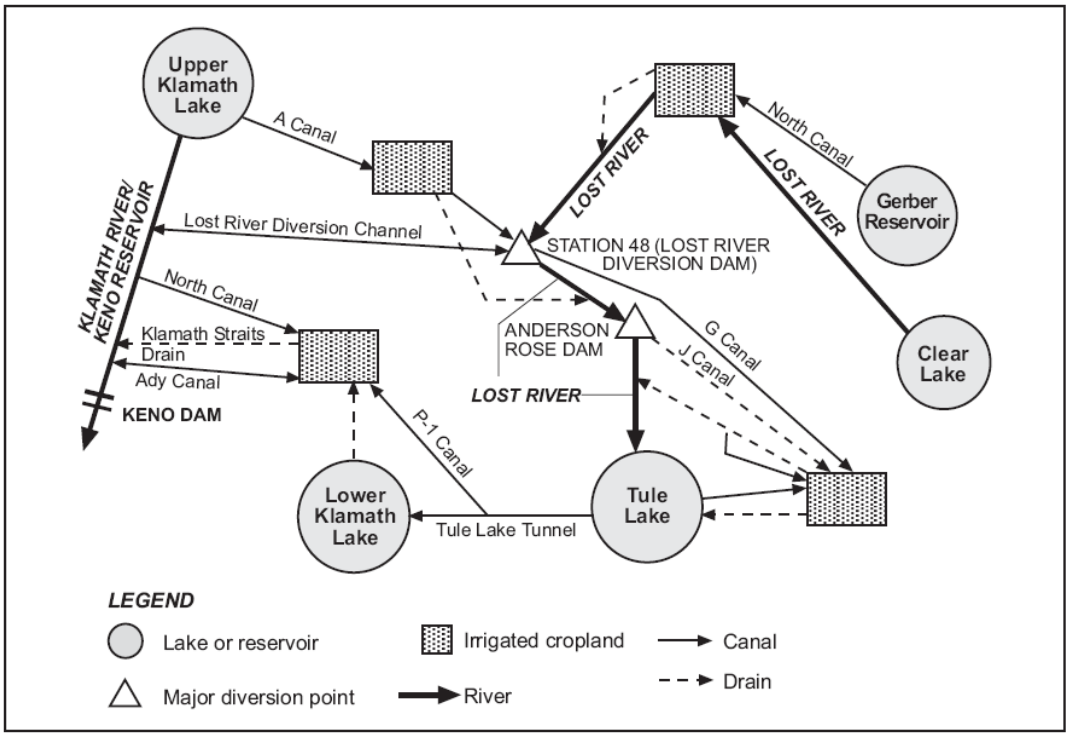

Figure 2-10. Schematic of Klamath Irrigation Project (from FWS, 2002 and FERC, 2007).

2.2.1. LINK DAM AND UPPER KLAMATH LAKE

Link River Dam on Link River at the head of Klamath River is just west of Klamath Falls, Oregon, and regulates flow from Upper Klamath Lake Reservoir. The dam is a reinforced concrete slab structure with a height of 22 feet and a crest length of 435 feet.

Upper Klamath/Agency Lake (UKL) is a shallow, hypereutrophic (high biological productivity) lake with extensive wetlands, and is fed by numerous shoreline springs, and several tributaries. This lake is the largest body of fresh water in Oregon and varies from 6 to 14 miles wide and is about 25 miles long. Upper Klamath/Agency Lake has a maximum surface area of approximately 83,000 acres and a active storage capacity between elevations 4136.0 and 4143.3, including Tulana and Goose Bays farms, of 515,400 acre-ft. The potential active capacity of a re-connected Agency Lake and Barnes Ranches between elevations 4136.0 and 4143.3 is 63,800 acre-ft. The “active” storage number is based upon the possible operational ranges of Link Dam, however, the current 2008 Biological Opinion sets a minimum lake elevation target of 4138.0 ft which reduces the active storage capacity of UKL and a re-connected Agency Lake and Barnes Ranches by approximately 127,700 acre-ft. Net inflow for the entire year averages 1.2 million acre-feet but ranges from 576,000 to 2.4 million acre-feet (Reclamation, 2005).

The Williamson River and Sprague River, a tributary to the Williamson River, drain the central and eastern part of the Upper Klamath River Basin into the Upper Klamath Lake, which empties to the Link River. The Klamath River begins at Lake Ewauna just south of Upper Klamath Lake and flows southwest into California. Flow for the entire Upper Klamath River Basin is recorded at the Klamath River gage at Keno, Oregon. The minimum flow release from Link Dam is 250 cfs June to Oct (USFWS, 2008) and 90 cfs otherwise (PacifiCorp, 2004).

2.2.2. KLAMATH IRRIGATION PROJECT

Reclamation's Klamath Irrigation Project developed substantial water storage and distribution systems and drainage of lakes and wetlands, and it currently includes about 240,000 acres of irrigable lands. There are about 150,000 irrigated agricultural acres served by water withdrawn from the Upper Klamath Lake and the Klamath River. Reclamation states that, during a normal year, the net use of irrigation project water is 1.25 acre-feet per acre, including water used by FWS in the Tule Lake and Lower Klamath National Wildlife Refuges. The main sources of water for this system are Upper Klamath Lake via the A canal, the Klamath River from Keno reservoir, and the naturally closed Lost River Basin (see Figure 2-10).

Before development of the Klamath Irrigation Project in 1905, the surface area of Lower Klamath Lake was often larger than Upper Klamath Lake. Flows from the Klamath River, supplemented by springs around the lake, supported a complex of wetlands and open water covering about 80,000 to 94,000 acres in the spring, during high water, and 30,000 to 40,000 acres in late summer. By 1924, however, development in the Klamath Irrigation Project area eliminated more than 90 percent of the Lower Klamath Lake's open water and marsh. Only about 4,700 acres of open water and wetland remain. Connections between the Klamath River and Lower Klamath Lake were severed by development, which changed the hydrology of both the lake and the river. Current connectivity between Lower Klamath Lake and the rest of the basin is limited to water pumped from Tule Lake and water from irrigation structures that lead to and from the present day Keno Reservoir (Reclamation, 2005).

Before the Klamath Irrigation Project, Tule Lake varied in surface area from 55,000 to more than 100,000 acres, averaging about 95,000 acres, at times larger than the former expanse of Upper Klamath Lake. Lost River was the main source of water to Tule Lake. Similar to Lower Klamath Lake, Tule Lake was connected seasonally to the Klamath River. During periods of high runoff, water from the Klamath River flowed into the Lost River slough and down the Lost River to Tule Lake. The direction of the river's flow is now determined by operators of the Klamath Irrigation Project depending on water needs. Most of the former bed of Tule Lake has been drained for agriculture, leaving about 9,450 to 13,000 acres of shallow lake and marshland (FERC, 2007).

By 1924, the Lower Klamath Lake, once directly connected to the Klamath River, was cut off and drained substantially by the Klamath Irrigation Project. The remaining marsh and lake areas are now managed primarily as Lower Klamath National Wildlife Refuge. Primarily maintained for waterfowl and water dependent species, this 53,600 acre refuge contains 12 wetland units that are supplied with water on a seasonal basis. Only Unit 2 (about 2,200 acres), with an average depth of about 3 feet, is maintained as a permanently flooded lake. Private agricultural lands are within the boundary of the former lake, as well (FERC, 2007). Reclamation (2005) contains a more detailed history of Lower Klamath Lake.

The map of the Klamath Project in 1908 is shown in Figure 2-11 and the map of the Klamath Project in 1998 is shown in Figure 2-12. Of particular note are the much reduced sizes of Lower Klamath Lake and Tule Lake, as well as the replacement of marsh lands with agricultural lands.

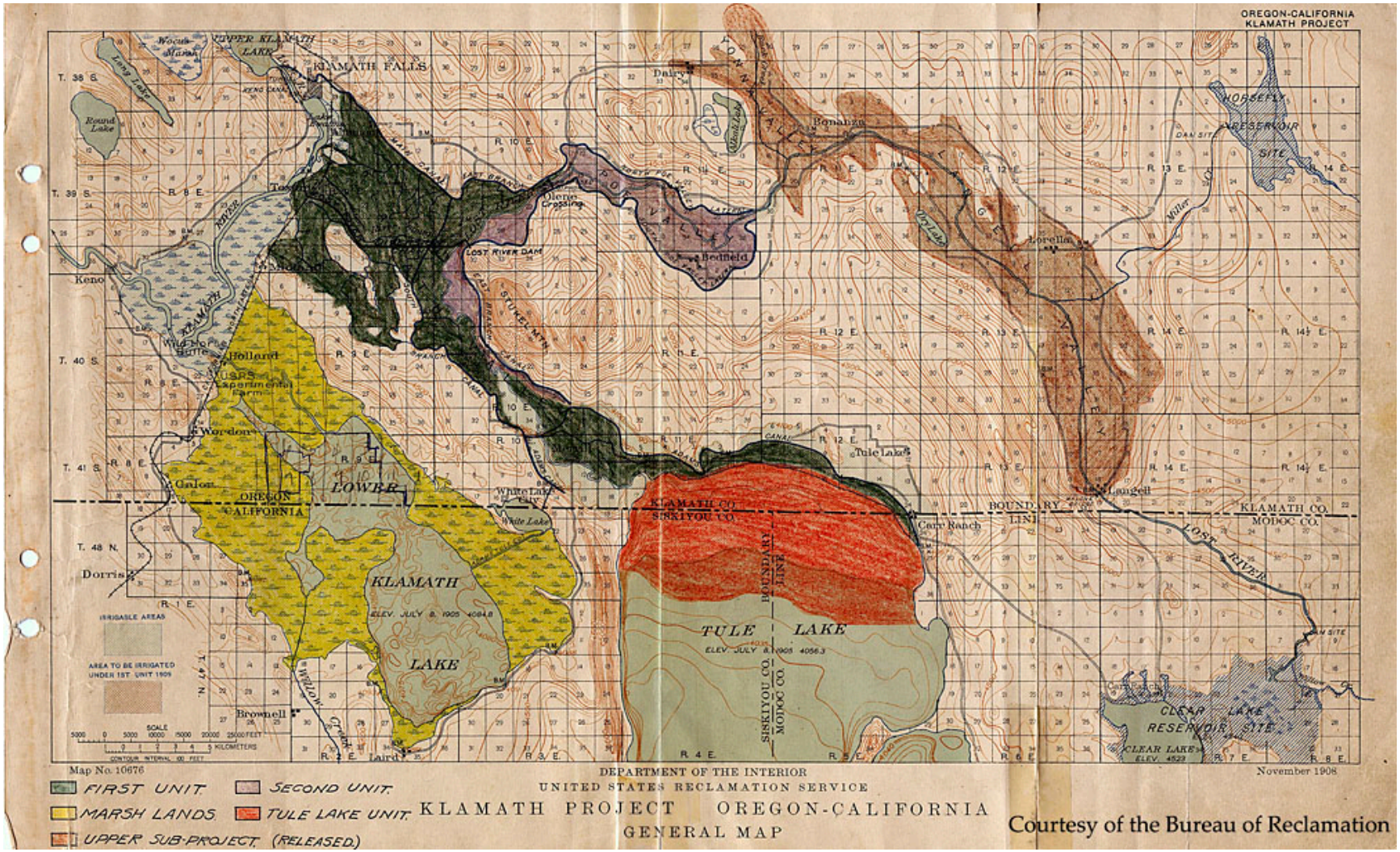

Figure 2-11. Map of Klamath Project in 1908, prior to implementation of the Klamath Project.

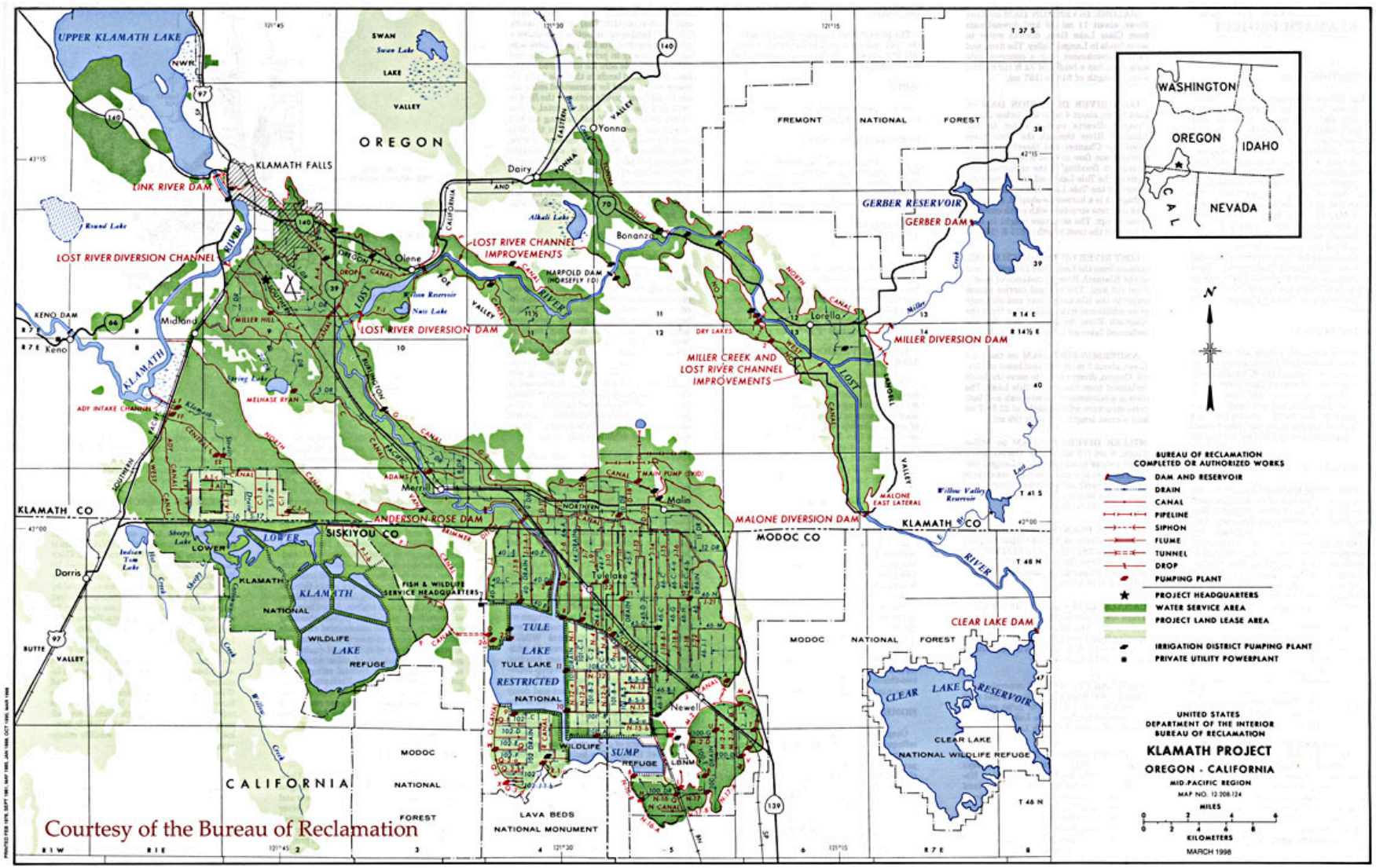

Figure 2-12. Map of Klamath Project in 1998.

2.2.3. KENO DEVELOPMENT

Information on the Keno Development is reproduced from PacifiCorp (2004a) below for convenience:

> *"Keno dam is a re-regulating facility located at approximately River mile (RM) 233, which is approximately 21 miles downstream of Link River dam (Figure B1.1-1). There is no power generating capability at this facility. The concrete dam has a height of 25 feet and a spillway section consisting of six 40-foot-wide spill gates. The impoundment upstream of the dam has a surface area of 2,475 acres and a total storage capacity of 18,500 acre-feet. There is a weir and orifice type fish ladder at the Keno dam.*
>
> *… In as much as possible, Keno dam is operated to maintain a steady reservoir elevation through all river flows and water year types, while continuing to provide enough water to meet flow requirements at Iron Gate dam. The steady reservoir elevation allows both the USBR and local irrigators to manage irrigation water. In operating Keno dam, PacifiCorp can more effectively schedule and plan load following operations at the J.C. Boyle powerhouse. Operating the reservoir in a re-regulating mode can result in river fluctuations below the dam, especially during high flow conditions.*
>
> *Flows from the USBR Project enter PacifiCorp's Project in Keno reservoir via the Klamath Straits Drain and Lost River diversion channel. These return flows can be highly variable and can be somewhat problematic for stable reservoir elevations. Flows from the USBR Project can vary approximately 775 cfs, each 200 cfs has the ability to affect the reservoir elevation approximately 0.2 feet in a 24-hour period. Hence, control of flows from the East Side Development and flow through Keno dam are crucial to maintain a constant elevation in Keno reservoir. In order to achieve a reservoir fluctuation within ± 0.1 feet, PacifiCorp and USBR coordinate and/or communicate their operations on a daily basis during periods of high flow fluctuation."*

2.2.4. J.C. BOYLE DEVELOPMENT

Information is reproduced from PacifiCorp (2004a) below for convenience

> *"The J.C. Boyle Development consists of a reservoir, a combination embankment and concrete dam, a water conveyance system, and a powerhouse on the Klamath River between about RM 228 and RM 220, which is downstream of the Keno dam and upstream of the Copco No. 1 dam. The purpose of the J.C. Boyle facility is to generate hydroelectric power.*
>
> ***DAM***
>
> *The embankment dam is a 68-foot-tall (at its maximum height above the original streambed) earthfill structure with a 15-foot side crest and a length of 413.5 feet at El. 3,800.0 feet msl. The concrete portion of the dam is 279 feet long and is composed of a spillway section, an intake structure, and a 115-foot-long gravity section of 23 feet maximum height between the intake block and the left abutment.*

The spillway is a concrete gravity ogee overflow section with three 36-foot-wide by 12-foot-high radial gates…The estimated spillway capacity at water surface El. 3,793 feet msl with all three gates open is 14,850 cfs. A 24-inch fish screen bypass pipe provides approximately 20 cfs of instream flow below the dam. The intake structure is located to the immediate left of the spillway and consists of a 40-foot-high reinforced concrete tower. It has four 11-foot, 2-inch-wide openings to the reservoir, each of which has a steel trash rack followed by a vertical traveling screen (0.25-inch mesh) with high pressure spray cleaners. Spray, along with any screened fish, are collected and diverted downstream of the dam...

A pool and weir fishway approximately 569 feet long with 63 pools is located at the dam for upstream fish passage. The fishway operates over a gross head range of approximately 55 to 60 feet.

The water conveyance infrastructure between the dam and the powerhouse has a total length of 2.56 miles. From the intake structure, the water flows through a 638-foot long, 14-foot-diameter, steel flowline. The flowline is supported on steel frames where it spans the Klamath River and discharges into an open power canal. The power canal is 2 miles long along a bench cut in the face of the river canyon. Depending on the terrain, the canal is either a double- or single-walled concrete flume. The power canal is provided with overflow structures at the upstream and downstream ends and terminates in a forebay. The forebay overflow section is equipped with float-operated gates, which release water during the hydraulic surge from the canal following any load rejection at the powerhouse. The released water discharges through a short, concrete-lined chute and returns to the bypass reach.

Water for power generation is drawn from the forebay through a 60-foot-wide and 17.9-foot-high trash rack with 2-inch bar spacing before entering a 15.5-foot-diameter, concrete-lined, horseshoe-section tunnel, which is 1,660 feet long. The last 57-foot length of the tunnel before the downstream portal is steel lined with the liner bifurcating into two 10.5-foot-diameter steel penstocks. The bifurcation is encased in a concrete anchor block, and a steel surge tank is mounted on the thrust block. Descending to the powerhouse, the penstocks reduce in two steps to 9 feet in diameter. Each penstock is 956 feet in length and is supported by ring girders seated on concrete footings.

RESERVOIR

The J.C. Boyle dam impounds a narrow reservoir of 420 surface acres (J.C. Boyle reservoir). The normal maximum and minimum operating levels are between El. 3,793 feet and El. 3,788 feet msl, a range of 5 feet. The reservoir contains approximately 3,495 acre-feet of total storage capacity and 1,724 acre-feet of active storage capacity.

POWERHOUSE

The conventional outdoor-type reinforced concrete powerhouse is located approximately 4.3 river miles downstream of the dam on the right bank of the river. There are two vertical-Francis turbines. Both have a rated discharge of 1,425 cfs and are rated 56,000 hp at 440 feet of net head. Both generators are rated at 42,500 kVA at 0.95 power factor (40 MW). Key information about J.C. Boyle powerhouse is summarized in Table A2.1-1. Two three-phase, 42,300-kVA, 11,000/236,000-V transformers step up the generator voltage for transmission interconnection."

There is a 100 cfs minimum flow requirement immediately below J.C. Boyle Dam (PacifiCorp, 2004).

2.2.5. COPCO NO. 1 DEVELOPMENT

Information is reproduced from PacifiCorp (2004a) below for convenience:

"The Copco No. 1 Development consists of a reservoir, dam, spillway, intake, and outlet works and powerhouse located on the Klamath River between approximately RM 204 and RM 198 near the Oregon-California border. Copco No. 1 is downstream of the J.C. Boyle dam and upstream of Copco No. 2 dam. The purpose of the facility is to generate hydroelectric power.

DAM

The Copco No. 1 dam is a concrete gravity arch structure with a 462-foot radius at the crest. As originally designed, the spillway crest was approximately 115 feet above the original river bed. After construction began, the river gravel was found to be over 100 feet deep at the dam site; this material was excavated and then backfilled with concrete, making the total height of the dam 230 feet, measured from the lowest depth of excavation to the spillway crest, and 250 feet to the top of the spillway deck.

The crest length between the rock abutments is approximately 410 feet. The upstream face of the dam is vertical at the top, then battered at 1 horizontal to 15 vertical. The downstream face is stepped, with risers generally about 6.0 feet in height.

The ogee-type spillway is located on the crest of the dam. It is divided into 13 bays controlled by 14-foot by 14-foot Tainter gates. The spillway crest is located at El. 2,593.5 feet msl. The normal operating reservoir water level is 1.5 feet below the top of the gates at El. 2,606.0 feet msl. The estimated spillway capacity at water surface El. 2,607.5 feet msl with all 13 gates open is 36,764 cfs.

Two intake structures are located at approximately invert El. 2,575.0 feet msl in the dam near the right abutment. The left intake houses four vertical lift gates. Two 10-foot-diameter (reducing to 8-foot-diameter) steel penstocks feed Unit No. 1 in the powerhouse. The right intake houses four vertical-lift gates. A single, 14-foot-diameter (reducing to two 8-foot-diameter) steel penstock feeds Unit No. 2. Facilities exist at the intake for future expansion of the powerhouse, but there are no plans to expand the Project capacity. There are two side-by-side trash racks, which measure 44 feet wide, 12.5 feet high, and have bar spacings of 3 inches, in front of each intake.

The low-level sluice outlet has been abandoned.

RESERVOIR

The Copco No. 1 reservoir is approximately 1,000 acres in extent and contains approximately 15,200 acre-feet of total storage capacity at elevation 2,607.5 and approximately 6,235 acre-feet of active storage capacity. The normal maximum and minimum operating levels are between El. 2,607.5 and El. 2,601.0 feet, respectively, a range of 6.5 feet.

POWERHOUSE

The Copco No. 1 powerhouse is a reinforced-concrete substructure with a concrete and steel superstructure enclosed by metal siding located at the base of Copco No. 1 dam on the right bank. The two turbines are double-runner, horizontal-Francis units, each with a rated discharge of 1,180 cfs, and rated at 18,600 hp at a net head of 125 feet. The generators are rated at 12,500 kVA at 0.8 power factor (10 MW). There are no turbine bypass valves. Unit 1 has three single-phase, 5,000-kVA, 2,300/72,000-V transformers to step-up the generator voltage for transmission interconnection. Unit 2 has three single-phase, 4,165-kVA,2,300/72,000-V transformers to step up the generator voltage for transmission interconnection."

2.2.6. COPCO NO. 2 DEVELOPMENT

Information is reproduced from PacifiCorp (2004a) below for convenience:

"The Copco No. 2 Development consists of a diversion dam, small impoundment, a water conveyance system, and a powerhouse. The dam is located approximately 1/4 mile downstream of Copco No. 1 dam at RM 198.3. The purpose of the Copco No. 2 facilities is to generate hydroelectric power.

DAM

The Copco No. 2 dam is a concrete gravity structure with an intake to the flowline on the left abutment and a 145-foot-long spillway section with five Tainter gates. The dam is 33 feet high, has an overall crest length of 335 feet and a crest width of 9 feet. The crest elevation is El.2,493 feet msl. The dam has a 132-foot-long earthen embankment with a gunite cutoff wall. The dam has a manual gate controlling a sluiceway adjacent to the intake. A corrugated metal flume provides approximately 5 cfs of instream flow in the bypass reach. The concrete gravity spillway section crest elevation is 2,473 feet msl. The estimated spillway capacity at water surface El.2,483 feet msl is 13,060 cfs with the five gates open.

The intake structure incorporates trash racks and a roller-mounted (caterpillar) bulkhead gate. The trash rack is 36.5 feet by 48 feet and has 2-inch bar spacing.

The flow line to the powerhouse consists of portions of 2,440 feet of concrete-lined tunnel, 1,313 feet of wood-stave pipeline, an additional 1,110 feet of concrete-lined tunnel, a surge tank, and two steel penstocks. The diameter of the tunnel and wood stave pipeline sections is a constant 16 feet. The two penstocks, one 405.5 feet long and one 410.6 feet long, range from 16 feet in diameter at the inlet to 8 feet in diameter at the turbine spiral cases.

RESERVOIR

The reservoir created by the Copco No. 2 dam is approximately 1/4-mile long and has a storage capacity of 73 acre-feet. At the normal water surface elevation of El. 2483 feet msl, there is very minimal active storage. El. 2,483 feet msl is both the maximum and minimum normal water surface. As a result, Copco No. 2 generation tracks Copco No. 1 generation.

POWERHOUSE

The powerhouse is a reinforced concrete structure that houses two vertical-Francis turbines. Each turbine has a rated discharge of 1,338 cfs and a rated capacity of 20,000 hp at 140 feet of net head. The synchronous generators are rated 15,000 kVA at 0.9 power factor (13.5 MW). There are three single-phase, 10/20-megavolt ampere (MVA), 6,600/72,000-V transformers for each generator to step up the voltage. There are also three single-phase, 10/20-MVA,73,800/230,00-V step-up transformers for interconnection to the transmission system."

There is a 1.5-mile-long bypassed reach between Copco No. 2 reservoir and powerhouse. There is currently no minimum flow requirement at this bypassed reach, but PacifiCorp states it normally releases 5 to 10 cfs via a 24-inch-diameter pipe at the dam (FERC, 2007).

2.2.7. IRON GATE DEVELOPMENT

Information is reproduced from PacifiCorp (2004a) below for convenience:

"The Iron Gate Development consists of a reservoir, an earth embankment dam, an ungated side channel spillway, intakes for the diversion tunnel and penstock, a steel penstock from the dam to the powerhouse, and the powerhouse. It is located on the Klamath River between approximately RM 196.8 and RM 190, approximately 20 miles northeast of Yreka, California. It is the farthest downstream hydroelectric facility of the Klamath Hydroelectric Project. The purpose of the Iron Gate facilities is to generate hydroelectric power.

DAM

Iron Gate Dam is a zoned earthfill embankment. The dam has a height of 189 feet from the rock foundation to the dam crest at El. 2.343.0 feet msl. The crest is 20 feet wide and approximately 740 feet long. It has a central, vertical-asymmetrical clay core. The dam is founded on a sound basalt rock foundation. There is a grout curtain in the bedrock beneath the impervious core.

There are fish trapping and holding facilities located on the random fill area at the dam toe. The top of the random fill area is at El. 2,189.0 feet msl. High- (El. 2,310.0 feet msl) and low-level (El. 2,250 feet msl) intakes for the fish facility water are incorporated into the dam.

In 2003, modifications were made to Iron Gate Dam to raise the dam crest elevation from El. 2343 feet msl to El. 2348 feet msl. The modifications included construction of a concrete wall extension along the dam crest, anchored into the existing dam structure….

The spillway is excavated in rock at the right dam abutment. It is an ungated chute spillway with a side channel entrance. The spillway crest is at El. 2,328.0 feet msl, 15 feet below the dam crest. The spillway crest is 727 feet long and consists of a concrete ogee and slab placed over the excavated rock ridge. The upper part of the channel is partly lined with concrete. At the end of the chute, a flip-bucket terminal structure is located approximately 2,150 feet downstream of the toe of the dam.

The diversion tunnel used during construction was driven through bedrock in the right abutment and is still in place. The tunnel terminates in a reinforced concrete outlet structure at the downstream toe of the dam. Control of the flow in the tunnel is provided by a slide gate approximately 112 feet upstream of the dam axis. The gate is housed in a reinforced concrete tower accessible by bridge from the dam crest. The intake is a reinforced concrete structure equipped with trash racks and is submerged on the floor of the reservoir approximately 380 feet upstream from the dam axis. Operation of the gate controlling flow through the tunnel is limited to emergency use during high flow events. If needed for such purposes, the tunnel can pass up to approximately 5,000 cfs.

The intake structure for the powerhouse is a 45-foot-high, free-standing, reinforced-concrete tower, located in the reservoir immediately upstream of the left dam abutment. It is accessed by a foot bridge from the abutment. It houses a 14-foot by 17-foot slide gate, which controls the flow into a 12-foot-diameter, welded-steel penstock. The penstock is concrete-encased where it penetrates the dam approximately 35 feet below the normal maximum reservoir level. The penstock is supported on concrete supports down the dam abutment. There is a trash rack at the penstock entrance, which is 17.5 feet by 45 feet with 4-inch bar spacing.

RESERVOIR

The reservoir formed upstream of the Iron Gate Dam is approximately 944 surface acres and contains approximately 58,794 acre-feet of total storage capacity (at El. 2,328.0 feet msl) and 3,790 acre-feet of active storage capacity. The normal maximum and minimum operating levels are between El. 2,328.0 feet msl and El. 2,324.0 feet msl, respectively, a range of 4 feet.

POWERHOUSE

The powerhouse is located at the base of the dam on the left bank. The Iron Gate powerhouse consists of a single vertical Francis turbine. The turbine has a rated discharge capacity 1,735 cfs, with a rated output of 25,000 at a rated net head of 154 feet. The synchronous generator is rated 18.947 kVA at 0.95 power factor (18 MW). In the event of a turbine shutdown, a synchronized Howell-Bunger bypass valve located immediately upstream of the turbine diverts water around the turbine to maintain flows downstream of the dam.

There is a single three-phase, 18,947-kVA, 6,600/69,000-V step-up transformer at the powerhouse to interconnect the PacifiCorp transmission system."

Minimum flows requirements and flow targets at Iron Gate are currently governed by the NMFS 2010 Biological Opinion (NMFS, 2010).

Table 2-1. Information on dam characteristics from PacifiCorp (2004a).

Table A2.1-1. Key data regarding the existing Klamath Hydroelectric Project developments.

Item	Link River Dam	Keno Development	J.C. Boyle Development	Copco No. 1 Development	Copco No. 2 Development	Fall Creek Development/ Spring Creek Diversion	Iron Gate Development
General Information							
Owner of the Dam	USBR	PacifiCorp	PacifiCorp	PacifiCorp	PacifiCorp	PacifiCorp	PacifiCorp
Purpose	Water supply; hydropower	Flow regulation	Hydropower	Hydropower	Hydropower	Hydropower; water supply	Hydropower
Completion Date	Dam: 1921 East Side: 1924 West Side: 1908	1967	1958	1918	1925	Fall Creek: 1903 Spring Creek: 1988	1962
Dam Location (river mile)	254.3	233.0	224.7	198.6	198.3	Not applicable	190.1
Powerhouse Location (river mile)	East Side: 253.7 West Side:253.3	None	220.4	198.5	196.8	Not applicable	190.0
Structural Features of the Dams							
Dam Type	Concrete	Concrete	Earthfill	Concrete	Concrete	Earthfill/Earthfill	Earthfill
Dam Height (ft)	16	25	68	126	33	7/6.5	173
Dam Length (ft)	435	680	693	415	278	95/66	740
Spillway Length (ft)	300	265	115	182	130	32/42 " dia. pipe	685
Number of Spill Gates	31	6	3	13	5	1/1	0
Spill Gate Type	Vertical lift	Tainter	Tainter	Tainter	Tainter	Vertical Lift/Vertical Lift	Ungated
Spillway Crest (ft msl)	4130.0[a]	4070.0	3781.5	2593.5	2454.0	3253.4/102 (local datum)	2328.0
Spillway Apron (ft msl)	Not applicable	4052.0	3763.5	2483.0	2452.0	3249.5/95 (local datum)	2164.0
Gross Head (ft) at Spillway	13	18	18	111	21	3.9/6.5	164
Spillway Energy Dissipaters?	No	No	Yes	Yes	No	No/No	Yes
Upstream Fish Passage Ladders?	Yes	Yes	Yes	No	No	No/No	No[b]

Table A2.1-1. Key data regarding the existing Klamath Hydroelectric Project developments.

Item	Link River Dam	Keno Development	J.C. Boyle Development	Copco No. 1 Development	Copco No. 2 Development	Fall Creek Development/ Spring Creek Diversion	Iron Gate Development
Juvenile Bypass Facilities?	No	Not applicable	Yes	No	No	No/No	No
Reservoir Information							
Reservoir Common Name	Upper Klamath Lake	Keno Reservoir	J.C. Boyle Reservoir	Copco Reservoir	Copco No. 2 Reservoir	No reservoir/ no reservoir	Iron Gate Reservoir
Distance to Upstream Dam (miles)	---	24.0	5.6	26.1	0.3	Not applicable/ not applicable	8.2
Reservoir Length (miles)	---	22.5	3.6	4.5	0.3	Run of river/ run of river	6.8
Maximum Surface Area (acres)[c]	90,000	2,475	420	1,000	40	Run of river/ run of river	944
Normal Maximum Depth (ft) from Normal Maximum Surface Elevation	Data not available	19.5	41.7	115.5	28	Unknown/5 ft	162.6
Maximum Depth Elevations (ft msl) from 2001-2002 Study[d]	---	4,065.5	3,751.8	2,492.0	---	No reservoir/ no reservoir	2,165.4
Normal Maximum Operating Surface Elevation (ft msl)	4,143.3	4,085.0	3,793	2,607.5	2,483.0	3,250.5/100.2 (local datum)	2,328.0
Normal Minimum Operating Surface Elevation (ft msl)	4137.0	Data not available	3,788	2601.0	Data not available	3250.5/100 (local datum)	2,324.0
Normal Annual Operating Fluctuation (ft)	6.3	0.5	5	6.5	Data not available	0/1	4.0
Total Storage Capacity (ac-ft)[e]	629,780	18,500	3,495	46,867	73	No reservoir/ no reservoir	58,794
Current (2001-2002) Estimate of Gross Storage Capacity[d]	NA	NA	NA	33,724	NA	No reservoir/ no reservoir	50,941
Active Storage Capacity (ac-ft)	486,830	495	1,724	6,235	Negligible	0/0	3,790
Average Flow (cfs)[f]	1,428	1,624	1,511	1,885	1,885	40/165	1,852

Table A2.1-1. Key data regarding the existing Klamath Hydroelectric Project developments.

Item	Link River Dam	Keno Development	J.C. Boyle Development	Copco No. 1 Development	Copco No. 2 Development	Fall Creek Development/ Spring Creek Diversion	Iron Gate Development
Retention Time (days)							
At Average Flow	185	6	1.2	12	0.020	<1 hour/ <1 hour	16
At 710 cfs	372	13	2.5	32	0.052	<1 hour/ <1 hour	42
At 1,500 cfs	176	6	1.2	15	0.025	<1 hour/ <1 hour	20
At 3,000 cfs	88	3	0.6	8	0.012	<1 hour/ <1 hour	10
At 10,000 cfs (extreme event)	26	1	0.2	2	0.004	<1 hour/ <1 hour	3
Power Generation Features							
Fish Screens	East Side: None West Side: None	Not applicable	Yes; four Rex traveling band screens	None	None	None/ none	None
Trash Racks	East Side: at entrance of wood-stave flow line; 28 x 28 ft with 2 3/4-inch spacing West Side: before canal headgates, 16 x 5 ft with 2.75-inch spacing; before penstock, 12 x 18 ft with 2-inch spacing	Not applicable	At intake to power canal 4 vertical traveling screens (0.25-mesh). Before tunnel and penstocks, 60 x 17.9 ft with 2-inch bar spacing.	Two 44 x 12.5 ft with 3-inch bar spacing	36.5 x 48 ft with 2-inch bar spacing	At entrance to penstock, 17.5 x 10.7 ft with 3-inch bar spacing/ none	At penstock entrance, 17.5 x 45 ft with 4-inch bar spacing

Table A2.1-1. Key data regarding the existing Klamath Hydroelectric Project developments.

Item	Link River Dam	Keno Development	J.C. Boyle Development	Copco No. 1 Development	Copco No. 2 Development	Fall Creek Development/ Spring Creek Diversion	Iron Gate Development
Diversion to Powerhouse	East Side: 1,729 ft wood-stave flow line; 1,362 ft steel flow line; surge tank West Side: 5,575 ft earthen canal; 140 ft steel penstock	Not applicable	Gated intake to 638-ft steel flow line; 2-mile concrete canal; small forebay; 2 steel penstocks	Three penstocks at the dam	Wood-stave flow line and rock tunnel to two steel penstocks	4,560-ft waterway to 42-inch (reducing to 30-inch) diameter penstock/ 6,850-ft waterway to Fall Creek	Gated intake tower to penstock at dam
Number of Turbines	East Side: 1 West Side: 1	None	2	2	2	3/0	1
Turbine Type	East Side: Vertical Francis West Side: Horizontal Francis	None	Vertical Francis	Horizontal Francis	Vertical Francis	Pelton/ not applicable	Vertical Francis
Turbine Generator Nameplate Capacity (MW)	East Side: 3.2 West Side: 0.6	None	Unit 1: 40 Unit 2: 40	Unit 1: 10 Unit 2: 10	Unit 1: 13.5 Unit 2: 13.5	Fall Creek: Unit 1: 0.5 Unit 2: 0.45 Unit 3: 1.25	18
Total Nameplate Generating Capacity (MW)	3.8	None	80	20	27	Fall Creek: 2.2	18
Gross Head (ft) at Powerhouse	East Side: 47 West Side: 48	None	463	123	152	Fall Creek: 730	158
Total Turbine Hydraulic Capacity (cfs)	East Side Rated: 1,200 Min: 200 West Side: 250	None	Rated: 2,850 Max: 3,000 Min: Unit 1: 344 Unit 2: 407	Rated: 3,200 Max: 3,560 Min: Unit 1: 241 Unit 2: 467	Rated: 3,200 Max: 3,250 Min: 258	Fall Creek: Rated: 60 Max: 30 Min: 2	Rated: 1,550 Max: 1,735 Min: 296

Table A2.1-1. Key data regarding the existing Klamath Hydroelectric Project developments.

Item	Link River Dam	Keno Development	J.C. Boyle Development	Copco No. 1 Development	Copco No. 2 Development	Fall Creek Development/ Spring Creek Diversion	Iron Gate Development
Powerhouse Construction	East Side: reinforced concrete structure West Side: reinforced concrete and wood structure	None	Reinforced concrete structure	Reinforced concrete substructure with a concrete and steel superstructure	Reinforced concrete structure	Reinforced concrete substructure with steel superstructure enclosed by metal siding/ not applicable	Reinforced concrete structure
Transmission Lines							
Line Designation	56-8	None	98	15, 26-1, 26-2	None	3 (two sections)/ not applicable	62
Length (mi)	0.36	None	0.24	1.23, 0.7, 0.7	None	1.65 total/ not applicable	6.55
Voltage (kV)	69	None	69	69, 69, 69	None	Both 69/ not applicable	69
Interconnections	Plant to tap on line 18	None	Plant to tap on line 18	Line 15 from Copco No. 1 switchyard to Copco No. 2 plant, line 26-1 from Copco No. 1 plant to switchyard, line 26-1 from Copco No. 1 plant to switchyard	None	Plant to tap point on line 18 (very short), Plant to Copco No. 1 switchyard/ not applicable	Plant to Copco No. 2

[a] The spillway crest at Link River dam is adjustable with stop logs; normal full pool elevation is shown.

[b] Two existing fish ladders serve the Iron Gate fish hatchery, but do not allow passage past the dam.

[c] Pool elevations for these values are unknown.

[d] Data from the Draft Bathymetry and Sediment Classification of the Klamath Hydropower Project Impoundments, J.M. Eilers and C.P. Gubala of JC Headwaters, Inc. prepared for PacifiCorp, March 2003.

[e] Total storage capacity is at normal full pool.

[f] Data for Keno is from USGS Gage 11509500. All other data are average daily turbine flows plus spill flows for 1994 through 1997 provided by PacifiCorp.

2.3. Reach and Tributary Descriptions

Information for the current conditions hydrology is taken from The United States Geological Survey (USGS) stream gages on the Klamath River (Table 2-2) and the FERC 2007 EIS. The USGS gages on the Klamath River are listed in Table 2-2. A flow duration analysis based upon daily average flows at the PacifiCorp dams is given in Table 2-3.

Table 2-2.USGS gages on the Klamath River.

USGS Gaging Station	Station Name	Drainage Area (mi^2)	Latitude	Longitude	Gage Elevation (feet)	Period of Record (Water Years)
11509500	Klamath River at Keno, OR	3,920	42°08’00”	121°57’40”	3,961	1905-1913 1930-2009
11510700	Klamath River below John C. Boyle Power Plant near Keno, OR	4,080	42°05’05”	122°04’20”	3,275	1959-2009
11512500	Klamath River below Fall Creek near Copco, CA	4,370	41°58’20”	122°22’05”	2,310	1924-1961
11516530	Klamath River below Iron Gate Dam, CA	4,630	41°55’41”	122°26’35”	2,162	1961-2009
11520500	Klamath River near Seiad Valley, CA	6,940	41°51’14”	123°13’52”	1,320	1913-1925 1952-2009
11523000	Klamath River at Orleans, CA	8,475	41°18’13”	123°32’00”	356	1927-2009
11530500	Klamath River near Klamath, CA	12,100	41°30’40”	123°58’42”	5.6	1911-1927 1932-1994, 1996, 1998-2009

Table 2-3. Daily flow duration – annual and seasonal (July 1 – November 31), based upon historical data.

% of time equaled or exceeded	Discharge (ft^3/s)							
	Annual				Seasonal (July 1 – Nov 31)			
	Keno	Boyle	Copco	Iron Gate	Keno	Boyle	Copco	Iron Gate
99	152	331	290	528	147	325	294	441
95	297	522	529	716	292	473	524	701
90	431	635	643	741	417	592	604	725
80	645	802	882	955	621	725	823	846
70	821	962	1088	1040	737	856	973	1000
60	990	1130	1269	1320	901	960	1150	1030
50	1180	1260	1483	1360	1020	1060	1273	1130
40	1440	1480	1730	1700	1180	1180	1470	1320
30	1800	1810	2104	1977	1390	1280	1670	1350
20	2390	2660	2640	2980	1580	1490	1905	1510
10	3120	3200	3350	3870	1960	1890	2300	1840
5	4320	4530	4486	5500	2450	2710	2720	2920
1	6875	7660	7295	9167	3300	3970	3536	4350

2.3.1. UPPER KLAMATH LAKE AND TRIBUTARIES TO UPPER KLAMATH LAKE

Upper Klamath Lake (UKL) receives most of its water from the Williamson and Wood Rivers. The Williamson River watershed consists of two sub-basins drained by the Williamson and Sprague Rivers, which together provide about 75 percent of the drainage area to Upper Klamath Lake (FERC, 2007). The Sycan River, a major tributary to the Sprague River, drains much of the northeastern portion of the watershed. Both the Williamson and Sprague River sub-basins are primarily forested with some areas of shrub and grassland, agriculture, and wetland and are largely within the Winema and Fremont National Forests,. The Wood River drains an area northeast of Upper Klamath Lake. The Wood River watershed extends from the southern base of the eastern slopes of the Cascade Mountains near Crater Lake to its confluence with the northern arm of Upper Klamath Lake, which is often referred to as Agency Lake. Although primarily forested, the Wood River watershed also contains extensive agricultural lands and wetlands. The balance of the water reaching Upper Klamath Lake is derived from direct precipitation, flows from small streams, irrigation canals, and ground water from springs and agricultural pumps.

Historical UKL elevations are given in Figure 2-13. Lake elevations have varied between 4136.8 and 4143.3 feet and more typically vary between 4138 and 4143.2 feet in a given year.

The historical 1961 – 2009 annual inflows into Upper Klamath Lake (UKL) are graphed in Figure 2-14 showing significant variation in the yearly inflow into UKL. Also shown in the figure is the 5-year moving average of the annual

inflows along with the average inflow over this period of record. A dry (1990), average (1961), and wet (1982) start year was identified based upon the 5-year moving average. The identification of the water year types is intended to be used to identify the sensitivity of a particular resource area to the dry and wet cycles that occur in the basin.

Figure 2-15 shows the autocorrelation of those yearly inflows and the approximate 95% confidence intervals of the autocorrelation coefficient. There is a significant positive correlation between one-year and the following year (lag 1). There is also significant negative correlation between years separated by 5 years (lag 5). This suggests that dry years occur more frequently after dry years and wet years occur more frequently after wet years.

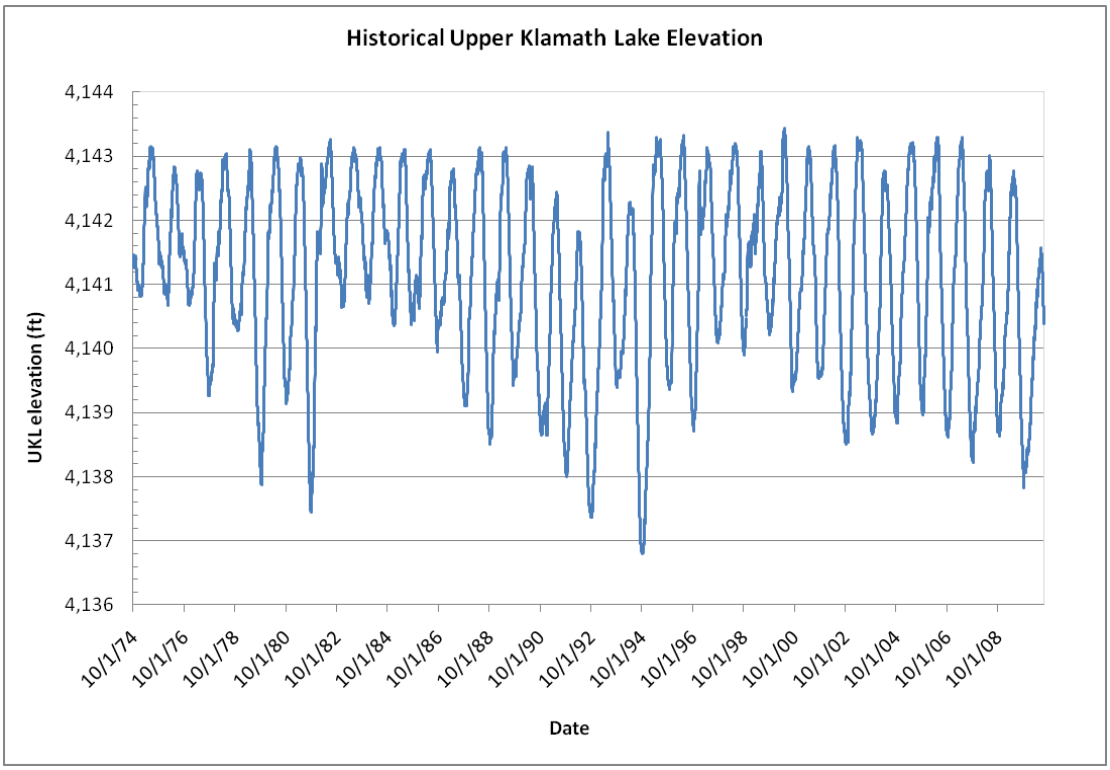

Figure 2-13. Daily UKL Elevations from Oct 1974 to July 2010.

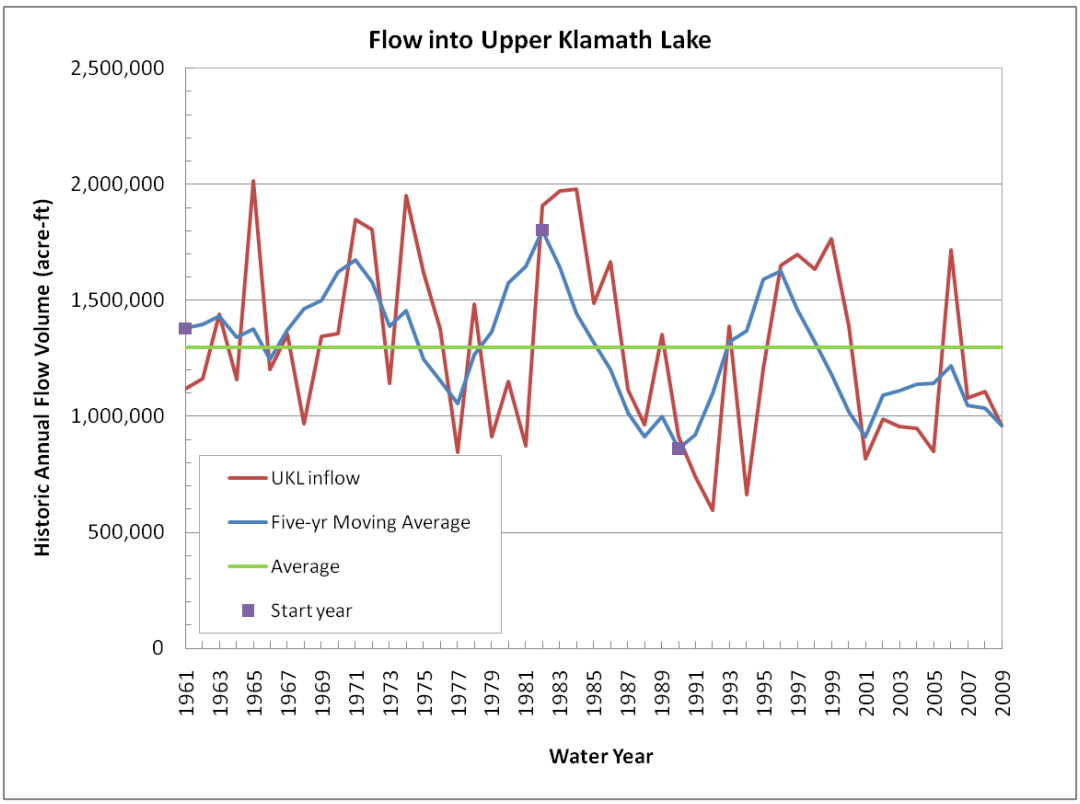

Figure 2-14. Annual inflows in UKL and representative start years based upon a 5-year moving average.

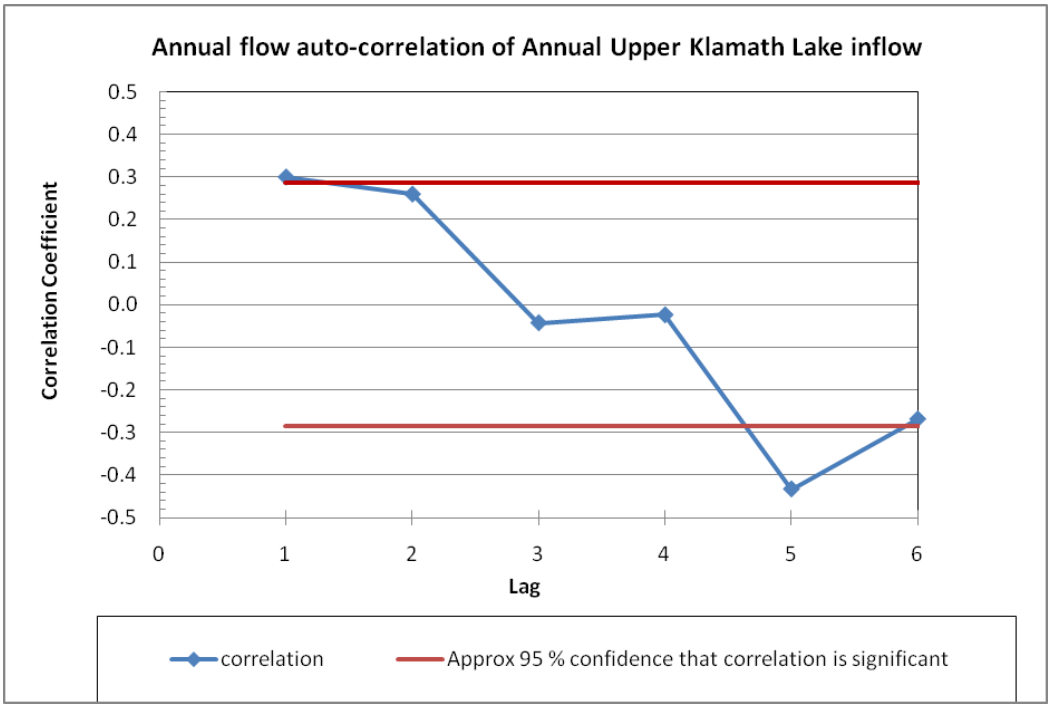

Figure 2-15. Autocorrelation of UKL inflows.

2.3.2. J.C. BOYLE TO J.C. BOYLE POWERPLANT (J.C. BOYLE BYPASSED REACH)

The 4.3-mile-long J.C. Boyle bypassed reach is a steep gradient section of the Klamath River from the dam to the powerhouse. Substantial groundwater enters the bypassed reach starting about 0.5 mile downstream of the dam. The average accretion in the bypassed reach is between 220 and 250 cfs and is relatively constant on a seasonal basis (FERC, 2007). The accretion is shown in the difference between the USGS Keno Gage and the USGS below J.C. Boyle Powerplant gage (Figure 2-16).

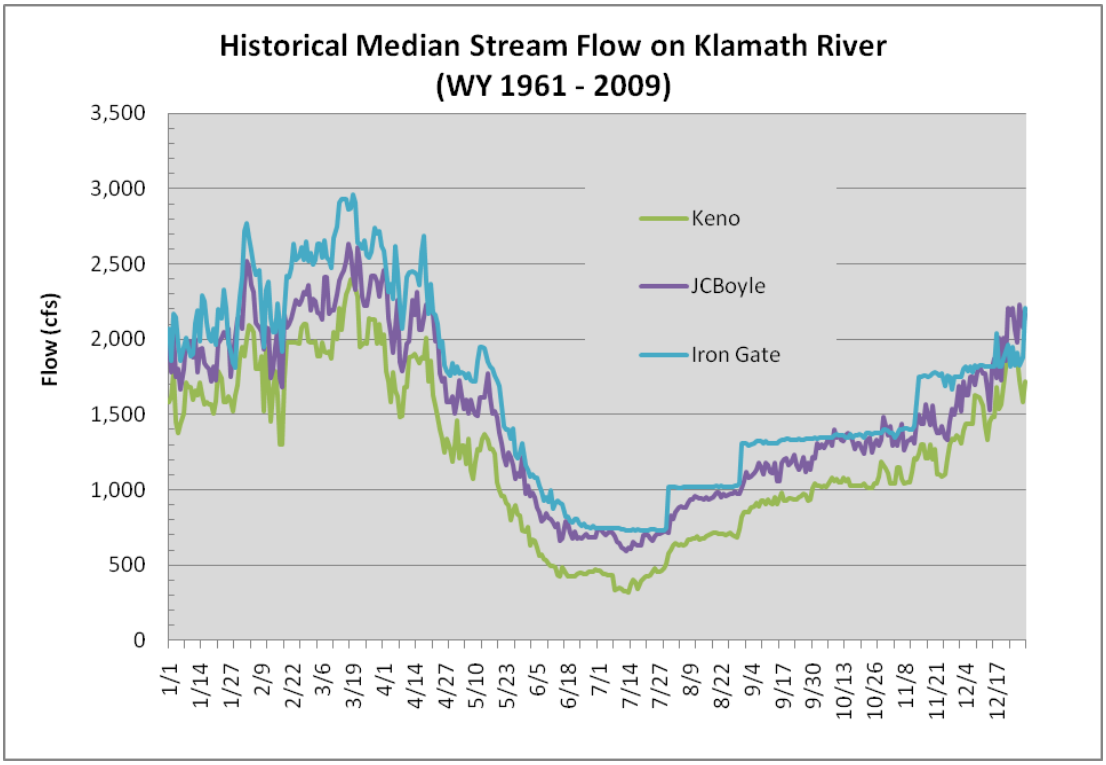

Figure 2-16. Median Flows at USGS stream gages from Keno to Iron Gate.

2.3.3. J.C. BOYLE POWERPLANT TO COPCO RESERVOIR (J.C. BOYLE PEAKING REACH)

Under current operations, when inflow to J.C. Boyle Reservoir is below 3,000 cfs, water is typically stored at night and flows during the day, the period of peak energy demand, are ramped up to either one unit operation (up to 1,500 cfs) or two unit operation (up to 3,000 cfs). PacifiCorp states that due to turbine efficiencies, the preferred flow through the powerhouse is 2,500 cfs, but this preferred flow is infrequently achieved on a daily average basis, during most months (FERC, 2007). When generation is not occurring and J.C. Boyle Dam is not spilling, normal flows in the peaking reach are about 320 to 350 cfs, com of

80 cfs from the fish ladder, 20 cfs from the juvenile fish bypass system, and the rest from spring accretion in the bypassed reach. Because of the popularity of whitewater boating on the J.C. Boyle reach, PacifiCorp considers the timing demands of commercial whitewater rafters as well as power demand, during May through mid October. The current license requires a ramping rate of 9 inches per hour for both up-ramping and down-ramping (FERC, 2007).

PacifiCorp has two direct diversion water rights along this reach for irrigation and stock watering at Copco ranch: 10 cfs and 2,300 acre-feet per year at the Owens ditch diversion and 5 cfs and 600 acre-feet per year at the Owens Island diversion -- both of which are gravity-fed diversions along the river (letter from R. Kanz, California State Water Resources Control Board, to the Commission, dated January 20, 2005).

Substantial tributaries in this reach include Rock Creek, at RM 213.9, and Shovel Creek at RM 206.5. PacifiCorp is currently diverting up to 15 cfs from Shovel Creek and Negro Creek (a tributary of Shovel Creek) during the summer for irrigation purposes (FERC, 2007).

The daily monthly flow duration data for each month for the Klamath River below J.C. Boyle Powerplant are given in “Appendix A. Flood Frequency Report” and shown Figure 2-17. The median daily average flow during the period 1961 to 2009 was between 1,800 and 2,200 cfs during the months of January through April, then decreasing to around 870 cfs for July. Historically, the median flows gradually increase back to 1,800 cfs by December. The minimum flow, during this period, was 320 cfs and occurred at least once in all months, though less frequently during the winter. The maximum daily average flow is around 10,000 cfs and has occurred during the months of January to March.

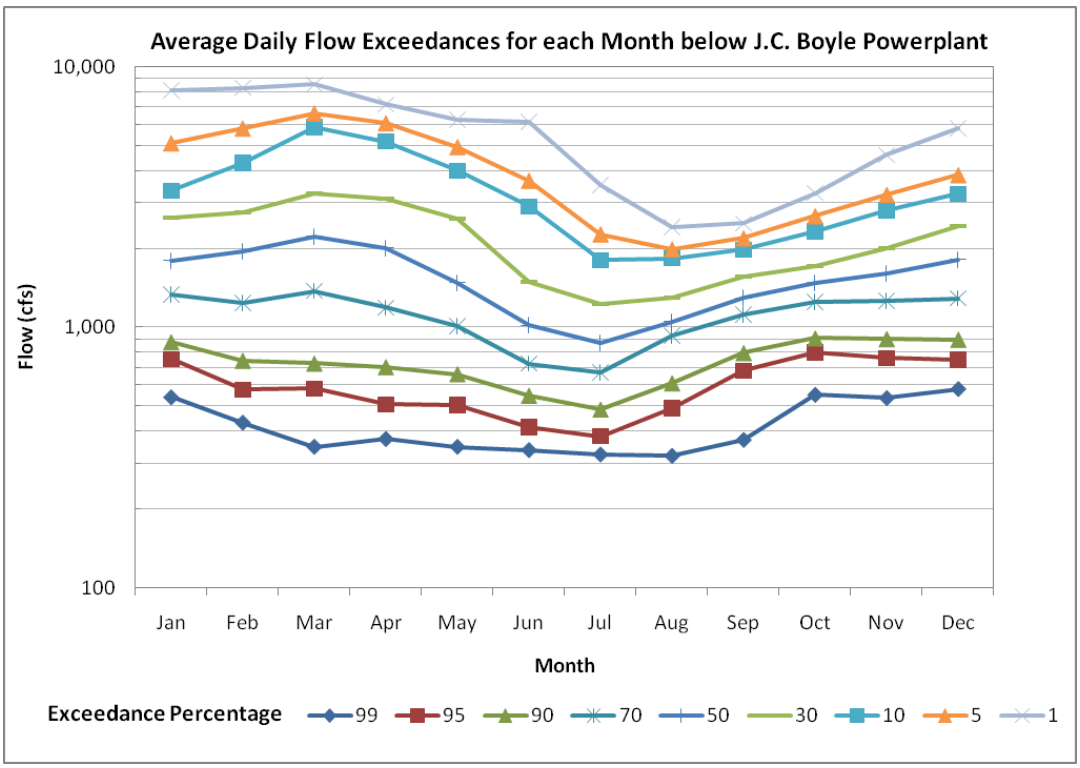

Figure 2-17. Daily flow exceedance percentages for J.C. Boyle Stream Gage below J.C. Boyle Powerplant for water years 1961 to 2010.

2.3.4. COPCO TO IRON GATE

The Copco No. 1 powerhouse can discharge up to 3,560 cfs directly into the 0.25-mile-long Copco No. 2 reservoir. PacifiCorp states that since the Copco No. 2 Reservoir has virtually no storage so the powerhouse acts as a virtual slave to discharge from Copco Reservoir and the water level within Copco No. 2 reservoir rarely fluctuates more than several inches. Spillage at Copco No. 2 dam would typically only occur when inflow exceeds the capacity of Copco No. 2 powerhouse, which occurs infrequently from November through April (FERC, 2007).

There is a 1.5-mile-long bypassed reach between Copco No. 2 reservoir and powerhouse. There is currently no minimum flow requirement for the bypassed reach, but PacifiCorp states it normally releases 5 to 10 cfs via a 24-inch-diameter pipe at the dam. PacifiCorp states that in this boulder-dominated, steeply-sloping bypassed reach accretion adds very little natural flow, unlike the J.C. Boyle bypassed reach (FERC, 2007). Discharge from Copco No. 2 powerhouse enters the upper reaches of the Iron Gate reservoir.

The daily average flows were recorded by USGS Gage #11512500 from water year (WY) 1923 to WY 1961 before the construction of Iron Gate Dam. An example of the flows is given in Figure 2-18. Copco 1 was operated as a peaking unit with flows during non-peak days of approximately 600 cfs. It is assumed that

flows would fluctuate on a daily basis in the Klamath River before the construction of Iron Gate Dam.

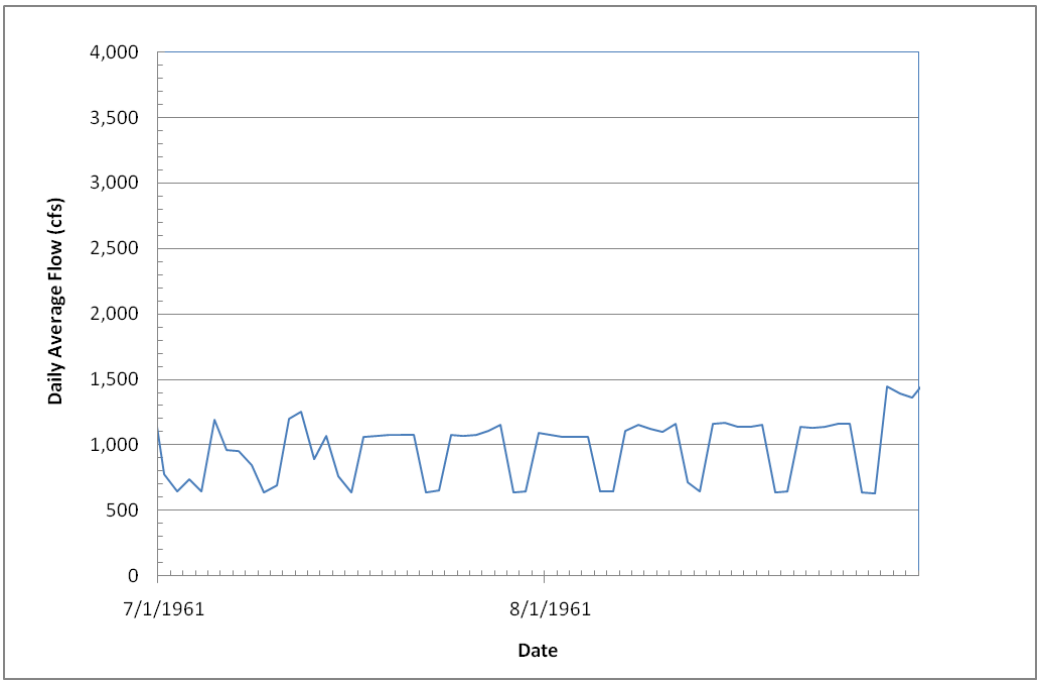

Figure 2-18. Typical daily average flows in Klamath River below Copco I before construction of Iron Gate Dam.

2.3.5. TRIBUTARIES TO IRON GATE

Two perennial tributaries, Jenny and Fall creeks, enter Iron Gate reservoir (see Figure 1-2). Spring Creek is a tributary to Jenny Creek, which flows for 1.2 miles from its source at Shoat Springs before it enters Jenny Creek at RM 5.5. Flow in Jenny Creek is altered by upstream Rogue River Irrigation Project reservoirs that store water during the high runoff season for irrigation. About 30 percent of the mean annual runoff (24,000 acre-feet) of the Jenny Creek watershed is diverted north into the Rogue River Basin. PacifiCorp estimates that inflow from Jenny Creek to Iron Gate Reservoir is normally between 30 and 500 cfs.

PacifiCorp operates a small diversion dam on Spring Creek to divert up to 16.5 cfs into Fall Creek. A Fall Creek dam diverts flow into a canal and penstock system leading to the Fall Creek powerhouse (FERC, 2007). PacifiCorp states that a water rights lawsuit with a local landowner precluded the Spring Creek diversions for most of the 1990s, but resumed diversions in 2003 when the lawsuit was decided in favor of PacifiCorp (FERC, 2007). The Spring Creek diversion, located 0.5 mile upstream of its confluence with Jenny Creek, diverts flow into a 1.3-mile-long canal until it enters Fall Creek about 1.7 miles upstream of the Fall Creek diversion. PacifiCorp estimates 5 cfs is the minimum observed flow in Spring Creek. The diversion dam on Fall Creek diverts up to 50 cfs of flow that bypasses 1.2 miles of a very steep gradient section of Fall Creek leading to the

Fall Creek powerhouse. The project's current license requires minimum flows of 0.5 cfs below the Fall Creek diversion and 15 cfs (or natural stream flow, whichever is less) downstream of the powerhouse.

USGS operated gage no. 11512000 on Fall Creek a short distance downstream of the Fall Creek powerhouse, the fish hatchery, and the city of Yreka intakes. During most of 1933 to 1959, the gage recorded a mean flow of 40 cfs and a minimum flow of 21 cfs. According to data from this gage, flow within Fall Creek does not vary much seasonally due to a reliable baseflow from groundwater springs that typically ranges from 30 to 50 cfs. The city of Yreka, California, operates a water supply intake downstream of the Fall Creek powerhouse and has water rights to withdraw up to 15 cfs. This facility is the sole normal water supply for the city and consists of two small impoundments, an intake structure, a pump and treatment plant, a cathodic protection field, and distribution pipelines, including the 24-inch diameter transmission main (letter from R. McNeil, Mayor, city of Yreka, California, to the Commission, dated November 29, 2006 as referenced by FERC, 2007). Intakes to the currently non-operating Fall Creek fish rearing facility are below the Yreka intake. Water rights include 10 cfs and 5,465 acre-feet per year between March 15 and December 15 for the Cal Fish & Game facility and 10 cfs from June 1 to November 1 for PacifiCorp (FERC, 2007).

2.3.6. DOWNSTREAM OF IRON GATE DAM

Downstream of Iron Gate dam, the Klamath River flows freely for 190 miles to its estuary and the Pacific Ocean. Four major tributaries enter this reach: the Shasta, Scott, Salmon, and Trinity rivers. These four tributaries contribute about 44 percent of the Klamath River Basin's mean annual runoff and have a substantial influence on the timing of peak and low flow rates within the Lower Klamath River (FERC, 2007).

The daily monthly flow duration data for each month for the Klamath River below Iron Gate Dam are given in "Appendix A. Flood Frequency Report" and shown in Figure 2-19. The median flows were between 1,900 and 2,600 cfs during the months of January through April, and between 700 cfs and 1,000 cfs for the months of June through August. The minimum flows recorded during the period 1961 to 2009 occurred in the summer and were as low as 400 cfs. Peak flows occur primarily from December through March.

The daily flows for the period of record are given in Figure 2-20. There is a substantial amount of variability in flow from year to year. It should be noted that the last 10 years have been a relatively dry period.

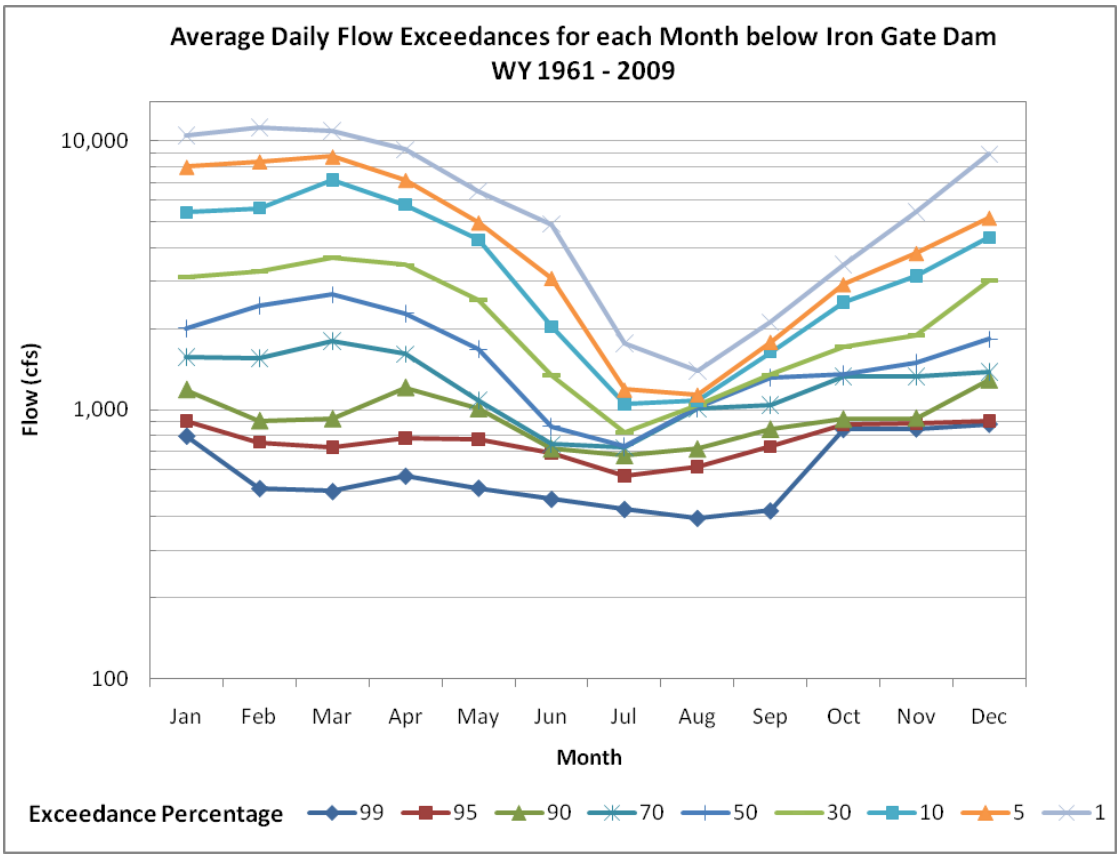

Figure 2-19. Daily flow exceedance percentages for each month below Iron Gate Dam for Period of Record WY 1961 – 2010 (USGS gage #11516530).

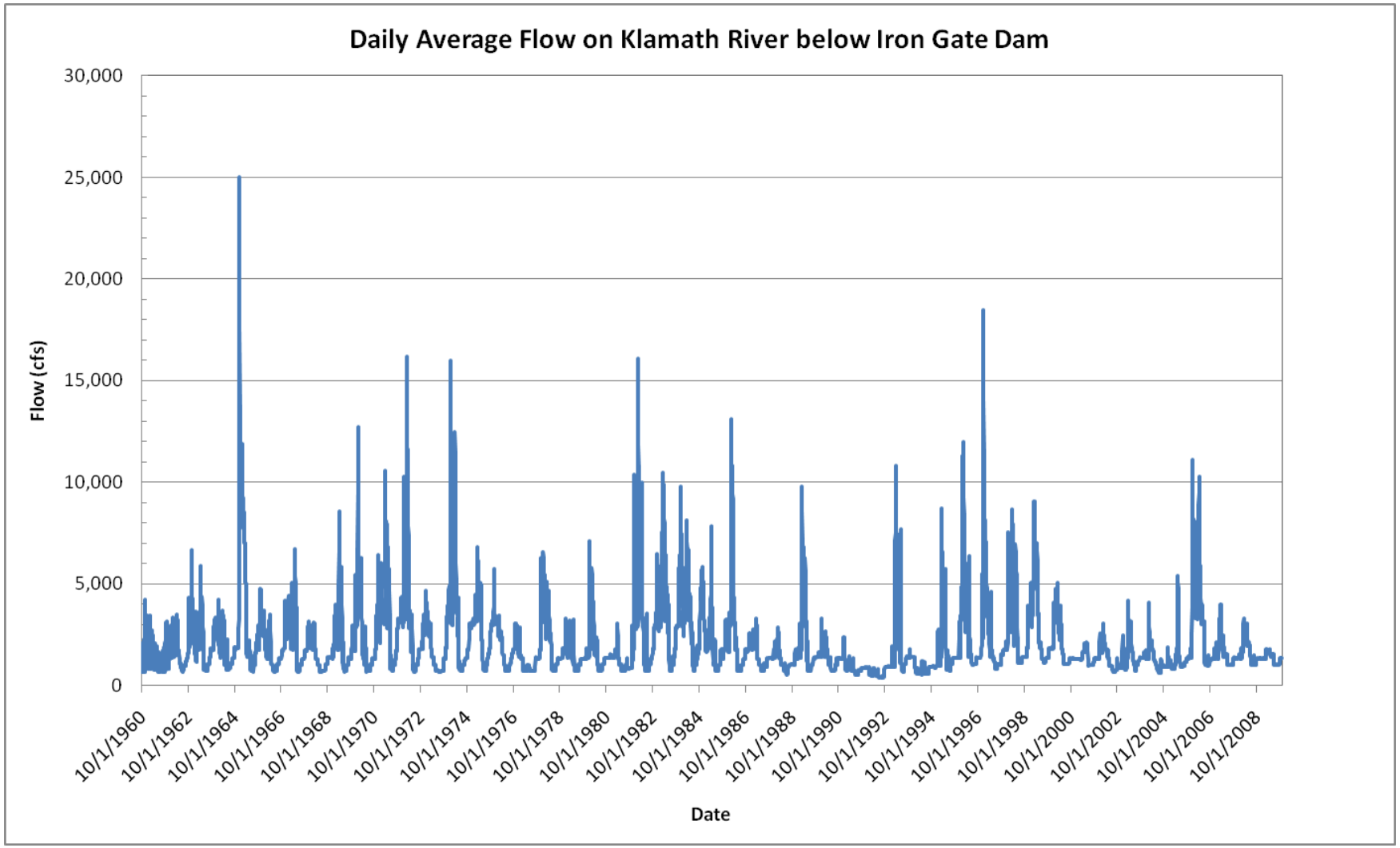

Figure 2-20. Plot of daily average flows below Iron Gate Dam from WY 1961 to 2009.

2.3.7. SHASTA RIVER

The Shasta River enters the Klamath River at RM 176.6, 13.5 miles downstream from Iron Gate dam. The Shasta River watershed includes the glaciated slopes of Mt Shasta, but is largely rangeland with substantial amounts of irrigated pastureland and agricultural area. The average precipitation in the watershed varies greatly with exposure and elevation, but is about 15 inches per year due to the rain shadow effect of the mountains to the west of the watershed. The hydrograph for the Shasta River near the confluence with the Klamath River shows a peak in the winter and minimum median flows under 40 cfs during July and August (FERC, 2007). The current hydrology of the Shasta River is affected by surface-water diversions, alluvial pumping, and the Dwinnell dam which creates Lake Shastina. Historically, springs and seeps dominated the hydrograph of the Shasta River resulting in a cool and stable river flow (NAS, 2004). Dwinnell dam, about 25 miles upstream from the Klamath River, controls 15 percent of the total drainage area of the Shasta River, The dam was constructed in 1928 and Lake Shastina has a normal storage capacity of 50,000 acre-feet. The majority of the water in Lake Shastina is retained during the winter and early spring for irrigation uses during the later spring and summer. Except for above average and wet water years, the only releases from Lake Shastina are to ensure sufficient flows to meet downstream water user requirements. Farther downstream, there are seven major diversion dams and numerous smaller dams or weirs on the Shasta River and its tributaries. When these diversions are in operation during the irrigation season, they substantially and rapidly reduce flows in the mainstem and completely dewater the main channel in some reaches of the river during the late summer of dry years (NAS, 2004).

2.3.8. SCOTT RIVER

The Scott River enters the Klamath River at RM 143, 47.1 miles downstream from Iron Gate dam. The Scott River watershed includes the heavily forested and relatively wet Salmon Mountains on its western divide, but these mountains create a rain shadow for the rest of the watershed. Similar to the Shasta River valley, many areas in the Scott River valley have been extensively altered for grazing and agriculture. Although the Scott River watershed is almost the same size as the Shasta River watershed, the hydrograph for the Scott River near the confluence with the Klamath River has 4 to 5 times higher median monthly flows in the winter and spring months (FERC, 2007). Somewhat similar to the Shasta River, the minimum monthly median flows near 50 cfs occur during August and September.

2.3.9. KLAMATH RIVER NEAR SEIAD VALLEY

The USGS gage Klamath River near Seiad Valley (#11520500) is located at RM 128.5, below the confluence of the Klamath River and Scott River. The daily

flows at various exceedance values for each month near Seiad Valley on the Klamath are shown in Figure 2-21. The minimum flow during this period was near 400 cfs during the month of August; which is similar to the minimum recorded flow at Iron Gate, indicating that during the driest years there is very little contribution from tributaries between Iron Gate to Seiad Valley. The median flow is about 3,000 cfs to 5,000 for the months of December through May. The median flow decreases to about 1000 cfs during July and then gradually increases to 3,000 cfs by December. The 10 % exceedance flow is at or above 10,000 cfs at Seiad Valley for the months of January through April.

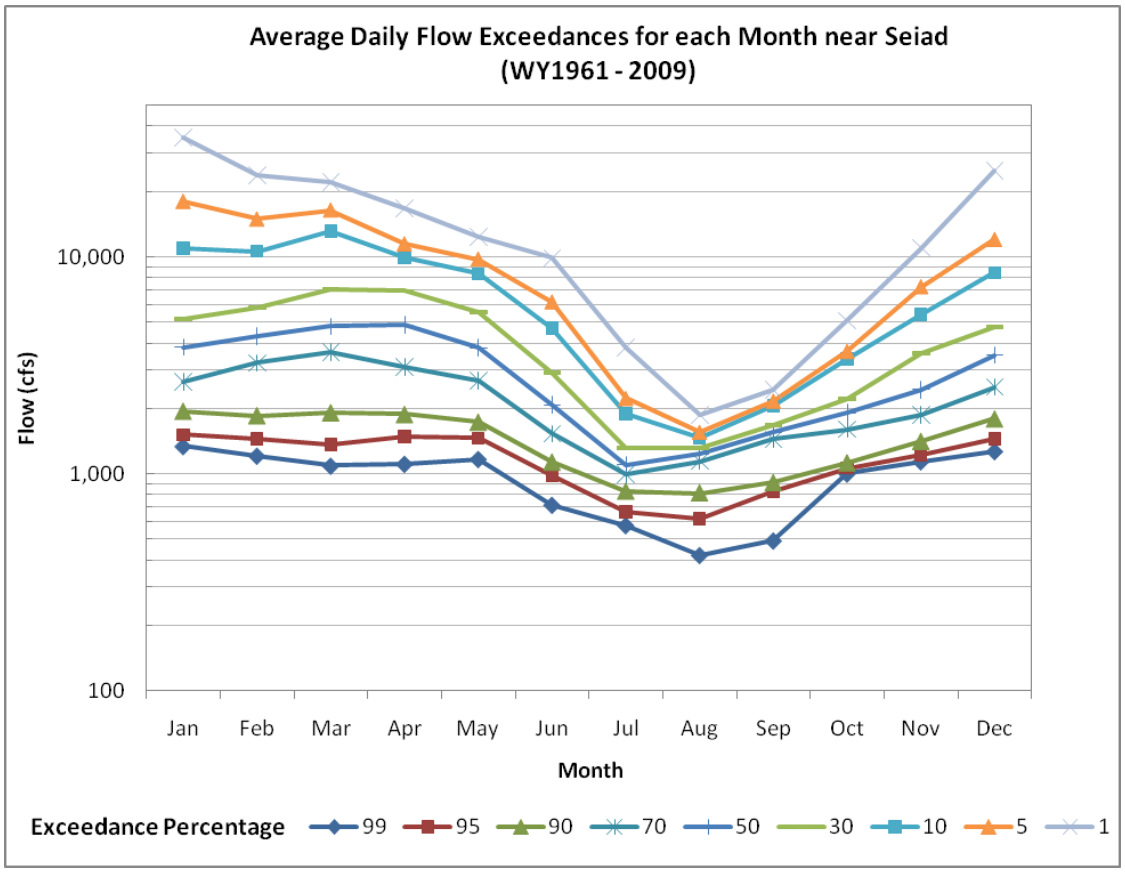

Figure 2-21. Daily flow exceedance percentages for each month near Seiad Valley for Period of Record WY 1961 – 2010 (USGS gage #11520500).

2.3.10. SALMON RIVER

The Salmon River enters the Klamath River at RM 66, 124.1 miles downstream from Iron Gate dam. The Salmon River watershed is generally steep, forested, and federally owned within the Klamath National Forest and several designated wilderness areas. The area is largely undisturbed except for logging, fires, and mining activity. The Salmon River hydrograph at the confluence with the Klamath River shows high average flows (3,375 cfs) during January, representing rain, or rain on snow events that are normally the peak flooding events during the winter. April and May have a more sustained and consistent spring high flow

period (median flow, 2,660 and 2,630 cfs, respectively) representing snowmelt from the higher terrain where a deep snowpack accumulates. The minimum monthly median flow of about 200 cfs occurs during September (FERC, 2007).

2.3.11. KLAMATH RIVER AT ORLEANS

The daily flows at various exceedance values for each month at Orleans on the Klamath River are shown in Figure 2-22 (USGS Gage #11523000). This gage is located below the confluence of the Klamath and the Salmon Rivers at RM 60. The median flow is greater than 9,000 cfs for the months of January through near the end of May, and then the median flow gradually drops to less than 2,000 cfs during the months of August through September. The minimum flow during the period 1961 to 2009 was slightly less than 700 cfs during the drought of 1992. The 90% exceedance flow was approximately 1200 cfs during the month of August and September. The 90% exceedance flow reaches a maximum during the months of March and April of approximately 5,000 to 6,000 cfs. The maximum daily flows occur during the months of December through February and have been above 200,000 cfs during these months.

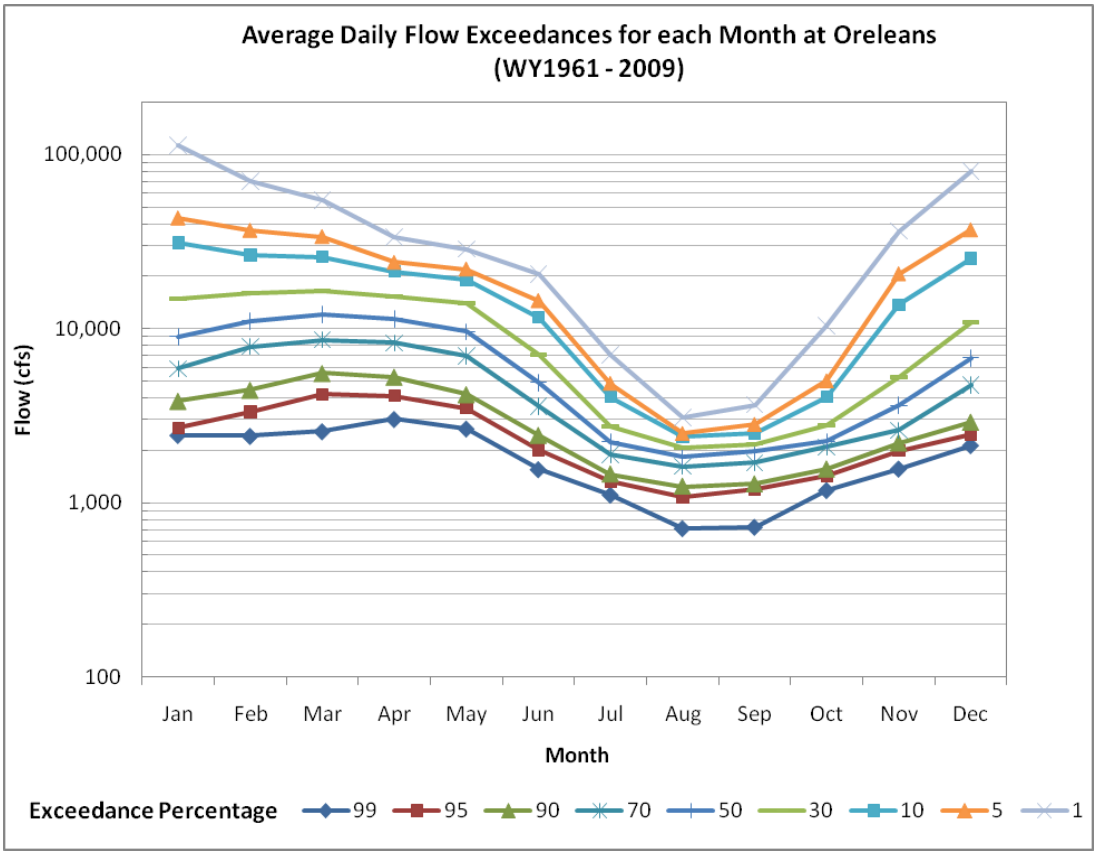

Figure 2-22. Historical stream flow statistics for every day of the year at Orleans on the Klamath River for WY 1961 – 2009, USGS gage #11523000.

2.3.12. TRINITY RIVER

The Trinity River enters the Klamath River at RM 40, 150 miles downstream of Iron Gate dam. The Trinity River is the largest tributary to the Klamath River. The Trinity watershed is generally wet, steep, forested, and federally owned within several national forests and wilderness areas. The Trinity River hydrograph at the confluence with the Klamath River show peak median monthly flows near 7,000 cfs occur in February and March, gradually declining to about 600 cfs in September (FERC, 2007).

A main feature of the Trinity River watershed is Trinity Lake. This reservoir has a storage capacity of 2.4 million acre-feet and is located 119 miles upstream from the Klamath River along the main branch of the Trinity River. Both Trinity Lake and, downstream, the much smaller Lewiston reservoir were constructed in the early 1960s as part of the Central Valley Project's Trinity River Division (TRD). During the first 10 years with these reservoirs and the TRD in full operation, an average of nearly 90 percent or 1.2 million acre-feet of the annual river flow at the Lewiston reservoir (drainage area of 692 square miles) was diverted via the Clear Creek Tunnel to Whiskeytown Lake and then into the Sacramento River system (Interior, 2000). About 1.1 million acre-feet per year were diverted during 1964 to 1986 and 0.73 million acre-feet during 1987 to 2000 (FERC, 2007).

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

- Improve the capability of the Trinity River Hatchery to mitigate for salmon and steelhead fishery losses that have occurred above Lewiston dam.

- Restore natural (instream spawning) salmon and steelhead production in the mainstem and tributaries below Lewiston dam to pre-dam levels.

- Contribute to fish harvest management.
- Compensate for deer and other wildlife losses from flooding of habitat and reduced streamflow resulting from diversions to the Central Valley Project.
- Develop and implement land management activities to stabilize watersheds and reduce sediment yield to Trinity River tributaries.

The Central Valley Project Improvement Act of 1992 further supported restoration objectives and acknowledged the federal government's trust responsibilities by specifying minimum releases of 340,000 acre-feet per year pending completion of a flow evaluation study (FERC, 2007).

The current flow release program from Lewiston dam to the Trinity River is based on the Trinity River Mainstem Fishery Restoration EIS, completed in October 2000. In December 2000, Interior issued the Record of Decision (Trinity ROD) for the Trinity River Mainstem Fishery Restoration, but these flows did not go into full effect until November 2004.

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

- providing physical fish habitat (i.e., appropriate depths and velocities) and suitable temperature regimes for anadromous salmonids; and
- restoring the riverine processes that create and maintain the structural integrity and spatial complexity of the fish habitats.

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

2.3.13. KLAMATH RIVER NEAR KLAMATH

The daily flows at various exceedance values for each month near Klamath on the Klamath River (USGS gage #11530500) are shown in Figure 2-23. This gage is sometimes affected by tidal influences during low flow periods. Releases from Iron Gate Dam still account for nearly 40 percent median flows of the low flow months of September and October -- close to the drainage area ratio of 38 percent between Iron Gate Dam and this location (FERC, 2007). During other months,

especially during the winter and spring, over 85 percent of the hydrograph at this location is from sources other than releases from Iron Gate Dam. The median flows are at or above 20,000 cfs for most of January through April and decrease to approximately 2,000 cfs during August and September. The minimum flows recorded during the period of WY 1961 to 2009 were approximately 1,400 cfs and occurred during August and September. The 90% exceedance flows were approximately 2,000 cfs during August and September. The maximum daily average flows, as high as 400,000 cfs, occur during December through March.

Figure 2-24 compares median flows throughout the basin at USGS stream gages throughout the Klamath Bain for the period WY 1961 to 2009. The median flows at Keno were lowest in July and were between 300 and 500 cfs, increasing to approximately 700 cfs in August. The median flows at Iron Gate were lowest in July and were approximately 700 cfs, increasing to 1,000 cfs in August. The median flows at Orleans were the lowest in August and September and were approximately 2,000 cfs. The median flows at near Klamath were lowest in August and September and were approximately 3000 cfs.

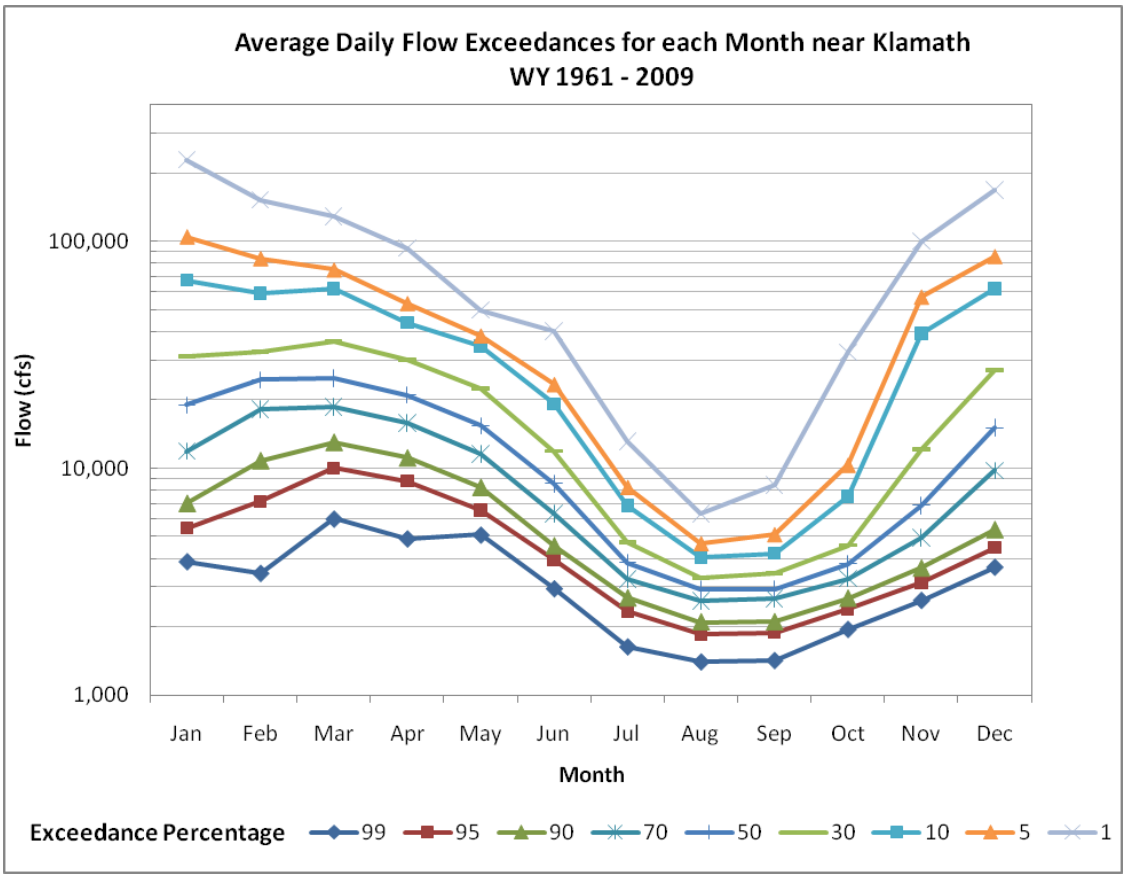

Figure 2-23. Historical stream flow statistics of the Klamath River at Klamath for WY 1961 – 2009, USGS gage #11530500.

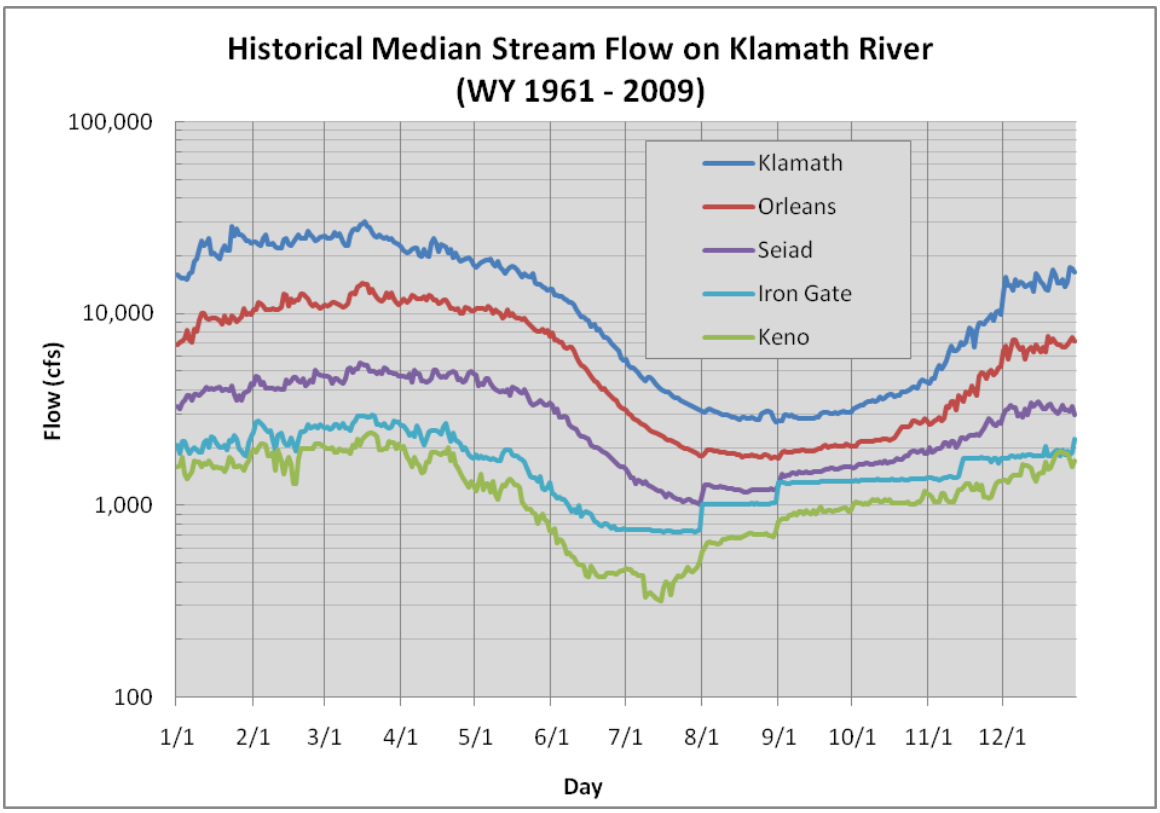

Figure 2-24. Median Flows at USGS stream gages on Klamath River for every day of the year at Keno, below Iron Gate, near Seiad Valley, at Orleans, and at Klamath.

2.4. Peak Flows

A flood frequency analysis at each of the gages and dams is described in "Appendix A. Flood Frequency Report" and discharge results are given in Table 2-4.

The peak flows at Iron Gate Dam are significantly greater than peak flows at J.C. Boyle Dam (Table 2-4) because of the tributaries that enter the Klamath River between the two dams. In particular, Jenny Creek contributes a large amount to the peak flow during the winter and spring months. The watershed area of Jenny Creek is 210 mi^2 and it is the largest single tributary between Keno Dam and Iron Gate Dam. Downstream of Iron Gate Dam, peak flows continue to increase substantially as tributaries enter the Klamath River. The 10-year discharge at Seiad Valley downstream of the Scott River is 56,500 cfs. The 10-year discharge at the mouth is estimated to be close to 300,000 cfs.

The 2-year and 5-year flood frequency discharges are given in Table 2-5 for the Klamath River and are graphed in Figure 2-26. The 2-year and 5-year flood computations for the period of record of 1961 – 2009 were based upon the exceedance values of 0.5 and 0.2, respectively. This period of record was chosen because all the gages used in the analysis had data for this period. The 5-year

flood at J.C. Boyle and Keno reaches were slightly larger than the 10-year floods computed in the flood frequency analysis of the large floods. This is because a different period of record was used in the analysis. The larger flood frequency analysis used a longer period of record that included the 1930s and 1940s which was a relatively dry period with smaller peak flows.

A longer gage record is available for Orleans and Keno stream gages and the average peak flows for the periods 1927 to 1961 and 1962 to 2009 are given in Figure 2-27. The average peak flow was greater during the period 1962 to 2009 than from 1927 to 1961 for both gages. The period between the 1930s and 1940s was relatively dry in this basin and the river experienced correspondingly small peak flows.

Table 2-4. Flood Frequency analysis on Klamath River for 10-year to 100-year floods based upon full period of record of each gage.

Gaging Station	Drainage Area (mi^2)	Discharge (ft^3/s)				
		Gage Base	10-yr Flood	25-yr Flood	50-yr Flood	100-yr Flood
Keno	3,920	4,000	8,642	10,350	11,200	11,800
Boyle	4,080	4,000	9,058	11,050	12,220	13,150
Copco	4,370	5,400	10,750	12,720	13,730	14,470
Iron Gate	4,630	N/A	15,610	21,460	26,280	31,460
Seiad	6,940	N/A	56,540	93,400	131,000	179,300
Orleans	8,470	N/A	163,100	230,300	287,000	348,900
Klamath	12,100	N/A	298,300	392,900	466,900	543,300

Table 2-5. Flood Frequency on Klamath River for 2-year to 5-year floods for the period of record from 1961 – 2009.

Gaging Station	Drainage Area (mi^2)	Discharge (ft^3/s)				
		Median Flow	Average Flood	1.5-yr Flood	2-yr Flood	5-yr Flood
Keno	3,920	1,180	5,593	3,350	5,290	8,920
Boyle	4,080	1,250	6,049	3,520	5,100	9,396
Iron Gate	4,630	1,370	7,978	4,380	6,030	10,980
Seiad	6,940	2,700	28,569	11,000	17,600	39,960
Orleans	8,470	4,870	93,998	56,000	63,500	142,600
Klamath	12,100	9,980	183,802	116,318	154,000	273,600

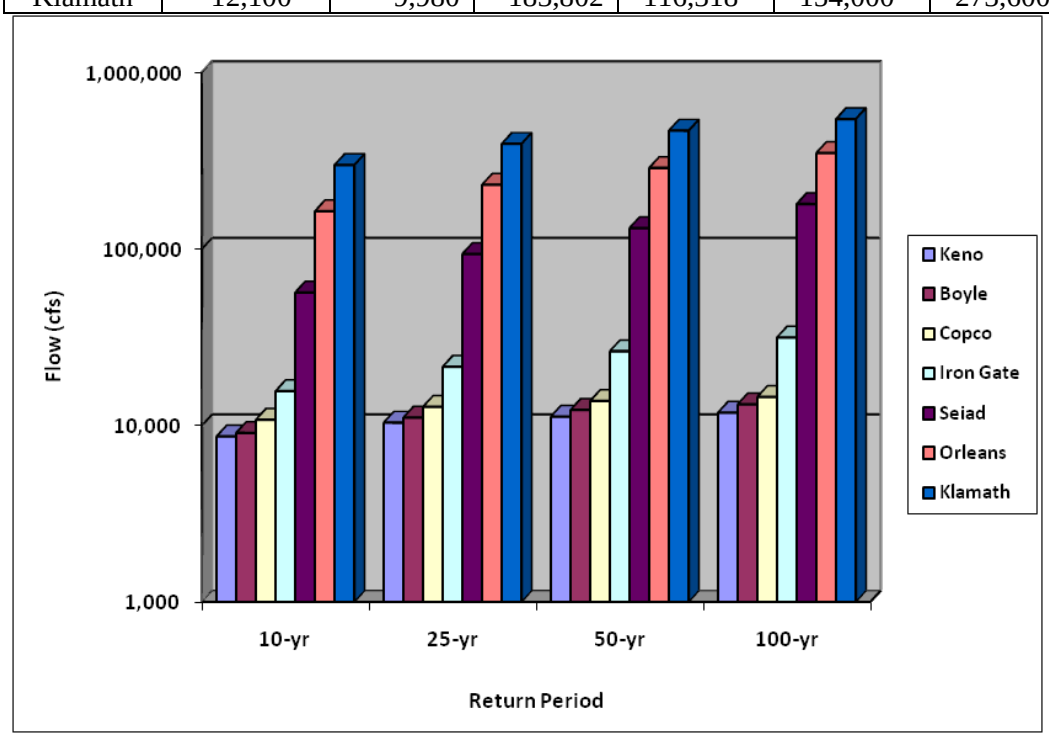

Figure 2-25. Flood-frequency recorded at USGS gages on Klamath River.

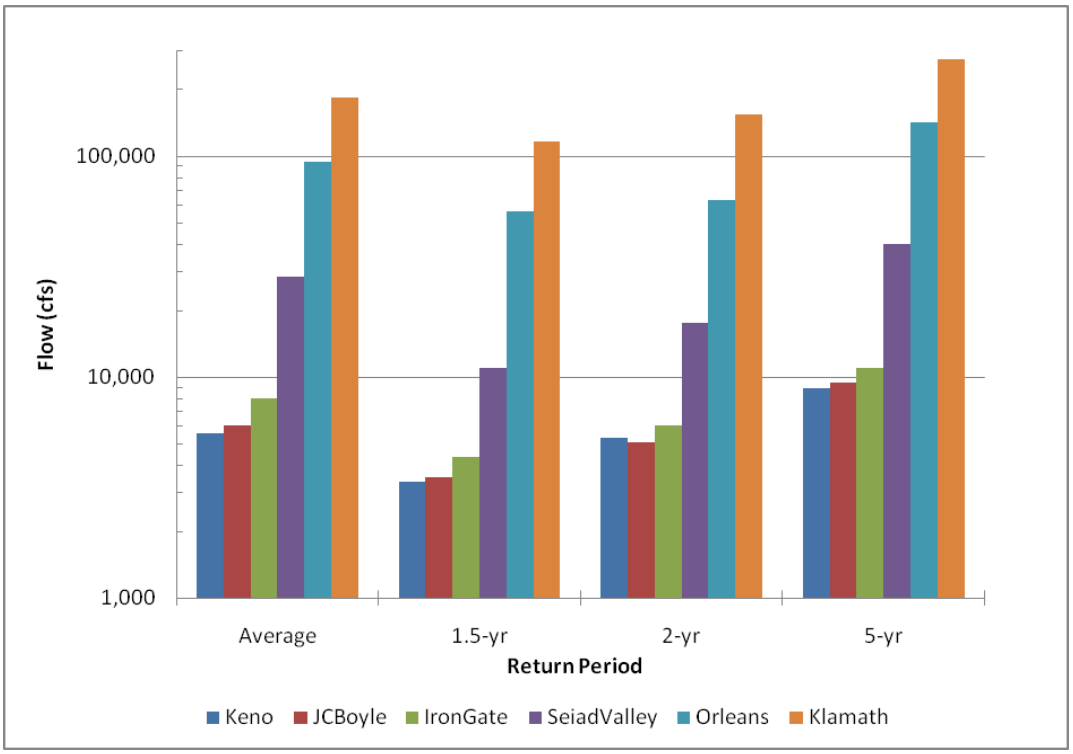

Figure 2-26. Flood frequency recorded at USGS gages on Klamath River for Floods with a Return Period of 5-years and less for the Period of Record 1961 – 2009.

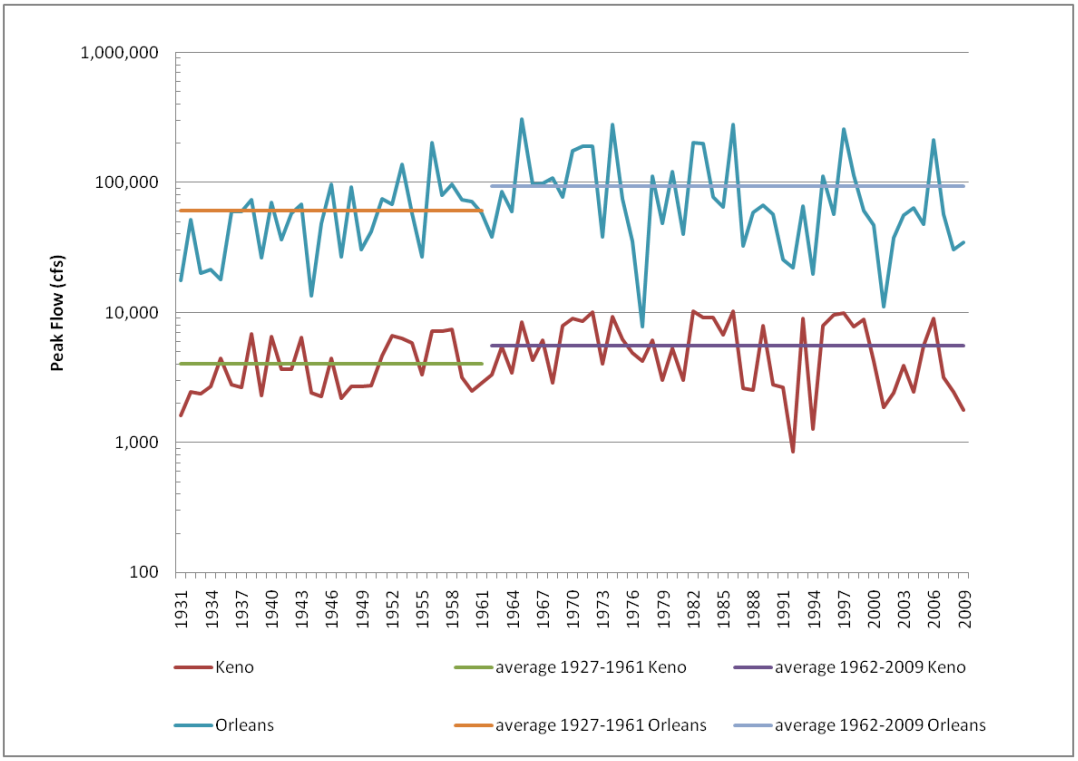

Figure 2-27. Historical peak flows at Keno and at Orleans on the Klamath River.