APPENDIX A1
PROJECT NOTATION, UNITS, AND CONVERSION

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1.0 PROJECT NOTATION

1.1 STANDARD UNITS

The standard units for the design of the project will be the following US Customary Units:

- Length: inch (in), feet (ft) and mile (mi)
- Area: acres
- Volume (reservoir): acre-feet (acre-ft)
- Volume (fluid): US gallons, million US gallons (gal, Mgal)
- Volume (concrete, earthfill): cubic yard (yd3)
- Mass: pound (lb), short tons (tons)
- Density: pounds per cubic foot (pcf)
- Pressure: pound-force per square foot (psf)
- Temperature: degrees Fahrenheit (°F)
- Power: horsepower (hp)
- Flow rate: cubic foot per second (cfs), cubic foot per minute (cfm) gallons per minute (gpm)

1.2 CONVERSIONS TO OTHER US CUSTOMARY UNITS

Other US Customary Units will also be used for preparation of the design. These units and conversion factors from the standard units (unless otherwise indicated) will be the following:

- Length: 1 ft = 12 inches (in)
- Length: 1 yard (yd.) = 3 ft
- Length: 1 mile (mi) = 5,280 ft
- Area: 1 acre = 43,560 square feet (sq. ft)
- Volume: 1 acre-ft = 43,560 cubic feet (ft^3)
- Volume: 1 acre-ft = 1,613 cubic yards (yd^3)
- Fluid volume: 1 Mgal = 1,000,000 gallons (gal)
- Mass: 1 ton = 2,000 pounds (lbs)
- Density: 1 short ton per cubic yard ($tons/yd^3$) = 74 pcf
- Pressure: 1 pound-force per square inch (psi) = 144 psf

- Pressure: 1 kilopound per square inch (ksi) = 1,000 psi

1.3 CONVERSIONS TO INTERNATIONAL SYSTEM OF UNITS (SI)

Typical conversion factors to the International System of Units (SI) from the standard units for the project are the following:

- Length: 1 ft = 0.305 meters (m)
- Length: 1 yd. = 0.914 m
- Length: 1 mi = 1.61 kilometers (km)
- Diameter: 1 in = 25.4 millimeters (mm)
- Area: 1 acre = 4,047 square meters (m^2)
- Area: 1 acre = 0.405 hectare (ha)
- Volume: 1 acre-ft = 1,233 cubic meters (m^3)
- Volume: 1 yd^3 = 0.765 m^3
- Volume: 1 ft^3 = 0.028 m^3
- Fluid volume: 1 gal = 3.785 litres (L)
- Fluid volume: 1 Mgal = 3,785 m^3
- Mass: 1 ton = 907 kilograms (kg)
- Mass: 1 ton = 0.907 tonnes (t)
- Density: 1 pcf = 16 kilograms per cubic meter (kg/m^3)
- Density: 1 pcf = 0.016 tonnes per cubic meter (t/m^3)
- Density: 1 $tons/yd^3$ = 1.19 tonnes per cubic meter (t/m^3)
- Pressure: 1 psf = 0.048 kilopascal (kPa)
- Pressure: 1 psi = 6.89 kilopascal (kPa)
- Power: 1 hp = 746 watts (W)
- Flow rate: 1 gpm = 0.227 cubic meters per hour (m^3/hr)
- Flow rate: 1 gpm = 0.063 litres per second (L/s)

APPENDIX A2
MAPPING, SURVEYS, AND SITE CONTROLS

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1.0 OVERVIEW

Project area mapping to document the existing site conditions across the project site was undertaken by the US Department of the Interior (USDOI) in 2009. LiDAR and 3D break-lines for approximately 170 miles on the Klamath River from Link River Dam, OR to the confluence with Elk Creek south of Happy Camp, CA, and surveys along with above and in-water cross-sections at each of nine bridges, were included in the study area (USDOI, 2010). The map projection for the project is as follows:

- Projection: California State Plane:
  - Zone: 1
  - FIPS zone: 0401
  - Vertical Datum: NAVD 1988
  - Horizontal Datum: NAD83
  - Unit: Feet

Site control will be established and verified by the Contractor. Scale factors will be established for the entire site for use in ground to UTM coordinate conversions if required.

Survey control will be established through surveyed benchmarks across the site. Benchmarks are expected to be established at the intake locations, along the penstock routes and at the powerhouse & switchyard locations. Benchmarks will also be established along the transmission line alignments and at major bridge and road crossings.

The Contractor will establish any other control points and benchmarks necessary to set out and construct the Works.

APPENDIX A3
GEOLOGICAL SETTING

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1.0 GENERAL

The Klamath River traverses multiple physiogeographic provinces starting in the Basin and Range Province of Oregon, traversing the High and Western Cascades, Klamath Mountains Province and the Coastal Ranges of northern California, and reaching the Pacific Ocean at Requa, 16 miles south of Crescent City. The Project area is predominantly contained in the Western and High Cascades. The Klamath River pre-dates the formation of the Cascade Mountain Range and maintained a relatively similar course through the mountain building events.

The bedrock of the Project Area comprises volcanic rocks (up to 45 million years old) and includes basalt and andesite lava flows, tuffs, tuff-breccias and volcaniclastic sandstone. The volcanic rocks are intruded by numerous dikes and plugs of andesite, rhyolite, and basalt. Many of the volcanoes associated with the Western Cascades have since eroded, but large shield volcanoes and vents of the High Cascades remain and are still active in present times.

Large deposits of coarse alluvium were deposited along the Klamath River during the period of the last glaciation when the river had a higher discharge. Lacustrine deposits were laid down in former temporary lakes that were created at the present-day sites of the Copco No. 1 and J.C. Boyle Reservoirs when the Klamath River was temporarily ‘dammed’ by volcanic activity.

2.0 J.C. BOYLE HYDROELECTRIC FACILITY

The topography in the area of the J.C. Boyle hydroelectric facility is predominantly a low-gradient bowl with gently rolling terrain. The steepest topography exists in the river canyons upstream and downstream of the reservoir. All the bedrock units in the area are estimated to be younger than 5 million years and associated with High Cascades volcanism from large stratovolcanic complexes and smaller shield volcanoes and vents; these are typically basaltic flows interlayered with volcaniclastics and hydrovolcanic deposits, leading to highly complex geology from a large variety of sources.

Faulting is very prominent in the J.C. Boyle Reservoir area and appears to be associated with extensional tectonics of the Basin and Range Province that began approximately 1.5 to 2.0 million years ago. The bowl topography of the reservoir area likely formed as a dropped-down basin. At least one fault splay is predicted to extend into the dam area (PanGEO, 2008).

The surficial deposits at the reservoir comprise lacustrine deposits as well as river alluvium and local colluvial deposits. The lacustrine deposits comprise older sediments that were laid down in a former lake that was created when the river was temporarily 'dammed' by volcanic activity and recent sediments, which were deposited within the reservoir.

3.0 COPCO NO. 1 AND COPCO NO. 2 HYDROELECTRIC FACILITIES

The area surrounding the Copco No. 1 and Copco No. 2 reservoirs is characterized by hillsides comprised of low gradient lava flows from surrounding shield volcanoes. The Copco Basalt (0.14 million years) makes up the vertical upper walls of the canyon in the vicinity of the dam site. The Copco Basalt was created by volcanic flows from vents on both sides of the river, which led to damming of the river and the formation of a lake in the same area as the present-day reservoir. The Western Cascades Volcanics underlie most of the slopes on the shoreline of the reservoir. This unit comprises andesite with interstratified tuff-breccia, volcaniclastic sandstone and tuffs.

Small faults that have been historically mapped in the area of the Copco No. 1 and No. 2 hydroelectric facilities typically trend west to northwest south of the river. Limited structural mapping of faults north of the river shows a northward trend.

The surficial deposits at the Copco No. 1 Reservoir comprise lacustrine deposits as well as river alluvium and local colluvial deposits. The lacustrine deposits mainly comprise sediments that were laid down in a former lake that was created when the river was temporarily 'dammed' by volcanic activity. Fine sediments, comprising silts and diatomite (siliceous skeletal remains of diatoms) were deposited in the lake. The formation of the lake resulted in fluvial terraces and fans developing further still from the contemporary course of the river. Recent lacustrine deposits have accumulated within the reservoir since its construction. Colluvium occurs locally around the shoreline of the Copco No. 2 Reservoir.

Natural groundwater springs can be observed and typically exist in the tuffaceous layers between impermeable lava flows and along lithological contacts. The rapidly cooled more porous lava flow tops and bottoms are common aquifers in the region.

4.0 IRON GATE HYDROELECTRIC FACILITY

The Iron Gate Dam and its reservoir lie entirely within the Western Cascades Geologic Province. The bedrock around the shoreline comprises andesite and basalt with volcanic breccia, tuff, tuffaceous siltstones, and sandstones. The Western cascades strata dip gently towards the east. Surficial deposits around the reservoir shoreline include colluvium and local alluvial deposits at drainage line intersections.

Natural springs are also found in numerous locations on the valley slopes surrounding the Iron Gate Reservoir.

References:

PanGEO Incorporated (PanGEO), 2008. Geotechnical Report – Klamath River Dam Removal Project. August. Seattle, Washington, USA.

PacifiCorp Energy Inc. (PacifiCorp), 2015a. J.C. Boyle Development: Supporting Technical Information Document, Section 5 – Geology and Seismicity. April 30. Portland, Oregon, USA.

PacifiCorp Energy Inc. (PacifiCorp), 2015b. Copco No. 1 Development: Supporting Technical Information Document, Section 5 – Geology and Seismicity. April 30. Portland, Oregon, USA.

PacifiCorp Energy Inc. (PacifiCorp), 2015c. Iron Gate Development: Supporting Technical Information Document, Section 5 – Geology and Seismicity. April 30. Portland, Oregon, USA.

APPENDIX A4
SEISMICITY

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1.0 DESIGN PARAMETERS FOR TEMPORARY STRUCTURES

A standard and guideline review of DSOD, the California Water Code, Caltrans, USACE, ASCE, FEMA, FERC, USBR, and Uniform Building Code documents did not yield clear design criteria for the seismic design of temporary structures. KP has also reviewed the latest Supporting Technical Information Documents (STIDs) provided by PacifiCorp as they pertain to geology and seismicity at J.C. Boyle, Copco No. 1, Copco No. 2, and Iron Gate. It was determined from these documents that the site-specific ground motion parameters for permanent structures were developed by Kleinfelder West Inc. (Kleinfelder) and Black & Veatch using the 2002 United States Geological Survey (USGS) database. The seismic design parameters presented in this appendix have been determined using the updated USGS seismic hazard database in conjunction with a design life equal to or less than one year. The current data provided by the USGS seismic hazard database is based on the 2014 model which incorporates the latest ground motion prediction models for shallow crustal earthquakes (known as the Next Generation Attenuation Models).

The probability of exceedance for the Operating Basis Earthquake (OBE) and Maximum Credible Earthquake (MCE) events were assessed to quantify the risk associated with structures having a design life of 1 year. The probability of exceedance was calculated using the following equation:

$$Q = 1 - e^{-L/T}$$

Where: Q = probability of exceedance

L = design life (years)

T = return period (years)

The resulting probabilities of exceedance are as-follows:

- OBE (1/475-year event): 0.2% probability of exceedance
- MCE (1/2475-year event): 0.04% probability of exceedance

The OBE event was selected for the design of temporary structures having a design life of one year or less. The spectral accelerations corresponding to the OBE event at each site are presented with the OBE PGAs in Table 1.1.

Table 1.1 Selected Seismic Design Parameters for Temporary Structures at Each Site

Site	Return Period (years)	2014 USGS[1] PGA (g)	2014 USGS[1] Sa (0.2 s)	2014 USGS[1] Sa (1.0 s)
J.C. Boyle	475	0.17	0.39	0.14
Copco No. 1	475	0.12	0.26	0.10
Copco No. 2	475	0.12	0.26	0.10
Iron Gate	475	0.11	0.25	0.10

NOTES:

1. PGA AND SPECTRAL ACCELERATION VALUES TAKEN FROM THE USGS UNIFIED HAZARD TOOL DABATASE (USGS).

2.0 DESIGN PARAMETERS FOR PERMANENT SLOPES

Permanent slopes are designed to the MCE values provided in the STIDs for the hydropower facilities. The STIDs are presented in Appendix J.

References:

Black & Veatch, 2010. Copco No. 1 Development Klamath River Hydroelectric Project, FERC Project No. 2082 – Seismic Analysis of Structures. January 12.

Black & Veatch, 2009. Technical Memorandum – Time Histories for J.C. Boyle Dam. September 4.

Black & Veatch, 2004. 5.A Seismicity – Iron Gate. September 15.

Kleinfelder West Inc. (Kleinfelder), 2009a. Geoseismic Evaluation Report – J.C. Boyle Dam. June 19. Salt Lake City, Utah, USA.

Kleinfelder West Inc. (Kleinfelder), 2009b. Geoseismic Evaluation Report – Copco No. 1 Dam. June 19. Salt Lake City, Utah, USA.

Kleinfelder West Inc. (Kleinfelder), 2009c. Geoseismic Evaluation Report – Iron Gate Dam. June 19. Salt Lake City, Utah, USA.

PacifiCorp Energy Inc. (PacifiCorp), 2015a. J.C. Boyle Development: Supporting Technical Information Document, Section 5 – Geology and Seismicity. April 30. Portland, Oregon, USA.

PacifiCorp Energy Inc. (PacifiCorp), 2015b. Copco No. 1 Development: Supporting Technical Information Document, Section 5 – Geology and Seismicity. April 30. Portland, Oregon, USA.

PacifiCorp Energy Inc. (PacifiCorp), 2015c. Iron Gate Development: Supporting Technical Information Document, Section 5 – Geology and Seismicity. April 30. Portland, Oregon, USA.

United States Geological Survey (USGS). Earthquake Hazards Program: Uniform Hazard Tool. (Accessed from: https://earthquake.usgs.gov/hazards/interactive/

APPENDIX A5
CLIMATE

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1.0 OVERVIEW

The Project sites are located in predominantly rural areas of southern Oregon and northern California, along the riparian corridors of the Klamath River and its tributaries. The local climate is characterized by cool, wet winters and warm, dry summers. Cold air temperatures generally occur from November through March and warmer air temperatures and drier conditions occur from April through October with summer air temperatures highest in July, August, and September. The summers are dry with occasional isolated thunderstorms from July to September (Oregon Watershed Enhancement Manual, 2001).

The area is characterized by varying precipitation with a drier climate near Klamath Falls, Oregon and a wetter climate in northern California. Most precipitation occurs in the winter months of November, December and January (Oregon Watershed Enhancement Manual, 2001). Due to generally high elevations, the upper plateau has cool temperatures and receives a substantial amount of snow, which accumulates into moderately deep snowpack (Oregon Watershed Enhancement Manual, 2001). At its higher elevations (above 5,000 feet), the Klamath Basin receives rain and snow during the late fall through to spring.

2.0 AVAILABLE DATA

The National Oceanic and Atmospheric Administration (NOAA) operate several cooperative climate stations in the region. The regional climate datasets most relevant to the Project sites are:

- Keno, Oregon: NCEI COOP #354403 (6 miles from J.C. Boyle facility)
- Copco Dam No. 1, California: NCEI COOP #041990 (located at Copco No. 1 facility)

The location of the regional climate stations and the Project sites are shown on Figure 2.1.

Figure 2.1 Regional Climate Station Locations and Project Locations

2.1 TEMPERATURE

Data from the regional climate station within the closest proximity to each site was selected to represent the temperatures at that Project site. Available temperature data for the regional climate stations are presented in Table 2.1. The mean annual air temperature range is 44 °F to 52 °F between Keno, Oregon climate stations and Copco Dam No. 1, California. The months with the highest mean temperatures for the stations are July through September with maximum monthly mean temperatures ranging between 68 °F and 75 °F. The lowest minimum monthly mean temperatures are in January and December ranging between 29 °F and 36 °F.

Table 2.1 Measured Regional Temperature Data Summary

Station Details[1]	Unit	Keno, OR	Copco Dam No. 1, CA
Station Number	-	35-4403	04-1990
Latitude	° ' "	42° 7' 46.92" N	41° 58' 46.92" N
Longitude	° ' "	121° 55' 46.92" W	122° 20' 16.08" W
Elevation	ft	4,116	2,703
Distance from Site			
Nearest Project Site(s)	-	J.C. Boyle	Copco No. 1, Copco No. 2, Iron Gate
Distance from Site	mi	6.2	6.0 from Iron Gate
Period of Record[2]	-	1927-2019	1959-2019
Measured Values[3, 4]			
Mean Annual	ºF	44.4	52.1
Mean Annual High	ºF	58.5	65.7
Mean Annual Low	ºF	29.1	38.6
Maximum Monthly Mean	ºF	68.4	75.3
Minimum Monthly Mean	ºF	29.0	35.9
Maximum Recorded Daily	ºF	103	115
Minimum Recorded Daily	ºF	-20	-2

NOTES:

1. DATA OBTAINED FROM NOAA ATLAS 14 – PRECIPITATION-FREQUENCY ATLAS OF THE UNITED STATES (2014).
2. THE PERIOD OF RECORD IDENTIFIES WHEN THE FIRST AND LAST MEASUREMENTS WERE TAKEN AND DOES NOT REPRESENT A CONTINUOUS PERIOD OF DATA COLLECTION.
3. MEASURED TEMPERATURE VALUES OBTAINED FROM NOAA REGIONAL CLIMATE CENTERS (ACIS, 2015).
4. MEASURED TEMPERATURE VALUES REPRESENT RECORDED DATA ONLY.

2.2 PRECIPITATION

Precipitation values for the project sites were derived in a similar manner to the temperature values, with the nearest regional climate station data providing the representative values for each specific project site. The wettest months are November through January. The proportion of precipitation falling as snow is directly correlated to temperature, which varies with each location within the Project region. In the upper watershed, snow is the primary form of precipitation for elevations above 5,000 feet.

The maximum daily rainfall range observed (recorded) at the regional climate stations is 3.0 inches and 6.0 inches for the Copco Dam No. 1 and Keno climate stations, respectively. The daily rainfall was converted to an equivalent 24-hr rainfall using a standard factor of 1.13 (Hershfield, 1961) resulting in maximum 24-hr rainfall of 3.4 inches to 6.8 inches for the Copco Dam No. 1 and Keno climate stations, respectively. The precipitation values are summarized in Table 2.2 and the mean monthly precipitation values are summarized in Table 2.3.

Table 2.2 Measured Regional Precipitation Summary[1, 2]

	Unit	Keno, OR	Copco Dam No. 1, CA
Period of Record[3]	-	1927-2019	1959-2019
Mean Annual Precipitation	in.	18.6	19.7
Mean Total Annual Rainfall	in.	13.4	18.0
Percentage of Annual Precipitation as Rain	%	72%	91%
Mean Total Annual Snowfall	in.	51.5	16.8
Mean Total Annual SWE[4]	in.	5.1	1.7
Maximum Recorded 24-hour Precipitation[5]	in.	6.8	3.4

NOTES:

1. DATA OBTAINED FROM NOAA REGIONAL CLIMATE CENTERS (ACIS, 2015).
2. MEASURED PRECIPITATION VALUES REPRESENT RECORDED DATA ONLY.
3. THE PERIOD OF RECORD IDENTIFIES WHEN THE FIRST AND LAST MEASUREMENTS WERE TAKEN AND DOES NOT REPRESENT A CONTINUOUS PERIOD OF DATA COLLECTION.
4. SWE – SNOW WATER EQUIVALENT. VALUES DETERMINED ASSUMING SNOW WATER EQUIVALENCY CONVERSION FACTOR OF 0.1 (NRCS).
5. MAXIMUM RECORDED 24-HOUR PRECIPITATION WAS DETERMINED BY APPLYING A 1.13 FACTOR (HERSHFIELD, 1961) TO THE MAXIMUM RECORDED DAILY PRECIPITATION.

Table 2.3 Measured Regional Mean Monthly Precipitation

	Keno, OR	Copco No. 1 Dam, CA	Keno, OR	Copco No. 1 Dam, CA	Keno, OR	Copco No. 1 Dam, CA
	Average Precipitation (in)		Average Number of Days with Precipitation >0.5 in		Average Total Snowfall (in)	
Jan	2.9	3.0	4	3	14.8	5.4
Feb	2.0	2.2	3	3	9.8	2.8
Mar	1.9	2.1	4	3	6.1	1.6
Apr	1.3	1.6	3	2	1.9	0.5
May	1.2	1.3	3	2	0.2	-
Jun	0.8	0.8	2	1	-	-
Jul	0.3	0.3	1	1	-	-
Aug	0.5	0.4	1	1	-	-
Sep	0.6	0.6	1	1	-	-
Oct	1.5	1.3	2	2	0.5	-
Nov	2.5	2.9	3	3	5.8	1.7
Dec	3.2	3.4	4	3	12.8	5.1
Mean Annual	18.6	19.7	32	24	51.5	16.8

The intensity duration frequency (IDF) data for the Copco Dam No. 1 climate station were provided by NOAA's Precipitation Frequency Data Server (NOAA, 2017). NOAA provides data for recurrence periods from 1 to 1,000 years with durations ranging from 5 minutes to 60 days. The IDF data for the Copco Dam No. 1 climate station is tabulated in Table 2.4 and are representative of the Copco No. 1, Copco No. 2, and Iron Gate Project Sites.

Table 2.4 IDF Data for Copco Dam No. 1 Climate Station (inches)

Duration	Recurrence Interval (yrs)									
	1-yr	2-yrs	5-yrs	10-yrs	25-yrs	50-yrs	100-yrs	200-yrs	500-yrs	1,000-yrs
5-min	0.10	0.14	0.20	0.24	0.31	0.36	0.41	0.47	0.62	0.77
10-min	0.15	0.20	0.28	0.35	0.44	0.51	0.59	0.68	0.89	1.10
15-min	0.18	0.25	0.34	0.42	0.53	0.62	0.72	0.82	1.07	1.33
30-min	0.24	0.33	0.45	0.55	0.70	0.82	0.95	1.09	1.42	1.76
60-min	0.32	0.44	0.60	0.74	0.94	1.10	1.27	1.46	1.91[1]	2.36[1]
2-hr	0.45	0.59	0.77	0.92	1.13	1.30	1.47	1.65	1.93[1]	2.38[1]
3-hr	0.55	0.70	0.90	1.07	1.30	1.47	1.65	1.84	2.09	2.41
6-hr	0.79	0.98	1.23	1.43	1.70	1.91	2.12	2.34	2.63	2.85
12-hr	1.10	1.36	1.70	1.98	2.36	2.66	2.96	3.26	3.68	4.01
24-hr	1.57	1.96	2.47	2.90	3.50	3.98	4.47	4.99	5.70	6.28
2-day	1.98	2.50	3.20	3.78	4.61	5.26	5.94	6.67	7.68	8.50
3-day	2.29	2.91	3.76	4.46	5.46	6.24	7.07	7.94	9.16	10.10
4-day	2.48	3.18	4.11	4.89	5.97	6.83	7.71	8.65	9.95	11.00
7-day	2.90	3.73	4.81	5.69	6.90	7.83	8.78	9.77	11.10	12.10
10-day	3.22	4.15	5.34	6.31	7.61	8.59	9.59	10.60	12.00	13.00
20-day	4.16	5.40	6.98	8.22	9.86	11.10	12.30	13.50	15.10	16.30
30-day	5.07	6.61	8.53	10.00	12.00	13.40	14.90	16.30	18.10	19.50
45-day	6.42	8.36	10.80	12.60	15.10	16.80	18.50	20.20	22.40	24.00
60-day	7.56	9.80	12.60	14.70	17.40	19.40	21.30	23.20	25.60	27.40

NOTES:

1. THE 500-YR AND 1,000-YR 60-MIN AND 2-HR VALUES WERE FLAGGED AS POTENTIALLY ERRONEOUS DUE TO MINIMAL INCREASE IN RAINFALL WITH INCREASE IN STORM DURATION.
2. IDF DATA TAKEN FROM NOAA'S PRECIPITATION FREQUENCY DATA SERVER (NOAA, 2017).

The IDF curves for the Keno climate station were determined using information provided by the Oregon Department of Transportation (ODOT) and supplemented by data available through the Western Regional Climate Center (WRCC). Intensity Duration Recurrence (IDR) information is dictated by the Oregon Rainfall IDR Curve Zone Map as stipulated in the ODOT Hydraulics Manual (ODOT, 2014). The Rainfall IDR Curve Zone Map is shown in Figure 2.2.

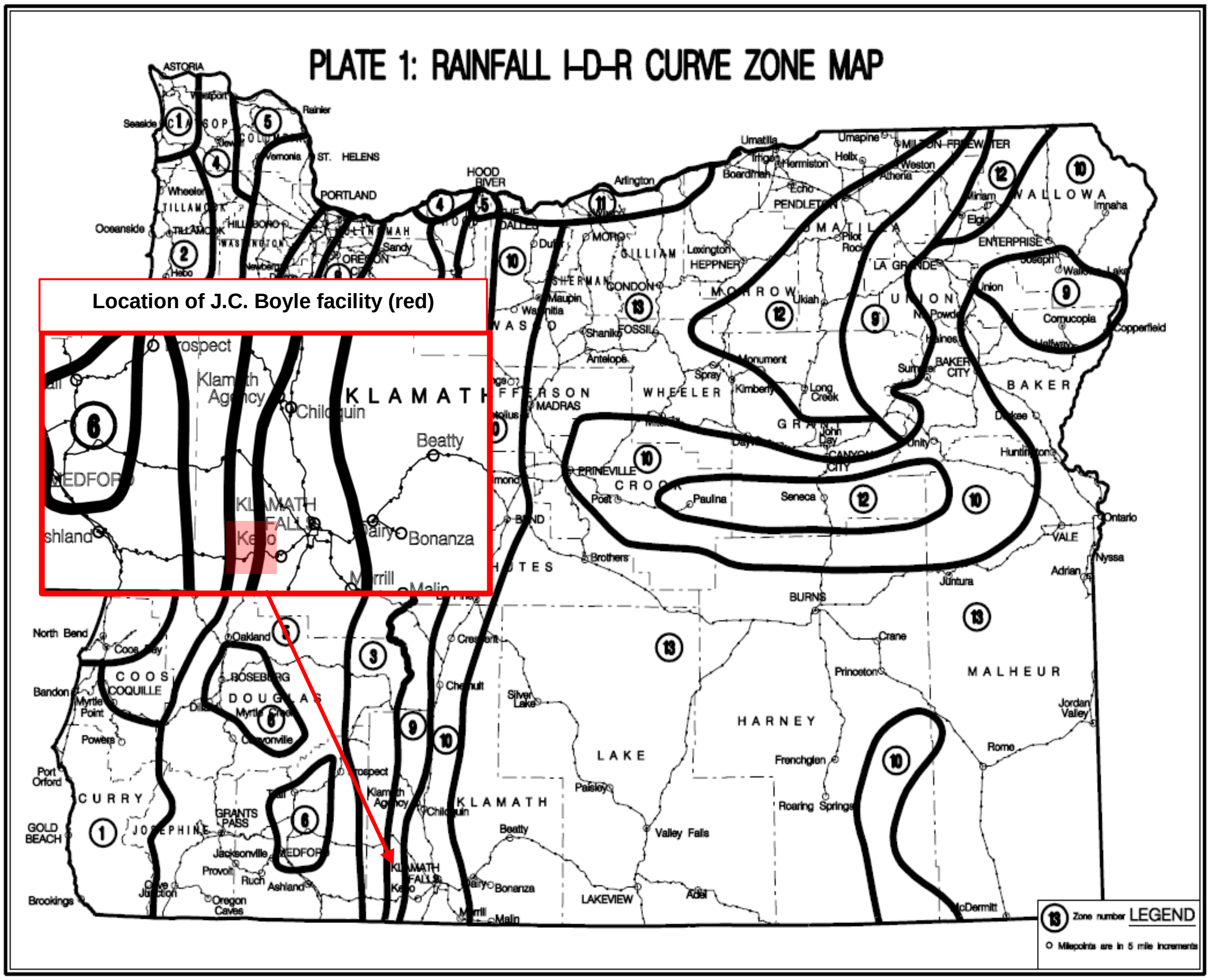

Figure 2.2 ODOT Rainfall IDR Curve Zone Map and Approximate Location of J.C. Boyle (ODOT, 2014)

The zoning map is used to identify which IDR data should be applied to a site. Zone 9 has been selected as representative of the IDR data for the J.C. Boyle project site based on the site location. The IDR rainfall intensity data for Zone 9 is tabulated in Table 2.5.

Table 2.5 IDR Data for Oregon Zone 9 (inches)

Duration	Recurrence Interval (yrs)					
	2-yrs	5- yrs	10-yrs	25-yrs	50-yrs	100-yrs
5-min	0.13	0.18	0.21	0.25	0.29	0.34
10-min	0.19	0.28	0.33	0.40	0.44	0.52
15-min	0.25	0.35	0.41	0.50	0.58	0.66
30-min	0.34	0.48	0.58	0.70	0.80	0.90
60-min	0.44	0.64	0.73	0.88	1.05	1.15
2-hr	0.58	0.82	0.90	1.04	1.20	1.38
3-hr	0.72	0.96	1.08	1.23	1.38	1.59
6-hr	1.02	1.32	1.50	1.62	1.80	2.04
24-hr	2.00	2.50	2.80	3.20	3.80	4.00

NOTES:

1. DATA FOR RECURRENCE PERIODS FROM 2 TO 100 YEARS WITH DURATIONS RANGING FROM 5 MINUTES TO 6 HOURS PROVIDED BY ODOT (ODOT, 2014).
2. 24-HOUR DURATION EVENT DATA PROVIDED BY WRCC PRECIPITATION FREQUENCY MAPS PUBLISHED IN NOAA ATLAS 2 AND REPRESENTS THE IDF DATA FOR THE WHOLE STATE OF OREGON (WRCC, 1973).

2.3 WIND

Regional wind data was not available for the Copco Dam No. 1 and Keno climate stations at the time of the preparation of this report. Wind is a design parameter required for the design of bridges and piers. The American Association of State Highway and Transportation Officials (AASHTO) requires a wind velocity at 30 ft (V_{30}) above low ground/above design water level and recommends the adoption of V_{30} = 100 mph in the absence of site-specific wind data (AASHTO, 2012). This value has been adopted for the design. Alternative wind velocities may be considered to evaluate freeboard requirements specific to wave run-up and set-up considerations.

References:

American Association of State Highway and Transportation Officials (AASHTO), 2012. Load and Resistance Factor Design Bridge Design Specifications. 6th Edition. Washington, DC, USA.

Applied Climate Information System (ACIS), 2015. Single Station Daily Data Listing. NOAA Regional Climate Centers. Retrieved from: http://scacis.rcc-acis.org/ (accessed June 21, 2019).

Hershfield, D. M., 1961a. Rainfall Frequency Atlas of the United States. Technical Paper No. 40, Weather Bureau, United States Department of Commerce, Washington, DC.

Natural Resources Conservation Services Oregon (NRCS). What is Snow Water Equivalent? United States Department of Agriculture (USDA). Retrieved from: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/or/snow/?cid=nrcs142p2_046155 (accessed July 4, 2019)

NOAA's National Weather Service - Hydrometeorological Design Studies Center, 2017. NOAA Atlas 14 Point Precipitation Frequency Estimates: CA. Retrieved from: https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=ca (accessed June 14, 2019).

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APPENDIX A6
HYDROLOGY

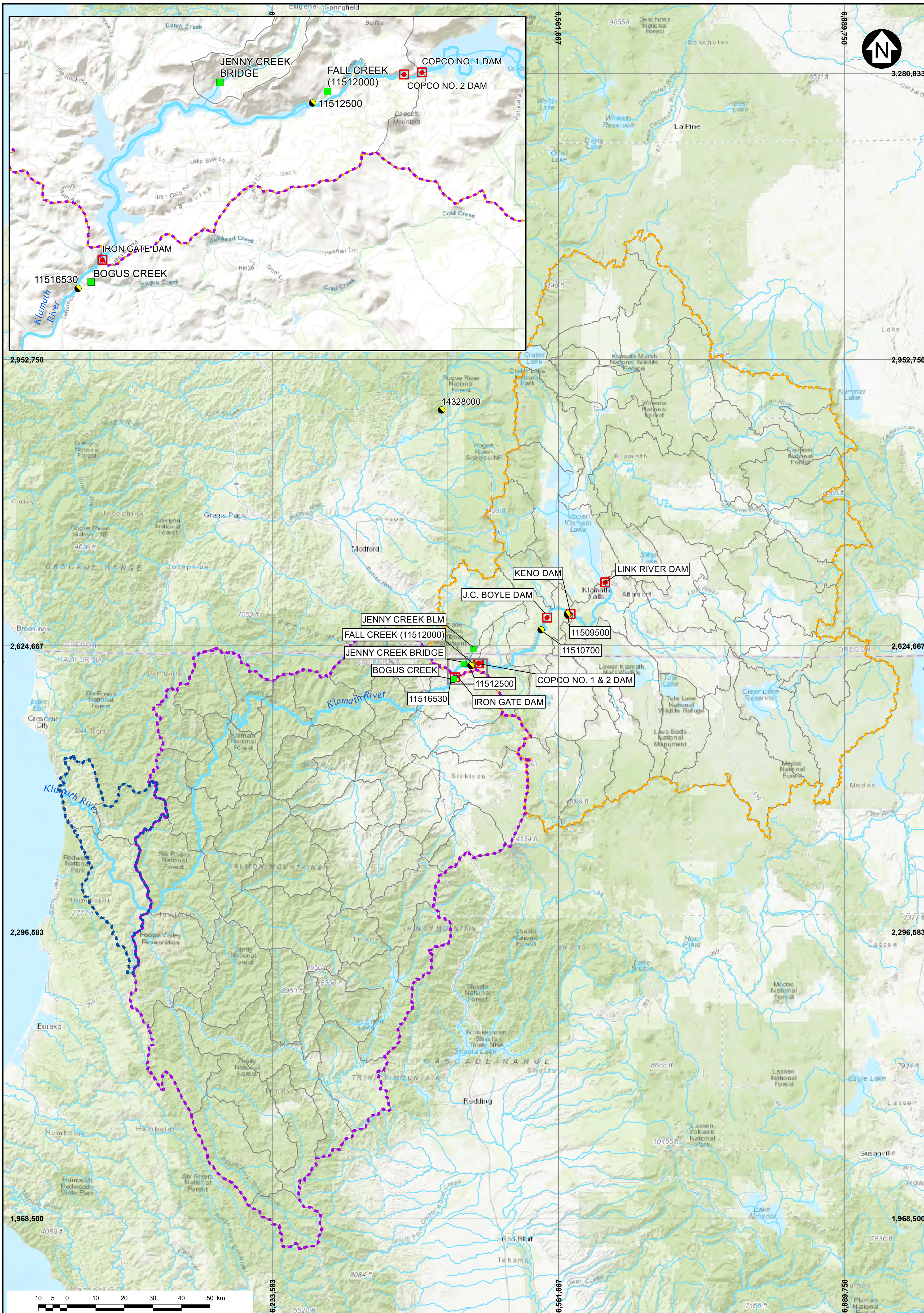
TABLE OF CONTENTS

1.0 WATERSHED DESCRIPTION

The Klamath River originates at the outlet of Upper Klamath Lake in southern Oregon and flows approximately 250 miles southwest through the Cascade Mountains of southern Oregon and northern California to the Pacific Ocean. The Upper Klamath Basin has five main lakes: Crater Lake, Upper Klamath Lake, Lower Klamath Lake, Clear Lake, and Tule Lake. The Upper Klamath Basin contains all the hydroelectric developments on the Klamath River, including the Klamath River Renewal Project (KRRP) sites. The Middle Klamath Basin extends 150-miles from Iron Gate Dam downstream to the Trinity River confluence. The Lower Klamath Basin starts at the Trinity River confluence and extends 43 miles downstream to the Pacific Ocean.

The Upper Klamath Basin has broad valleys shaped by volcanoes and active faulting. The fault-bounded valleys contain all the large, natural lakes and large wetlands of the Klamath Basin. The Klamath River flows through mountainous terrain from J.C. Boyle Dam to Iron Gate Dam. Downstream of Iron Gate Dam, and for most of the river's length from there to the Pacific Ocean, the river maintains a relatively steep, high-energy channel (NRC, 2004).

A map of the reach containing the four PacifiCorp dams covered by the KRRP is given on Figure 1.1.



LEGEND:

- ADDITIONAL HYDROLOGY STATION
- USGS STATION
- DAM LOCATION
- KLAMATH RIVER
- LOWER KLAMATH BASIN
- MIDDLE KLAMATH BASIN
- UPPER KLAMATH BASIN
- SUB-CATCHMENT

NOTES:

1. BASE MAP: ESRI ONLINE TOPOGRAPHIC MAP.
2. COORDINATE GRID IS IN METRES.
COORDINATE SYSTEM: NAD 1983 2011 STATEPLANE CALIFORNIA I FIPS 0401 FT US.
3. THIS FIGURE IS PRODUCED AT A NOMINAL SCALE OF 1:1,250,000 FOR 11x17 (TABLOID) PAPER. ACTUAL SCALE MAY DIFFER ACCORDING TO CHANGES IN PRINTER SETTINGS OR PRINTED PAPER SIZE.

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KLAMATH RIVER RENEWAL PROJECT

KLAMATH WATERSHED BASIN

Knight Piésold CONSULTING

P/A NO.	REF NO.
VA103-640/1	9

FIGURE 1.1 REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
0	27MAY'22	ISSUED WITH REPORT	ELK	KK	AS

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2.0 KLAMATH RIVER AVERAGE MONTHLY FLOW CONDITIONS

The US Bureau of Reclamation (USBR) stores, diverts, and conveys the waters of the Klamath and Lost Rivers to serve authorized Klamath Irrigation Project (Irrigation Project) purposes. The Bureau is required to meet contractual obligations in compliance with state and federal laws and to carry out the activities necessary to maintain the Irrigation Project and maintain its proper long-term functioning and operation. Biological assessments have been prepared to evaluate the potential effects of the continued operation of the Irrigation Project on species listed as threatened or endangered under the Endangered Species Act (ESA). The biological assessments have been prepared pursuant to Section 7(a)(2) of the ESA of 1973, as amended (16 United States Code [USC.] § 1531 et seq.).

Several Section 7 Consultations and Biological Opinions (BiOp's) have governed the operation of Upper Klamath Lake (UKL) and the Irrigation Project since the 1990's (USBR, 2012). The consultations involve the National Marine Fisheries Service (NMFS), also known as NOAA Fisheries, as well as the US Fish and Wildlife Service (FWS) and the USBR. The USBR currently meets its obligations under the ESA by operating the Irrigation Project in accordance with the latest FWS and NMFS BiOp, dated March 29, 2019. This BiOp is based on information provided in the USBR's Final Biological Assessment (USBR, 2018) and is effective April 1, 2019 through March 31, 2029. The latest BiOp operating conditions will govern the Klamath River during the dam removal and reclamation activities of the KRRP.

The USBR uses results generated by the Water Resources Integrated Modeling System (WRIMS) to identify the Klamath River and Upper Klamath Lake hydrographs that are likely to occur due to implementing the proposed operations across the full range of reasonably foreseeable annual precipitation and hydrologic patterns. WRIMS is a generalized water resources modeling system for evaluating operational alternatives of large, complex river basins. USBR has developed a WRIMS model specific to the Klamath Basin, which is referred to as the Klamath Basin Planning Model (KBPM). The KBPM incorporates the 2019 BiOp operating conditions and models the Klamath River flows. WRIMS is used to estimate mainstem Klamath River flows at the US Geological Survey (USGS) gages located near the Keno and Iron Gate Dam facilities. While the KBPM captures the hydrology under a wide range of plausible conditions, the unique sequencing and patterns of climatological and hydrological events that will occur in the future cannot be predicted.

There are 36 years (October 1980-November 2016) of daily average flows for the Keno and Iron Gate USGS gages as modeled using the KBPM (USBR, 2018). These daily flows were used to calculate the monthly average inflows for each of the four KRRP facilities. The Keno values were prorated by the ratio of the respective drainage areas to generate values for J.C. Boyle. The Iron Gate values were prorated by drainage area to generate values for Copco No. 1 and Copco No. 2. Area proration is a conventional method to determine flows at ungaged locations, particularly for locations on the same river system (Maidment, 1993). The monthly average flows for the four KRRP sites are shown in Table 2.1 and on Figure 2.1 for each facility. In addition to the monthly average flows for the period of record, Figure 2.1 also includes the range of average monthly flows at each facility for the 36 years of BiOp flows used in the KBPM model. Figure 2.2 is an example ensemble plot of daily average flows at the Iron Gate USGS gage on which each line represents a single year (also referred to as a spaghetti plot). This figure overlaps 36 years of BiOp flows on a common x-axis that spans January 1 to December 31, and highlights the variability of maximum daily flows in each month.

Table 2.1 Monthly Average Flows at Project Sites

Facility	Keno[1]	J.C. Boyle[2]	Copco No. 1[2,3]	Iron Gate[1]
Drainage Area (mi²)	**3,920**	**4,080**	**4,370**	**4,630**
Month	**Monthly Average Flow (cfs)**			
January	1,450	1,500	1,910	2,030
February	1,820	1,900	2,360	2,500
March	2,690	2,800	3,230	3,430
April	2,270	2,370	2,790	2,950
May	1,690	1,760	2,110	2,230
June 1 – 15	1,280	1,330	1,620	1,720
June 16 – 30	920	960	1,210	1,280
July 1 – 15	710	740	990	1,050
July 16 – 31	730	760	990	1,050
August	730	760	980	1,040
September 1 – 15	780	810	1,030	1,090
September 16 – 30	760	790	1,030	1,090
October 1 – 15	780	810	1,050	1,120
October 16 – 31	860	890	1,140	1,210
November 1 – 15	940	980	1,230	1,300
November 16 – 30	910	950	1,240	1,310
December	1,070	1,110	1,490	1,580
Average Annual Flow (cfs)	1,330	1,390	1,710	1,820
Average Annual Unit Flow (cfs/mi²)	0.34	0.34	0.39	0.39

NOTES:

1. 2019 BIOP FLOWS (USBR, 2018) WERE USED AS THE REPRESENTATIVE INCOMING FLOWS TO THE FACILITY BASED ON THE PERIOD OF RECORD FROM 1980 - 2016.
2. J.C. BOYLE INFLOWS WERE CALCULATED USING THE 2019 BIOP FLOWS AT THE USGS KENO GAGE USING LINEAR AREA PRORATION. COPCO NO. 1 INFLOWS WERE CALCULATED USING THE 2019 BIOP FLOWS AT THE USGS IRON GATE GAGE USING LINEAR AREA PRORATION.
3. MONTHLY AVERAGE INFLOWS AT COPCO NO. 2 ARE ASSUMED TO BE THE SAME AS THE MONTHLY AVERAGE INFLOWS AT COPCO NO. 1.

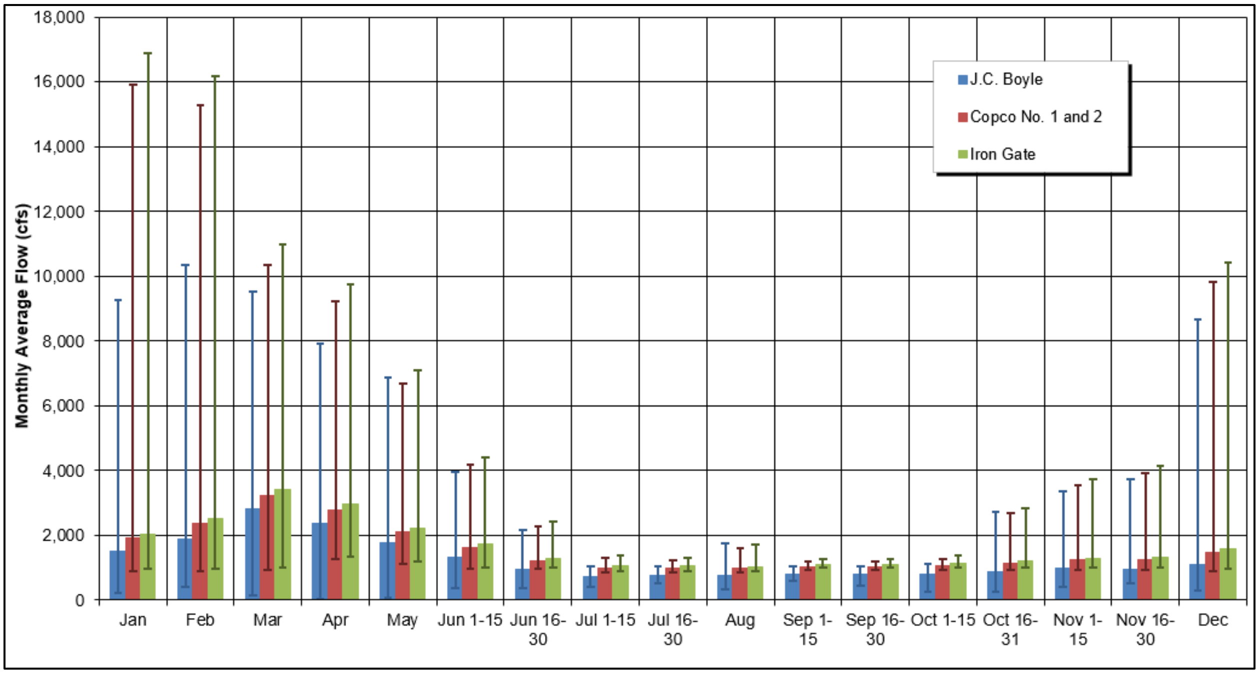

Figure 2.1 Monthly Average BiOp Flows at Project Sites

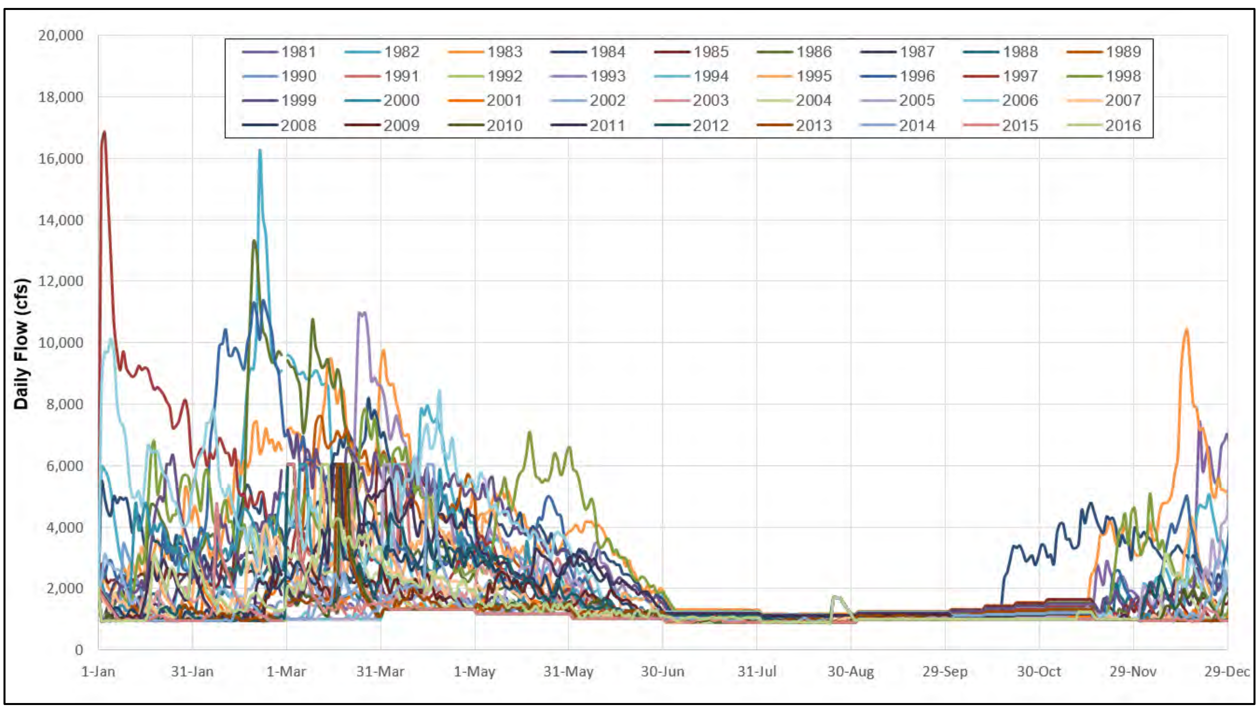

Figure 2.2 Daily Average BiOp Flows at the Iron Gate USGS Gage

The annual patterns of stream flows apparent in the above hydrographs are characterized by the following throughout the Klamath basin:

- High flows in the spring (March and April) due to spring snowmelt runoff (freshet), in the Upper Klamath basin and unregulated tributaries.
- Lower flows in mid-summer to late fall (July through October) due to reduced precipitation during the summer months.
- Increasing flows throughout the winter months (November through February) due to progressively increasing precipitation (which falls as snow in the upper elevations and rain in the lower elevations).

The regulation of Upper Klamath Lake is done with respect to the streamflow patterns seen on Figure 2.1.

- The reservoirs are not designed to mitigate floods and are typically full during the annual peak flows due to the timing of these events and, therefore, attenuation of these storms is limited. During the summer months when the reservoirs have more storage capacity the flood attenuation potential is greater.

The tributary flows contribute high flows during freshet that cannot be mitigated compared to much lower flows during the summer period when flow is mostly from the mainstem. The annual hydrograph on Figure 2.1 indicates that the highest monthly average flows occur in March during spring runoff, but the largest peak flow events generally occur in January and February, as indicated by the maximum range of daily flows shown on Figure 2.2. These peak flows are driven by rain on snow events and govern the annual flood events.

The peak floods at Iron Gate can be substantially greater than the peak floods at J.C. Boyle due to the tributaries that enter the Klamath River between the two facilities. The largest tributary between the Keno and Iron Gate facilities is Jenny Creek which contributes a high amount of flow during the late winter and spring snowmelt months. The hydrology of Jenny Creek is further described in Section 5.1.

3.0 KLAMATH RIVER PEAK FLOODS FOR EXISTING CONDITIONS

3.1 ANNUAL PEAK FLOODS

3.1.1 METHODOLOGY

Various return period design flood estimates, representing existing conditions, are required for design purposes. Peak flood estimates for the Project area were developed using both the historical USGS gage streamflow data and the developed 2019 BiOp flow data (USBR, 2018). Annual peak flows were determined from both datasets and used to estimate the annual return period peak flows. Flood frequency analyses were performed on the annual peak flow data using the HEC-SSP software, following the Bulletin 17B method for Log-Pearson Type III distribution (USGS, 1982). A detailed description of the analyses for each dataset is outlined in the sections below.

3.1.2 HISTORIC USGS GAGE DATA

The USGS operates several stream gages on the Klamath River within proximity of the Project area. The station details of the regional datasets most relevant to the KRRP are provided in Table 3.1 and shown on Figure 1.1.

Table 3.1 USGS Regional Streamflow Gaging Stations

USGS Gaging Station No.	Station Name	Drainage Area (mi²)	Longitude	Latitude	Period of Record
11509500	Klamath River at Keno, OR	3,920	42°08'00"	121°57'40"	1905-1913 1930-2017
11510700	Klamath River below John C. Boyle Power Plant near Keno, OR	4,080	42°05'05"	122°04'20"	1959-2017
11512500	Klamath River below Fall Creek near Copco, CA	4,370	41°58'20"	122°22'05"	1923-1961
11516530	Klamath River below Iron Gate Dam, CA	4,630	41°55'41"	122°26'35"	1960-2017

The annual peak flow data for the USGS gages was imported to the United States Army Corps of Engineers' (USACE) HEC-SSP software (V2.1) and used for the flood frequency analyses. A low flow threshold, below which flows did not fit the distribution, were determined by assessing the flood-frequency curves. The data visually fit within the 95 percent confidence limit of the distribution for all locations except J.C. Boyle. Accordingly, the J.C. Boyle data below 3,400 cfs was identified as low flow outliers and the Bulletin 17B procedures were followed to adjust the flood probabilities to account for these low outliers.

The period used for the peak flow analysis is from 1960 onwards. The USGS records for the J.C. Boyle and Iron Gate Dam gages begin after 1960 and account for the effects of many of the reservoirs within the Klamath River basin. This period also includes the flood of record for the Klamath region, which occurred in December 1964 (water year 1965). Copco No. 1 has a peak flow record for the period of 1923 to 1961, which is outside the selected period of analysis. Accordingly, the return period peak flows for Copco No. 1 were calculated by scaling the flood flows at Iron Gate according to the methodology described in "Estimation of Peak discharges for Rural, Unregulated streams in Western Oregon" (USGS, 2005). This approach, which indicates direct linear scaling with an exponent 1.0, results in conservative flood estimates for Copco No. 1 since the peak floods at Iron Gate are substantially greater than the peak floods at J.C. Boyle due to the tributary flows that enter the Klamath River between the two facilities.

Annual peak flood results using the historical USGS data are presented in Table 3.2.

3.1.3 2019 BIOLOGICAL OPINION DATA

The 2019 BiOp flows (USBR, 2018) are comprised of 36 years (1980-2016) of average daily flows for both the USGS gages at Keno and Iron Gate. The daily flows were converted to instantaneous peak floods using conversion factors that were calculated by comparing the annual maximum instantaneous flows to the corresponding daily flows using data available from the USGS gages located downstream of J.C. Boyle (11510700, Klamath River BLW John C Boyle Powerplant, Nr Keno OR) and downstream of Iron Gate Dam (11516530, Klamath River below Iron Gate Dam, CA). The locations of these gages are shown on Figure 1.1. The comparisons indicate that the annual maximum instantaneous floods are approximately 10% higher than the daily flows for the same day. Conversion factors of 1.10 and 1.12 were used to adjust the available 2019 BiOp daily flows into instantaneous peak floods for the Keno and Iron Gate data, respectively. The instantaneous peak flood data at Keno and Iron Gate were used for the flood frequency analyses.

The J.C. Boyle and the Copco No. 1 annual peak floods were calculated using the area proration methodology described in "Estimation of Peak discharges for Rural, Unregulated streams in Western

Oregon" (USGS, 2005), based on the annual BiOp flood frequency results for the Keno and Iron Gate facilities, respectively. The peak flood results from the Iron Gate facility were used in preference to those at Keno to estimate flood values at the Copco No. 1 facility because the Iron Gate flows demonstrate proportionally greater flood flows than the flows at the upstream facility and therefore better represent the effects of the relatively large peak flow contributions from the mostly unregulated tributary creeks and rivers that inflow between the upstream facility and Copco No. 1.

Annual peak flood results using the 2019 BiOp flow data are presented in Table 3.2.

3.1.4 ANNUAL PEAK FLOOD VALUES FOR DESIGN

The historic USGS data and the 2019 BiOp data were both used to estimate annual return period floods at the Klamath River hydroelectric facilities under existing conditions. The 2019 BiOp operating conditions may change the timing and/or volumes of the Klamath River and, therefore, needed to be included in the peak flood analysis in addition to the historical flows seen at the USGS gages. The 2019 BiOp operating conditions are especially important for the monthly peak floods as these floods are more influenced by the regulation of the Klamath River from the upstream facilities. The flood values selected as the recommended design values are the maximum values between these two datasets, as shown in Table 3.2. The annual return period floods at Copco No. 1 are also used as representative of the annual return period floods for Copco No. 2.

Table 3.2 Annual Peak Floods for Existing Conditions

Location	Drainage Area (mi^2)	Annual Percent Probable Flood (cfs)							
		50%	20%	10%	5%	2%	1%	0.50%	0.20%
Historic USGS Data									
J.C. Boyle	4,080	5,300	8,500	10,300	11,700	13,300	14,200	15,000	15,800
Copco No. 1	4,370	5,600	10,300	14,000	18,200	24,200	29,400	35,000	43,200
Iron Gate	4,630	5,900	10,900	14,900	19,300	25,700	31,200	37,100	45,800
2019 Biological Opinion Data									
J.C. Boyle	4,080	7,000	8,400	9,500	10,400	11,800	12,900	14,100	15,600
Copco No. 1	4,370	7,100	9,400	11,500	14,000	17,800	21,300	25,500	32,100
Iron Gate	4,630	7,500	10,000	12,200	14,800	18,900	22,600	27,000	34,100
Recommended Design Values									
J.C. Boyle	4,080	7,000	8,500	10,300	11,700	13,300	14,200	15,000	15,800
Copco No. 1	4,370	7,100	10,300	14,000	18,200	24,200	29,400	35,000	43,200
Iron Gate	4,630	7,500	10,900	14,900	19,300	25,700	31,200	37,100	45,800

3.1.4.1 ANNUAL FLOWS WITH HIGH PROBABILITY OF EXCEEDANCE

The 2019 BiOp data were used to estimate the annual peak floods at the Klamath River hydroelectric facilities that have high probabilities of exceedance that will occur more frequently. These values were determined as per the methodology described in Section 3.1.1 and are summarized in Table 3.3. The annual percent probable floods at Copco No. 1 are used as representative of the annual percent probable floods for Copco No. 2.

Table 3.3 Flows with High Probabilities of Exceedance

Location	Drainage Area (mi²)	Annual Percent Probable Flood (cfs)		
		99.9%	80.0%	66.7%
J.C. Boyle[1]	4,080	4,600	5,900	6,400
Copco No. 1[2]	4,370	5,200	5,900	6,400
Iron Gate	4,630	5,500	6,300	6,800

NOTES:

1. CALCULATED BASED ON KENO RESULTS (USING 2019 BIOP FLOWS) USING METHODOLOGY DESCRIBED IN "ESTIMATION OF PEAK DISCHARGES FOR RURAL, UNREGULATED STREAMS IN WESTERN OREGON" (USGS, 2005).
2. CALCULATED BASED ON IRON GATE RESULTS (USING 2019 BIOP FLOWS) USING METHODOLOGY DESCRIBED IN "ESTIMATION OF PEAK DISCHARGES FOR RURAL, UNREGULATED STREAMS IN WESTERN OREGON" (USGS, 2005).

3.2 PEAK FLOODS FOR MONTHLY TIME PERIODS

3.2.1 GENERAL

A flood frequency analysis was performed for monthly periods to better define the risk of flooding events occurring during the dam removal period. The flood frequency analysis used to determine monthly return period peak flows was the same as that used for the annual return period flows, as described in previous sections. The data indicate that the areal extent of freshet snowmelt contributing to peak flows diminishes greatly in the second half of June, and therefore the month of June was divided into two periods for peak flood analysis purposes: June 1 to June 15 and June 16 to June 30. Additional months that were subdivided into two periods include July, September, October, and November. These months were subdivided to support the proposed construction schedule.

3.2.2 HISTORIC USGS GAGE DATA

Daily data for the USGS stations (J.C. Boyle and Iron Gate Dam, Table 3.1) were used to calculate the monthly peak floods. Daily discharge data from January 1960 up until the most recent data available were used for the monthly flood frequency analyses.

The Iron Gate data source was USGS station 11516530. The J.C. Boyle data source was USGS station 11510770 and flows below 3400 cfs were treated as low flow outliers due to the influence of upstream activity. The daily flows of both datasets were converted to equivalent instantaneous 24-hr floods using the conversion factors developed for each site during the annual flood frequency analysis, as discussed above. It is recognized that the instantaneous to daily ratios would tend to vary monthly depending on the source of the flood flows and the amount of upstream flow regulation, but the regulation from upstream reservoirs would tend to limit the size of the ratios to less than the annual peak ratios, so use of annual ratios results in reasonably conservative instantaneous peak flow estimates.

A flood frequency analysis was performed on the monthly peak flows using the HEC-SSP software (V2.1), following the Bulletin 17B method for Log-Pearson Type III distributions (USGS, 1982). The monthly peak floods for Copco No. 1 were calculated using non-linear proration with calculated Iron Gate monthly peak values using the methodology described in “Estimation of Peak Discharges for Rural, Unregulated Streams in Western Oregon” (USGS 2005). Table 3.4 provides the flood frequency results for the specified time periods.

The historic USGS flows are regulated flows and are influenced by the operation of the reservoirs on the Klamath River. This regulation makes it possible for some monthly peak flows to be higher at J.C. Boyle than at Iron Gate.

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TABLE 3.4

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PEAK FLOODS FOR SPECIFIED TIME PERIOD USING HISTORIC USGS GAGE DATA

Location	Drainage Area (mi²)	Month	Instantaneous Peak Floods for Specified Time Period (cfs)							
			50% Probable Flood	20% Probable Flood	10% Probable Flood	5% Probable Flood	2% Probable Flood	1% Probable Flood	0.5% Probable Flood	0.2% Probable Flood
		Jan	2,600	4,400	6,000	8,000	11,100	14,000	15,000	15,800
		Feb	2,700	4,900	6,900	9,200	13,000	14,200	15,000	15,800
		Mar	3,500	6,300	8,500	10,900	13,300	14,200	15,000	15,800
		Apr	3,400	5,700	7,400	9,200	11,600	13,600	15,000	15,800
		May	2,600	4,300	5,500	6,800	8,500	9,900	11,300	13,400
		Jun 1 - 15	1,500	2,400	3,200	4,200	5,800	7,300	9,100	12,100
		Jun 16 - 30	1,200	1,700	2,200	2,700	3,400	4,100	4,800	5,900
		Jul 1 - 15	1,000	1,400	1,700	2,100	2,700	3,200	3,900	4,900
J.C. Boyle[1]	4,080	Jul 16 - 31	1,000	1,200	1,400	1,500	1,600	1,700	1,800	2,000
		Aug	1,400	1,500	1,600	1,700	1,800	1,800	1,800	1,900
		Sep 1 - 15	1,400	1,700	1,900	2,100	2,400	2,500	2,700	3,000
		Sep 16 - 30	1,500	1,900	2,200	2,400	2,800	3,000	3,200	3,500
		Oct 1 - 15	1,700	2,200	2,500	2,900	3,400	3,800	4,200	4,700
		Oct 16 - 31	1,700	2,400	2,800	3,300	4,000	4,600	5,200	6,100
		Nov 1 - 15	1,800	2,600	3,200	3,800	4,700	5,500	6,300	7,500
		Nov 16 - 30	2,000	2,900	3,600	4,400	5,400	6,300	7,200	8,500
		Dec	2,500	3,900	5,100	6,300	8,200	9,900	11,700	14,400
		Jan	3,000	5,800	8,400	11,800	17,600	23,400	30,500	42,800
		Feb	3,000	5,800	8,400	11,800	17,600	23,400	30,500	42,800
		Mar	4,100	7,400	10,200	13,000	17,100	20,500	23,900	29,000
		Apr	3,600	6,500	8,900	11,100	14,400	17,000	19,700	23,400
		May	2,600	4,500	5,900	7,400	9,400	11,000	12,700	15,100
		Jun 1 - 15	1,500	2,500	3,400	4,500	6,400	8,200	10,500	14,100
		Jun 16 - 30	1,200	1,800	2,200	2,700	3,500	4,100	4,900	6,100
		Jul 1 - 15	900	1,200	1,600	2,000	2,600	3,200	4,100	5,300
Copco No. 1[2]	4,370	Jul 16 - 31	900	1,000	1,100	1,200	1,300	1,400	1,500	1,600
		Aug	1,100	1,300	1,500	1,600	1,800	2,000	2,100	2,400
		Sep 1 - 15	1,300	1,600	1,800	1,900	2,100	2,200	2,300	2,500
		Sep 16 - 30	1,300	1,600	1,900	2,100	2,400	2,500	2,700	3,000
		Oct 1 - 15	1,500	2,000	2,500	2,900	3,700	4,300	5,100	6,200
		Oct 16 - 31	1,500	2,200	2,700	3,300	4,200	5,100	6,000	7,500
		Nov 1 - 15	1,700	2,500	3,300	4,100	5,400	6,600	7,900	10,000
		Nov 16 - 30	1,900	3,000	4,000	4,900	6,500	7,800	9,300	11,700
		Dec	2,500	5,000	7,400	10,700	16,600	22,600	30,500	43,200
		Jan	3,200	6,100	8,900	12,500	18,700	24,800	32,400	45,400
		Feb	3,200	6,100	8,900	12,500	18,700	24,800	32,400	45,400
		Mar	4,300	7,900	10,800	13,800	18,100	21,700	25,400	30,800
		Apr	3,800	6,900	9,400	11,800	15,300	18,000	20,900	24,800
		May	2,800	4,800	6,300	7,900	10,000	11,700	13,500	16,000
		Jun 1 - 15	1,600	2,600	3,600	4,800	6,800	8,700	11,100	15,000
		Jun 16 - 30	1,300	1,900	2,300	2,900	3,700	4,400	5,200	6,500
		Jul 1 - 15	1,000	1,300	1,700	2,100	2,800	3,400	4,300	5,600
Iron Gate[3]	4,630	Jul 16 - 31	1,000	1,100	1,200	1,300	1,400	1,500	1,600	1,700
		Aug	1,200	1,400	1,600	1,700	1,900	2,100	2,200	2,500
		Sep 1 - 15	1,400	1,700	1,900	2,000	2,200	2,300	2,400	2,600
		Sep 16 - 30	1,400	1,700	2,000	2,200	2,500	2,700	2,900	3,200
		Oct 1 - 15	1,600	2,100	2,600	3,100	3,900	4,600	5,400	6,600
		Oct 16 - 31	1,600	2,300	2,900	3,500	4,500	5,400	6,400	8,000
		Nov 1 - 15	1,800	2,700	3,500	4,400	5,700	7,000	8,400	10,600
		Nov 16 - 30	2,000	3,200	4,200	5,200	6,900	8,300	9,900	12,400
		Dec	2,700	5,300	7,900	11,300	17,600	24,000	32,400	45,800

M:\1\03\00640\01\A\Data\Task 0900 - 90% Design\08 - Hydrology\2_Flood Frequency Analysis\[Flood Frequency Analysis - Monthly.xlsm]Table - Monthly_USGS_b

NOTES:

1. DATA SOURCE USGS STATION 11510770 "KLAMATH RIVER BLW JOHN C.BOYLE PWRPLNT, NR KENO,OR", PERIOD OF RECORD 1959 TO 2019. PERIOD OF RECORD USED IN ANALYSIS 1960 TO 2019 TO COINCIDE WITH THE IRON GATE PERIOD OF RECORD. FLOWS BELOW 3,400 cfs WERE CENSORED LOW FLOW OUTLIERS DUE TO THE INFLUENCE OF UPSTREAM DAM ACTIVITIES.
2. CALCULATED USING NON-LINEAR PRORATION WITH IRON GATE USING METHODOLOGY DESCRIBED IN "ESTIMATION OF PEAK DISCHARGES FOR RURAL, UNREGULATED STREAMS IN WESTERN OREGON" (USGS, 2005).
3. DATA SOURCE USGS STATION 11516530 "KLAMATH R BL IRON GATE DAM CA", PERIOD OF RECORD 1960 TO 2019. PERIOD OF RECORD USED IN ANALYSIS 1960 TO 2019.
4. ANALYSIS USES HISTORIC USGS GAGE DATA. THESE FLOWS ARE INFLUENCED BY THE OPERATION OF THE RESERVOIRS ON THE KLAMATH RIVER AND ARE, THEREFORE, REGULATED. THE REGULATION MAKES IT POSSIBLE FOR PEAK FLOWS TO BE HIGHER AT J.C. BOYLE THAN AT IRON GATE.
5. THE DATA INDICATE THAT FOR SOME MONTHS THERE IS A TRANSITION IN THE HYDROLOGY IN THE MIDDLE OF THE MONTH. MONTHS WHEN THIS OCCURS INCLUDE JUNE, JULY, SEPTEMBER, OCTOBER, AND NOVEMBER. FOR ANALYSIS PURPOSES THESE MONTHS HAVE BEEN DIVIDED INTO TWO PERIODS: 1st TO 15th AND 16th TO 30th/31st OF EACH MONTH.

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3.2.3 2019 BIOLOGICAL OPINION DATA

The 2019 BiOp daily flows for the Keno and Iron Gate facilities were used to estimate the monthly peak floods for the KRRP hydroelectric facilities. The peak daily flow in each specified period was determined and converted to an instantaneous peak flow using the conversion factor of 1.10. A flood frequency analysis was performed on these peak floods using HEC-SSP (V2.1), following the Bulletin 17B method for Log-Pearson Type III distributions (USGS, 1982).

The peak floods for specified time periods at J.C. Boyle and Copco No. 1 were calculated using the methodology described in USGS (2005), based on the results for the Keno and Iron Gate facilities, respectively. The return period floods for specified periods at Copco No. 1 are used as representative for Copco No. 2. Table 3.5 provides the flood frequency results for the specified time periods.

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TABLE 3.5

KIEWIT INFRASTRUCTURE WEST CO.
KLAMATH RIVER RENEWAL PROJECT

PEAK FLOODS FOR SPECIFIED TIME PERIOD
USING 2019 BIOLOGICAL OPINION DATA[1]

Location	Drainage Area (mi^2)	Month	Instantaneous Peak Floods for Specified Time Period (cfs)							
			50% Probable Flood	20% Probable Flood	10% Probable Flood	5% Probable Flood	2% Probable Flood	1% Probable Flood	0.5% Probable Flood	0.2% Probable Flood
Keno[2]	3,920	Jan	2,000	3,700	5,400	7,400	10,600	13,700	17,400	23,500
		Feb	2,200	4,500	6,700	9,300	13,700	18,000	23,100	31,600
		Mar	6,000	7,700	8,400	8,900	9,200	9,400	9,500	9,600
		Apr	4,300	6,500	7,800	9,000	10,500	11,500	12,500	13,700
		May	2,700	4,000	4,800	5,600	6,600	7,300	7,900	8,800
		Jun 1 - 15	1,800	2,800	3,500	4,200	5,300	6,100	7,100	8,400
		Jun 16 - 30	1,300	1,800	2,200	2,700	3,600	4,400	5,300	6,800
		Jul 1 - 15	900	1,100	1,200	1,200	1,300	1,400	1,500	1,600
		Jul 16 - 31	900	1,000	1,100	1,200	1,300	1,400	1,400	1,500
		Aug	1,000	1,200	1,200	1,300	1,400	1,400	1,500	1,600
		Sep 1 - 15	1,000	1,100	1,100	1,200	1,200	1,300	1,300	1,400
		Sep 16 - 30	1,000	1,100	1,100	1,200	1,300	1,300	1,400	1,400
		Oct 1 - 15	1,000	1,100	1,200	1,300	1,400	1,400	1,500	1,600
		Oct 16 - 31	1,000	1,200	1,400	1,700	2,400	3,000	3,900	5,400
		Nov 1 - 15	1,000	1,400	1,800	2,300	3,400	4,400	5,800	8,500
		Nov 16 - 30	1,100	1,800	2,500	3,500	5,300	7,200	9,700	14,400
		Dec	1,800	3,200	4,400	5,800	8,000	10,100	12,500	16,300
J.C. Boyle[3]	4,080	Jan	2,100	3,900	5,600	7,700	11,000	12,900	14,100	15,600
		Feb	2,300	4,700	7,000	9,700	11,800	12,900	14,100	15,600
		Mar	6,300	8,000	8,800	9,300	9,600	9,800	9,900	10,000
		Apr	4,500	6,800	8,100	9,400	10,900	12,000	13,000	14,300
		May	2,700	4,200	5,000	5,800	6,900	7,600	8,200	9,200
		Jun 1 - 15	1,800	2,800	3,500	4,400	5,500	6,400	7,400	8,800
		Jun 16 - 30	1,400	1,800	2,300	2,800	3,600	4,400	5,000	6,300
		Jul 1 - 15	900	1,100	1,300	1,300	1,400	1,500	1,600	1,700
		Jul 16 - 31	900	1,000	1,100	1,200	1,300	1,300	1,300	1,400
		Aug	1,000	1,200	1,200	1,400	1,500	1,500	1,600	1,700
		Sep 1 - 15	1,000	1,100	1,000	1,200	1,200	1,400	1,400	1,500
		Sep 16 - 30	1,000	1,100	1,000	1,200	1,300	1,400	1,500	1,500
		Oct 1 - 15	1,000	1,100	1,300	1,400	1,500	1,500	1,600	1,700
		Oct 16 - 31	1,000	1,200	1,500	1,800	2,500	3,100	3,900	5,300
		Nov 1 - 15	1,000	1,400	1,800	2,300	3,400	4,400	5,900	8,600
		Nov 16 - 30	1,100	1,900	2,600	3,600	5,300	7,200	9,600	14,000
		Dec	1,900	3,300	4,600	6,000	8,300	10,500	13,000	15,600
Copco No. 1[4]	4,370	Jan	2,400	4,500	6,800	9,600	14,600	19,700	25,500	32,100
		Feb	2,900	5,800	8,500	11,800	17,400	21,300	25,500	32,100
		Mar	6,500	8,500	9,200	9,800	10,200	10,400	10,600	10,700
		Apr	4,600	6,900	8,500	10,000	11,900	13,200	14,500	16,100
		May	2,900	4,300	5,400	6,400	7,900	9,000	10,300	11,900
		Jun 1 - 15	1,900	2,900	3,700	4,500	5,600	6,600	7,700	9,400
		Jun 16 - 30	1,400	1,900	2,400	2,900	3,600	4,400	5,100	6,400
		Jul 1 - 15	1,100	1,300	1,500	1,600	1,800	2,000	2,200	2,500
		Jul 16 - 31	1,100	1,200	1,300	1,300	1,400	1,400	1,400	1,500
		Aug	1,200	1,300	1,300	1,400	1,400	1,400	1,500	1,500
		Sep 1 - 15	1,100	1,200	1,300	1,300	1,400	1,400	1,400	1,500
		Sep 16 - 30	1,100	1,200	1,300	1,300	1,400	1,400	1,400	1,500
		Oct 1 - 15	1,200	1,300	1,400	1,500	1,600	1,600	1,700	1,800
		Oct 16 - 31	1,100	1,400	1,600	2,000	2,600	3,200	4,000	5,400
		Nov 1 - 15	1,200	1,500	1,900	2,400	3,500	4,500	6,000	8,700
		Nov 16 - 30	1,300	2,000	2,700	3,700	5,400	7,200	9,700	14,000
		Dec	2,000	3,800	5,700	8,100	12,400	17,100	22,900	32,100
Iron Gate[5]	4,630	Jan	2,500	4,800	7,200	10,200	15,500	20,900	27,000	34,100
		Feb	3,100	6,100	9,000	12,500	18,500	22,600	27,000	34,100
		Mar	6,900	9,000	9,800	10,400	10,800	11,000	11,200	11,300
		Apr	4,800	7,300	9,000	10,600	12,600	14,000	15,400	17,100
		May	3,000	4,600	5,700	6,800	8,400	9,600	10,900	12,600
		Jun 1 - 15	2,000	3,000	3,800	4,600	5,900	7,000	8,200	10,000
		Jun 16 - 30	1,500	2,000	2,500	3,000	3,700	4,400	5,200	6,500
		Jul 1 - 15	1,200	1,400	1,600	1,700	1,900	2,100	2,300	2,600
		Jul 16 - 31	1,200	1,300	1,400	1,400	1,500	1,500	1,500	1,600
		Aug	1,300	1,400	1,400	1,500	1,500	1,500	1,600	1,600
		Sep 1 - 15	1,200	1,300	1,400	1,400	1,500	1,500	1,500	1,600
		Sep 16 - 30	1,200	1,300	1,400	1,400	1,500	1,500	1,500	1,600
		Oct 1 - 15	1,300	1,400	1,500	1,600	1,700	1,700	1,800	1,900
		Oct 16 - 31	1,200	1,500	1,700	2,100	2,700	3,300	4,100	5,500
		Nov 1 - 15	1,300	1,600	2,000	2,500	3,600	4,600	6,100	8,800
		Nov 16 - 30	1,400	2,100	2,900	3,800	5,500	7,300	9,800	14,000
		Dec	2,100	4,000	6,000	8,600	13,200	18,100	24,300	34,100

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NOTES:

1. 2019 BIOLOGICAL OPINION FLOWS (USBR, 2018) WERE PROVIDED FOR THE PERIOD FROM 1981 TO 2016. FLOWS WERE PROVIDED AT KENO (USGS GAGE 11509500) AND IRON GATE (USGS GAGE 11516530).
2. CALCULATED USING 2019 BIOP FLOWS AT KENO. A FACTOR OF 1.10 WAS APPLIED TO ADJUST DAILY AVERAGE FLOW TO DAILY PEAK FLOW.
3. CALCULATED USING NON-LINEAR AREA PRORATION WITH 2019 BIOP FLOWS AT KENO USING METHODOLOGY DESCRIBED IN "ESTIMATION OF PEAK DISCHARGES FOR RURAL, UNREGULATED STREAMS IN WESTERN OREGON" (USGS, 2005).
4. CALCULATED USING NON-LINEAR AREA PRORATION WITH 2019 BIOP FLOWS AT IRON GATE USING METHODOLOGY DESCRIBED IN "ESTIMATION OF PEAK DISCHARGES FOR RURAL, UNREGULATED STREAMS IN WESTERN OREGON" (USGS, 2005).
5. CALCULATED USING 2019 BIOP FLOWS AT IRON GATE. A FACTOR OF 1.12 WAS APPLIED TO ADJUST DAILY AVERAGE FLOW TO DAILY PEAK FLOW.
6. THE DATA INDICATE THAT FOR SOME MONTHS THERE IS A TRANSITION IN THE HYDROLOGY IN THE MIDDLE OF THE MONTH. MONTHS WHEN THIS OCCURS INCLUDE JUNE, JULY, SEPTEMBER, OCTOBER, AND NOVEMBER. FOR ANALYSIS PURPOSES THESE MONTHS HAVE BEEN DIVIDED INTO TWO PERIODS: 1st TO 15th AND 16th TO 30th/31st OF EACH MONTH.
7. THE CEREMONIAL FLOW RELEASES FOR THE YUROK BOAT DANCE CEREMONY WILL BE DEFERRED FOR THE DRAWDOWN YEAR. THESE FLOWS HAVE, THEREFORE, BEEN REMOVED FROM THE DATASET.

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3.2.4 MONTHLY PEAK FLOOD RESULTS

The Historic USGS data and 2019 BiOp data were both used to determine the monthly peak floods at the Klamath River reservoirs under existing conditions. The flood values selected as the recommended design values are the maximum calculated values, as shown in Table 3.6 for J.C. Boyle, Copco No. 1 and Iron Gate. An example visual interpretation of Table 3.6 for selected time periods is shown for Iron Gate on Figure 3.1. The monthly return period floods at Copco No. 1 are used as representative of the monthly return period floods for Copco No. 2.

The results show that for all facilities the peak floods for specified time periods decrease from April through to August. The peak flood results then increase from September through to March.

When considering the application of the monthly peak floods in relation to deconstruction activities near the river or reservoirs, embankment dam removal periods, or instream works, the designer/contractor should carefully consider the flows, water levels, and risk levels associated with the probable flood events in the time period that the work will take place or the time period that the structure will remain in place.

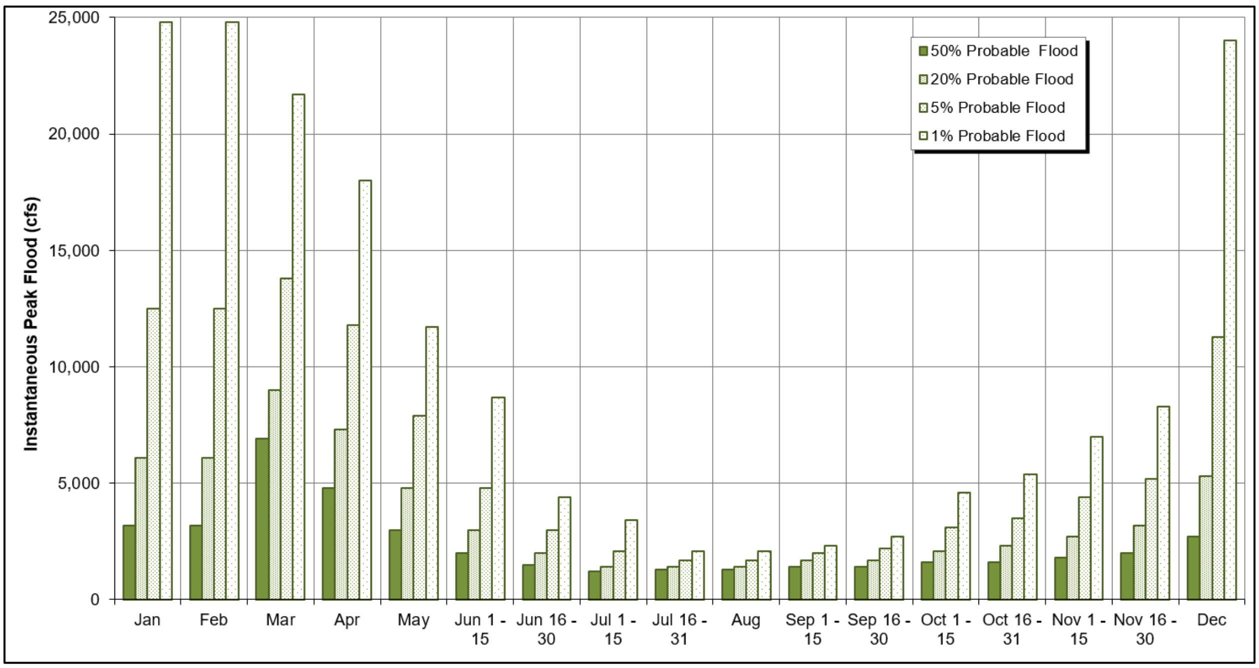

Figure 3.1 Iron Gate Peak Floods per Specified Time Period

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TABLE 3.6

KIEWIT INFRASTRUCTURE WEST CO.
KLAMATH RIVER RENEWAL PROJECT

RECOMMENDED DESIGN VALUES OF MONTHLY PEAK FLOODS

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Location	Drainage Area (mi^2)	Month	Instantaneous Peak Floods for Specified Time Period (cfs)								Average Monthly Flow (cfs)
			50% Probable Flood	20% Probable Flood	10% Probable Flood	5% Probable Flood	2% Probable Flood	1% Probable Flood	0.5% Probable Flood	0.2% Probable Flood	
J.C. Boyle	4,080	Jan	2,600	4,400	6,000	8,000	11,100	14,000	15,000	15,800	1,500
		Feb	2,700	4,900	7,000	9,700	13,000	14,200	15,000	15,800	1,900
		Mar	6,300	8,000	8,800	10,900	13,300	14,200	15,000	15,800	2,800
		Apr	4,500	6,800	8,100	9,400	11,600	13,600	15,000	15,800	2,370
		May	2,700	4,300	5,500	6,800	8,500	9,900	11,300	13,400	1,760
		Jun 1 - 15	1,800	2,800	3,500	4,400	5,800	7,300	9,100	12,100	1,330
		Jun 16 - 30	1,400	1,800	2,300	2,800	3,600	4,400	5,000	6,300	960
		Jul 1 - 15	1,000	1,400	1,700	2,100	2,700	3,200	3,900	4,900	740
		Jul 16 - 31	1,400	1,500	1,600	1,700	1,800	1,800	1,800	2,000	760
		Aug	1,400	1,500	1,600	1,700	1,800	1,800	1,800	1,900	760
		Sep 1 - 15	1,400	1,700	1,900	2,100	2,400	2,500	2,700	3,000	810
		Sep 16 - 30	1,500	1,900	2,200	2,400	2,800	3,000	3,200	3,500	790
		Oct 1 - 15	1,700	2,200	2,500	2,900	3,400	3,800	4,200	4,700	810
		Oct 16 - 31	1,700	2,400	2,800	3,300	4,000	4,600	5,200	6,100	890
		Nov 1 - 15	1,800	2,600	3,200	3,800	4,700	5,500	6,300	8,600	980
		Nov 16 - 30	2,000	2,900	3,600	4,400	5,400	7,200	9,600	14,000	950
		Dec	2,500	3,900	5,100	6,300	8,300	10,500	13,000	15,600	1,110
Copco No. 1	4,370	Jan	3,000	5,800	8,400	11,800	17,600	23,400	30,500	42,800	1,910
		Feb	3,000	5,800	8,500	11,800	17,600	23,400	30,500	42,800	2,360
		Mar	6,500	8,500	10,200	13,000	17,100	20,500	23,900	29,000	3,230
		Apr	4,600	6,900	8,900	11,100	14,400	17,000	19,700	23,400	2,790
		May	2,900	4,500	5,900	7,400	9,400	11,000	12,700	15,100	2,110
		Jun 1 - 15	1,900	2,900	3,700	4,500	6,400	8,200	10,500	14,100	1,620
		Jun 16 - 30	1,400	1,900	2,400	2,900	3,600	4,400	5,100	6,400	1,210
		Jul 1 - 15	1,100	1,300	1,600	2,000	2,600	3,200	4,100	5,300	990
		Jul 16 - 31	1,200	1,300	1,500	1,600	1,800	2,000	2,100	2,400	990
		Aug	1,200	1,300	1,500	1,600	1,800	2,000	2,100	2,400	980
		Sep 1 - 15	1,300	1,600	1,800	1,900	2,100	2,200	2,300	2,500	1,030
		Sep 16 - 30	1,300	1,600	1,900	2,100	2,400	2,500	2,700	3,000	1,030
		Oct 1 - 15	1,500	2,000	2,500	2,900	3,700	4,300	5,100	6,200	1,050
		Oct 16 - 31	1,500	2,200	2,700	3,300	4,200	5,100	6,000	7,500	1,140
		Nov 1 - 15	1,700	2,500	3,300	4,100	5,400	6,600	7,900	10,000	1,230
		Nov 16 - 30	1,900	3,000	4,000	4,900	6,500	7,800	9,700	14,000	1,240
		Dec	2,500	5,000	7,400	10,700	16,600	22,600	30,500	43,200	1,490
Iron Gate	4,630	Jan	3,200	6,100	8,900	12,500	18,700	24,800	32,400	45,400	2,030
		Feb	3,200	6,100	9,000	12,500	18,700	24,800	32,400	45,400	2,500
		Mar	6,900	9,000	10,800	13,800	18,100	21,700	25,400	30,800	3,430
		Apr	4,800	7,300	9,400	11,800	15,300	18,000	20,900	24,800	2,950
		May	3,000	4,800	6,300	7,900	10,000	11,700	13,500	16,000	2,230
		Jun 1 - 15	2,000	3,000	3,800	4,800	6,800	8,700	11,100	15,000	1,720
		Jun 16 - 30	1,500	2,000	2,500	3,000	3,700	4,400	5,200	6,500	1,280
		Jul 1 - 15	1,200	1,400	1,700	2,100	2,800	3,400	4,300	5,600	1,050
		Jul 16 - 31	1,300	1,400	1,600	1,700	1,900	2,100	2,200	2,500	1,050
		Aug	1,300	1,400	1,600	1,700	1,900	2,100	2,200	2,500	1,040
		Sep 1 - 15	1,400	1,700	1,900	2,000	2,200	2,300	2,400	2,600	1,090
		Sep 16 - 30	1,400	1,700	2,000	2,200	2,500	2,700	2,900	3,200	1,090
		Oct 1 - 15	1,600	2,100	2,600	3,100	3,900	4,600	5,400	6,600	1,120
		Oct 16 - 31	1,600	2,300	2,900	3,500	4,500	5,400	6,400	8,000	1,210
		Nov 1 - 15	1,800	2,700	3,500	4,400	5,700	7,000	8,400	10,600	1,300
		Nov 16 - 30	2,000	3,200	4,200	5,200	6,900	8,300	9,900	14,000	1,310
		Dec	2,700	5,300	7,900	11,300	17,600	24,000	32,400	45,800	1,580

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NOTES:

1. RECOMMENDED DESIGN VALUES ARE BASED ON THE MAXIMUM VALUES BETWEEN THE ANALYSIS COMPLETED USING THE HISTORIC USGS GAGE DATA AND THE 2019 BIOP FLOW DATA.
2. HISTORIC USGS DATA SOURCE FOR ANALYSIS: USGS STATION 11516530 "KLAMATH R BL IRON GATE DAM CA", PERIOD OF RECORD 1960 TO 2019. PERIOD OF RECORD USED IN ANALYSIS 1960 TO 2019.
3. 2019 BIOP FLOW DATA SOURCE FOR ANALYSIS: 2019 BIOLOGICAL OPINION FLOWS (USBR, 2018) PROVIDED FOR THE PERIOD 1981 TO 2016. FLOWS WERE PROVIDED AT IRON GATE (USGS GAGE 11516530).
4. THE DATA INDICATE THAT FOR SOME MONTHS THERE IS A TRANSITION IN THE HYDROLOGY IN THE MIDDLE OF THE MONTH. MONTHS WHEN THIS OCCURS INCLUDE JUNE, JULY, SEPTEMBER, OCTOBER, AND NOVEMBER. FOR ANALYSIS PURPOSES THESE MONTHS HAVE BEEN DIVIDED INTO TWO PERIODS: 1st TO 15th AND 16th TO 30th/31st OF EACH MONTH.
5. RECOMMENDED DESIGN VALUES FOR THE SECOND HALF OF JULY ARE DICTATED BY THE AUGUST PEAK MONTHLY FLOOD VALUES FOR DAM SAFETY PURPOSES.

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4.0 KLAMATH RIVER ANNUAL DAILY FLOW DURATION

Daily flow duration curves show the percentage of time that a flow is likely to equal or exceed a specified value on an annual or monthly basis. The flow duration curves for the KRRP hydroelectric facilities were created with the following inputs:

- Developed using the 2019 Biological Opinion Flows (2019 BiOps) provided by USBR (2018).
- 2019 BiOps for USGS gage 11509500 Klamath River at Keno, OR were translated to the J.C. Boyle facility using linear area proration.
- 2019 BiOps for USGS gage 11516530 Klamath River below Iron Gate Dam, CA were translated to the Copco No. 1 facility using linear area proration. The flows for the Copco No. 1 facility were also used for the Copco No. 2 facility.

The annual and monthly daily flow duration curves based on the 2019 BiOp flows are shown below in Tables 4.1 to 4.4 and on Figures 4.1 to 4.3 for the KRRP facilities.

Table 4.1 Flow Duration Flows Based on 2019 BiOp Flows – Annual

% of Time Equaled or Exceeded	Discharge (cfs)			
	Keno	J.C. Boyle	Copco No. 1	Iron Gate Dam
99%	300	320	850	900
95%	500	530	850	900
90%	570	590	900	950
80%	640	660	940	1,000
75%	660	690	940	1,000
70%	690	720	970	1,030
60%	760	790	1,050	1,110
50%	820	860	1,110	1,180
40%	920	950	1,250	1,320
30%	1,130	1,170	1,540	1,630
25%	1,400	1,460	1,780	1,880
20%	1,770	1,840	2,210	2,340
10%	2,860	2,980	3,430	3,630
5%	4,140	4,310	4,780	5,060
1%	6,680	6,960	7,630	8,080

Table 4.2 Flow Duration Flows Based on 2019 BiOp Flows – Monthly – J.C. Boyle

% of Time Equaled or Exceeded	Discharge (cfs)																	
	Monthly																	Annual
	Jan	Feb	Mar	Apr	May	Jun 1 - 15	Jun 16 - 30	Jul 1 - 15	Jul 16 - 31	Aug	Sep 1 - 15	Sep 16 - 30	Oct 1 - 15	Oct 16 - 31	Nov 1 - 15	Nov 16 - 30	Dec	
99%	360	440	290	230	190	210	250	380	500	460	570	410	240	240	300	510	420	320
95%	470	510	550	770	740	620	590	530	580	550	660	560	610	580	620	560	490	530
90%	520	540	690	890	860	740	660	590	610	590	690	660	690	670	680	590	520	590
80%	580	600	1,060	1,000	940	800	710	640	650	620	720	690	740	740	760	630	570	660
75%	600	630	1,220	1,040	980	820	730	660	670	630	730	710	750	760	790	650	590	720
70%	620	650	1,440	1,120	1,030	860	750	670	690	650	750	720	770	780	820	660	610	720
60%	660	720	1,800	1,450	1,140	940	780	700	730	670	770	760	790	820	870	680	650	790
50%	720	940	2,220	1,870	1,410	1,030	820	740	760	700	800	790	810	850	910	710	680	860
40%	970	1,580	2,650	2,330	1,720	1,170	890	760	790	740	830	810	840	880	940	740	740	950
30%	1,530	2,220	3,350	2,840	2,110	1,440	970	790	820	790	860	860	870	930	990	780	970	1,170
25%	1,850	2,540	3,880	3,390	2,330	1,670	1,020	810	830	810	880	880	890	950	1,030	820	1,240	1,840
20%	2,160	2,980	4,770	3,790	2,530	1,950	1,080	840	850	850	910	900	910	980	1,090	910	1,530	1,840
10%	3,500	4,320	5,840	4,920	3,180	2,490	1,520	900	930	1,000	950	950	1,000	1,120	1,250	1,560	2,350	2,980
5%	4,870	6,010	6,660	5,670	3,870	2,910	1,830	960	980	1,360	1,010	980	1,060	1,220	1,370	3,090	3,250	4,310
1%	8,280	8,880	8,560	6,860	5,290	4,350	2,580	1,120	1,060	1,560	1,070	1,060	1,170	3,090	3,630	3,970	5,640	6,960

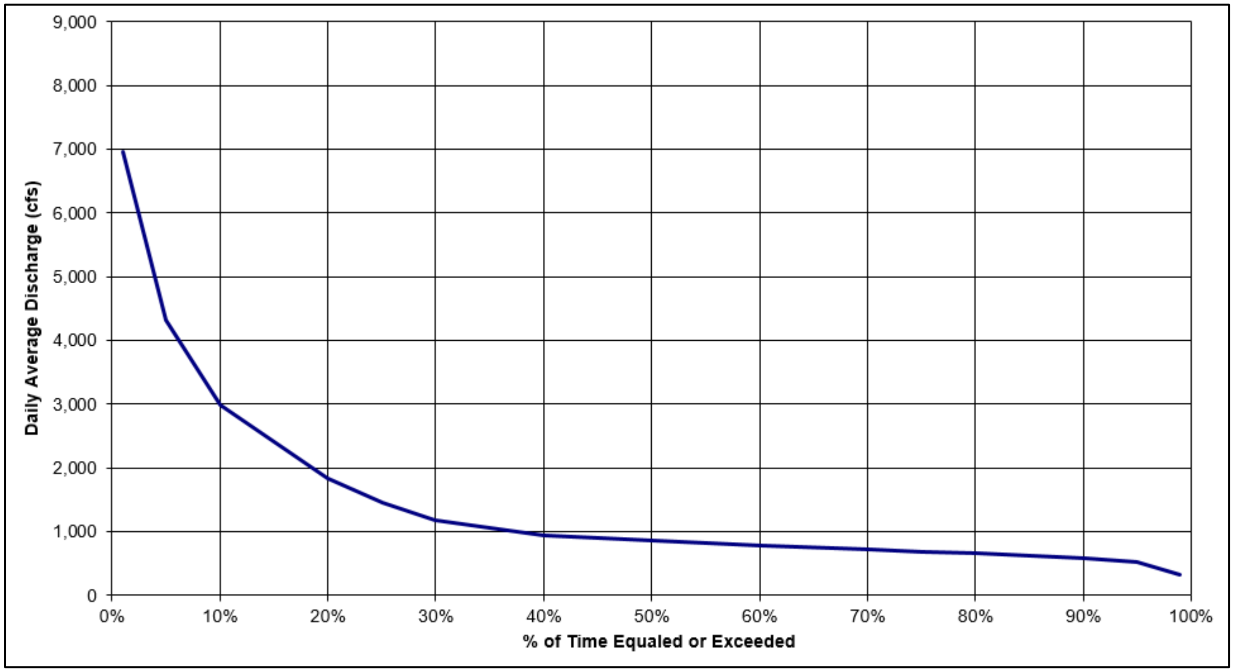


Figure 4.1 J.C. Boyle Annual Flow Duration Curve

Table 4.3 Flow Duration Flows Based on 2019 BiOp Flows – Monthly – Copco No. 1 and Copco No. 2

% of Time Equaled or Exceeded	Discharge (cfs)																	
	Monthly																	Annual
	Jan	Feb	Mar	Apr	May	Jun 1 - 15	Jun 16 - 30	Jul 1 - 15	Jul 16 - 31	Aug	Sep 1 - 15	Sep 16 - 30	Oct 1 - 15	Oct 16 - 31	Nov 1 - 15	Nov 16 - 30	Dec	
99%	900	900	940	1,250	1,110	970	960	850	850	850	940	940	940	940	940	940	900	850
95%	900	900	940	1,250	1,110	970	970	850	850	850	940	940	940	940	940	940	900	850
90%	900	900	1,080	1,250	1,110	970	970	850	850	850	940	940	940	940	940	940	900	900
80%	900	900	1,520	1,280	1,240	1,040	970	850	850	850	940	940	940	940	1,000	940	900	940
75%	900	940	1,630	1,410	1,290	1,080	970	860	870	850	940	940	960	990	1,050	940	900	940
70%	900	990	1,800	1,540	1,350	1,130	970	890	900	850	940	940	990	1,020	1,100	940	900	970
60%	970	1,120	2,210	1,810	1,430	1,200	990	930	950	850	940	940	1,030	1,070	1,130	940	900	1,050
50%	1,120	1,390	2,640	2,230	1,700	1,300	1,050	970	990	890	1,010	1,000	1,030	1,090	1,150	940	930	1,110
40%	1,420	1,980	3,120	2,780	2,080	1,480	1,120	1,000	1,000	960	1,070	1,080	1,060	1,110	1,160	940	1,060	1,250
30%	1,930	2,570	3,850	3,320	2,470	1,660	1,190	1,060	1,050	1,040	1,100	1,100	1,080	1,150	1,240	1,020	1,440	1,540
25%	2,280	2,920	4,430	3,920	2,700	1,840	1,230	1,080	1,060	1,050	1,100	1,110	1,100	1,190	1,260	1,080	1,600	1,780
20%	2,580	3,400	5,200	4,270	2,940	2,140	1,410	1,110	1,080	1,060	1,130	1,130	1,130	1,220	1,300	1,220	1,860	2,210
10%	3,980	4,820	6,080	5,260	3,620	2,830	1,770	1,160	1,160	1,110	1,160	1,160	1,200	1,350	1,460	1,960	2,800	3,430
5%	5,340	6,980	7,110	5,750	4,250	3,250	2,050	1,180	1,180	1,460	1,160	1,160	1,250	1,440	1,550	3,300	4,020	4,780
1%	9,070	10,460	8,920	7,220	5,430	4,560	2,780	1,410	1,250	1,600	1,190	1,190	1,350	3,020	3,870	4,070	6,770	7,630

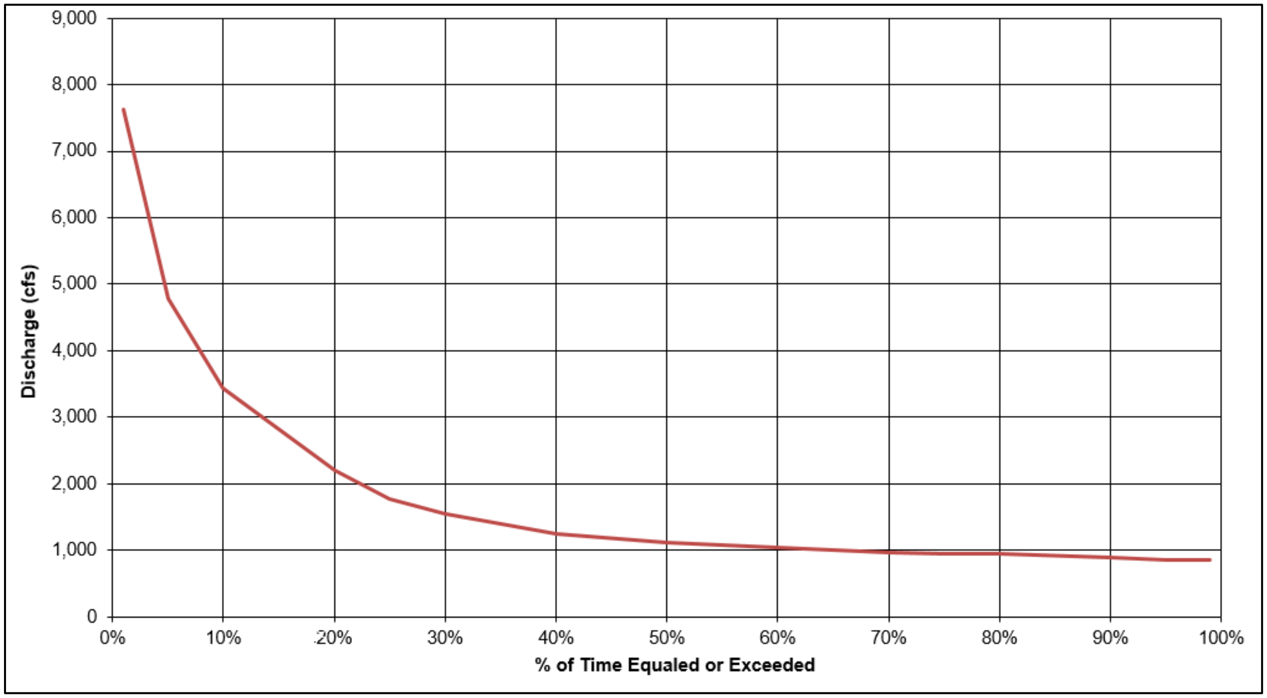


Figure 4.2 Copco No. 1 and Copco No. 2 Annual Flow Duration Curve

Table 4.4 Flow Duration Flows Based on 2019 BiOp Flows – Monthly – Iron Gate Dam

% of Time Equaled or Exceeded	Discharge (cfs)																	
	Monthly																	Annual
	Jan	Feb	Mar	Apr	May	Jun 1 - 15	Jun 16 - 30	Jul 1 - 15	Jul 16 - 31	Aug	Sep 1 - 15	Sep 16 - 30	Oct 1 - 15	Oct 16 - 31	Nov 1 - 15	Nov 16 - 30	Dec	
99%	950	950	1,000	1,330	1,180	1,030	1,020	900	900	900	1,000	1,000	1,000	1,000	1,000	1,000	950	900
95%	950	950	1,000	1,330	1,180	1,030	1,030	900	900	900	1,000	1,000	1,000	1,000	1,000	1,000	950	900
90%	950	950	1,150	1,330	1,180	1,030	1,030	900	900	900	1,000	1,000	1,000	1,000	1,000	1,000	950	950
80%	950	950	1,610	1,360	1,320	1,100	1,030	900	900	900	1,000	1,000	1,000	1,000	1,060	1,000	950	1,000
75%	950	1,000	1,730	1,500	1,370	1,150	1,030	910	930	900	1,000	1,000	1,010	1,040	1,110	1,000	950	1,000
70%	950	1,050	1,910	1,640	1,430	1,190	1,030	950	960	900	1,000	1,000	1,050	1,080	1,110	1,000	950	1,030
60%	1,030	1,180	2,340	1,920	1,520	1,270	1,050	980	1,010	900	1,000	1,000	1,090	1,130	1,190	1,000	950	1,110
50%	1,180	1,470	2,800	2,360	1,810	1,380	1,110	1,030	1,040	940	1,070	1,080	1,100	1,160	1,210	1,000	980	1,180
40%	1,500	2,090	3,310	2,950	2,200	1,570	1,180	1,050	1,060	1,020	1,130	1,140	1,120	1,180	1,230	1,000	1,120	1,320
30%	2,040	2,730	4,080	3,520	2,620	1,760	1,260	1,120	1,110	1,100	1,160	1,160	1,150	1,220	1,320	1,080	1,520	1,630
25%	2,420	3,100	4,700	4,150	2,860	1,950	1,300	1,140	1,120	1,110	1,170	1,170	1,170	1,260	1,330	1,150	1,700	1,880
20%	2,730	3,600	5,510	4,530	3,110	2,270	1,490	1,180	1,150	1,130	1,200	1,190	1,200	1,290	1,380	1,300	1,970	2,340
10%	4,220	5,110	6,450	5,570	3,840	2,990	1,870	1,230	1,230	1,180	1,230	1,230	1,270	1,430	1,540	2,070	2,960	3,630
5%	5,650	7,390	7,530	6,090	4,500	3,440	2,180	1,250	1,250	1,550	1,230	1,230	1,330	1,520	1,640	3,500	4,260	5,060
1%	9,600	11,080	9,450	7,650	5,760	4,830	2,950	1,490	1,320	1,700	1,260	1,260	1,430	3,200	4,110	4,310	7,170	8,080

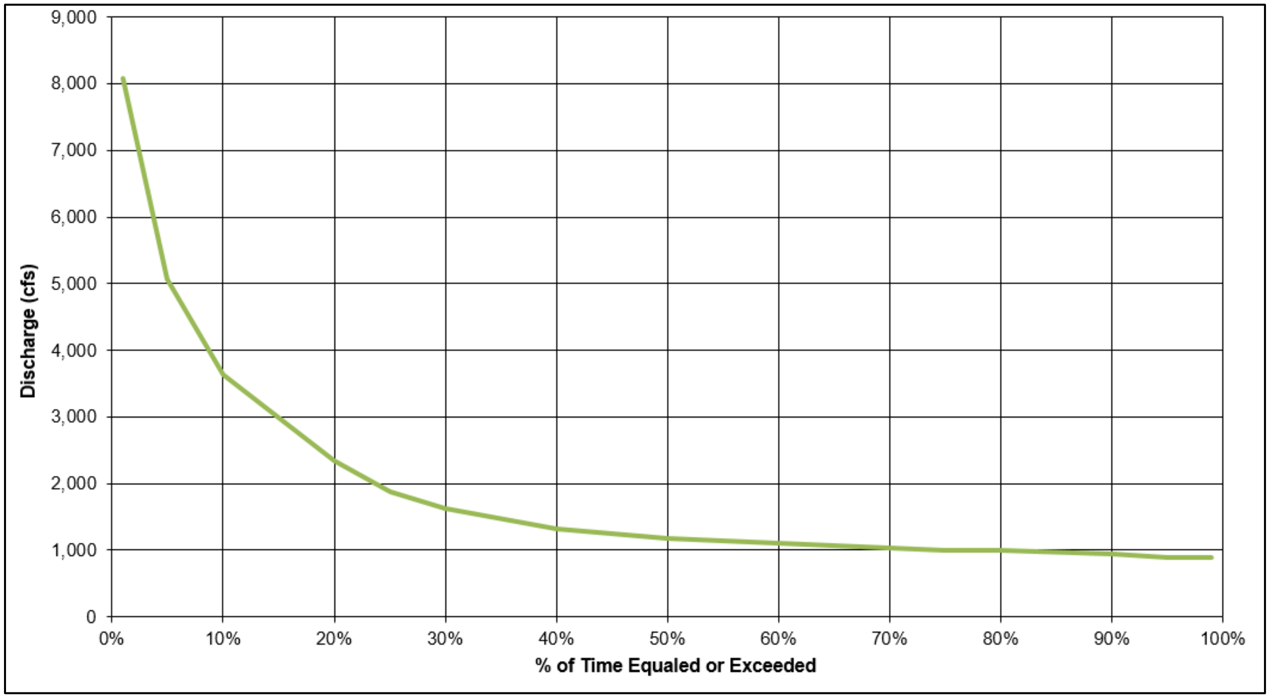


Figure 4.3 Iron Gate Dam Annual Flow Duration Curve

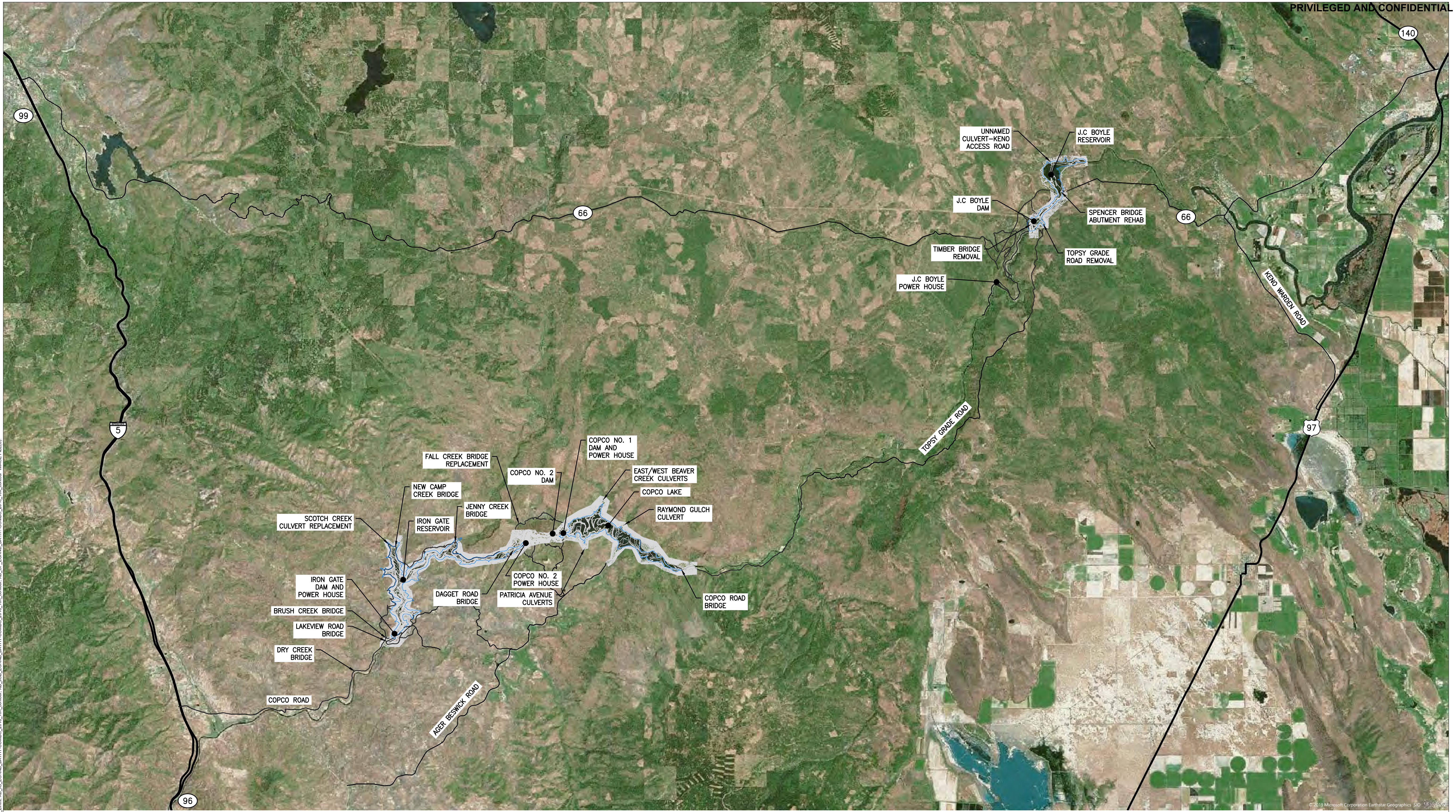
5.0 FLOWS FOR ROADS AND BRIDGE CROSSINGS

Located within the KRRP area are various roads, bridges, and culvert crossings. The locations of road, bridge, and culvert sites identified for improvement, monitoring, or construction purposes are identified on Figure 5.1.

The primary design goal for the roads, bridges, and culverts component of the KRRP is to modify the existing transport infrastructure to accommodate safe construction access throughout the KRRP site and to maintain existing public access during all stages of the project, from initial construction through to final removal of the hydroelectric facilities, and subsequent restoration. To facilitate this transportation design goal, design flood estimates for ungaged locations within the KRRP area are required.

Most of the transportation points of interest (POIs) are located on tributaries to the Klamath River, with the remaining POIs located directly on the Klamath River. The peak design floods at the ungaged locations were estimated by characterizing the tributary flows within the Klamath Basin between the J.C. Boyle and Iron Gate facilities. The Jenny Creek tributary represents a substantial portion of the incoming flows between the J.C. Boyle and the Iron Gate facilities. While Jenny Creek does have irrigation diversions and the flows are therefore partially regulated, this regulation effect is much smaller than that caused by the reservoirs on the mainstem of the Klamath River, and likely has little impact on the highest peak flows.

Many of the other larger tributary streams to the Klamath River are also regulated with irrigation structures, but as with Jenny Creek, the effects of these regulations on the largest peak flows is likely limited. The return period peak design flows calculated for all tributary streams are based on flow records for unregulated streams.



PLAN
1"= 7500'

0 7500 15000 22500
HORIZ 1" =7500', VERT 1" = 7500'

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
0	27MAY'22	ISSUED WITH REPORT	JCO	ELG/WAL	SRM

SAVED: M:\1\03\00640\01\A\Acad\FIGS\B03, 5/20/2022 11:43:53 AM , WLAHODA PRINTED: 5/20/2022 11:44:27 AM, Key Plan, WLAHODA ACAD VERSION: 23.1S (LMS TECH)
XREF FILE(S): XC-Klamath Access Routes; X_Klamath_Access_Rd_Lines; XD_IG_EGRND_BATHY-COMBO_2018_10ft_contour; XD_JCB_EGRND_BATHY-COMBO_2018_10ft_contour; XD_CP_EGRND_BATHY-COMBO_2018_10ft_contour IMAGE FILE(S):

KIEWIT INFRASTRUCTURE WEST CO.

KLAMATH RIVER RENEWAL PROJECT

LOCATION OF TRANSPORTATION POINTS OF INTEREST (POI)

Knight Piésold CONSULTING

P/A NO. VA103-640/1 | REF NO. 9

FIGURE 5.1 | REV 0

5.1 JENNY CREEK TRIBUTARY

Jenny Creek is a tributary to the Klamath River that discharges into the Iron Gate reservoir. The flow at Jenny Creek represents approximately 40% of the tributary and overland flow area between J.C. Boyle and Iron Gate facilities. There is an inactive USGS hydrology station located at the outlet of Jenny Creek (USGS Station JENNY C NR COPCO CA, 11516500); however, peak flow data for this gage are only available from 1923 to 1928, and the quality of the data is uncertain. This station has a drainage area of 205 mi^2 (210 mi^2 at the Jenny Creek bridge), and the records indicate annual peak flows ranging from 420 cfs to 1,960 cfs, with a six-year average of about 1,000 cfs. Relative to peak flows recorded at other creeks in the region, these values seem low.

The Bureau of Land Management (BLM) has a hydrology gage on Jenny Creek (located below Spring Creek at UTM 10T 0553140 / 4652570 (Lat/Long: 42.02335, -122.35817) with a drainage area of approximately 195 mi^2. The BLM data consists of average daily flows and annual peak flows for the period of 1998 to 2018. BLM notes that the rating curve may not be applicable and may require updating. The information for this gage has not undergone QA/QC procedures and is therefore provisional. Nonetheless, the data are believed to be the best Jenny Creek specific flow data currently available, and as such, these data were used to complete a hydrologic analysis for Jenny Creek.

5.1.1 AVERAGE MONTHLY FLOW

The average monthly flows for Jenny Creek at the Jenny Creek Bridge were calculated, as presented in Table 5.1 and on Figure 5.2. These data were prorated from the BLM gage location to the Jenny Creek bridge.

Table 5.1 Monthly Average Flow for Jenny Creek at Jenny Creek Bridge (Provisional)

Month	Monthly Average Flow (cfs)
January	121
February	181
March	305
April	225
May	136
June	41
July	16
August	15
September	16
October	19
November	29
December	87

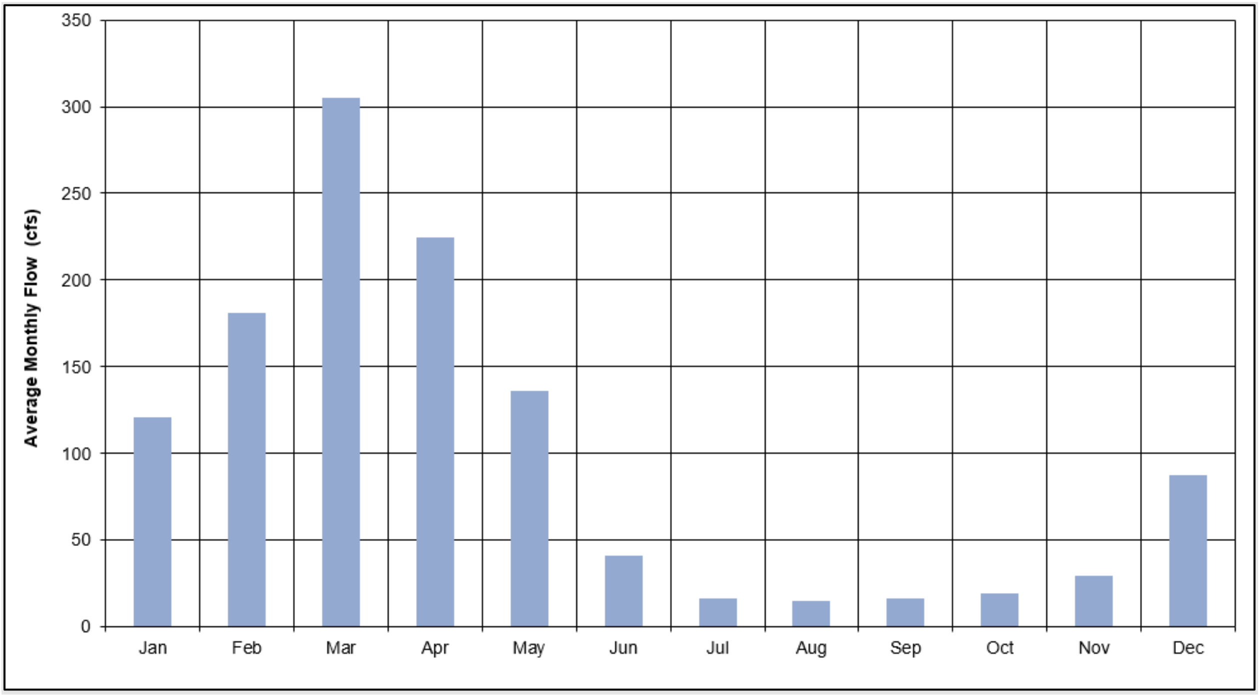


Figure 5.2 Monthly Average Flow for Jenny Creek at Jenny Creek Bridge (Provisional)

5.1.2 ANNUAL PEAK FLOODS

A summary of the available stream gage data used for the regional hydrology assessment of the tributary streams is provided in Table 5.2 below, and the station locations are shown on Figure 5.3.

Table 5.2 Summary of Streamflow Gage Records

Gage	Gage Operator/ Number	Basin Area (mi^2)	Period of Record	Notes
Klamath Tributary near Keno, OR	USGS 11509400	1.02	1964-1981	Annual peak flow estimates only. Includes the 1964 flood.
Fall Creek at Copco CA	USGS 11512000	14.6	1928 - 1959	Peak streamflow available. Does not include 1964 flood.
Fall Creek at Copco CA	PacifiCorp	14.6	2015 - 2017	Hourly data available. Not QA/QC'd. Does not include 1964 flood.
Bogus Creek	PacifiCorp	53.7	2014 - 2018	15-minute data available. Not QA/QC'd. Does not include 1964 flood.
Jenny Creek	BLM	195	1998 - 2018	15-minute data available. Not QA/QC'd. Does not include 1964 flood.
Rogue River above Prospect, OR	USGS 14328000	312	1909 - 2017	15-minute data available. Includes 1964 flood record.

Figure 5.3 Regional Streamflow Gage Locations

A regional flow assessment was performed on available peak flow data for the stream gages listed in Table 5.2. The characteristics of the gaged basins as well as the lengths of available streamflow records were considered when determining the suitability of a gage for estimating flood flows for Jenny Creek. The PacifiCorp gages on Bogus Creek and Fall Creek were excluded due to insufficient stream gage data for the analysis. The USGS gage data for Fall Creek at Copco and the Klamath Tributary near Keno were excluded because their drainage areas are outside of the range of 0.50 to 1.50 times the size of the Jenny Creek drainage area, as recommended by the USGS (2005). Data for the USGS stream gage on Rogue River above Prospect (gage number 14328000) were selected as the most appropriate dataset for calculating return period peak flows for Jenny Creek because of the similarity of Rogue River and Jenny Creek watersheds in terms of drainage area and mean basin elevation. In addition, Rogue River has a lengthy period of record, which dates from 1909 to 2017 and includes the flood of record for the Klamath region (December 1964).

A flood frequency analysis was completed for the entire period of record for the Rogue River using the HEC-SSP (V2.1), following the Bulletin 17B method for the Log-Pearson Type III distribution (USGS, 1982).

The Rogue River flood frequency results were then transposed using the area proration methodology described in "Estimation of Peak discharges for Rural, Unregulated streams in Western Oregon" (USGS, 2005) to calculate the peak flood flows for Jenny Creek at the bridge. A scaling exponent of 1.0 was used for the transposition, as recommended in USGS (2005).

A flood frequency analysis was also performed on the BLM Jenny Creek annual peak flood data using HEC-SSP (V2.1), following the Bulletin 17B method for the Log-Pearson Type III distribution (USGS, 1982). The calculated peak flood values were prorated to the Jenny Creek bridge location using the methods outlined in USGS (2005) and a scaling exponent of 1.0.

The flood frequency analysis results based on both the USGS Rogue River and the BLM Jenny Creek datasets are presented in Table 5.3.

Table 5.3 Flood Frequency Analysis for Jenny Creek Bridge

Percent Probable Flood	Jenny Creek Bridge Peak Floods (cfs)	
	Design Values - Prorated from Rogue River USGS gage, 1909 - 2017	Prorated from Jenny Creek BLM gage, 1998 - 2017
50%	3,100	1,400
20%	5,000	2,700
10%	6,500	4,000
5%	8,000	5,500
2%	10,100	8,000
1%	11,900	10,400
0.5%	13,900	13,200
0.2%	16,600	17,700

The two sets of values agree reasonably well for events greater than the 5% probable flood, while the Rogue River values are higher for events smaller than the 5% probable flood. Flood events greater than the 5% probable flood are typically used for the design of hydraulic structures.

5.2 ANNUAL PEAK FLOODS FOR LOCATIONS OTHER THAN JENNY CREEK

Design flood estimates for ungauged locations for road, bridge, and culvert crossings within the KRRP area were determined by scaling regional peak flows according to the crossing location. For ungaged locations located on the Klamath River, the annual peak floods were determined based on the design flood estimates from the closest appropriate dam facility, which were linearly prorated by the ratio of the respective drainage areas to the location of interest.

For ungaged locations on tributary streams of the Klamath River, the annual peak floods were calculated based on the annual peak flood values for the USGS gage on Fall Creek (gage number 11512000) using non-linear drainage area proration. The Fall Creek stream gage data were selected for the analysis based on drainage area size and mean basin elevation, which are generally representative of the watersheds pertaining to the majority of the POI's that are located on tributary streams much smaller than Jenny Creek. In addition, the Fall Creek record length is reasonably long, at 32 years, and though it is dated (1928 to 1959), it is the most appropriate record available for small streams.

A flood frequency analysis was performed on the Fall Creek annual peak flood data using HEC-SSP (V2.1), following the Bulletin 17B method for the Log-Pearson Type III distribution (USGS, 1982). The calculated peak floods were then non-linearly prorated to the POI locations. The scaling exponent for drainage area was investigated to determine the appropriate value to use for the smaller drainage areas of the POIs. A review of the various USGS regional regression equations for determining peak floods for Oregon and California for the Klamath region indicates scaling exponents ranging from 0.5 to 1.0, although most of the values tend to be towards the upper end of the range, and therefore a value of 0.9 was selected for design purposes.

Preliminary design flood values estimated for roads, bridges, and culverts are provided on a site-by-site basis in Table 5.4.

Table 5.4 Annual Peak Floods for Roads, Bridges, and Culvert Structures

Location	Drainage Area (mi^2)	Annual Percent Probable Flood (cfs)[6]						
		50%	10%	5%	2%	1%	0.5%	0.2%
Scotch Creek Culvert[1]	17.9	170	450	600	850	1,070	1,320	1,710
New Camp Creek Bridge[1]	19.8	180	490	660	930	1,170	1,440	1,870
Jenny Creek Bridge	210	1,400	4,000	5,500	8,000	10,300	13,100	17,700
Timber Bridge Removal[2,3]	4,080	7,000	10,300	11,700	13,300	14,200	15,000	15,800
East/West Beaver Culverts[1]	5.6	60	160	210	300	370	460	600
Raymond Gulch Culvert[1]	2.5	28	80	103	140	180	220	291
Patricia Avenue Culverts[1]	0.4	5	15	20	28	35	43	56
Copco Road Bridge[2,3]	4,340	7,100	13,900	18,100	24,000	29,200	34,800	42,900
Unnamed Culvert Keno Access Road[1]	12.2	120	320	430	600	750	930	1,210
Spencer Bridge[2,3]	4,050	6,900	10,200	11,600	13,200	14,100	14,900	15,700
Topsy Grade Road Culvert[1]	2.2	30	70	90	130	160	200	260
Daggett Road Bridge[2,3,4]	4,370	7,100	14,000	18,200	24,200	29,400	35,000	43,200
Fall Creek Bridge[1]	12.2	120	320	430	600	750	930	1,210
Brush Creek Bridge[1]	5.0	50	140	190	270	340	420	540
Lakeview Road Bridge[2,3,5]	4,630	7,500	14,900	19,300	25,700	31,200	37,100	45,800
Dry Creek Bridge[1]	8.9	90	240	320	450	570	700	910

NOTES:

1. VALUES ARE CALCULATED BASED ON FALL CREEK ANNUAL PEAK FLOOD RESULTS USING NON-LINEAR DRAINAGE AREA PRORATION WITH A SCALING FACTOR OF 0.9 (USGS, 2005).
2. VALUES ARE BASED ON ANNUAL PEAK FLOOD RESULTS FROM THE CLOSEST APPROPRIATE DAM FACILITY, WHICH WERE LINEARLY PRORATED BY THE RATIO OF THE RESPECTIVE DRAINAGE AREAS.
3. THE SITE IS LOCATED ON THE KLAMATH RIVER AND THEREFORE THE FLOW DATA ARE REGULATED.
4. THE DRAINAGE AREA OF THE COPCO NO. 1 FACILITY WAS USED FOR THE DRAINAGE AREA OF POINT OF INTEREST.
5. THE DRAINAGE AREA OF THE IRON GATE FACILITY WAS USED FOR THE DRAINAGE AREA OF POINT OF INTEREST.

6.0 POST-DAM REMOVAL PEAK FLOODS

The KRRP dams currently create upstream reservoirs and pass flood flows through spillways. The routing of flows through the reservoirs and over the spillways necessitates a rise in the reservoir levels and the associated temporary storage of flow volumes, which results in an attenuation of flood peak discharges. With the removal of the dams, there will be no more flood attenuation, which will impact the flood magnitudes in the future. This section presents post dam removal peak flows for use in designing permanent features at the former dam sites.

A hydrologic model was developed to estimate the change in the magnitude of the peak floods post-dam removal, which simulates flows in the Klamath River from downstream of the Keno Dam to downstream of the Iron Gate Dam, as described in Attachment 1 (KP Memo VA22-00403). The model was set up using HEC-HMS (v 4.3) to route the flows through the Copco No. 1 reservoir and spillway and then through the Iron Gate reservoir and spillway. Routing effects from the J.C. Boyle and Copco No. 2 reservoirs and spillways were omitted as these reservoirs have negligible active storage volumes. Once the model was calibrated using tributary inflows for various recorded storm events for the pre-dam removal case, the same storms were modelled again with the dams removed.

6.1 ANNUAL PEAK FLOODS

Two empirical equations were developed from the post-dam removal modeling results to aid in estimating the effects on peak floods that may result from the removal of the dams, as discussed in Attachment 1 (KP Memo VA22-00403). Using these empirical equations and the annual peak floods from Table 3.2 (that include attenuation), the post-dam removal annual peak floods were calculated per facility and are shown in Table 6.1.

Table 6.1 Post-Dam Removal Annual Peak Floods

Location	Drainage Area (mi^2)	Annual Percent Probable Flood (cfs)							
		50%	20%	10%	5%	2%	1%	0.5%	0.2%
J.C. Boyle	4,080	7,000	8,500	10,300	11,700	13,300	14,200	15,000	15,800
Copco No. 1	4,370	11,200	15,400	19,900	24,300	29,400	32,700	36,800	45,400
Iron Gate	4,630	11,700	16,200	20,900	25,400	30,500	33,600	39,000	48,100

The J.C. Boyle Dam reservoir provides minimal attenuation of peak floods, therefore there is negligible increase to the peak flood events. As such, the annual peak floods in Table 3.2 are also used to represent the post-dam removal floods for this facility. The annual return period floods at Copco No. 1 are used as representative of the annual return period floods for Copco No. 2.

6.2 PEAK FLOODS FOR MONTHLY TIME PERIODS

The post-dam removal empirical equations are applicable to peak events that result from snowmelt and/or rain-on-snow events, including the annual peak events. When there is less rainfall during the low flow summer months, the monthly peak flood events are primarily driven by releases from Upper Klamath Lake and there is less contribution from tributary and overland sources. Accordingly, peak flows during the summer months tend to be sustained for extended periods and there is little attenuation as these flows pass through the power generation facilities to the downstream. As such, the empirical equations developed for post-dam removal peak flows are not applicable to high flows that occur during the period between June 16 and September 30. The post-dam removal high flows during this period will likely be similar to the existing conditions.

The monthly peak floods from Table 3.6 were used to calculate the post-dam removal monthly peak floods per facility by applying the empirical equations (see Attachment 1) to the flows between October 1 to June 15, and by adopting the current values (Table 3.6) for flows from June 15 to September 30. The estimated post-dam removal flows are shown in Table 6.2.

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TABLE 6.2

KIEWIT INFRASTRUCTURE WEST CO.
KLAMATH RIVER RENEWAL PROJECT

POST-DAM REMOVAL MONTHLY PEAK FLOODS

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Location	Drainage Area (mi²)	Month	Instantaneous Peak Floods for Specified Time Period (cfs)								Average Monthly Flow (cfs)
			50% Probable Flood	20% Probable Flood	10% Probable Flood	5% Probable Flood	2% Probable Flood	1% Probable Flood	0.5% Probable Flood	0.2% Probable Flood	
J.C. Boyle	4,080	Jan	2,600	4,400	6,000	8,000	11,100	14,000	15,000	15,800	1,500
		Feb	2,700	4,900	7,000	9,700	13,000	14,200	15,000	15,800	1,900
		Mar	6,300	8,000	8,800	10,900	13,300	14,200	15,000	15,800	2,800
		Apr	4,500	6,800	8,100	9,400	11,600	13,600	15,000	15,800	2,370
		May	2,700	4,300	5,500	6,800	8,500	9,900	11,300	13,400	1,760
		Jun 1 - 15	1,800	2,800	3,500	4,400	5,800	7,300	9,100	12,100	1,330
		Jun 16 - 30	1,400	1,800	2,300	2,800	3,600	4,400	5,000	6,300	960
		Jul 1 - 15	1,000	1,400	1,700	2,100	2,700	3,200	3,900	4,900	740
		Jul 16 - 31	1,400	1,500	1,600	1,700	1,800	1,800	1,800	2,000	760
		Aug	1,400	1,500	1,600	1,700	1,800	1,800	1,800	1,900	760
		Sep 1 - 15	1,400	1,700	1,900	2,100	2,400	2,500	2,700	3,000	810
		Sep 16 - 30	1,500	1,900	2,200	2,400	2,800	3,000	3,200	3,500	790
		Oct 1 - 15	1,700	2,200	2,500	2,900	3,400	3,800	4,200	4,700	810
		Oct 16 - 31	1,700	2,400	2,800	3,300	4,000	4,600	5,200	6,100	890
		Nov 1 - 15	1,800	2,600	3,200	3,800	4,700	5,500	6,300	8,600	980
		Nov 16 - 30	2,000	2,900	3,600	4,400	5,400	7,200	9,600	14,000	950
		Dec	2,500	3,900	5,100	6,300	8,300	10,500	13,000	15,600	1,110
Copco No. 1	4,370	Jan	5,800	9,600	12,900	17,300	23,700	28,800	33,200	44,900	1,910
		Feb	5,800	9,600	13,000	17,300	23,700	28,800	33,200	44,900	2,360
		Mar	10,500	13,000	15,300	18,700	23,200	26,400	29,200	32,500	3,230
		Apr	8,000	11,000	13,500	16,400	20,300	23,100	25,700	28,800	2,790
		May	5,700	7,900	9,700	11,600	14,200	16,300	18,400	21,100	2,110
		Jun 1 - 15	4,200	5,700	6,800	7,900	10,300	12,600	15,600	20,000	1,620
		Jun 16 - 30	1,400	1,900	2,400	2,900	3,600	4,400	5,100	6,400	1,210
		Jul 1 - 15	1,100	1,300	1,600	2,000	2,600	3,200	4,100	5,300	990
		Jul 16 - 31	1,200	1,300	1,500	1,600	1,800	2,000	2,100	2,400	990
		Aug	1,200	1,300	1,500	1,600	1,800	2,000	2,100	2,400	980
		Sep 1 - 15	1,300	1,600	1,800	1,900	2,100	2,200	2,300	2,500	1,030
		Sep 16 - 30	1,300	1,600	1,900	2,100	2,400	2,500	2,700	3,000	1,030
		Oct 1 - 15	3,600	4,400	5,100	5,700	6,800	7,600	8,700	10,100	1,050
		Oct 16 - 31	3,600	4,700	5,400	6,300	7,500	8,700	9,800	11,700	1,140
		Nov 1 - 15	3,900	5,100	6,300	7,400	9,100	10,600	12,200	15,000	1,230
		Nov 16 - 30	4,200	5,800	7,200	8,400	10,500	12,100	14,600	19,900	1,240
		Dec	5,100	8,500	11,600	15,900	22,700	28,200	33,200	45,400	1,490
Iron Gate	4,630	Jan	6,100	9,900	13,500	18,100	24,800	29,900	34,100	47,700	2,030
		Feb	6,100	9,900	13,700	18,100	24,800	29,900	34,100	47,700	2,500
		Mar	11,000	13,700	16,000	19,700	24,200	27,500	30,300	33,400	3,430
		Apr	8,300	11,500	14,200	17,300	21,300	24,100	26,800	29,900	2,950
		May	5,800	8,300	10,200	12,200	15,000	17,200	19,300	22,100	2,230
		Jun 1 - 15	4,400	5,800	6,900	8,300	10,800	13,300	16,400	21,000	1,720
		Jun 16 - 30	1,500	2,000	2,500	3,000	3,700	4,400	5,200	6,500	1,280
		Jul 1 - 15	1,200	1,400	1,700	2,100	2,800	3,400	4,300	5,600	1,050
		Jul 16 - 31	1,300	1,400	1,600	1,700	1,900	2,100	2,200	2,500	1,050
		Aug	1,300	1,400	1,600	1,700	1,900	2,100	2,200	2,500	1,040
		Sep 1 - 15	1,400	1,700	1,900	2,000	2,200	2,300	2,400	2,600	1,090
		Sep 16 - 30	1,400	1,700	2,000	2,200	2,500	2,700	2,900	3,200	1,090
		Oct 1 - 15	3,800	4,500	5,300	6,000	7,100	8,000	9,100	10,600	1,120
		Oct 16 - 31	3,800	4,800	5,700	6,500	7,900	9,100	10,300	12,300	1,210
		Nov 1 - 15	4,100	5,400	6,500	7,800	9,400	11,100	12,900	15,800	1,300
		Nov 16 - 30	4,400	6,100	7,500	8,800	11,000	12,700	14,900	19,900	1,310
		Dec	5,400	8,900	12,200	16,700	23,700	29,300	34,100	48,100	1,580

M:\1\03\00640\01\A\Data\Task 2200 - Project Support\Hydrology Update Post Removal\Flood Frequency Analysis Update\[Post-Dam Removal Peak Floods - Monthly - 100% DCD.xlsm]Table_Post-Dam Removal Monthly

NOTES:

1. PEAK FLOOD CALCULATIONS ARE BASED ON METHODOLOGY PRESENTED IN KP MEMO "REVISED KLAMATH RIVER FLOOD HYDROLOGY – POST DAM REMOVAL" (VA22-00321, MARCH 2022).
2. PRE-DAM REMOVAL ANNUAL PEAK FLOOD VALUES WERE REQUIRED FOR CALCULATIONS AND ARE TAKEN FROM TABLE 3.2, APPENDIX A6, 100% DESIGN REPORT (VA103-640/1-9, REV 0).
3. THE POST-RIVER DIVERSION MONTHLY PERCENT PROBABLE FLOODS AT COPCO NO. 1 ARE USED AS REPRESENTATIVE OF THE POST-RIVER DIVERSION ANNUAL PERCENT PROBABLE FLOODS FOR COPCO NO. 2.
4. THE PEAK FLOODS HAVE NOT BEEN ADJUSTED FOR THE SUMMER PERIOD BETWEEN JUNE 16 TO SEPTEMBER 30. THE PEAK FLOODS DURING THIS PERIOD ARE ASSUMED TO BE UNAFFECTED POST-RIVER DIVERSION.
5. THE PEAK FLOODS HAVE NOT BEEN ADJUSTED FOR THE J.C. BOYLE FACILITY AS THE RESERVOIR PROVIDES MINIMAL ATTENUATION OF PEAK FLOODS. THE PEAK FLOODS IN TABLE 3.2, APPENDIX A6, 100% DESIGN REPORT (VA103-640/1-9, REV 0) ARE ASSUMED TO BE UNAFFECTED POST-RIVER DIVERSION.

REV	DATE	DESCRIPTION	PREP'D	RVW'D
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Attachments:

VA22-00403 Revised Klamath River Flood Hydrology – Post Dam Removal

References:

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APPENDIX A7
DESIGN CRITERIA

TABLE OF CONTENTS

1.0 INTRODUCTION

The following design criteria were developed in a collaborative manner by the Klamath River Renewal Project Team (i.e. KRRC, Kiewit, KP, RES, and Camas).

These design criteria provide the agreed basis for KP's design of Kiewit's reservoir drawdown and dam removal scope of work, and related activities including construction access improvements.

The design criteria are presented in the following tables:

- Table A7.1 – Diversion Tunnels
- Table A7.2 – Reservoir Drawdown
- Table A7.3 – Embankment Dam Removal
- Table A7.4 – Concrete Dam and Structures Removal
- Table A7.5 – Roads, Bridges, and Culverts
- Table A7.6 – Material Deposition
- Table A7.7 –Dam Site Permanent Works

Overarching design criteria and roles for the following key topics are addressed below:

- Flood design criteria for embankment dam removal
- Final dam breach criteria for Iron Gate Dam
- River channel design criteria

2.0 FLOOD DESIGN CRITERIA FOR EMBANKMENT DAM REMOVAL

Embankment dam crest elevations during the various stages of removal shall meet the following criteria with regards to flood passage. Design of the excavations for J.C. Boyle and Iron Gate dams shall provide for a dam section that can safely retain water, meet stability criteria, and have a crest elevation that is 3 feet greater than needed to allow for passage of a 1% probable flood for that time of year. As embankment removal advances, a point is reached where in advance of breach where the crest elevation is no longer required to be above the 1% probable flood elevation, and instead it is to be kept above a 5% probable flood elevation for that time of year.

3.0 FINAL DAM BREACH CRITERIA FOR IRON GATE DAM

The final dam breaches will be timed to avoid periods of high inflow to limit the magnitude of peak outflow through the breaches.

The final breach of Iron Gate Dam is unique because it will have the largest impounded water volume at the time of final breach and because it is located farthest downstream of the four facilities being removed. The specific target for peak outflow discharge is approximately 6,000 cfs, as measured at USGS Gaging Station No. 11516530, Klamath River below Iron Gate Dam. This criterion is based on the estimated bankfull discharge of 5,000 to 6,000 cfs in the Klamath River downstream of Iron Gate Dam, as provided by the Yurok Tribe.

KRRC is responsible for the following aspects related to the final dam breaches, which are not addressed in these design criteria:

- Public safety, including public communication and public access restriction outside of Kiewit controlled construction areas (as required).
- Assessment and mitigation (as required) of potential downstream impacts associated with the final breach outflow wave, including sediment transport and deposition.

4.0 RIVER CHANNEL DESIGN CRITERIA

The design criteria and roles for the final river channels through the existing dam sites are further described below:

- Final channel, floodplain and canyon wall geometry throughout the removal extents shall provide a geomorphically appropriate transition between cross sections, that is passable to fish species of concern, immediately upstream and downstream of the previous dam location.
- The KRRP Team has collectively agreed on specific criteria related to the geomorphically appropriate transition of the final river channel, floodplain, and canyon walls, including depth of concrete removal below the remediated river channel, thickness of riverbed fill material to be placed over concrete structures left in place below the remediated riverbed, lateral extent of dam structure removals, and the upstream and downstream extents and elevations for dam removal excavations. These agreed criteria are documented in Tables A7.4 and A7.7.
- Kiewit/KP's scope for design of the final fish volition channels comprises the footprints of the existing dams and historic cofferdams. The Habitat Contractor will review the designs and provide acceptance for volitional fish passage and will be responsible for scope outside the footprint limits of the existing dams and historic cofferdams.

The limits of excavation at each of the dam sites is based on the site foundation geology.

- J.C. Boyle: The bedrock at the foundation is rough with ridges and high points. The volitional fish passage channel bottom will be on top of the encountered rock features. Channel roughening does not require dental cleaning between the rough rock ridges and high points as these features should be preserved. Boulders and large rocks from the historic dam construction will be encountered at the downstream toe of the dam as it is excavated. These are recognized roughening features and will be graded to the channel configuration.

- Copco No. 1: The dam site is within a narrow rock-walled canyon. The rock walls undulate, and resident talus material is located between the rock formation. The rock walls and foundations at the concrete dam will be excavated to bedrock or the agreed concrete excavation limit, and then backfilled. Upstream of the dam, there is a combination of construction waste material (soil, rock, and other construction debris). The construction waste material will be removed to the higher of bedrock, stable talus, or the designed longitudinal channel bottom profile. The designed longitudinal channel profile will tie into existing channel bathymetry upstream of the historic cofferdam and the existing channel profile downstream of the Copco No. 1 powerhouse.
- Copco No.2: The dam site is on a soil foundation. The concrete dam will be excavated to the concrete excavation limit and then backfilled to match the adjacent channel.
- Iron Gate: The dam site is a U-shaped rock-walled and bottomed canyon. The dam will be excavated to the higher of bedrock limits or to the designed longitudinal channel bottom profile.

Erosion protection:

- Erosion protection will be provided for permanent fill slopes within the dam excavation footprints. Erosion protection is not required on bedrock slopes.
- Additional rock or other materials requested by the Habitat Contractor for aquatic habitat purposes to be shown on the Habitat Contractor design documents.

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TABLE A7.1

KIEWIT INFRASTRUCTURE WEST CO.
KLAMATH RIVER RENEWAL PROJECT

DIVERSION TUNNELS
DESIGN CRITERIA

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Feature/Consideration	Criteria	Remarks	Reference
1.0 TUNNEL IMPROVEMENTS			
Hydrostatic and Hydrodynamic Pressure	• Conditions that will occur when reservoir level is consistent with the 1% flood event.	• Maintain balaced hydrostatic pressures across tunnel liner or rock consistent with the existing conditions. • This criteria applies to the tunnel and all associated works and apertanances including valves, gates, and venting.	• USACE EM 1110-2-2901, 1997
Diversion Tunnel Water Velocity	• For all drawdown hydrologic requirements: - Unlined Rock: <10 ft/sec - Concrete: <20 ft/sec	• The diversion tunnel operation during drawdown and deconstruction are about 10 months in duration, reinforced concrete will be used for short sections of tunnel where velocities over 20 ft/s are required	•USBR Design Standards No. 3, Chapter 4: Tunnels, Shafts and Caverns (2014)
Diversion Tunnel Air Flow	• Natural air flow within tunnel or installed venting shall be designed to mitigate adverse pressure conditions and cavitation that may compromise tunnel integrity for all drawdown or hydrologic scenarios up to and including the 1% Flood Event	• Dr. H.Falvey is the project reviewer	• Engineering Monograph No. 41 (Falvey, 1980)
Tunnel Ground Support	• Safe Construction Access	• Where modifications are not required for hydraulic drawdown criteria above, ground support shall be provided for safe construction access	• USACE EM 1110-2-2901, 1997
Portal Slope Protection	• Safe Construction Access	• Where modifications are not required for hydraulic drawdown criteria above, ground support shall be provided for safe construction access	• USACE EM 1110-1-2908, 1994 • USACE EM 1110-2-1902, 2003
Tunnel/Shaft Closure (Post Drawdown)	• Ensure no public access, pedestrian or vehicle is possible following drawdown. • Include provision for tunnel seepage		

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TABLE A7.2

KIEWIT INFRASTRUCTURE WEST CO.
KLAMATH RIVER RENEWAL PROJECT

RESERVOIR DRAWDOWN
DESIGN CRITERIA

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Feature/Consideration	Criteria	Remarks	Reference
1.0 OPERATING REQUIREMENTS			
Daily Minimum Downstream Flows	Downstream of Iron Gate as measured at the USGS Gage: • Sept through Nov, March 1,000 cfs • Dec through Feb 950 cfs • April 1,325 cfs • May 1,175 cfs • June 1,025 cfs • July and Aug 900 cfs	• Minimum flows will be dictated by USBR requirements which may supersede the Biological Opinion flows as set out.	• USBR, BIOP 2019
Normal Maximum Operating Surface Elevation (ft msl)	• J.C. Boyle = 3,796.7 ft		FERC Licence Application - Exhibit A (2004) - NAVD88 Elevations
	• Copco Lake = 2,611.0 ft		
	• Iron Gate = 2,331.3 ft		
Normal Minimum Operating Surface Elevation (ft msl)	• J.C. Boyle = 3,791.7 ft		
	• Copco Lake = 2,604.5 ft		
	• Iron Gate = 2,327.3 ft		
3.0 DRAWDOWN			
Initial Drawdown	• To begin on or about January 1 of the drawdown year.		
Reservoir Drawdown Rate	• Target drawdown water surface level rate approximately 5 ft/day	• Each facility is unique relative to reservoir area capacity and proposed drawdown. Actual drawdown will be based on the actual inflow conditions during the applicable water year	
4.0 GEOTECHNICAL REQUIREMENTS			
4.1 Slope Stability of Reservoir Rim			
Minimum Required FOS	• Drawdown = 1.2	• Reservoir Drawdown criterion applies to existing dam embankment slopes	• USBR Design Standard No. 13 • USACE EM 1110-2-1902, 2003
	• Long-term, Post Drawdown = 1.5		• USBR Design Standard No. 13 • USACE EM 1110-2-1902, 2003
Design Earthquake for Temporary Construction	• Refer to Seismicity design criteria found in Appendix A4		

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REV	DATE	DESCRIPTION	PREP'D	RVW'D
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TABLE A7.3

KIEWIT INFRASTRUCTURE WEST CO.
KLAMATH RIVER RENEWAL PROJECT

EMBANKMENT DAM REMOVAL
DESIGN CRITERIA

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Feature/Consideration	Criteria	Remarks	Reference
1.0 PRE EMBANKMENT REMOVAL REQUIREMENTS			
Iron Gate Dam STID	• STID Section 8 - Stability and Stress Analyses		• PacifiCorp, Klamath Hydroelectric Project FERC No. P-2082 Iron Gate Hydroelectric Development (NatDam: CA00325), Supporting Technical Information Document(STID) Rev.2 (4-30-2015)
JC Boyle Dam STID	• STID Section 8 - Stability and Stress Analyses		• PacifiCorp, Klamath Hydroelectric Project FERC No. P-2082 J.C. Boyle Hydroelectric Development, Supporting Technical Information Document(STID) Rev.2 (4-30-2015)
2.0 EMBANKMENT REMOVAL REQUIREMENTS			
Minimum Freeboard Elevation (embankment)	• Dam deconstruction will be staged to provide a remaining dam section that can safely retain water and meet stability and stress requirements		• See Project STID
	• Freeboard will be provided during dam deconstruction of 3 ft or greater for a 1% probable flood at that time of year.		• USBR Design Standard No. 13
	• In the late stages of dam deconstruction, freeboard will be provided of 3 ft or greater for a 5% probable flood at that time of year.		
Final Dam Breach Rate	• J.C. Boyle and Iron Gate final dam breaches shall be designed to maximize the amount of material removal by the flow of the Klamath River • The timing of final dam breaches will avoid periods of high inflow • The target peak outflow for the final breach of Iron Gate Dam is approximately 6000 cfs, as measured at USGS Gaging Station No. 11516530, Klamath River below Iron Gate Dam.	The impounded water surface level at the time of final dam breach will depend on hydrologic conditions during the drawdown period. The peak outflow discharge is based on estimated bankfull discharge of 5000 to 6000 cfs downstream of Iron Gate Dam.	DJ Bandowski, Yurok Tribe, e-mail correspondence, March 10, 2022.
Design Earthquake for Temporary Construction	• Design earthquake to be per Appendix A4		
3.0 SLOPE STABILITY			
3.1 Minimum Factors of Safety for Temporary Slopes			
Reservoir Drawdown	• FOS = 1.3		• USBR Design Standard No. 13 • USACE EM 1110-2-1902, 2003

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0	27MAY'22	ISSUED WITH REPORT VA103-640/1-9	SDR	NB

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TABLE A7.4

KIEWIT INFRASTRUCTURE WEST CO.
KLAMATH RIVER RENEWAL PROJECT

CONCRETE DAM AND STRUCTURES REMOVAL
DESIGN CRITERIA

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Feature/Consideration	Criteria	Remarks	Reference
1.0 PRE CONCRETE DAM REMOVAL REQUIREMENTS			
Copco No.1 Dam STID	• STID Section 8 - Stability and Stress Analyses		• PacifiCorp, Klamath Hydroelectric Project FERC No. P-2082 Copco 1 Hydroelectric Development, Supporting Technical Information Document(STID) Rev.2 (4-30-2015)
Copco No.2 Dam	• Low-hazard potential rated structure, not required to have an STID		
2.0 COPCO NO. 1 CONCRETE DAM PROPERTIES			
Cement Efficiency	• 10 psi/lb/cu yd		• ACI (1996)
Concrete Unconfined Compressive Strength	• Main section of dam = 4000 psi (minimum) • Upstream and downstream cutoff wall = 3000 psi (minimum)	• No records of compressive stress analysis are reported for the concrete of the dam • Construction drawings and photographs indicate the main section of the dam is constructed of a mixture of concrete and hand-placed large stones	• Construction Drawings and Photographs
Concrete Tensile Strength	• Static = 430 psi	• Based on splitting tensile test studies	
	• Dynamic = 640 psi		• ACI (1996)
Existing Reinforcing Steel	• 30-pound Rails	• Horizontal rails are placed at 8 ft center to center • Vertical rails are placed at 12 ft center to center • Upper cutoff wall construction consists of one layer of horizontal and vertical rails	• Construction Drawings and Photographs
	• 0.75" - 1.25" square bars	• Used in the construction of spillway piers, deck, and other sections requiring more complex shapes	
	• Yield strength: Fy = 27 ksi		• ACI 562 (2016)
3.0 STRUCTURE REMOVAL AND DEMOLITION			
In-Channel Concrete Removal	• Concrete in river channel will be removed to a depth intended to prevent future development of fish passage impediments, as reviewed and agreed by KRRP Habitat Contractor		
	• Copco No. 1: The elevation for concrete removal at the base of the concrete dam within the dam footprint fish volition channel is 2,472.1 ft. The specific agreed thickness of riverbed fill placement over the final concrete surfaces within the dam footprint fish volition channel is 10 ft.		
	• Copco No. 2: The elevation for concrete removal within the dam footprint fish volition channel is 2,453.5 ft. Riverbed fill material will be placed to blend with natural riverbed material at the fill extents.		
Out-of-Channel Concrete Removal	• Concrete removal depth and final grading to blend with natural topography. Concrete should not be removed where concrete is necessary for rock integrity and stability	• Removal depth to be confirmed during dam deconstruction	
Cutoff Wall Removal	• The cutoff walls that protrude above the river bed surface under the J.C. Boyle and Iron Gate embankments will be removed		
	• Gunite Cutoff Wall at Copco No 2. will be partially removed and buried, as reviewed and agreed by KRRP Habitat Contractor		
4.0 DAM STRUCTURAL STABILITY CRITERIA			
Stability and Stress Analyses	• Copco No.1 reservoir pre-drawdown dam modification analyses to follow STID		• PacifiCorp, Klamath Hydroelectric Project FERC No. P-2082 Copco 1 Hydroelectric Development, Supporting Technical Information Document(STID) Rev.2 (4-30-2015)

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TABLE A7.5

KIEWIT INFRASTRUCTURE WEST CO.
KLAMATH RIVER RENEWAL PROJECT

ROADS, BRIDGES, AND CULVERTS
DESIGN CRITERIA

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Feature/Consideration	Criteria	Remarks	Reference
1.0 SITES AND ENVIRONMENT			
1.1 Hydrology and Hydraulics			
Temporary Bridge Soffit Minimum Freeboard Requirements	• Minimum freeboard for temporary bridges will be 1 ft during 5% annual probable flood. Distance is measured from water surface elevation to the lowest point on the bridge deck.	• Minimum freeboard for temporary bridges will be 1 ft during 5% Flood Events.	
Design Storm/Discharge Data	• Temporary Structures = 5% annual probable flood • Permanent Structures = 1% annual probable flood		• AASHTO
Scour	• Temporary Structures = 5% annual probable flood • Permanent Structures = Per AASHTO		• AASHTO
1.2 Seismicity			
Temporary Bridge	• Seismic Design Spectra is 10% probability of exceedence in 10 years. Site Modified spectral response for lateral acceleration = 0.082 (period = 0.2s) (USGS)		• Caltrans LRFD - Memo to Designers (May 2011) Site Seismicity for Temporary Bridges and Stage Construction.
Permanent Box Culverts	• MCE - 2% Probablity of Exceedence in 50 years • Site modified Peak Ground Acceleation (PGA_M) = 0.452		ASCE7-16
Permanent Steel Plate Arch Culvert	• MCE - 2% Probablity of Exceedence in 50 years • Site modified Peak Ground Acceleation (PGA_M) = 0.237		ASCE7-17
2.0 ROADS			
2.1 Basic Design Policies			
Temporary and Construction Access Roads Speed Limits	• 15 mph		
2.2 Roadway Geometry Design and Structure Standards			
Permanent Roads	• Match to existing per agreed to MOUs based on pre-job video as agreed to.		
Temporary Roads	• Per The Project Company		
2.3 Temporary Construction Access at Dam Sites (General)			
Design Vehicle	• 45 ton off-highway articulated haul truck	• CAT 745	
Minimum Lane Width	• 15 ft		
Safety Berm	• 3 ft where exposed to side slope.		
Minimum Curve Radius	• 35 ft		
Road Grade	• Normal road grade = ≤7% • Maximum road grade = 15%	• An exception to maximum road grade is made at the J.C. Boyle facility for portions of the lower penstock access road in order to minimize slope cuts.	
Surfacing Water Management	• As required in order to maintain safe and effective contruction access.		
2.4 Temporary Construction Access at Dam Sites (Specific)			
Copco No. 1 Right Bank Construction Access / Haul Roads	See specific design criteria memo: KP Ref VA21-00436, found in Appendix F5.		
Iron Gate Haul Road	See specific design criteria memo: KP Ref VA22-00428, found in Appendix F6.		
2.5 Public Roadway Geometric Cross Section			
Lane Width	• 11 ft minimum, or match existing width		
Number of Lanes During Construction	• Maintain one lane minimum with traffic control; • Temporary full lane closure as needed with prior approval		
Temporary roadway max turning radius	• Outside turning radius of 65'	Supplier provided turning radii.	• Per The Project Company
2.6 Pavement Design - Copco Road Rehabilitation			
Replacement of Paved Road Surfaces	• Match to existing per agreed to MOUs based on pre-job video as agreed to.		• AASHTO 1993
Replacement of Gravel Road Surfaces	• Match to existing per agreed to MOUs based on pre-job video as agreed to.		
2.7 Roadside Design			
Cut/Fill Slopes	• 1V:3H or flatter	• Embankment slopes no steeper than 1V3H wherever practical and, ideally, 1V6H or flatter.	
3.0 BRIDGES AND CROSSINGS			
General	• Replacement bridges, box culverts, and steel plate arch culvert crossings will be standard prefabricated structures, designed and supplied by a supplier.		• Per The Project Company
Strength I	• For modular highway bridges, and modular construction bridges carrying vehicular traffic and crossing over state highways, local roads, or railroads, the design vehicular live load must be HL-93 as specified in AASHTO-CA LRFD BDS Article 3.6.1.2.		• Caltrans - Memo to Designers 12-9 (Sep 2018)
Strength II	• For modular construction bridges, the design vehicular live load and special equipment loads are specified by the contractor. Load factors for Strength II as specified in AASHTOCA LRFD BDS must be applied.		• Caltrans - Memo to Designers 12-9 (Sep 2018)

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ROADS, BRIDGES, AND CULVERTS
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Feature/Consideration	Criteria	Remarks	Reference
Strength III	• For modular highway and construction bridges, wind load must be as specified in AASHTOCA LRFD BDS Article 3.8.1.2 multiplied by a reduction factor of 0.84 corresponding to 10% probability of exceedance in 10 years.		• Caltrans - Memo to Designers 12-9 (Sep 2018)
Strength V	• For modular highway and construction bridges, the wind load must be as specified in AASHTO-CA LRFD BDS Article 3.8.1.		• Caltrans - Memo to Designers 12-9 (Sep 2018)
Fatigue I	• For modular highway bridges, and modular construction bridges carrying vehicular traffic and crossing over state highways, local roads, or railroads, the infinite fatigue life design requirements as specified in AASHTO-CA LRFD BDS Article 6.6.1.2.2 must be applied.		• Caltrans - Memo to Designers 12-9 (Sep 2018)
Extreme Event I	• For modular bridges designated as “standard”, seismic load must be as specified in Caltrans Memo to Designers 20-2 “Site Seismicity for Temporary Bridges and Stage Construction”. • Force capacities must be based on the expected material properties in accordance with Caltrans Seismic Design Specifications for Steel Bridges.		• Caltrans - Memo to Designers 12-9 (Sep 2018)
Extreme Event II	• Vehicular railing must be designed for TL-4 design forces as specified in AASHTO-CA LRFD BDS Article A13.2. The regulatory speed limit must be posted for 45 MPH or less. • All components in the load path of the modular bridge system must be designed for TL-4 design forces as specified in AASHTO-CA LRFD BDS Article A13.2.”		• Caltrans - Memo to Designers 12-9 (Sep 2018)
Service I	• For modular highway bridges designated as “standard”, the vehicular live load HL-93 deflection must not exceed the limit of span length/800.		• Caltrans - Memo to Designers 12-9 (Sep 2018)
3.2 Temporary Bridge Strengthening			
Fall Creek	Temporary intermediate support system to accommodate HL93 Vehicle Loads.		
Dry Creek	Temporary intermediate support system to accommodate HL93 Vehicle Loads.		
Bridge Access	• Open to public		
Impact Loads on Foundations	• Impact load of floating debris = 1000 lbs • Maximum Impact Force of Woody Debris on Floodplain Structures (USACE, 2002)		Technical Report ERDC/CRREL TR-02-2 - (USACE, 2002)
3.3 Temporary Construction Access Bridge - Daggett			
Roadway width	• 1 lane (18 ft)		
Foundations	• Designed to accommodate construction loads during bridge installation (loads provided by supplier) • Design Vehicle = HL93 • Maximum bearing reactions to be provided by supplier. • Check flood for analyzing structural stability at the extreme event limit state = 5% event • Abutment design as per AASHTO Section 11.6.		AASHTO
Erosion Protection	• As per California Bank and Shore Rock Slope		• California Bank and Shore Rock Slope Protection Design (2000)
Bridge Access	• Construction Traffic Only at Daggett Road Temporary Bridge.		
3.4 Materials			
Structural steel			ASTM A709
Minimum Tensile Yield Strength	• fy = 36 ksi		
Minimum Ultimate Yield Strength	• fu = 65 ksi		
Unit Weight	• γ_{STEEL} = 0.284 lb/in^3		
Cast-in-place concrete (CIPC)			AASHTO - 5.4.2.1.
28-day min. Compressive strength	• f'c = 4 ksi		
Unit Weight	• γ_{CONC} = 0.145 kcf	• Normal Weight with f'c ≤ 5.0 ksi	
Pre-cast reinforced concrete	By suppliers		
Reinforcing steel for CIPC			AASHTO - 5.4.3.1
Minimum Yield strength	• f'y = 60 ksi		
Unit Weight	• γSTEEL = 0.490 kcf		
8.0 AQUATIC ORGANISM PASSAGE			
Design Flows	High Design Flow Adult Salmonids: • 1% annual probable flood or 0.5*Q2; High Design Flow Juvenile Salmonids: • 10% annual probable flood or 0.1*Q2; Low Design Flow Adult Salmonids: • 50% annual probable flood or 3 cfs; Low Design Flow Juvenile Salmonids: • 95% annual probable flood or 1 cfs		• NMFS 2019 • CDFW Part IX

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TABLE A7.5

KIEWIT INFRASTRUCTURE WEST CO.
KLAMATH RIVER RENEWAL PROJECT

ROADS, BRIDGES, AND CULVERTS
DESIGN CRITERIA

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Feature/Consideration	Criteria	Remarks	Reference
Maximum Culvert Velocities	Stream Simulation Design Method - Mimic upstream hydraulic conditions Hydraulic Design Criteria for Max Juvenile Velocity: • 1 fps Max Adult Velocity: • varies with culvert length		• NMFS 2019 • CDFW Part IX
Minimum Flow Depth	Adult Salmonids minimum depth: 1 ft Juvenile Salmonids minimum depth: 0.5		• NMFS 2019 • CDFW Part IX
Crossing Criteria - Channel Form and Slope	• Crossing width < 1.5 Active Channel Width • Channel slope < 6% • Conveys sediment and debris		• CDFW Part XII • Technical White Paper 2017.06.20 • NOAA 2011 • NMFS 2019
8.1 Stream Design			
Rock Scour and Slope Protection	• Stable Rock Gradation based on USACE equations, • Side Slope >/= to 1.5 H :1 V • USACE Method for Steep Slopes for bed slopes >2% • Minimum blanket thickness >1.5*d50 or d100		• NCHRP Report 568 • USACE EM 1110-2-1601
Large Wood Structures	• Meet criteria described in Reservoir Restoration for Bank Stabilization		• USBR & ERDC National Large Wood Manual
Stream stabilization	• Design Flood = 1% PPE • Engineered Stream Bed Material sized using CDFW methodology • Active channel width equal to active channel width in unimpaired reaches • Overbanks <0.5*Active chanel width		• CDFW Part XIII Fish Passage Design and Implementation
9.0 CULVERTS			
9.1 Temporary/Permanent Culverts			
General	• Temporary Culverts and Permanent Culverts shall be designed in accordance with the appropriate references for each state.		• AASHTO
9.2 Hydraulic Capacity			
Permanent Culvert Design Flow	• 2% annual probable flood		• AASHTO
Permanent Culvert Check Flood	• 1% annual probable flood		• AASHTO
Temporary Bypass Flows	• Monthly 5% annual probable flood		
9.3 Design Loads			
Vehicle Load	• Culverts shall be designed for HL-93 vehicle loads		• AASHTO
9.4 Existing Culverts			
Existing culvert replacement	• Replace in kind when needed.		

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TABLE A7.6

KIEWIT INFRASTRUCTURE WEST CO.
KLAMATH RIVER RENEWAL PROJECT

MATERIAL DISPOSAL
DESIGN CRITERIA

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Feature/Consideration	Criteria	Remarks	Reference
1.0 DISPOSAL REQUIREMENTS AND LOCATIONS			
1.1 J.C. Boyle			
Excavated Embankment Materials	• Shall be disposed in the J.C. Boyle disposal sites	• Embankment riprap will be excavated and stockpiled for later use	
Concrete Rubble	• Concrete rubble shall be disposed in scour hole below power canal spillway		
	• Concrete rubble from J.C. Boyle powerhouse and penstock anchors shall be disposed in the J.C. Boyle tailrace and covered with native materials to blend with surrounding topography		
	• Concrete rubble in the scour hole shall be covered with a 4 ft minimum thickness cover		
1.2 Copco No. 1 and No. 2			
Concrete Rubble	• Concrete rubble from Copco No. 1 and Copco No. 2 dam shall be disposed in Copco disposal site • The disposal site shall be stripped of subsoil prior to rubble placement, and stockpiled to be used later to cover the disposal site		
	• Concrete footings from Copco No. 2 Woodstave Penstock shall be laid down and buried on site using the adjacent access road material		
	• Concrete rubble from Copco No. 2 powerhouse and penstock anchors shall be disposed in the Copco No. 2 tailrace and covered with native materials to blend with surrounding topography		
Woodstave Penstock	• Wood from the woodstave penstock will be transported off site and disposed of in a licenced facility		
1.3 Iron Gate			
Excavated Embankment Materials	• Excavated embankment materials shall be disposed in the spillway and in the disposal sites. The spillway shall be filled first to the maximum extent possible while still meeting the requirements for stability		
Concrete Rubble	• Concrete rubble shall be disposed of in the disposal sites and covered with a minimum 3 feet of excavated embankment material		
1.4 Common Criteria			
Partially Removed Concrete Structures	• Partially removed concrete structures shall be covered with a minimum of 2 ft of stable fill		
Cover	• The disposal sites shall be covered with fill and shall be designed to meet the ecological design criteria and blend into the landscape as naturally as possible		
Slope Stability	• Minimum required FOS = 1.5 for Long-term slope stability • Design earthquake for permanent construction		
Drainage	• Maximum exit gradient for seepage • Design storm for surface drainage and erosion control/protection design		

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TABLE A7.7

KIEWIT INFRASTRUCTURE WEST CO.
KLAMATH RIVER RENEWAL PROJECT

DAM SITE PERMANENT WORKS
DESIGN CRITERIA

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Feature/Consideration	Criteria	Remarks	Reference
1.0 GENERAL			
Design Life	• 50 years		
Design Flood for River Channel Erosion Protection	• 1% probable flood	• Erosion protection will be provided for permanent fill slopes within the dam excavation footprints. Erosion protection is not required on bedrock slopes. • Habitat features: additional rock or other materials requested by Habitat Contractor for aquatic habitat purposes to be shown on the Habitat Contractor design documents.	
Seismic Parameters	• As per the STID for the respective sites		

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