6. Future Hydrology Conditions

6.1. No Action Alternative

The documentation for the flow operations under No Action Alternative is given in: Appendix E. Documentation of Hydrology Simulations for the Klamath Dam Removal . Several Section 7 Consultations and Biological Opinions (BO's) have governed operation of Upper Klamath Lake (UKL) and the Klamath Project (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. A comparison between the No Action Alternative and the KBRA is presented in Section 6.2.

6.1.1. FLOOD FREQUENCY

There are no significant changes to the flood frequency analysis presented in Section 2.

6.1.2. DAILY FLOWS

The daily flows under the No Action Alternative were generated assuming the 2010 National Marine and Fisheries (NMFS) biological opinion is in place. The details of the hydrologic simulation are given in Appendix E. Documentation of Hydrology Simulations for the Klamath Dam Removal Studies. The results of the simulations are described in the next section. More analysis of the daily flows is given in the following section.

6.2. Dam Removal Alternative

6.2.1. FLOOD FREQUENCY

PacifiCorp does not operate Iron Gate and Copco 1 dams primarily for flood control, but the reservoirs do exhibit minor flood control benefits because of the volume of flow required to overtop the spillway. There has been some confusion over the flood control benefit provided by the reservoirs and this in part can be explained because PacifiCorp makes the following two, somewhat contradictory, statements in their 2004 FERC license application:

> "The potential for high runoff conditions occurs each year from approximately November through April. Because the Project reservoirs provide little active storage, UKL provides the only meaningful storage in the basin to ameliorate high flow events." (Exhibit B 2-7, PacifiCorp, 2004).

> "During high runoff season, PacifiCorp will frequently draft down Copco and Iron Gate reservoirs by 4 to 7 vertical feet each. The vacant storage created by this draft is then available to manage all or some portion of the high flows as they accumulate from sub-basin tributaries downstream of the Link River dam. This vacant storage also allows for better management of flows below Iron Gate."
> (Exhibit B 2-8, PacifiCorp, 2004).

Based upon these statements, we conclude that flood control is not the primary purpose of Copco 1 and Iron Gate, but there may be small non-quantified ancillary benefits to flood control.

An attempt to estimate the flood control benefit provided by these reservoirs was modeled by performing a level pool routing of an estimated 100-year flood hydrograph through the reservoirs. The flood of record that occurred in Dec 1964 was used as a basis to develop the shape of the hydrograph.

First, an instantaneous hydrograph of the 1964 flood was developed based upon the daily average flows and the recorded peak flows. For all days except the day in which the peak occurred, the instantaneous flow was assumed to pass through the daily average flow at 12 pm of that day and the flow at the transition between days was computed as the average flow between the two days. For the day in which the peak occurred, the timing of the peak was determined to conserve the volume of the flow for that day. A plot of the daily average flow, the measured peak flow, and the estimated instantaneous flow is shown in Figure 6-1.

Then, this instantaneous hydrograph was routed through Iron Gate and Copco 1 reservoirs. The effect of J.C. Boyle Dam is ignored because it is approximately 35 miles upstream of Iron Gate Dam and is significantly smaller than either Iron Gate or Copco 1 dams. Level-pool routing was used to estimate the attenuation effects of Iron Gate and Copco 1 reservoirs, as described in the following equation:

$$\frac{S_{n+1} - S_n}{\Delta t} = \frac{I_{n+1} + I_n}{2} - \frac{O_{n+1} + O_n}{2}$$

where:

$\underline{S_n}$ = Storage within reservoir at time n
I_n = Inflow to reservoir at time n
O_n = Outflow from reservoir at time $n = CWH^{1.5}$
W = Width of spillway
H = Depth over spillway
C = Discharge coefficient

The storage vs. elevation relationships are taken from the hydrology simulations. The spillway elevations and widths are given in Table 2-1. A discharge coefficient, $C = 3$, is used in all simulations.

The ordinates of the Dec 1964 hydrograph were then multiplied by a constant fraction until the peak of the hydrograph downstream of Iron Gate equaled the 100-year flood peak estimated for the current conditions (Section 2). The 100-year flood peak after dam removal is the peak of the hydrograph before it is routed through the reservoirs. The synthetic 100-year flood is attenuated by about 7% by Copco and Iron Gate reservoirs (Table 6-1).

Fifteen minute data is available for the Iron Gate gage from 1988 until the present. The flood attenuation of floods in 1989, 1993, 1996, 1997, and 2005 were also simulated. The percent reduction in the peak was computed for each of the floods and the results are given in Table 6-1.

This assessment does not account for fact that Jenny Creek comes in downstream of Copco Reservoir. Jenny Creek is the largest tributary between Keno and Iron Gate dams. The attenuation reported in Table 6-1 are overestimates of the actual attenuation because a large portion of the peak flow events are due to the floods occurring on Jenny Creek and Copco Reservoir does not affect flows from Jenny Creek. A more detailed assessment of flood attenuation is recommended to quantify more accurately the attenuation of Copco and Iron Gate reservoirs.

The increase in the peak flow due to the removal of Iron Gate and Copco dams will decrease in the downstream direction because the of the flood routing in the channel and the timing of flood flows at Iron Gate do not perfectly correlate with the timing of flood flows in the tributaries. For example, if the peak flow is increased at Iron Gate Dam, but the peak flows at Seiad Valley are primarily due to the flood flows from the Scott River there may be no significant impact at Seiad Valley due to a small increase in peak flow at Iron Gate.

Table 6-1. Flood attenuation of Iron Gate and Copco 1 reservoirs below Iron Gate Dam.

Flood	Peak Flow No Action	Peak Flow Dam Removal	% Reduction below Iron Gate Dam
Synthetic 100-yr flood	31,460	33,800	6.9
1989	10,200	10,300	1.2
1993	11,100	11,400	2.7
1996	11,200	11,300	1.1
1997	20,500	21,400	4.0
2005	12,400	12,800	3.0

The National Weather Service (NWS) provides river stage forecasts for the Klamath River for the USGS gages at Seiad Valley, Orleans and Klamath. They currently do not publish a forecast provided at Iron Gate gage. However, they

work with PacifiCorp to issue flood warnings to Siskiyou County. After removal of Copco and Iron Gate dams, it is likely that NWS will publish a forecast at the Iron Gate gage. The contact information for the NWS office responsible for the forecasting is:

National Weather Service
Medford Weather Forecast Office
4003 Cirrus Drive
Medford, OR 97504-4198
(541) 776-4303
http://www.wrh.noaa.gov/mfr/

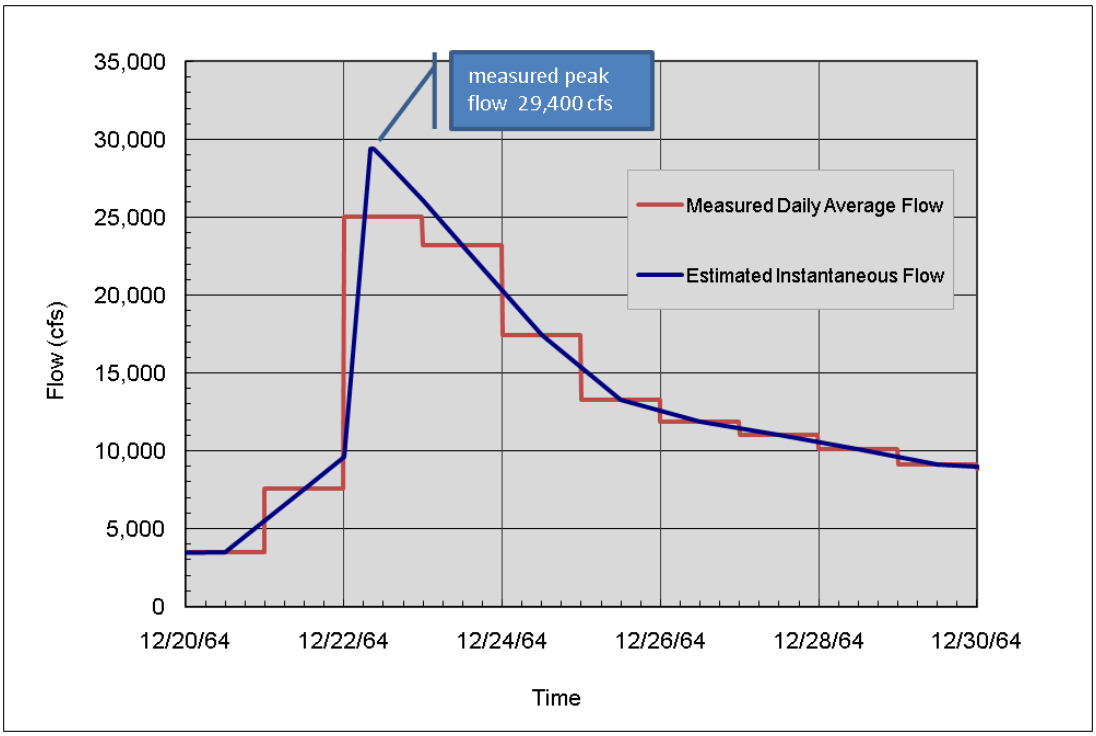

Figure 6-1. Daily average flows, measured peak flow, for Dec 1964 flood, peak of record for Iron Gate gage.

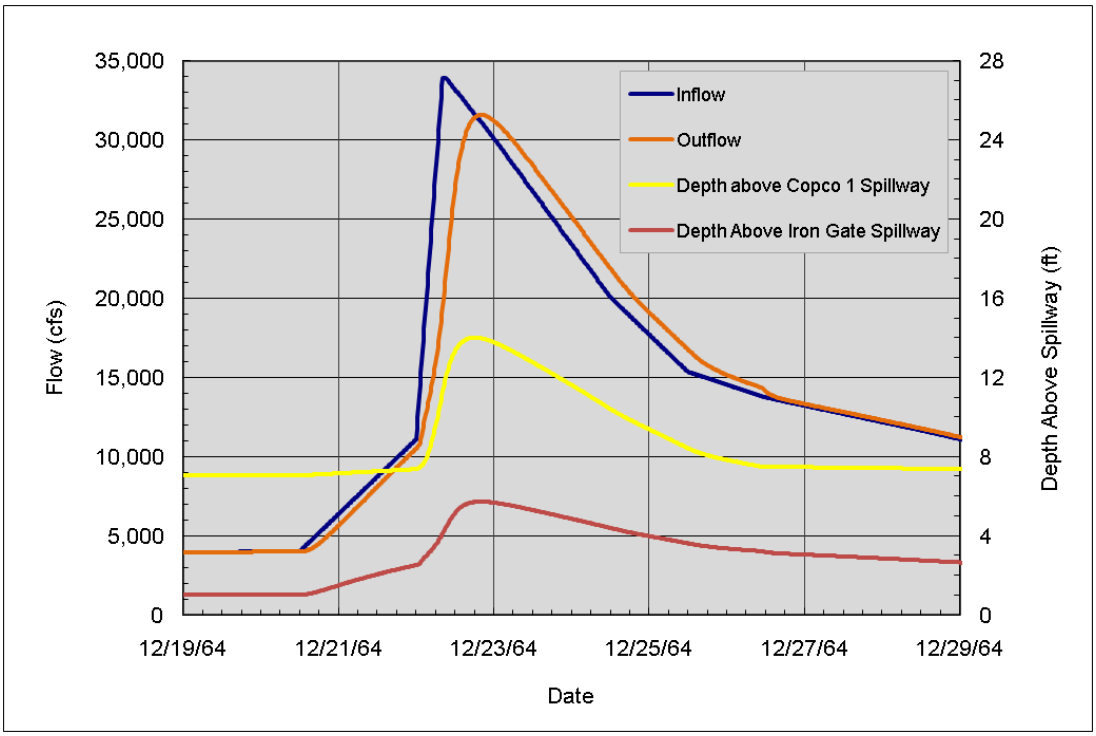

Figure 6-2. Inflow into Copco 1 Reservoir and outflow from Iron Gate dam for Dec 1964 flood.

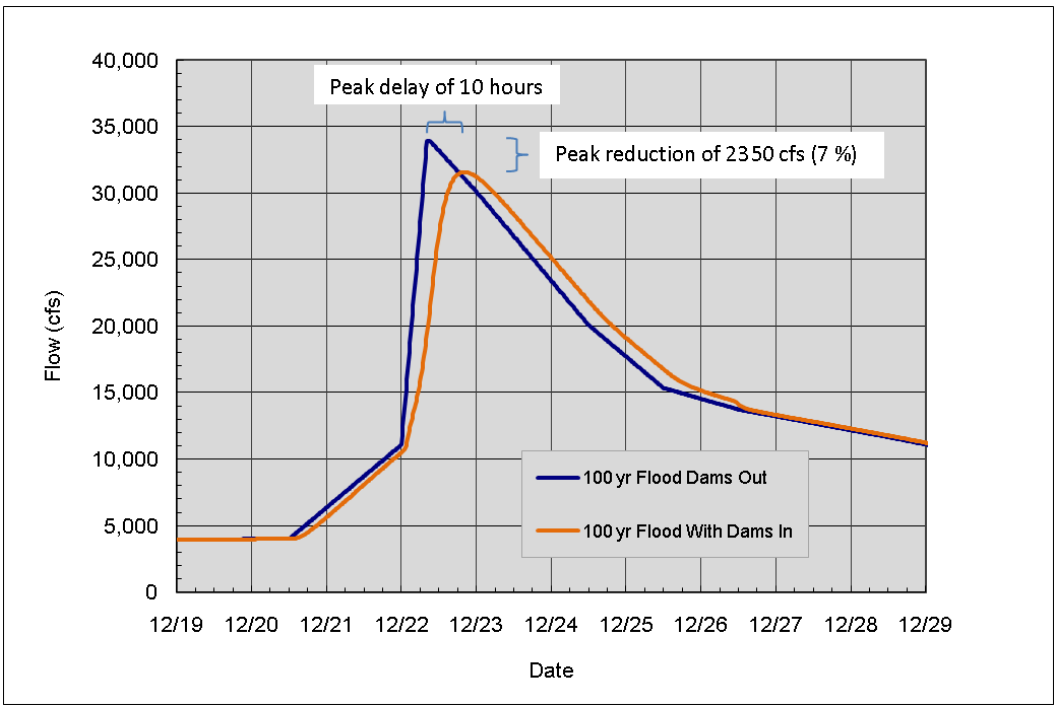

Figure 6-3. Difference between 100-year flood No Action and Dam Removal Alternatives.

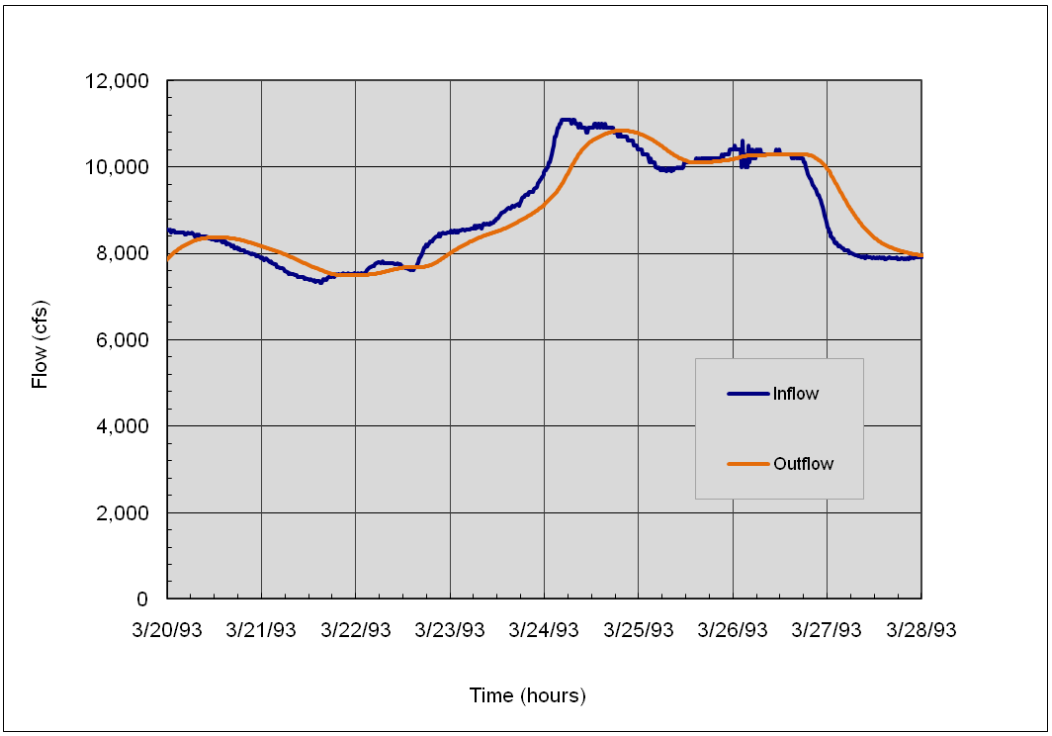

Figure 6-4. Inflow and outflow for March 1993 flood.

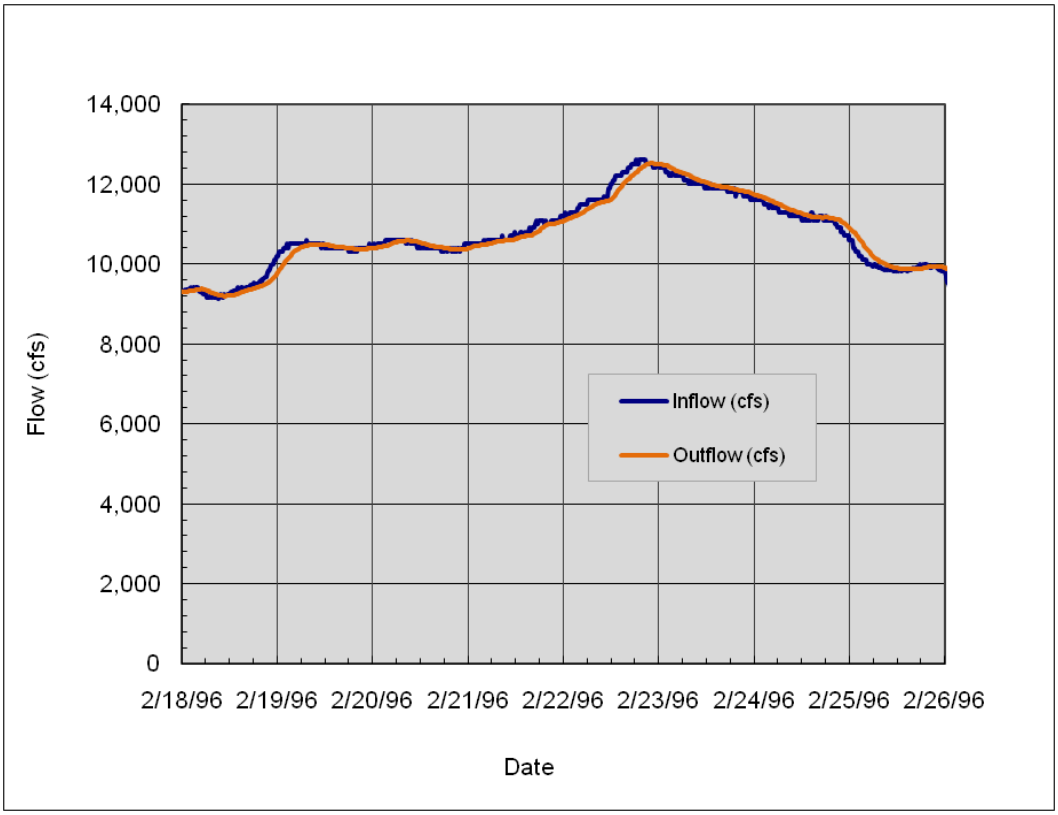

Figure 6-5. Inflow and outflow for Feb 1996 flood.

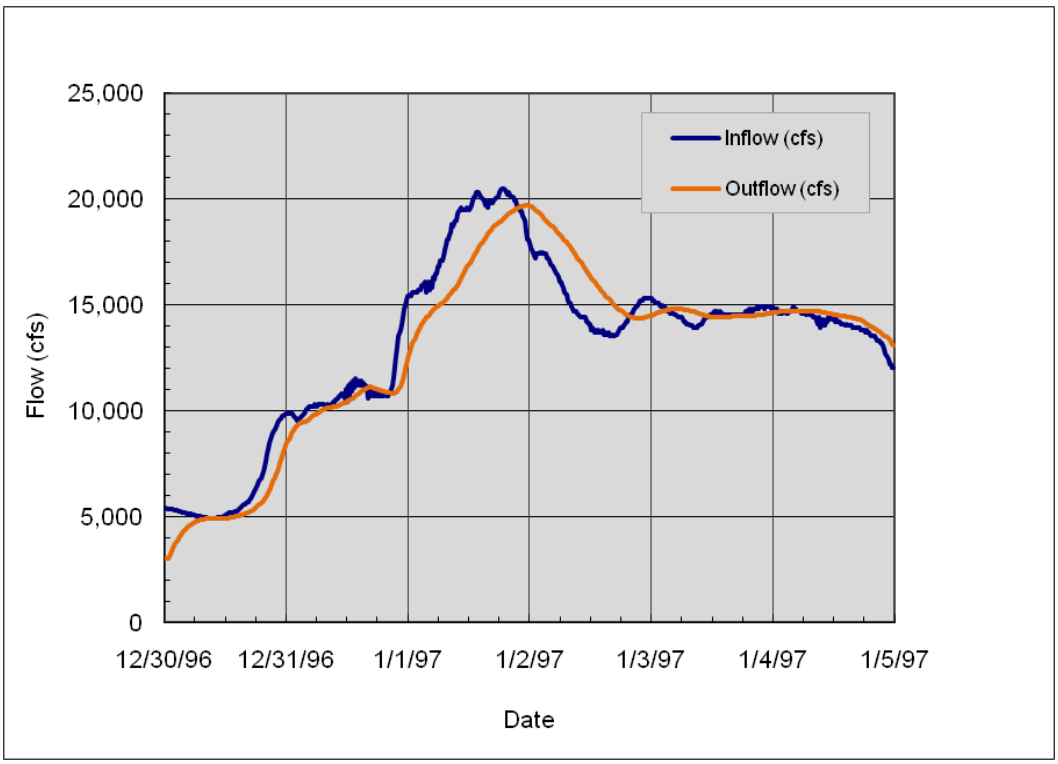

Figure 6-6. Flood routing through Copco I and Iron Gate dams for January 1997 flood.

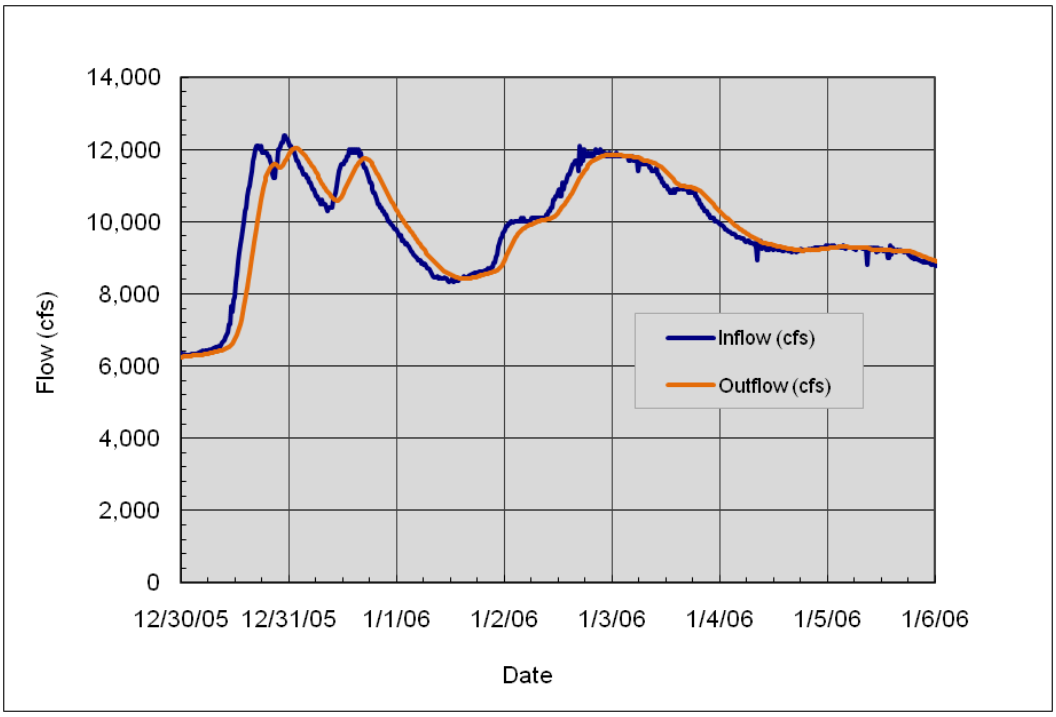

Figure 6-7. Flood routing through Copco I and Iron Gate dams for December 2005 flood.

6.2.2. DAILY FLOWS

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 details on the hydrologic modeling can be found in Appendix E. Documentation of Hydrology Simulations for the Klamath Dam Removal Studies. Flow duration data on the Klamath River at Keno Dam, Iron Gate Dam, and at Seiad Valley and Upper Klamath Lake elevations for the No Action and Dam Removal Alternatives are given in Appendix F. Exceedance Flows for No Action and Dam Removal Alternatives.

The flows discussed in this section were generated using the Index Sequential method (IS). The IS method relies upon historical flow data to generate a set of flows under future operational conditions. A 51-year hydrologic scenario from WY 2012 to WY 2062 was generated by using the historical flow record from 1961 – 2009 (49 years of data). The first two years are repeated to obtain a 51 water years and 50 calendar years. If a start year of 1961 is chosen, the hydrologic period from 1961 – 2009 is simulated followed by WYs 1961 and 1962. If a start year of 1982 is chosen, the period 1982 – 2009, then 1961 – 1983 is simulated.

The inflows to the UKL and Klamath River were computed based upon the historic stream flow measurements for the tributaries that have such measurements and computed inflows for other flow contributions that are not measured such as groundwater contributions and smaller tributaries. The KBRA flow operations were enforced in the Dam Removal Alternative to determine the monthly or biweekly lake elevations, water deliveries, and stream flows. The bi-weekly or monthly data was then disaggregated at Keno Dam into daily flows. These daily flows were routed down the Klamath River.

Results from Index Sequential (IS) method with a 1961 start year

UKL elevations for the Dam Removal Alternative are generally higher than under the No Action Alternative (Figure 6-8). The only exception is that for the 10% Exceedance level, the No Action Alternative has higher lake elevations for all months except June. Lake elevation exceedance curves for the entire year are shown in Figure 6-9. UKL elevations are generally higher at exceedance percentages of more than 10% under the Dam Removal Alternative than under the No Action Alternative. Under the Dam Removal Alternative, UKL will completely fill less often, but for most years, the elevations will be higher in the fall and winter.

The average flow at Iron Gate stream gage and the average Upper Klamath Lake (UKL) elevation are given at Figure 6-10 for both the No Action and Dam Removal Alternative. The 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 are for 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.

Figure 6-11 contains the 10%, 50%, and 90% exceedance flows below Keno Dam for the No Action and Dam Removal Alternatives. The 10% exceedance flows under the Dam Removal Alternative are greater for the months of January through April and less for the months of November and December. Generally, the 50% exceedance flows are similar throughout most of the year. The No Action Alternative 90% exceedance flows are about 300 to 360 cfs larger during the months of October to December and about 175 cfs larger during the months of January and February.

The daily average flows below Iron Gate Dam for the 10%, 50%, and 90% exceedance levels are shown in Figure 6-12. The 10% exceedance flows under the Dam Removal Alternative are about 5 to 10 % greater for the months of January through March. The 50% exceedance flows under the Dam Removal Alternative are about 5 to 15 % greater for the months of April and June to August and about 15 to 20 % less for the months of October to December. The 90% exceedance flows are similar for the two alternatives from March to September, but for the months of October to February, the No Action Alternative 90% exceedance flows are about 20 to 30 % larger (290 to 360 cfs larger).

The higher flows for the Dam Removal Alternative during the months of January through April below Iron Gate Dam are partly due to the fact that the simulations include pulse flows that would be implemented under the KBRA. An example of the comparison between daily flows is shown Figure 6-13. Under the Dam Removal Alternative, more years have peak flows above 5,000 cfs. Based upon the 50 year hydrologic simulation of daily average flows, the 2-year flood was approximately 5,700 cfs under the Dam Removal Alternative and 3,500 cfs under the No Action Alternative. Under the Dam Removal Alternative, the 5-year flood was increased to 10,000 cfs from 8,700 cfs under the No Action Alternative.

The monthly flow at Iron Gate Dam and the monthly UKL elevation are given in Figure 6-14. The plot demonstrates the generally higher UKL elevations under the Dam Removal Alternative and the sometimes smaller fall flows under the Dam Removal Alternative.

The 50% exceedance flows at the Seiad Valley, Orleans, and Klamath stream gages are given in Figure 6-15. There is very little difference between the two simulations except for November and December at the Seiad Valley and Orleans. The 50% exceedance flows near the Klamath Mouth at Klamath are nearly identical between the alternatives. The 50% exceedance flows under the Dam Removal are approximately 20 to 25% smaller for the months of November and December at Seiad Valley and about 10% less for the months of November and December at Orleans. The 90% exceedance flows are shown in Figure 6-16. These follow a very similar pattern as the 50% exceedance flows.

Flow-duration curves for the entire year at Klamath River at Keno Dam, Iron Gate Dam, Seiad Valley, Orleans, and at Klamath are shown in Figure 6-17 and Figure 6-18. The annual flow duration curve at Iron Gate Dam is similar between the No Action and Dam Removal Alternatives, but the Dam Removal Alternative 90% exceedance flow is 960 cfs versus 1090 cfs for the No Action Alternative. The 50% exceedance flow is 1,330 cfs under the Dam Removal Alternative and 1,420 cfs under No Action Alternative at Iron Gate Dam. The flows for all exceedance values are within 10% at Seiad Valley, 7% at Orleans, and 3 % at Klamath.

The annual flow at Keno Dam and annual agricultural supply is shown in Figure 6-19. The annual flow at Keno Dam is generally similar between the two alternatives except for a few dry years (2042, 2043, and 2045). These correspond to dry years in the historical record (1991, 1992, and 1994). In these dry years, the agricultural supply is significantly reduced under the No Action 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 years. The flows under the No Action Alternative follow the requirements of the No Action Alternative (See Table 1 of “Upper Klamath 2010 Biological Opinion Operations”, Appendix E). The monthly average flows at Iron Gate under No Action and Dam Removal Alternatives for this dry period are shown in Figure 6-20.

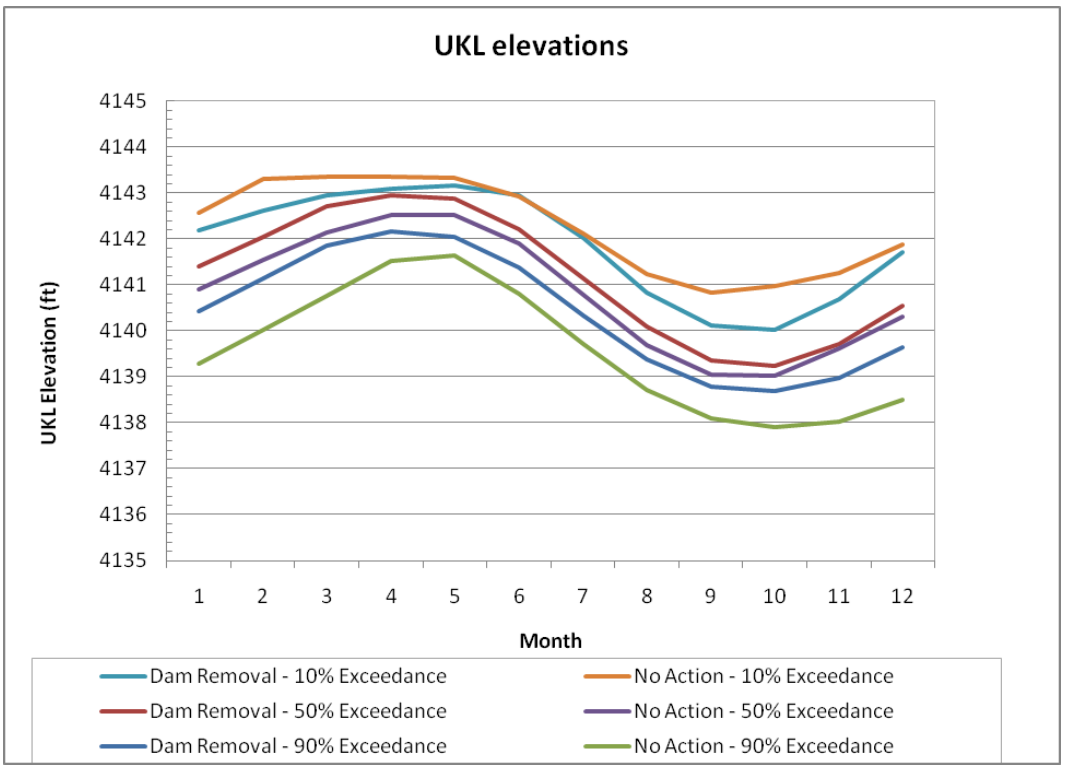

Figure 6-8. Lake elevations at various exceedance levels in Upper Klamath Lake.

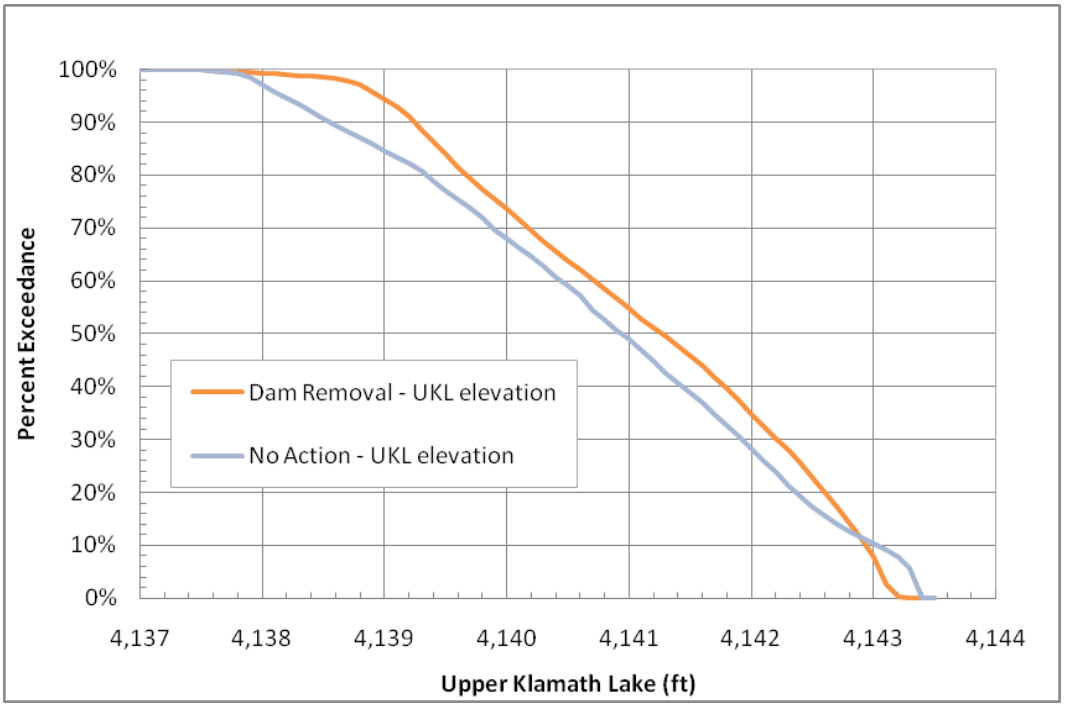

Figure 6-9. Upper Klamath Lake (UKL) elevations under No Action and Dam Removal Alternatives.

Figure 6-10. Average monthly flows at Iron Gate Dam and UKL elevations for No Action and Dam Removal Alternatives.

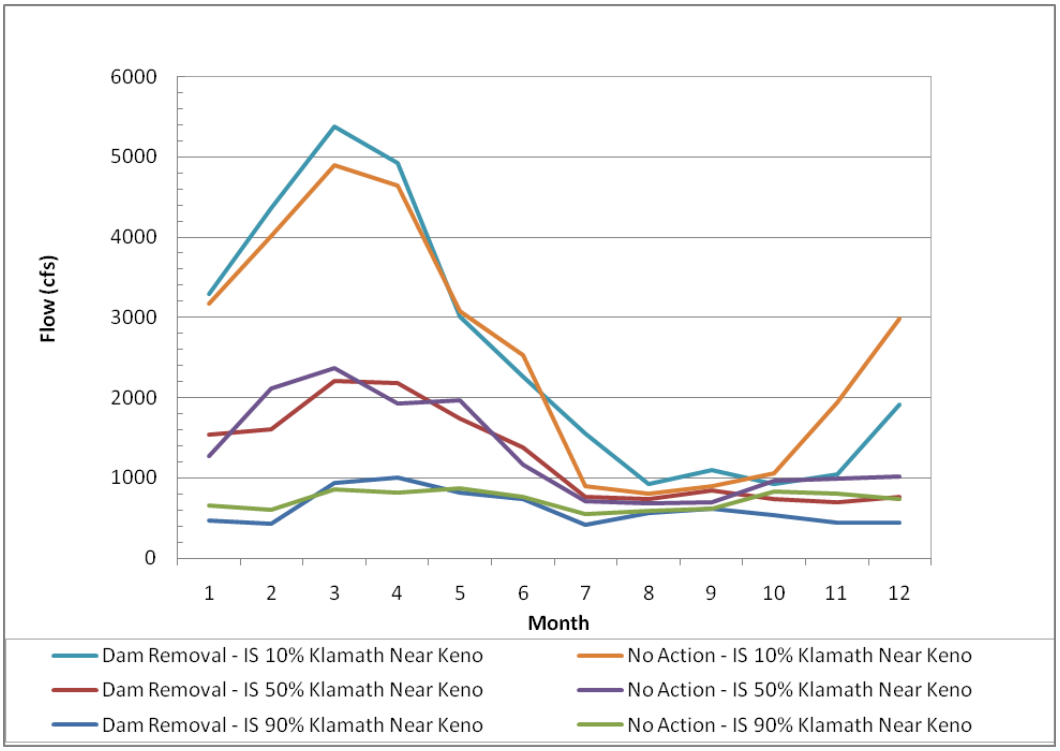

Figure 6-11. Dam Removal and No Action Alternatives exceedance flows below Keno.

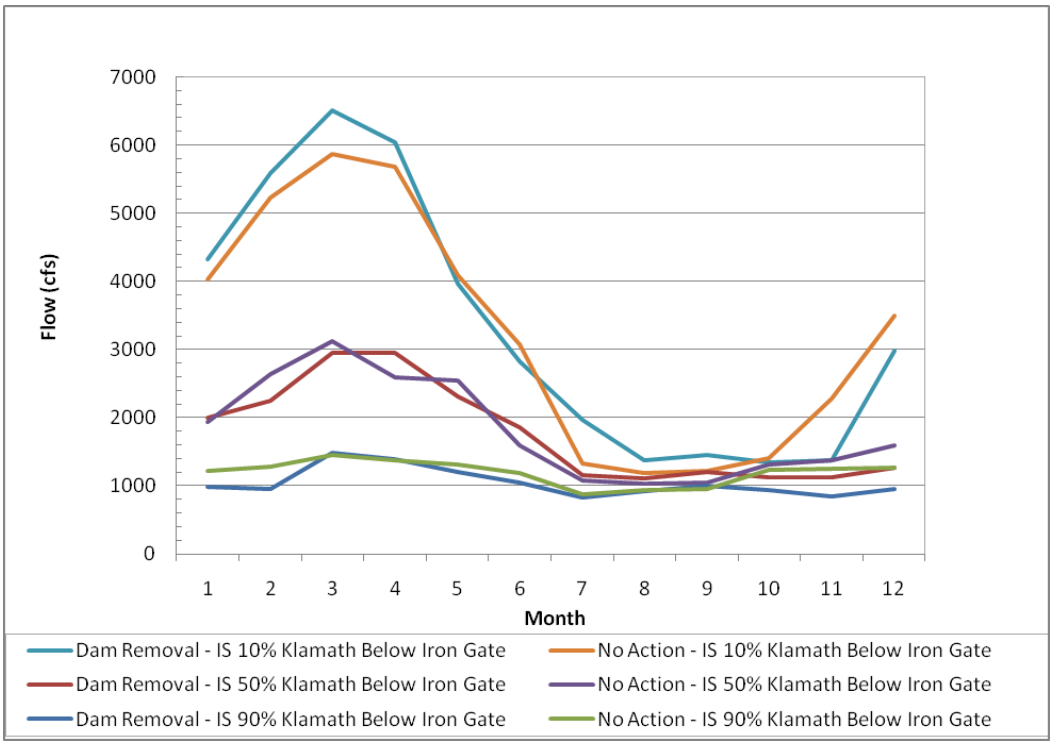

Figure 6-12. Exceedance flows below Iron Gate Dam for Dam Removal and No Action Alternatives.

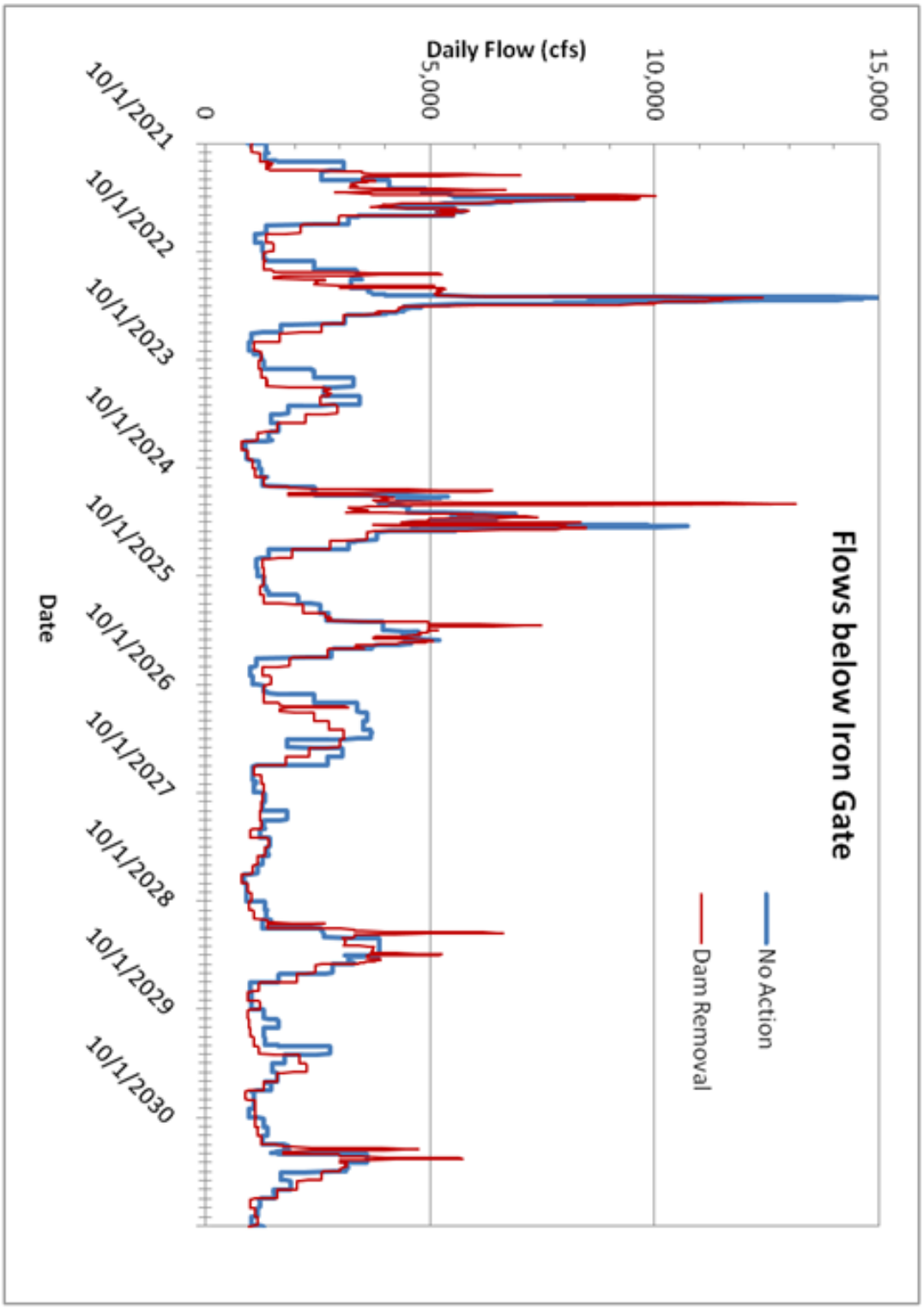

Figure 6-13. Daily flows during the Dam Removal and No Action Alternatives.

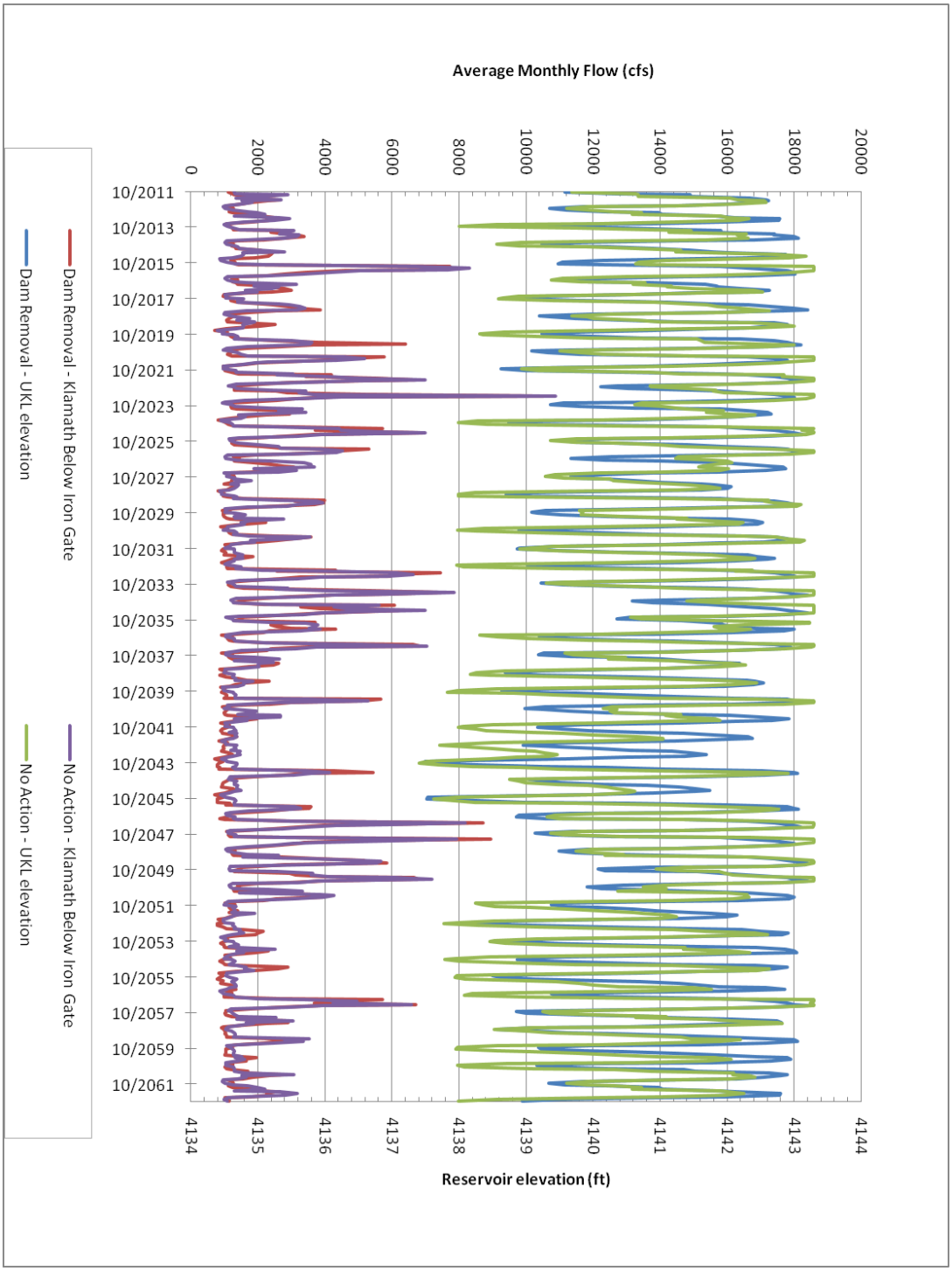

Figure 6-14. Comparison between monthly flows at Iron Gate dam and reservoir elevations for No Action and Dam Removal Alternatives.

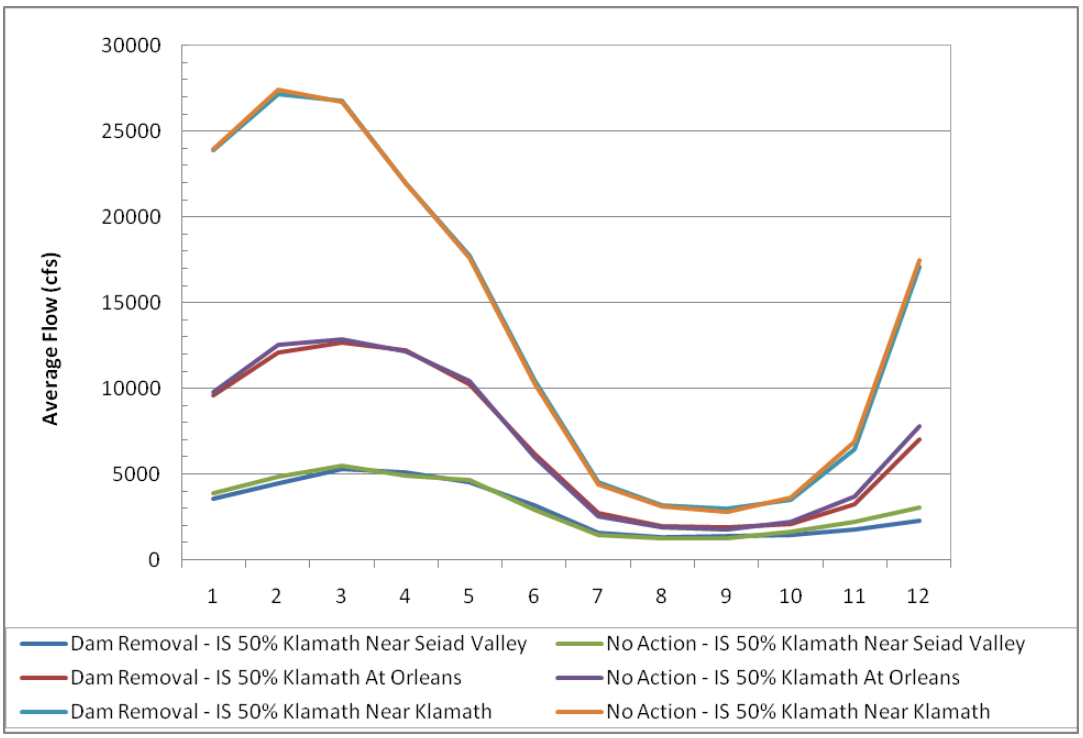

Figure 6-15. 50% Exceedance flows near Seiad Valley, Orleans, and Klamath for Dam Removal and No Action Alternatives.

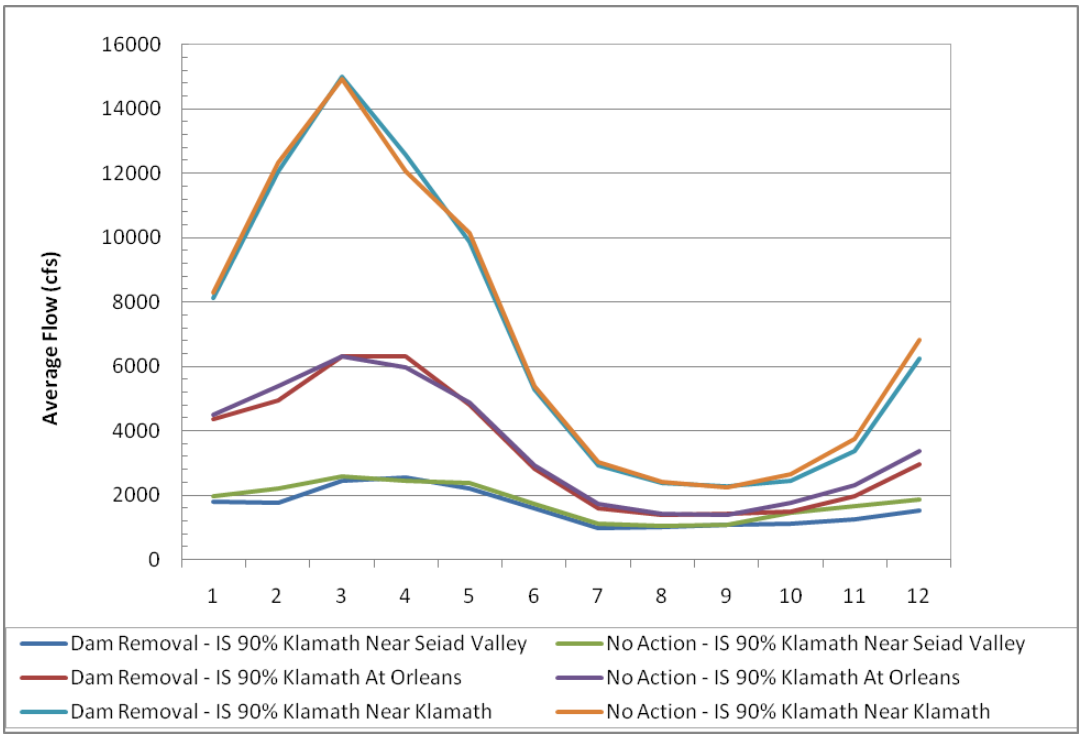

Figure 6-16. 90% Exceedance flows near Seiad Valley, Orleans, and Klamath for Dam Removal and No Action Alternatives.

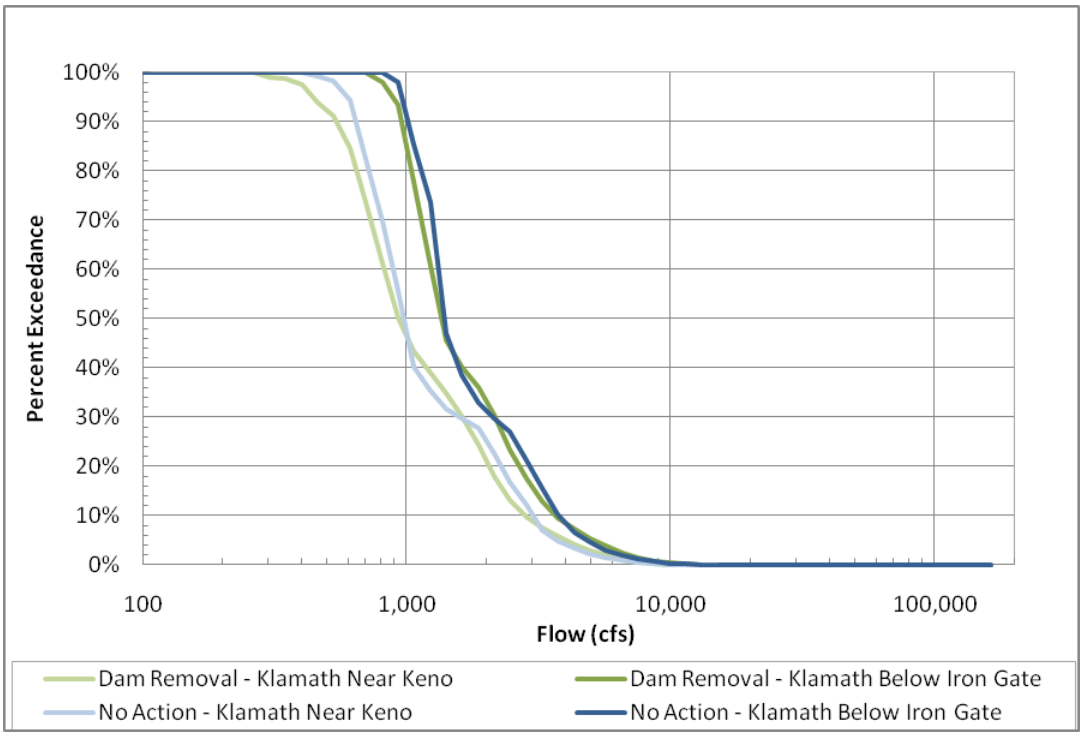

Figure 6-17. Flow duration at Keno Dam and below Iron Gate Dam under No Action and Dam Removal Alternatives.

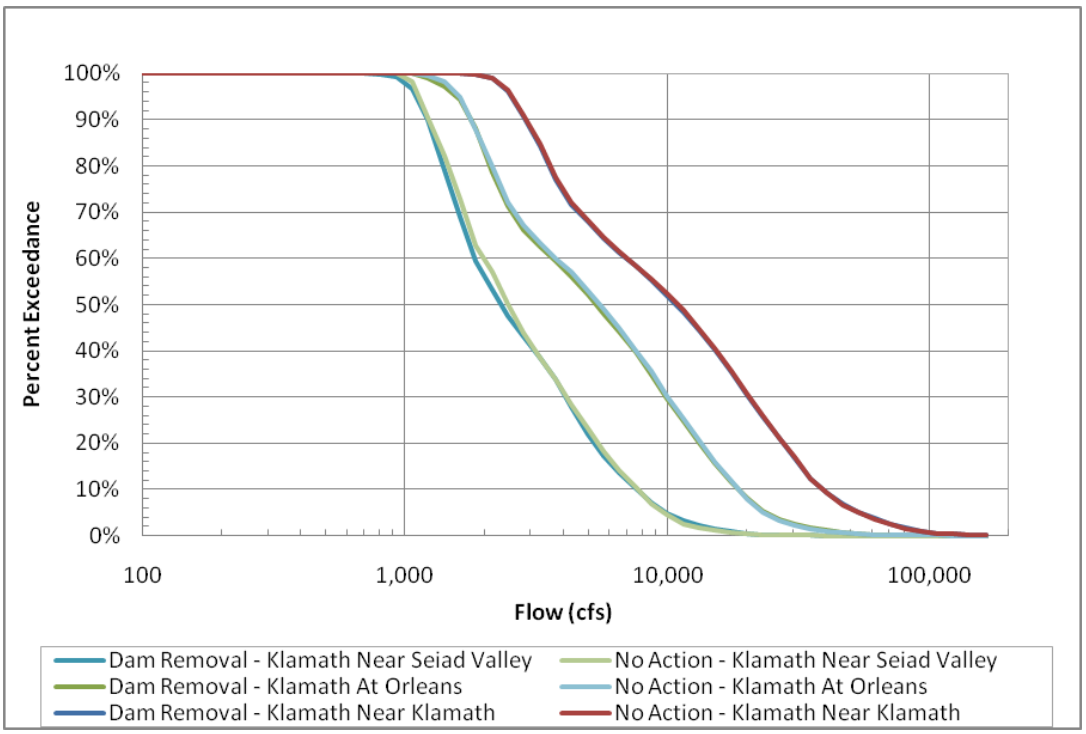

Figure 6-18. Flow duration at Seiad Valley, at Orleans, and at Klamath for the BO and KBRA.

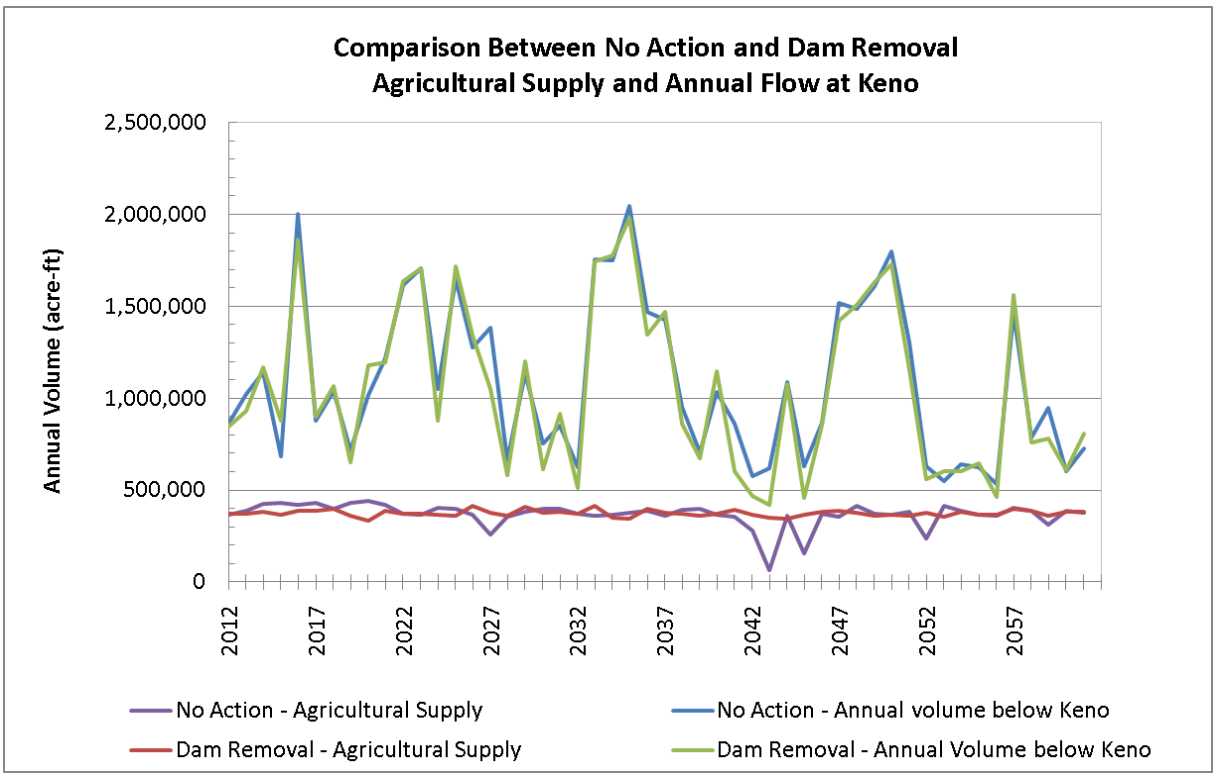

Figure 6-19. Annual flows under the No Action and Dam Removal Alternatives.

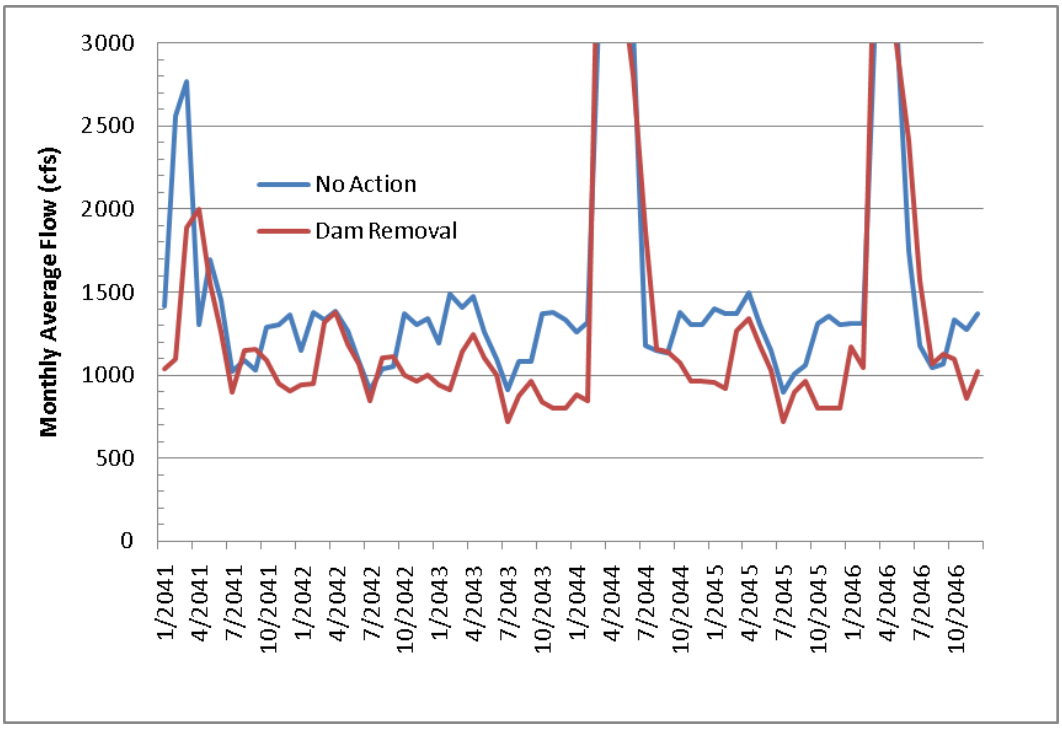

Figure 6-20. Monthly average flows at Iron Gate during period 2041 – 2046, which includes the driest period of the 50-yr simulation.