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Managing Water in the West

Technical Report No. SRH-2011-02

Hydrology, Hydraulics, and Sediment Transport Studies for the Secretary's Determination on Klamath River Dam Removal and Basin Restoration

Klamath River, Oregon and California
Mid-Pacific Region

U.S. Department of the Interior
Bureau of Reclamation

April 2011

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0. Executive Summary

The surface hydrology, groundwater hydrology, hydraulics, geomorphology, and sediment transport of the Klamath River Basin are analyzed as they pertain to the No Action and Dam Removal Alternatives of the Secretarial Determination on Klamath Dam Removal and Basin Restoration. The studies summarized in this document are consistent with those identified in the Project Management Plan for the Secretarial Determination on Klamath Dam Removal and Basin Restoration (PMP). The studies are intended to address the effects of the Klamath Basin Restoration Agreement (KBRA) and the Klamath Hydroelectric Settlement Agreement (KHSA).

Surface Water Hydrology

The No Action Alternative assumes that the current Klamath Project Operational conditions exist in the future. Several Section 7 Consultations and Biological Opinions (BO's) have governed operation of Upper Klamath Lake (UKL) and the Klamath Project since the late 1990's. The consultations involve the National Marine Fisheries Service (NMFS), also known as NOAA Fisheries, the U.S. Fish and Wildlife Service (FWS), and the Bureau of Reclamation (Reclamation). The latest FWS BO and the NMFS BO, dated March 15, 2010, are the basis of the operating criteria used by the Klamath Project Simulation Model (KPSIM) in the No Action Alternative.

The flows under the Dam Removal Alternative will be governed by the Klamath Basin Restoration Agreement (KBRA). The KBRA has the objective of restoring and sustaining fisheries while establishing reliable water and power supplies. The KBRA includes a potential operating scheme that was modeled based upon historical data and used a version of the Klamath Project Simulation Model (KPSIM). The hydrologic operations modeling under the Dam Removal Alternative are guided by this KBRA potential operating scheme.

The daily averaged reservoir elevations, water deliveries, and flows in the Klamath River were simulated under these two alternatives for a 50-yr period. The monthly average water surface elevations in UKL are higher under the Dam Removal Alternative than the No Action Alternative for every month of the year. In general, the average monthly flows at Iron Gate are relatively similar between the two alternatives. The exceptions to this are the months of October to December, where the average flows are about 200 to 400 cfs less under Dam Removal Alternative than under the No Action Alternative, and in April, where the flows are about 300 cfs higher under the Dam Removal Alternative than under the No Action Alternative. The differences in flow and lake elevations are due to differences in water deliveries to agriculture and wildlife refuges and to the flow releases at Link Dam. The PacifiCorp dams do not significantly affect average monthly flows because PacifiCorp operations do not remarkably alter the normal

pool elevation throughout the year. The annual average flow at Iron Gate Dam under the Dam Removal Alternative is approximately 2% less.

The annual flow at Keno Dam is generally similar between the two alternatives except for the few driest years on record. In these dry years, the agricultural supply is significantly reduced under the No Action Alternative, whereas the agricultural supply is much less severely impacted under the Dam Removal Alternative; therefore, more flow is released to the Klamath River under the No Action Alternative than under the Dam Removal Alternative. At Iron Gate Dam from July through November, the flows are commonly around 800 cfs under the Dam Removal Alternative during these extremely dry years whereas the flows are more commonly between 1000 and 1300 cfs under the No Action Alternative.

The daily variability in flow is generally greater under the Dam Removal Alternative because of the ability to incorporate pulse flows into the operational rules under the KBRA. In addition, the natural variability in the tributary flow between J.C. Boyle and Iron Gate is not damped by the presence of the PacifiCorp Dams.

The removal of the Iron Gate and Copco No. 1 Dams will result in the removal of a relatively small storage volume that slightly attenuates floods. It is conservatively estimated that the discharge of 100-yr flood would increase by approximately 7% immediately downstream of Iron Gate after Dam Removal. This will slightly increase flood elevations immediately downstream of Iron Gate Dam.

The difference in streamflow between the No Action and Dam Removal Alternatives decreases in the downstream direction and the differences are not considered significant after the confluence with the Trinity River.

Groundwater Hydrology

Removal of the PacifiCorp Dams will not have a significant impact on the regional groundwater conditions. However, the removal of the dams may have a measureable impact on well immediately adjacent to the reservoirs. There are a significant number of private domestic wells exist in the river valley from upstream of Keno Dam to downstream of Iron Gate Dam. There are sixteen locatable wells within 2.5 miles of J.C. Boyle Reservoir, twenty-two locatable wells within 2.5 miles of Copco Reservoir, and twenty-five locatable wells within 2.5 miles of Iron Gate Reservoir – all are private domestic wells.

It does not appear that a significant number of private wells will be adversely impacted to any major degree. In most cases, the anticipated impacts will be negligible in the case of wells more than a ½ mile or more from the reservoir, or will only have minor lowering of the water elevations in the wells to a new baseline elevation. It is not anticipated that the new baseline will be significantly

below the old river channel bed – which is likely to be the new baseline once the reservoirs are drained.

In cases where a well is anticipated to experience significant drops in water elevations, a recommended mitigation action would be to deepen an existing well or replace it if deepening is not an option.

Hydraulics

Because of the slight increase in peak flood flows immediately below Iron Gate Dam, there will be a slight increase in flood elevations. The most significant increase will occur just downstream of Iron Gate Dam from Bogus Creek to Willow Creek where the average increase in the 100- year flood elevations is expected to be about 1.5 feet. Downstream of the Humbug Creek (about 18 miles downstream of Iron Gate Dam), the increase in 100-year elevations are not considered significant because there will be attenuation effects in the channel and the peak flows in the tributaries will not perfectly coincide with the peak flow at Iron Gate.

Sediment Transport

The sediment stored in the PacifiCorp Reservoirs is predominantly silt, clay and organic material that is 80 to 90 % water and highly erodible. Drawdown of the four PacifiCorp Dams will release approximately 1/3 to 2/3 of the approximately 15 million yd^3 of sediment that will be stored in the reservoirs by 2020. If there is a wet year, more material will be eroded and if there is a dry year, less material will be eroded from the reservoirs. The river will return to its pre-dam alignment at each reservoir and have a similar width to pre-dam conditions. The sediment that is left behind in the reservoirs will raise the floodplain terraces above the pre-dam conditions and the floodplains are expected to be inundated less frequently than typical floodplains in the basin. High flows will gradually widen the floodplain, but this process is expected to occur slowly over several decades.

Over 80 % of the reservoir sediment is fine sediment (silt, clays, and organics). Most of this material will be transported to the ocean during the period of drawdown which will last from January 1, 2020 to mid March, 2020. The maximum sediment concentrations during this period may be more than 10,000 mg/l downstream of Iron Gate. The tributaries entering Klamath River will significantly reduce these concentrations to less than 2,000 mg/l at the mouth of the Klamath River.

If there is a wet year, it may take longer to drain Iron Gate Reservoir because of its limited outlet capacity and there may be sediment concentrations larger than 1,000 mg/l as late as June. If there is a dry year, the sediment concentration will be higher during the drawdown period because of less dilution of sediment by the flow.

Sediment concentrations are expected to resume to background levels by the end of the summer 2020 regardless of type of hydrology present. There will be aggressive hydro seeding of the reservoir material immediately following dam removal which will stabilize the sediment from erosion due to rainfall. In addition, the reservoir sediment dramatically increases its resistance to erosion once it dries out.

The bed material within the reservoirs and between Iron Gate to Cottonwood Creek is expected to have a high content (30 to 50 %) of sand immediately following reservoir drawdown until a flushing flow moves the sand sized material out of the reach. The flushing flow is expected to have to be at least 6,000 cfs and of several days to weeks to return the bed to bed dominated by cobble and gravel with a sand content less than 20%. After the flushing flow, the bed is expected to maintain fractions of sand, gravel, and cobble which would be expected under natural conditions.

The mobility of the bed downstream of Iron Gate Dam to Cottonwood Creek will be increased by the removal of the dams. The return of the natural gravel supply to this reach will increase the frequency of gravel mobilization from once every four years to once every other year.

Climate Change Effects

Five different Global Circulation Models were used to generate five different possible climate change scenarios. Three of the five climate change simulations show an increase in annual inflow while the other two show a decrease in annual inflow. However, all climate change simulations show a more rapid snow melt period. They all indicate a greater proportion of the annual inflow occurring during the months of November through March and a decrease in the proportion of inflow occurring May through October. The three wet climate change simulations have greater annual flow volumes, but the average flow in the summer and fall are similar to the simulations without climate change. Most all the increase in annual flows occurs from December to April. The dry climate change simulations show significantly smaller average flows throughout all months, except for March where the hotter climate can cause more precipitation to fall as rain and also cause faster snowmelt. The general expectation is that under climate change the flows entering UKL in the later winter and early spring (February to April) will be similar or higher than current flows, but that flows in May through October will be similar or lower than current flows. Flows into UKL during the winter may be either lower or higher than current conditions.

1. Introduction

The Reclamation Mid-Pacific Regional Office (MP) requested that the Reclamation Technical Service Center (TSC) perform hydrologic, hydraulic, and sediment transport studies to support the Secretarial Determination on Klamath Dam Removal and Basin Restoration. The studies summarized in this document are consistent with those identified in the Project Management Plan for the Secretarial Determination on Klamath Dam Removal and Basin Restoration (PMP). The studies are intended to address the effects of the Klamath Basin Restoration Agreement (KBRA) and the Klamath Hydroelectric Settlement Agreement (KHSA).

There are two alternatives analyzed in this document from the years 2012 to 2061: the “No Action” and “Dam Removal” Alternatives.

The No Action Alternatives includes the following features:

1. JC Boyle, Copco 1, Copco 2, and Iron Gate dams owned by PacifiCorp will remain and continue to generate hydropower on the Klamath River.

2. No additional fish passage will be installed at the PacifiCorp dams.

3. The Klamath Irrigation Project operations from 2012 to 2061 will be governed by the National Marine and Fisheries Service (NMFS) 2010 Biological Opinion.

The Dam Removal Alternatives includes the following features:

1. JC Boyle, Copco 1, Copco 2, and Iron Gate dams will be removed by December 31, 2020 and a free flowing river will be established by that date.

2. Reservoir drawdown of J.C. Boyle, Copco 1, and Iron Gate dams will begin on November 15, 2019 or January 1, 2020.

3. The sediment behind all dams will not be removed or stabilized by mechanical means prior to drawdown.

4. The Klamath Project operations from 2012 to 2061 will be governed by the KBRA settlement.

Chapters 1 through 5 of this report describe the current surface water hydrology, groundwater hydrology, stream hydraulics, geomorphology, and sediment characteristics of the Klamath River. Chapters 6 through 9 analyze the future conditions under the No Action and Dam Removal Alternatives. Chapter 10

presents some specific impacts to infrastructure caused by the Dam Removal Alternative. Chapter 11 presents the effects of Climate Change on the alternatives.

An overview of the entire Klamath River Basin is shown in Figure 1-1. The Klamath Basin is generally divided into Upper and Lower Basins. The Upper Basin (above Iron Gate Dam) is shown in Figure 1-2 and the Lower Basin (below Iron Gate Dam) is shown in Figure 1-3. The Upper Klamath River Basin is bordered by the Sacramento River Basin to the south, closed basins within the Great Basin to the east and north, and the Rogue River Basin to the northwest. Most of the precipitation occurs during the late fall, winter, and spring and is predominately in the form of snow above elevations of 5,000 feet. The Lower Klamath River Basin includes the river area downstream from Iron Gate Dam, flowing unimpeded by dam controls for 190 miles, which passes through the Klamath Estuary and into the Pacific Ocean. The major tributaries entering the river include the Shasta, Scott, Salmon, and Trinity Rivers. These four rivers provide 44 percent of the mean annual runoff, heavily influencing the hydrology of the Klamath River Basin. Flow for the entire Upper Klamath River Basin is recorded at the Klamath River gage below Keno Dam, Oregon.

An overview of the reach containing the four PacifiCorp dams being analyzed for removal is given in Figure 1-4. The four dams, J.C. Boyle, Copco No. 1, Copco No. 2, and Iron Gate dams, are located in the Upper Klamath Basin and downstream of Upper Klamath Lake (UKL). Upper Klamath Lake is fed by the Williamson, Sprague, and Wood Rivers. Upper Klamath Lake is now controlled by Link River Dam and empties into the Link River. The Klamath River begins at Lake Ewauna just south of Upper Klamath Lake and flows southwest into California. Lower Klamath Lake, once directly connected to the Klamath River, was cut off by 1924 and drained substantially by the Klamath Irrigation Project. The remaining marsh and lake areas are now managed primarily as Lower Klamath National Wildlife Refuge.

A water surface profile of the reach from above UKL on the Williamson River to the Ocean along the Klamath River is given in Figure 1-5. The slope upstream of Keno Dam is much smaller than the slope of the Klamath River below Keno Dam. Keno Reservoir is kept at approximately 4085 feet in elevation and the elevation of UKL is usually between 4136 and 4143 feet. These large reservoirs have profound effects on the hydrology and sediment transport of the basin. A profile of the Klamath River is given in Figure 1-6 from Keno Dam to Indian Creek. The bed profile is obtained from a bathymetric survey from Iron Gate Dam to Indian Creek and a LiDAR survey from Link Dam to Happy Camp, CA. The water surface slope is also shown in Figure 1-6. Discussion and details on the PacifiCorp dams on the Klamath River are given in section 2.2 - dams, Water Diversion, and Hydropower Facilities. (See also: Table 2-1).

Previous analyses of sediment impacts during dam removal have been conducted by GEC (Gathard Engineering Consulting) (2006), Stillwater Sciences (2008), and Phillip Williams and Associates, Ltd (2009). Water quality impacts of dam

removal have been analyzed by Stillwater Sciences (2009a) and biological effects of dam removal have been analyzed by Stillwater Sciences (2009b).

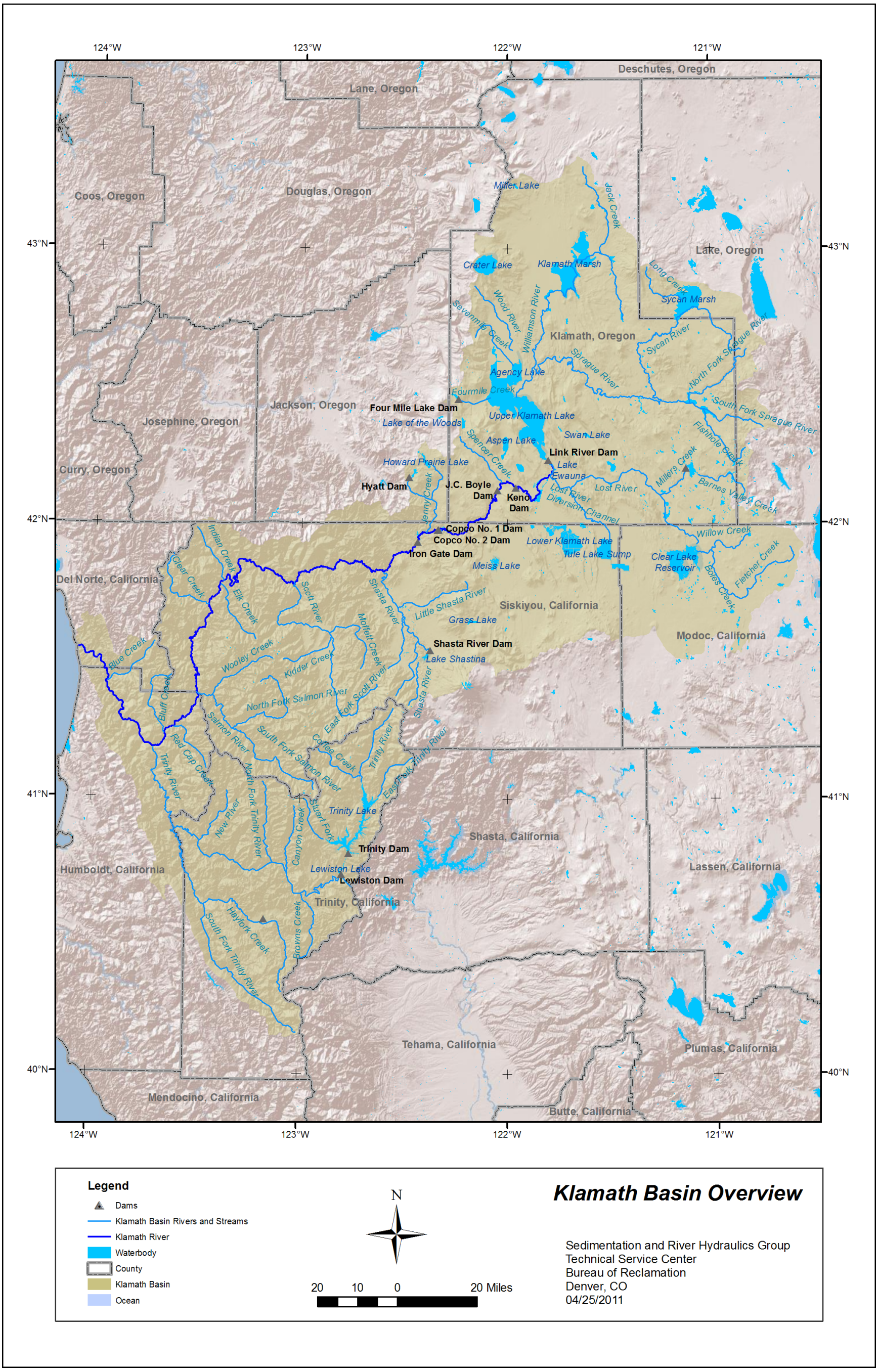

Figure 1-1. Overview of Klamath River Basin.

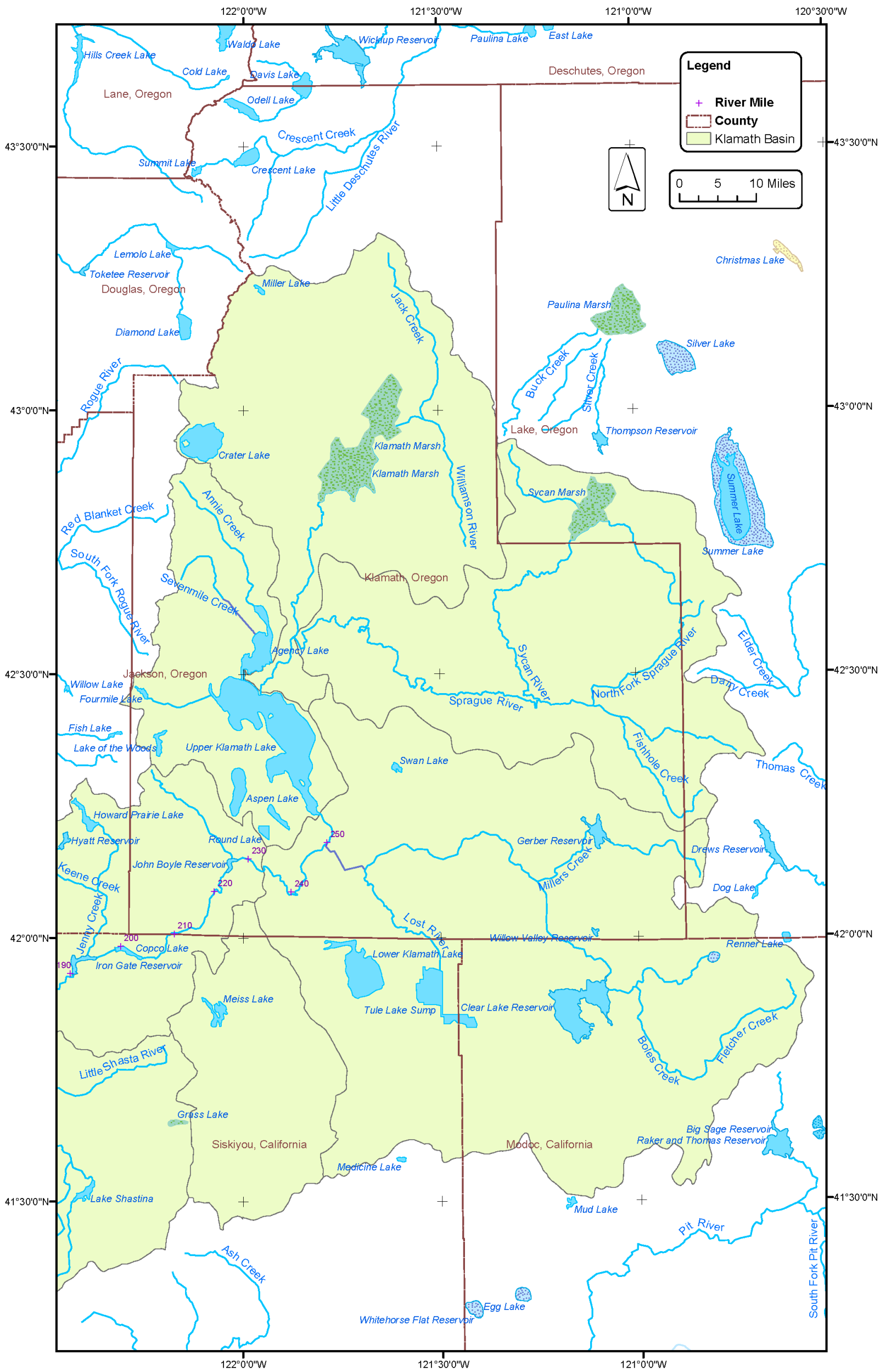

Figure 1-2. Overview of Upper Klamath Basin.

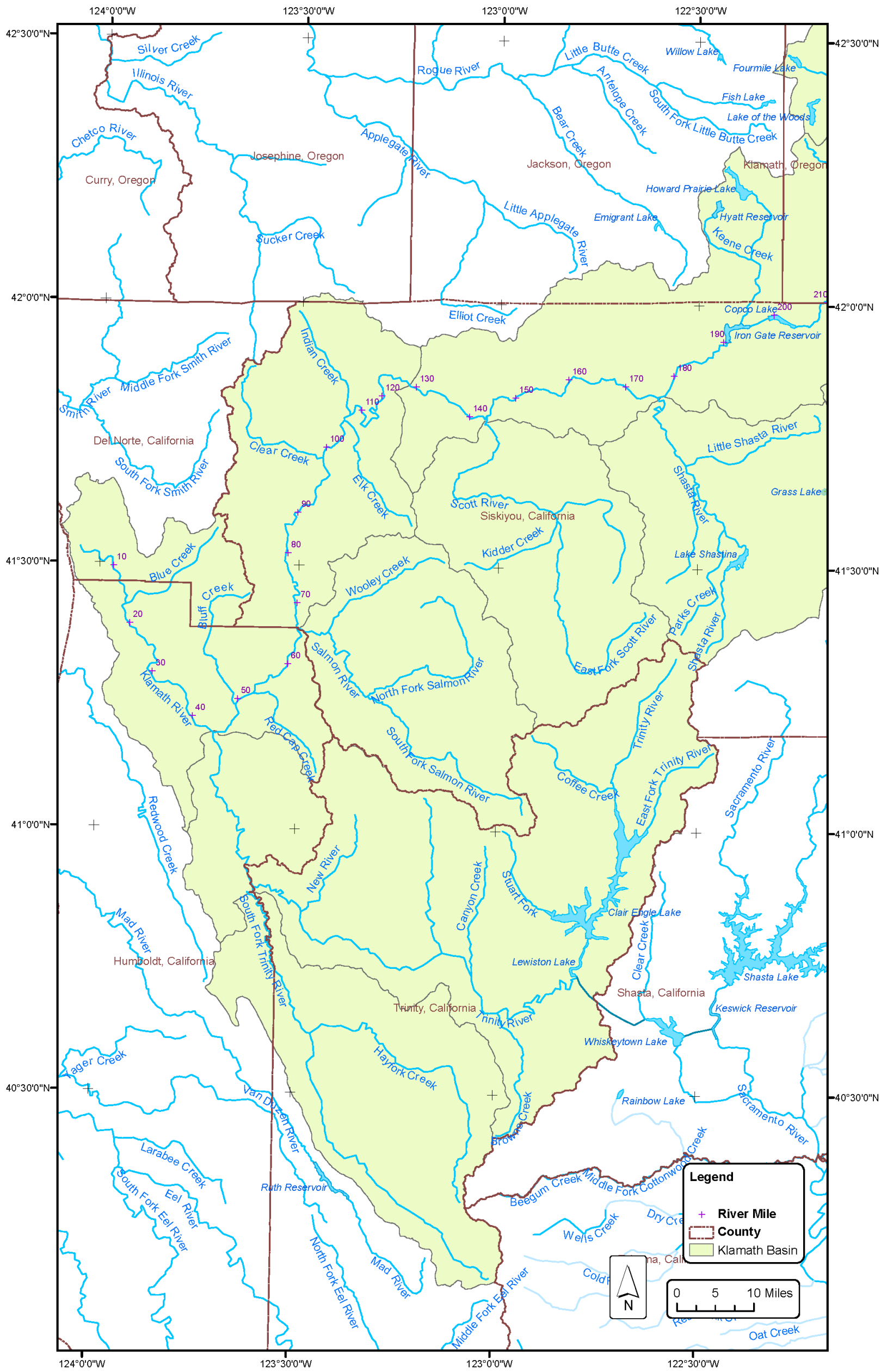

Figure 1-3. Overview of Lower Klamath Basin.

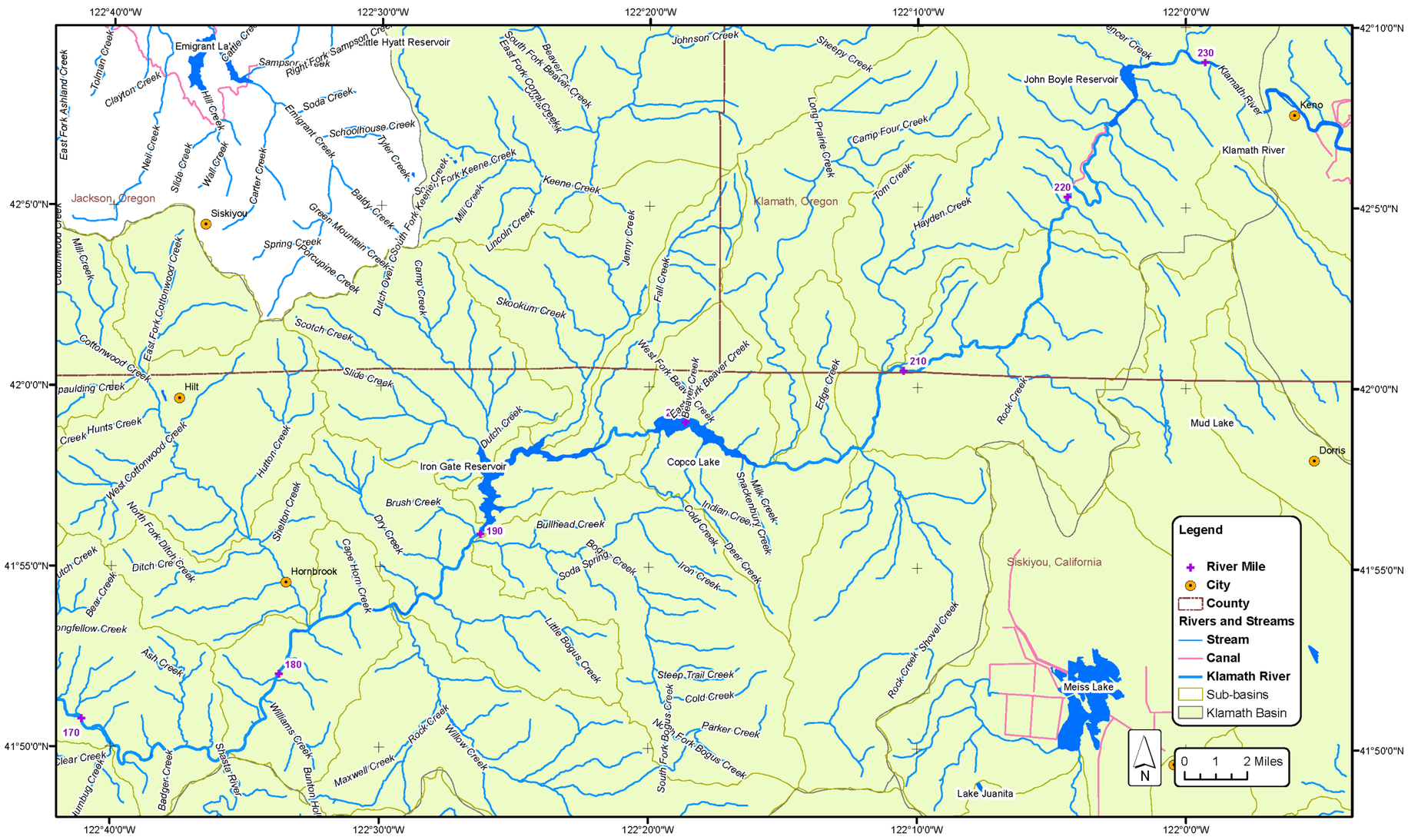

Figure 1-4. Overview of Klamath River from J.C. Boyle Reservoir to Shasta River.

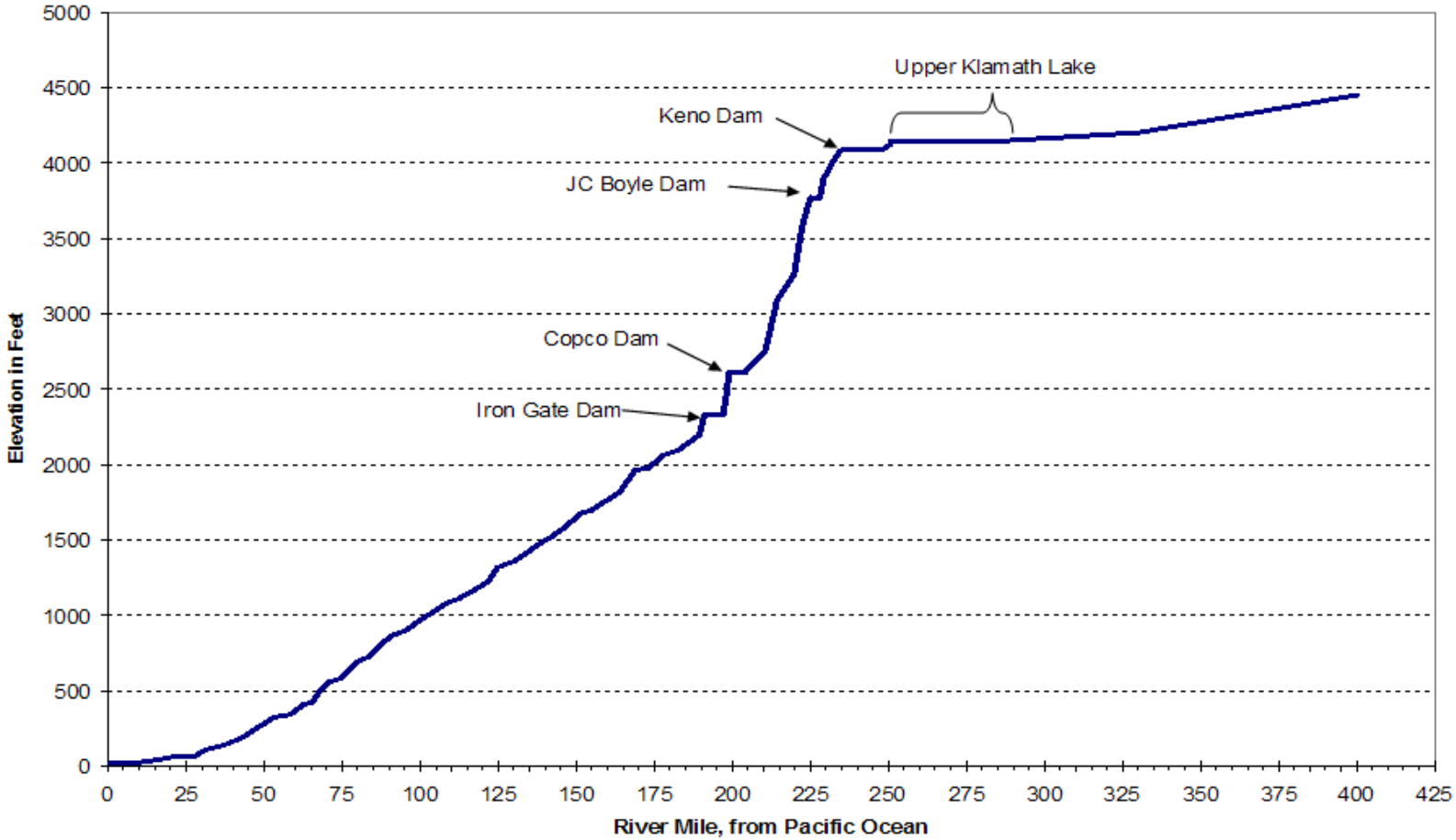

Figure 1-5. Water Surface Profile of Klamath and Williamson Rivers from ocean to above Upper Klamath Lake.

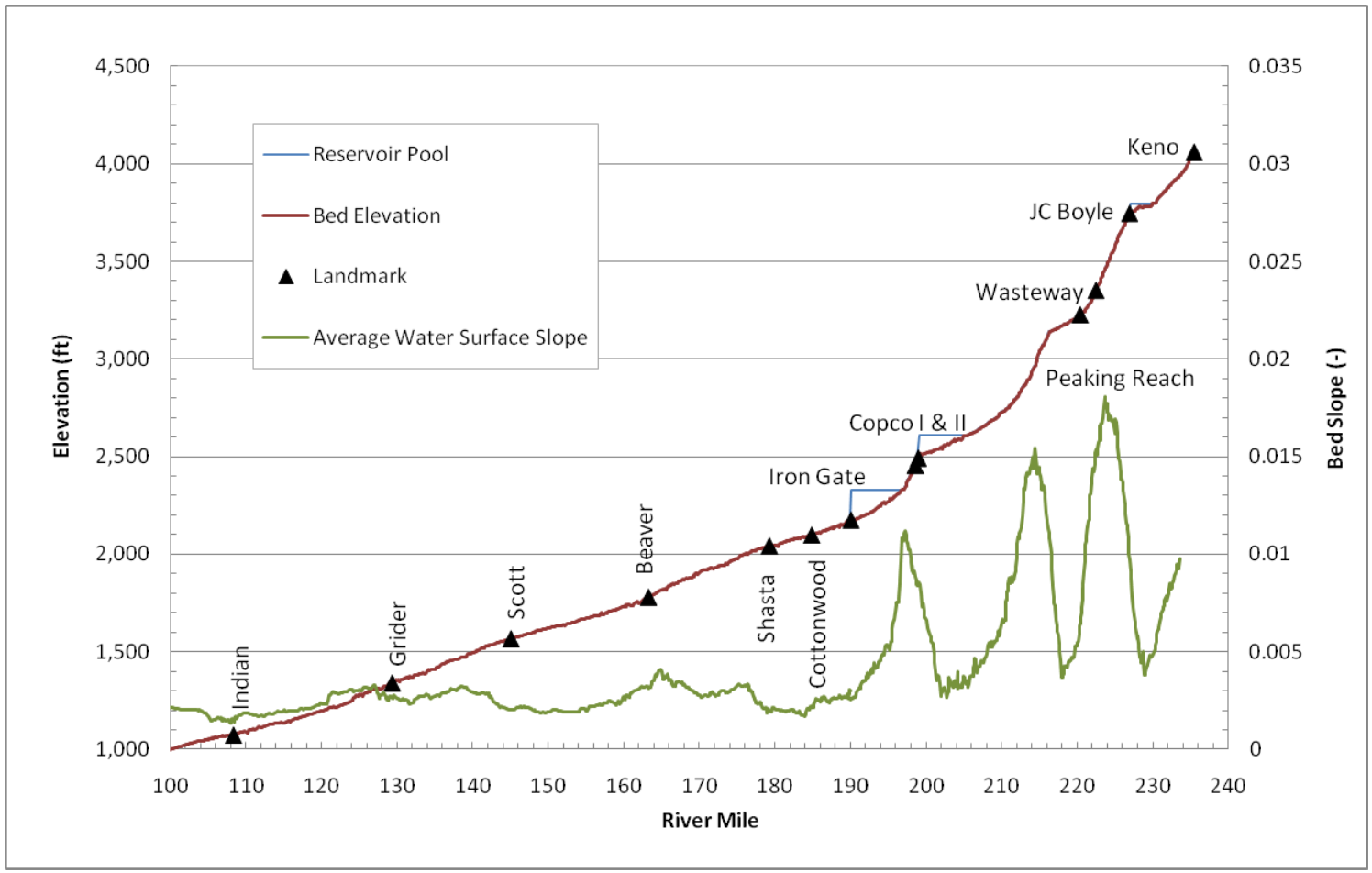

Figure 1-6. Bed elevation and water surface slope in reach from Keno to Happy Camp.