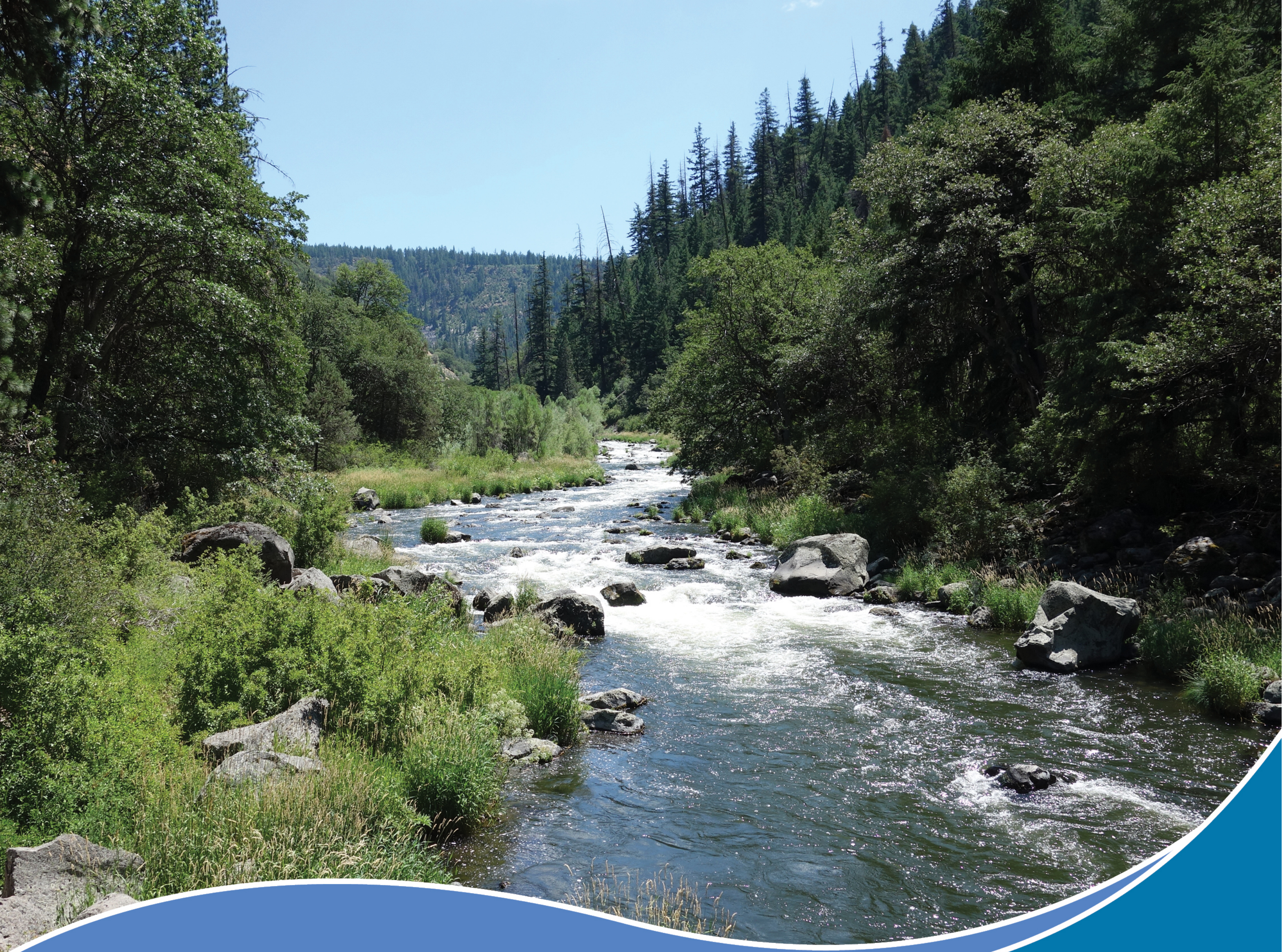
UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION

Klamath River Renewal Corporation	**Project Nos. 14803-001;**
PacifiCorp	**2082-063**

AMENDED APPLICATION FOR SURRENDER OF LICENSE FOR MAJOR PROJECT AND REMOVAL OF PROJECT WORKS

Attachment A-1

Lower Klamath Project Biological Assessment



Lower Klamath Project

Biological Assessment

KLAMATH RIVER RENEWAL CORPORATION

March 2021

Prepared for:

The Renewal Corporation

Prepared by:

Renewal Corporation Technical Representatives:

AECOM Technical Services, Inc.
300 Lakeside Drive, Suite 400
Oakland, California 94612

Camas, LLC
680 G Street, Suite C
Jacksonville, Oregon 97530

CDM Smith
1755 Creekside Oaks Drive, Suite 200
Sacramento, California 95833

River Design Group
311 SW Jefferson Avenue
Corvallis, Oregon 97333

Camas, LLC
680 G Street, Suite C
Jacksonville, Oregon 9753

Resource Environmental Solutions, LLC
22 Battery Street, Suite 508
San Francisco, California 94111

Table of Contents

List of Tables

List of Figures (Appendix A)

Appendices

Acronyms and Abbreviations

AFA	Aphanizomenon flos-aquae (a nitrogen-fixing cyanobacteria)
ASR	Aquatic Scientific Resources
ATWG	Aquatic Technical Work Group
BA	Biological Assessment
BLM	Bureau of Land Management
BMP	best management practice
BO	Biological Opinion
BOD	biological oxygen demand
BRT	Biological Review Team
°C	degrees Celsius
California HSRG	California Hatchery Scientific Review Group
CBD	Center for Biological Diversity
CDFG	California Department of Fish and Game (now CDFW)
CDFW	California Department of Fish and Wildlife
CDWR	California Department of Water Resources
CEF	Coho Enhancement Fund
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
CFR	Code of Federal Regulations
cfs	cubic feet per second
cfm	cubic feet per minute
CHSU	critical habitat subunit
CNDDB	California Natural Diversity Database
CNPS	California Native Plant Society
CWA	Clean Water Act
cy	cubic yard
DOI	United States Department of the Interior
DSOD	California Division of Safety of Dams
DPS	Distinct Population Segment
EFH	Essential Fish Habitat
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
EPIC	Environmental Protection Information Center
ESA	federal Endangered Species Act
ESU	Evolutionarily Significant Unit

°F	degrees Fahrenheit
FERC	Federal Energy Regulatory Commission
FR	Federal Register
ft	feet
GEC	Gathard Engineering Consulting
GIS	geographic information system
HCP	Habitat Conservation Plan
HGMP	Hatchery Genetic Management Plan
IHN	infectious haematopoietic necrosis
IM	Interim Measure
in	inch
IOD	Immediate Oxygen Demand
IOP	Interim Operations Plan
ISAB	Independent Scientific Advisory Board
KBRA	Klamath Basin Restoration Agreement
KHP	Klamath Hydroelectric Project
KHSA	Klamath Hydroelectric Settlement Agreement
KP	Knight Piésold Consulting
KPO	Klamath Project Operations
KRRP	Klamath River Renewal Project
KRTT	Klamath River Technical Team
kV	kilovolt
lbs	pounds
LRS	Lost River suckers
LWD	large woody debris
m	meters
m2	square meters
mg	milligram
mg/L	milligram per liter
µg/L	micrograms per liter
min	minute
mm	millimeters
mph	miles per hour
MSNO	Master Site Number
NCRWQCB	North Coast Regional Water Quality Control Board
nDPS	Northern Distinct Population Segment
NEPA	National Environmental Policy Act

NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
NRCS	Natural Resources Conservation Service
NSO	northern spotted owl
NWFSC	Northwest Fisheries Science Center
NWR	National Wildlife Refuge
ODFW	Oregon Department of Fish and Wildlife
ODEQ	Oregon Department of Environmental Quality
OWHM	ordinary high water mark
PBF	Physical and Biological Feature
POEA	polyethoxylated tallow amine
RM	River Mile
RT	round trip
sDPS	Southern Distinct Population Segment
sf	square feet
SNS	shortnose suckers
SONCC	Southern Oregon Northern California Coast
SSC	suspended sediment concentration
SWRCB	State Water Resources Control Board
TER	Terrestrial Resources
TMDL	total maximum daily load
TN	total nitrogen
TP	Total Phosphorous
TSS	total suspended solids
USACE	United States Army Corps of Engineers
USBR	United States Bureau of Reclamation
USDA	United States Department of Agriculture
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
USEPA	United States Environmental Protection Agency
VFP	Volitional Fish Passage
WaterKeepers	WaterKeepers Northern California
WDFW	Washington Department of Fish and Wildlife
WHO	World Health Organization
WSL	water surface level

WY	water year
YOY	young of the year
yr	year
YTEP	Yurok Tribe Environmental Program

Chapter 1: Introduction and Background

1. INTRODUCTION AND BACKGROUND

1.1 Purpose of the Biological Assessment

This Biological Assessment (BA) was prepared by the Klamath River Renewal Corporation (the Renewal Corporation), the designated non-federal representative of the Federal Energy Regulatory Commission (FERC) for the license surrender for the Lower Klamath Project. The Renewal Corporation and its technical representatives prepared this BA in accordance with Section 7(c) of the federal Endangered Species Act (ESA) to evaluate the effects to ESA-listed species from the proposed removal of four hydroelectric developments on the Klamath River: J.C. Boyle, Copco No. 1, Copco No. 2, and Iron Gate (Proposed Action).

The ESA requires federal agencies to ensure that any action authorized, funded, or carried out is not likely to jeopardize the continued existence of listed species, or result in the destruction or adverse modification of critical habitat. To fulfill this requirement, FERC, as the Action Agency, must submit a BA in accordance with 50 Code of Federal Regulations (CFR) Part 402 of the implementing regulations for the ESA. Pursuant to Section 7(a)(2) of the ESA, if FERC determines that the Proposed Action may affect a listed species or a species proposed for listing or designated or proposed critical habitat, it must consult with the United States Fish and Wildlife Service (USFWS) on listed terrestrial species and inland fish and with the National Marine Fisheries Service (NMFS) on listed marine species and anadromous (migrating between the ocean and fresh water) fish. As described in Section 1.6, this document contains an Essential Fish Habitat (EFH) assessment in Appendix K. Pursuant to the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act), federal agencies must consult with NMFS regarding any of their actions authorized, funded, or undertaken, or proposed to be authorized, funded, or undertaken, that may adversely affect EFH.

The Proposed Action (fully described in Chapter 2) includes the removal of the four hydroelectric developments (developments, in this context, include the dams and their associated hydroelectric generation facilities and support structures) over an approximately 20-month period, which includes a 6- to 9-month period of site preparation and a subsequent 12-month period for full reservoir drawdown and removal of the four developments. The Proposed Action includes removal of the dams, power generation facilities, water intake structures, canals, pipelines, and ancillary buildings and the partial removal of transmission lines and the dam foundations to restore a free-flowing river. The Proposed Action also includes the restoration of the areas formerly inundated by the reservoirs, reconnecting streams and stabilizing lands disturbed by the dam facility removal.

The purpose of the project is to facilitate large-scale fisheries restoration by addressing system-wide limiting factors such as lack of fish passage, warm fall temperatures, blue-green algae blooms, sediment supply and transport disruptions, and other factors. The final outcome will be a free-flowing river with normative ecological function for fish passage and water temperature. Thus, the Proposed Action will have short-term impacts to fish and wildlife species as a result of dam demolition and sediment release for the purpose of establishing long-term benefits as the river and the fish and wildlife species recover.

The removal of the four dams will provide a free-flowing river with volitional fish passage from downstream of Keno Dam to the Pacific Ocean. Dam removal is expected to aid in the recovery of ESA-listed coho salmon (*Oncorhynchus kisutch*) by:

- Providing access to historical anadromous fish habitat in the reach upstream of the Iron Gate Dam site to the headwaters of the Klamath Basin via the existing fish passage facilities at Keno Dam and Link River Dam[1]. This will increase the geographic distribution and genetic diversity of coho salmon in the Klamath, thus improving the long-term viability and recovery of this species.
- Restoring the recruitment of gravel (i.e., the natural process of gravel transport and deposition) in the Hydroelectric Reach (the reach of the Klamath River that encompasses the four dams and associated facilities) and downstream of Iron Gate Dam, which will benefit fish spawning, food production, and provide habitat for juvenile Pacific lamprey.
- Creating a more mobile streambed. This is expected to reduce fish disease by decreasing the population of annelid worms that serve as an alternate host for *Ceratonova shasta* (*C. shasta*), a deadly fish disease that causes significant juvenile coho salmon and Chinook salmon (*O. tshawytscha*) mortality in some years.
- Improving water quality.

The process of reservoir drawdown and dam removal will have acute short-term impacts, but similar efforts in other rivers (Elwha, Condit, Marmot) demonstrate that the river system and its fish resources are capable of recovering quickly after the short-term impacts have subsided.

1.2 Project Background

The Klamath Basin's hydrologic system consists of a complex of interconnected rivers, lakes, marshes, dams, diversions, wildlife refuges, wilderness areas, other federal and state lands, and private lands. Alterations to the natural hydrologic system began in the late 1800s and accelerated in the early 1900s. Currently, there is a complex network of water uses in the Klamath Basin, including the United States Bureau of Reclamation's (USBR's) Klamath Project (explained below), the operation of several hydroelectric dams by the privately owned PacifiCorp, and diversions by private users.

1.2.1 PacifiCorp's Klamath Hydroelectric Project

PacifiCorp's Klamath Hydroelectric Project (KHP) (FERC Project No. 2082) was constructed between 1911 and 1962 and included eight developments: the East and West Side power facilities (on the Link River) and the Keno, J.C. Boyle, Copco No. 1, Copco No. 2, Fall Creek, and Iron Gate facilities. Operation of the KHP, with the exception of Fall Creek, is made possible by water releases by USBR from Upper Klamath Lake via Link River Dam, a facility owned by USBR and operated by PacifiCorp. However, Link River Dam and Upper

[1] The proposed action does not include improvements at Keno Dam or Link River Dam.

Klamath Lake (see Figure 1-1 [all figures referenced in this BA are in Appendix A]) are not part of the KHP. Fall Creek powerhouse operates from the flows in Fall Creek, a tributary to the Klamath River.

Although USBR's Link River Dam and PacifiCorp's Keno Dam currently have fish ladders, none of the other mainstem dams were constructed with fish ladders sufficient to pass anadromous fish[2], and, as a result, fish have been blocked from accessing the upper reaches of the Klamath Basin for more than a century since the start of construction of Copco No. 1 Dam in 1911. Beginning in 1956, Iron Gate Dam (the most downstream mainstem dam) flow releases were generally governed by guidelines outlined in the FERC license, commonly referred to as "FERC minimum flows." The current FERC license was originally issued in 1954, prior to enactment of the ESA, and expired on March 1, 2006; the KHP is now operating under annual licenses from FERC. On February 25, 2004, PacifiCorp filed an application with FERC for a new license. In parallel with the FERC relicensing process, PacifiCorp engaged in relicensing settlement talks with a wide range of parties, culminating in a settlement agreement in 2010 taking a portion of the project into a decommissioning action. This is described in more detail in Section 1.2.3.

1.2.2 USBR's Klamath Project

Separate from the KHP and located upriver, the USBR's Klamath Project is a water-management project intended to supply irrigation water for agricultural uses in the Upper Klamath Basin. The project also supplies water to the Tule Lake National Wildlife Refuge and the Lower Klamath National Wildlife Refuge. Management of USBR's Klamath Project affects the baseline conditions in the Klamath River that are considered when evaluating the effects of the Proposed Action. In 2010, NMFS issued a Biological Opinion (BO) on the operation of USBR's Klamath Project to address potential effects on two listed species of sucker (Lost River sucker [*Deltistes luxatus*] and shortnose sucker [*Chamistes brevirostris*]) and coho salmon. Subsequently, USBR developed a new operation plan and NMFS and USFWS issued a new joint BO in 2013. More recently, USBR's Klamath Project operations were governed by the 2013 BO and a 2017 court-ordered injunction, which required USBR to implement flushing flows and emergency dilution flows intended to reduce and mitigate the effects of *Ceratonova shasta* (*C. shasta*) on coho salmon in the Klamath River.

In 2017, USBR formally reinitiated consultation with NMFS and USFWS on the continued operation of the Klamath Project in response to consecutive years of drought and the 2014 and 2015 exceedance of incidental take of coho salmon. Based on information provided in USBR's Final BA and subsequent addenda and clarifications, NMFS and USFWS issued BOs on USBR's Klamath Project operations in 2019 (NMFS 2019a and USFWS 2019a); the BOs were subsequently modified by an Interim Operations Plan (IOP) in 2020 as a result of litigation brought by the Yurok Tribe. The NMFS and USFWS BOs and the IOP cover USBR's Klamath Project operations from April 1, 2019, through March 31, 2024. USBR is presently engaged in a re-consultation effort that will provide a new operating plan and BOs by March 1, 2023, and will govern operations during and after dam removal. USBR is coordinating with the Renewal Corporation to ensure its plans and dam removal will work together.

[2] The J.C. Boyle facility has a fish ladder that is marginally suitable for redband trout.

1.2.3 The Klamath Hydroelectric Settlement Agreement

Stakeholders began efforts to reach agreement on the multifaceted issues in the Klamath Basin in the early 2000s, and the efforts to reach a settlement increased in 2001 and 2002, following the water-related farming and fisheries crises experienced in the Klamath Basin during those years. Declining fish populations led to the federal listing of coho salmon as a threatened species (NMFS 1997). In 2002, between 33,000 and 78,000 returning adult Chinook salmon, coho salmon, and steelhead (*O. mykiss*) perished in the mainstem Klamath River from a fish disease outbreak that was intensified by low flows, high water temperatures, high densities, and extended residence time of migrating fish (Guillen 2003, Belchik et al. 2004). In 2005, the commercial salmon ocean harvest was heavily restricted; in 2006, more than 700 miles of the Oregon and California coast were closed to salmon fishing to protect the weak Klamath stock in a mixed-stock ocean fishery; and in 2008, federal authorities declared the West Coast ocean salmon fishery a failure. The likelihood that low salmon stocks will continue, coupled with significant operational changes PacifiCorp would need to make to continue operating the KHP, led Klamath Basin stakeholders and Native American Tribes to begin collaborative discussions with PacifiCorp and others, with the goal of developing mutually beneficial agreements as a sustainable option for addressing the problems facing the Klamath Basin's natural resources.

Official negotiations that led to the Klamath Hydroelectric Settlement Agreement (KHSA) and Klamath Basin Restoration Agreement (KBRA) settlement began in 2005. The KHSA was an outcome of FERC's Alternative Dispute Resolution Procedures, as outlined in the Energy Policy Act of 2005 (18 CFR 385.601, et seq.), wherein the parties elected to set aside differences to reach resolution on a settlement in furtherance of the interests of the parties. As established in Section 1.1 and Section 1.2 of the KHSA, many of the parties to the settlement maintained that facilities removal would help restore Klamath Basin resources, and the Signatory Parties agreed that settlement would help reduce conflicts among Klamath Basin communities.

In 2010, the KHSA was signed, whereby PacifiCorp and other parties agreed to pursue the proposed removal of the four lower hydroelectric developments as an alternative to relicensing. The KHSA was the culmination of years of negotiations by a diverse group of stakeholders. Signatories to the 2010 KHSA included federal, state, and local governments, Tribes, PacifiCorp, and nine conservation and fishing groups.

1.2.4 Amended KHSA

When Congress did not ratify the KBRA and certain provisions of the KHSA, the parties reconvened to amend the KHSA. The KHSA was amended in April 2016, and the Renewal Corporation was formed to serve as the dam removal entity. The KBRA was not funded by Congress; therefore, it is no longer a viable action and is not evaluated herein.

1.2.5 Previous Relevant ESA Consultations and Permits

In accordance with Section 10(a)(1)(B) of the ESA, PacifiCorp finalized two Habitat Conservation Plans (HCPs) for interim operation of the Klamath hydroelectric facilities prior to the potential removal of the four hydroelectric developments as part of the KHSA or prior to implementation of mandatory fishways that would be required under any new license for the KHP if the KHSA is terminated for any reason. The HCP for coho salmon was finalized in 2012 (PacifiCorp 2012), and the HCP for Lost River and shortnose suckers was finalized in 2013 (PacifiCorp 2013b). NMFS and USFWS issued associated incidental take permits for coho salmon and Lost River and shortnose suckers, respectively. Under the HCPs, PacifiCorp is responsible for implementing several extensive conservation measures, as described in Section 4.6.8 (Water Quality) and Section 4.8.1.1 (Aquatic Habitat) of the HCPs.

In 2012, USBR requested early consultation with NMFS and USFWS and a preliminary BO pursuant to Section 7(a)(3) of the ESA and the EFH provisions of the Magnuson-Stevens Act for the proposed removal of the four hydroelectric developments. On November 19, 2012, NMFS and the USFWS issued a joint preliminary BO, and NMFS issued a Magnuson-Stevens Act EFH consultation response, based on USBR's proposed action for dam removal (NMFS and USFWS 2012).

On October 31, 2014, NMFS issued a Scientific Research and Enhancement Permit to CDFW in accordance with ESA section 10(a)(1)(A), which authorizes take of ESA-listed Southern Oregon Northern California Coast (SONCC) coho salmon Evolutionarily Significant Unit (ESU) associated with implementation of the Hatchery and Genetic Management Plan for the Iron Gate Hatchery coho salmon program.

1.2.6 FERC License Transfer and Surrender

Pursuant to Sections 7.1.5 and 7.1.7 of the KHSA, on September 23, 2016, PacifiCorp and the Renewal Corporation filed a "Joint Application for Approval of License Amendment and License Transfer" (Transfer Application) seeking a separate license for the J.C. Boyle, Copco No. 1, Copco No. 2, and Iron Gate developments (the Lower Klamath Project), and to transfer the license for the Lower Klamath Project from PacifiCorp to the Renewal Corporation. Concurrent with this filing, the Renewal Corporation filed an Application for Surrender of License for Major Project and Removal of Project Works (Surrender Application), seeking FERC's approval of an application to surrender the license for the Lower Klamath Project.

FERC noticed the Transfer Application and the Surrender Application on November 10, 2016. FERC initiated informal consultation with (a) the USFWS and NMFS under Section 7 of the ESA and the joint agency implementing regulations at 50 CFR Part 402; and (b) NMFS under Section 305(b) of the Magnuson-Stevens Act and implementing regulations at 50 CFR Part 600.920. FERC also designated the Renewal Corporation as the non-federal representative for carrying out informal consultation, pursuant to Section 7 of the ESA and Section 305(b) of the Magnuson-Stevens Act.

On March 15, 2018, FERC amended the KHP license, which created the Lower Klamath Project (FERC Project No. 14803), consisting of J.C. Boyle, Copco No. 1, Copco No. 2, and Iron Gate developments. On June 21, 2018, FERC stayed the effectiveness of the license amendment for the Lower Klamath Project pending its final action on the transfer application.

On July 15, 2020, FERC approved a partial transfer of license to the Renewal Corporation. It required PacifiCorp to remain as co-licensee following the Renewal Corporation's acceptance of such transfer through license surrender. On November 17, 2020, PacifiCorp and the Renewal Corporation filed an Amended

License Surrender Application. This application included the Definite Decommissioning Plan, which is the Renewal Corporation's comprehensive plan to physically remove the Lower Klamath Project and achieve a free-flowing condition and volitional fish passage, site remediation and restoration, and avoidance of adverse downstream impacts. On the same date, a Memorandum of Agreement (MOA) was reached between PacifiCorp, the states of California and Oregon, the Renewal Corporation, and the Yurok and Karuk Tribes. An amended license transfer application was filed on January 13, 2021, that incorporated provisions from both the FERC's July 15 partial transfer of license order as well as the MOA. The application proposed that the states will be co-licensees (rather than PacifiCorp) with the Renewal Corporation for purpose of license surrender. On February 25, 2021, the Renewal Corporation filed with FERC final decommissioning design specifications and sixteen management plans establishing the resource protection measures.

1.3 Project Summary

The Proposed Action, as described in detail in Chapter 2 of this BA, includes the decommissioning and removal of four dams (Iron Gate, Copco No. 1, Copco No. 2, and J.C. Boyle) and associated facilities on the Klamath River by the Renewal Corporation. The Proposed Action extends from Iron Gate Dam in California to the upstream extent of J.C. Boyle Reservoir in Oregon. Figure 1-1 (Appendix A) provides an overview of the Klamath River watershed and the locations of the four dams, and Table 1-1 provides the position of key geographic locations discussed within this BA in river miles of the Klamath River as a distance from the Pacific Ocean. River miles were determined using a river route derived from 2018 bathymetric surveys and represent the best available information.

Table 1-1: Position of Key Locations on the Klamath River in River Miles

Location	River Mile	Location	River Mile
Proposed Action	193.1 to 234.1	Humbug Creek	173.9
Link River at Klamath Falls	260.5	Beaver Creek	163.3
Highway 97 bridge	255.3	Horse Creek	149.5
Keno Dam	239.2	Kinsman rotary screw trap	147.6
Upstream extent of J.C. Boyle Reservoir	234.1	Scott River	145.1
Spencer Creek	233.4	Tom Martin Creek	144.6
Highway 66 bridge	232	O'Neil Creek	139.1
J.C. Boyle Dam	230.6	Walker Creek	135.2
J.C. Boyle Powerhouse	226	Seiad Valley	132.5
Shovel Creek	212	Grider Creek	132.1
Upstream/downstream reach of Copco No. 1 reservoir delineation	205	Seiad Creek	131.9
Copco No. 1 Dam and Powerhouse	202.2	West Grider Creek	131.8
Copco No. 2 Dam	201.8	Portuguese Creek	128
Copco No. 2 Powerhouse	200.3	Cade Creek	110.9

Location	River Mile	Location	River Mile
Fall Creek (Iron Gate)	199.8	Elk Creek	107.1
Jenny Creek	197.4	Sandy Bar Creek	77.8
Camp Creek (Iron Gate)	195.2	Stanshaw Creek	77.1
Iron Gate Dam and Powerhouse	193.1	Salmon River	66.3
Bogus Creek	192.6	Orleans	59
Dry Creek	190.9	Camp Creek	57.4
Little Bogus Creek	189.8	Trinity River	43.4
Willow Creek	188	Roach Creek	30.8
Cottonwood Creek	185.1	Terwer Creek	5.8
Shasta River	179.3	Terwer gage	5.8
Tree of Heaven Campground	174.4	Lower estuary	0.5

Prior to removal of the dams and hydropower facilities, the Renewal Corporation will draw down the water surface in each reservoir to an elevation that is as low as possible while also facilitating evacuation of accumulated sediment and creating a dry work area for facility removal activities. In general, reservoir drawdown below the normal operating ranges will begin on January 1 of the drawdown year and will extend until reservoir levels have stabilized at or below the level of the historic cofferdams. After reservoir drawdown is accomplished, remaining reservoir sediments will be considered stabilized, and dam and hydropower facility removal will begin.

The Proposed Action is described in detail in Chapter 2:

- Section 2.1 describes the drawdown timing and duration, as well as any infrastructure modifications necessary to facilitate drawdown.
- Section 2.2 describes the drawdown rates.
- Section 2.3 details the facility removal and summarizes pertinent activities, material volumes, truck trips, and other construction means and methods.
- Section 2.4 describes plans for restoration of the reservoir areas, which will begin after drawdown, continue throughout the year, and extend into the subsequent year. Vegetation establishment could extend into several subsequent years.
- Section 2.5 describes other components of the Proposed Action, including road and bridge improvements, improvements to the City of Yreka's water conveyance pipeline across Iron Gate Reservoir, removal and creation of various recreation facilities adjacent to the reservoirs, and fish hatchery modifications and improvements.
- Section 2.6 describes the conservation measures to reduce the Proposed Action's effects to listed aquatic and terrestrial species.
- Section 2.7 provides a summary of, and schedule for, the in-water work activities associated with the Proposed Action.

1.4 Listed Species and Critical Habitat

The Renewal Corporation has coordinated closely with federal and state agencies, including NMFS, USFWS, CDFW, Oregon Department of Fish and Wildlife (ODFW), Bureau of Land Management (BLM), and United States Forest Service (USFS) for current information on the listed species and critical habitat included in this BA.

The Renewal Corporation obtained information on federally listed species that may be affected by the Proposed Action from the following sources:

- USFWS and NMFS lists of federally listed endangered, threatened, proposed, and candidate species and critical habitats;
- Federal and state databases, including the Information for Planning and Consultation database, the California Natural Diversity Database (CNDDB), and the Oregon Biodiversity Information Center, as well as information from the BLM and USFS;
- The California Native Plant Society online Inventory of Rare and Endangered Vascular Plants of California (CNPS 2018) was searched for the United States Geological Survey (USGS) 7.5-minute quadrangles that fall within the Action Area (i.e., the Klamath River corridor and the Upper Klamath Lake and the surrounding quadrangles);
- Results of plant and wildlife surveys conducted by PacifiCorp in 2002 through 2004 (PacifiCorp 2004a);
- BAs and BOs developed by the USFWS and NMFS for the Klamath Basin, including:
  - NMFS (2002) – Biological Opinion on the USBR Klamath Project operations
  - NMFS (2010a) – Biological Opinion for Operation of the USBR Klamath Project between 2010 and 2018
  - USFWS and NMFS (2012) – Joint Preliminary Biological Opinion on the Proposed Removal of Four Dams on the Klamath River
  - NMFS (2012) -Biological Opinion for the Interim Operations Habitat Conservation Plan
  - NMFS and USFWS (2013) – Biological Opinion Addressing the Effects of Proposed [USBR] Klamath Project Operations from May 31, 2013 through March 31, 2023 on Five Federally Listed Threatened and Endangered Species
  - NMFS (2019a) – Biological Opinion and Essential Fish Habitat Response, Klamath Project Operations from April 1, 2019 through March 31, 2024
  - USFWS (2019a) – Biological Opinion on the Effects of Proposed Klamath Project Operations from April 1, 2019, through March 31, 2029, on the Lost River Sucker and the Shortnose Sucker
  - USBR (2019) – Biological Assessment on the Effects of Proposed Klamath Project Operations from April 1, 2019, through March 31, 2029 on Federally Listed Threatened and Endangered Species

This BA also uses information presented in the 2012 BA:

- Species profiles developed by NMFS (http://www.nmfs.noaa.gov/pr/species/) and USFWS (http://www.fws.gov/arcata/ and https://ecos.fws.gov/ecp/);
- 2012 Klamath Facilities Removal Environmental Impact Statement/Environmental Impact Report (EIS/EIR) and appendices (USBR and CDFW 2012); and
- Numerous scientific studies, assessments, and surveys.

Table 1-2 lists the federally threatened and endangered species and designated and proposed critical habitat evaluated in this BA. The potential effects on these species and critical habitat are discussed in further detail in Chapter 5. Appendix B provides a list of the species that were considered but excluded from further analysis in this BA because they do not occur in the Action Area or are not currently federally listed but may become listed before or during implementation of the Proposed Action. Appendix B summarizes information on each of the species' distributions and habitat associations.

Table 1-2: Federally Threatened and Endangered Species and Designated Critical Habitat Evaluated in the BA

Scientific Name	Common Name	Listing[1]	Critical Habitat[2]	Portion of Action Area
Fish				
Oncorhynchus kisutch	SONCC coho salmon	T	Y	Upper, middle, and lower Klamath Basin
Acipenser medirostris	Southern Distinct Population Segment (DPS) green sturgeon	T	Y	Marine
Thaleichthys pacificus	Southern DPS eulachon	T	Y	Lower Klamath River
Deltistes luxatus	Lost River sucker	E	Y	Upper Klamath Basin
Chasmistes brevirostris	Shortnose sucker	E	Y	Upper Klamath Basin
Salvelinus confluentus	Bull trout	T	Y	Upper Klamath Basin
Birds				
Strix occidentalis caurina	Northern spotted owl	T	Y	May occur within 1.5 miles of project limits of work
Amphibians				
Rana pretiosa	Oregon spotted frog	T	Y	Upper Klamath Basin in tributaries to Upper Klamath Lake; Middle Klamath Basin in upper reaches of Spencer Creek
Mammals				
Orcinus orca	Southern Resident killer whale	E	Y, Proposed Revision	Marine

Scientific Name	Common Name	Listing[1]	Critical Habitat[2]	Portion of Action Area
Key: [1] Listing E Federally Endangered T Federally Threatened	[2] Critical Habitat Y Yes -designated critical habitat occurs in Action Area			

1.5 New Consultation on the Proposed Action

The removal of the four Klamath dams was previously evaluated in the USBR 2012 BA and Joint Preliminary BO (NMFS and USFWS 2012). While the Proposed Action is fundamentally the same as the action evaluated in the 2012 BA and Joint Preliminary BO (NMFS and USFWS 2012), there are important changes to the Proposed Action requiring a new initiation of consultation. These changes include FERC as the federal Action Agency, the flows reviewed under the NMFS and USFWS 2019 BOs on operation of the USBR's Klamath Project and IOP, listed species and/or species status under ESA, and current baseline environmental conditions.

To date, several workshops and numerous conference calls have been held with agency representatives in support of consultation under Section 7 of the ESA and Section 305(b) of the Magnuson-Stevens Act. These workshops have primarily focused on discussing the potential short-term effects the project may have on federally threatened and endangered species currently inhabiting the Klamath River as balanced against long-term recovery effects, current and potential measures that may be implemented to reduce short-term effects, and the development of a monitoring plan to ensure the effectiveness of proposed measures. On May 23, 2017, the Renewal Corporation met with representatives of federal and state agencies and Tribes to discuss the Proposed Action and kick off the consultation and coordination processes for Section 7 compliance and for compliance with other regulatory standards. As part of this consultation, the Renewal Corporation convened an Aquatic Technical Work Group (ATWG) composed of agency and tribal fisheries scientists to review and update the aquatic resource mitigation measures included in the 2012 EIS/EIR.

Dates and a brief description of the topics discussed at each workshop or meeting are provided below:

- April 28, 2017, Lower Basin Agency Meeting – overview of proposed 2017 project activities, including schedule, review and discussion of mitigation measures previously included in the 2012 BO, EIS/EIR, and a Detailed Plan specific to threatened and endangered species identified in the 2012 project Action Area. Attendees included the Renewal Corporation, NMFS, USFWS, and CDFW.
- May 23, 2017, Aquatic and Terrestrial Resource Meeting – discussion of concerns specific to aquatic resource relocation and potential mortality rates of spawning and juvenile species, analysis of coho salmon effects in the BA, and proposed mitigation measures. This meeting also included a discussion on proposed survey plans and potential minimization measures for terrestrial species, including northern spotted owl (NSO) and listed plants. USFWS and NMFS provided input on the listed species and potential effects to be included in the evaluation presented in this BA. Attendees included the Renewal Corporation, NMFS, USFWS, CDFW, Oregon Department of Environmental

Quality (ODEQ), North Coast Regional Water Quality Control Board (NCRWQCB), State Water Resources Control Board (SWRCB); and the Hoopa Valley, Yurok, Karuk, and Klamath tribes.

- May 24, 2017, Aquatic Resources Measures Planning Meeting (Suckers) – Sucker genetics, trapping and relocation, and potential mitigation measures. Attendees included the Renewal Corporation, USFWS, and USGS.
- June 13, 2017, Aquatic Resources Measures Planning Meeting – discussion of the 2012 Aquatic Resource Mitigation Measures, development and implementation of an effectiveness monitoring plan, and revised Aquatic Resource Measures Specific to Mainstem Spawning, Outgoing Juveniles, and Pacific Lamprey. Attendees included the Renewal Corporation, NMFS, USFWS, CDFW, and the Hoopa Valley, Yurok, and Karuk tribes.
- June 19, 2017, Aquatic Resources Measures Planning Meeting (Suckers) – sampling/salvage of suckers and appropriate methodology, relocation of suckers, and permitting options. Attendees included the Renewal Corporation, USFWS, USGS, CDFW, ODFW, and Klamath tribes.
- July 27, 2017, Agency Visit to Project Site – site visit with a focus on terrestrial resources measures and overview of project components. Attendees included the Renewal Corporation, USFWS, CDFW, ODFW, and Oregon Department of State Lands.
- August 15, 2017, Aquatic Resources Measures Planning Meeting – ongoing discussions pertaining to refinements to the 2012 Aquatic Resource Mitigation Measures, development and implementation of an effective monitoring plan, and revised Aquatic Resource Measures Specific to Mainstem Spawning, Outgoing Juveniles, and Pacific Lamprey. Attendees included the Renewal Corporation,NMFS, USFWS, CDFW, ODFW, ODEQ, SWRCB, and the Hoopa Valley, Yurok, and Karuk tribes.
- October 26, 2017, Aquatic Resources Measures Planning Meeting – proposed monitoring periods, laboratory experiments for turbidity and suspended sediments, evaluation of spawning habitat, and salmonid behavioral response to high sediment loads. Attendees included the Renewal Corporation, NMFS, USFWS, CDFW, ODFW, and the Hoopa Valley, and Yurok tribes.
- October 27, 2017, Terrestrial Resources Coordination Call – updates on terrestrial resources measures development, proposed field survey schedule, and species-specific discussions. Attendees included the Renewal Corporation, USFWS, CDFW, SWRCB, and ODFW.
- November 20, 2017, Terrestrial Resources Coordination Call – updates on terrestrial resources measures, proposed field survey schedule and results of 2017 reconnaissance work, and species-specific discussions. Attendees included the Renewal Corporation, USFWS, CDFW, SWRCB, and ODFW.
- December 6, 2017, Section 7 Informal Consultation Meeting – Discussion of needed updates to the BA, including project and baseline changes, schedule, Action Area, and new species. Attendees included the Renewal Corporation, USFWS, and NMFS.
- January 10, 2018, Terrestrial Resources Coordination Call – updates on terrestrial resources measures, proposed field studies, and species-specific discussions. Attendees included the Renewal Corporation, USFWS, CDFW, ODFW, and SWRCB.

- February 8, 2018, Section 7 Informal Consultation Call – provided updates on progress on the BA, reviewed the action area, species lists, and schedule. Attendees included the Renewal Corporation, NMFS, and USFWS.
- February 13, 2018, Terrestrial Resources Coordination Call – Updates on terrestrial resources measures, field studies schedule and approach, and species-specific discussions. Attendees included the Renewal Corporation, USFWS, CDFW, ODFW, and SWRCB.
- March 6, 2018, Section 7 Informal Consultation Call – provided an update on the progress on the BA, follow up on items from the previous meeting, and a request for clarification from the Services on the Action Area definition. Attendees included the Renewal Corporation, NMFS, and USFWS.
- March 28, 2018, Terrestrial Resources Coordination Call – reporting on field survey results from February, schedule update, and discussion of projects and activities for cumulative effects analysis. Attendees included the Renewal Corporation, USFWS, CDFW, ODFW, and SWRCB.
- March 30, 2018, Section 7 Informal Consultation Call – provided an update on progress on the BA, discussed hatchery considerations, current status of orca, cumulative effects analysis, and ongoing coordination with USBR. Attendees included the Renewal Corporation, NMFS, and USFWS.
- April 24, 2018, Terrestrial Resources Coordination Call – report on field survey results from March and April, schedule update for field surveys, and species-specific discussions. Attendees included the Renewal Corporation, USFWS, CDFW, ODFW, and SWRCB.
- May 3, 2018, Section 7 Informal Consultation Call – discussion of dam removal hydrology. Attendees included the Renewal Corporation, NMFS, and USFWS.
- May 18, 2018, Section 7 Informal Consultation Meeting – review and discussion of the first three sections of the BA, schedule updates, and field survey updates. Attendees included the Renewal Corporation, NMFS, and USFWS.
- June 14, 2018, Terrestrial Resources Coordination Call – reports on field survey results from May, schedule update for upcoming field work, and species-specific discussions. Attendees included the Renewal Corporation, USFWS, CDFW, ODFW, and SWRCB.
- June 14, 2018, Section 7 Informal Consultation Call – discussion of flood-proofing projects and United States Army Corps of Engineers (USACE) jurisdiction. Attendees included the Renewal Corporation, USACE, and NMFS.
- July 23, 2018, Terrestrial Resources Coordination Call – reports on field surveys conducted in June and July, schedule for upcoming field work, and species-specific discussions. Attendees included the Renewal Corporation, USFWS, CDFW, ODFW, and SWRCB.
- September 26, 2018, Terrestrial Resources Coordination Call – reports on field surveys conducted in August and species-specific discussions. Attendees included the Renewal Corporation, USFWS, CDFW, ODFW, and SWRCB.
- November 1, 2018, Section 7 Informal Consultation Call – webinar providing an overview of the Draft BA. Attendees included the Renewal Corporation, USFWS, and NMFS.

- March 13, 2019, Terrestrial Resources Coordination Call – reports on field surveys conducted in February and species-specific discussions. Attendees included the Renewal Corporation, USFWS, CDFW, ODFW, and SWRCB.
- May 8, 2019, Section 7 Informal Consultation Meeting – review schedule for project and consultation. Attendees included the Renewal Corporation, USFWS, NMFS, and PacifiCorp.
- June 3, 2019, Terrestrial Resources Coordination Call – reports on field surveys conducted in April and May, schedule for upcoming fieldwork, project updates, and discussions. Attendees included the Renewal Corporation, USFWS, CDFW, ODFW, and SWRCB.
- September 24, 2019, Section 7 Informal Consultation Meeting – review and discussion of the 30% design, introduction to the project design-build team, schedule updates, and field survey updates. Attendees included the Renewal Corporation, Kiewit Team, NMFS, USFWS, and USACE.
- October 4, 2019, Meeting of the ATWG – presented 2019 data collection results, reviewed aquatic resource measures, and presented preliminary aquatic organism salvage plans. Attendees included the Renewal Corporation, Kiewit Team, NMFS, USFWS, ODFW, CDFW, and Yurok and Karuk tribes.
- October 18, 2019, Agency Visit to Project Site – site visit with a focus on proposed in-water work activities below Iron Gate Dam prior to reservoir drawdown, with discussion of potential minimization measures. Attendees included the Renewal Corporation, NMFS, CDFW, and PacifiCorp.
- November 15, 2019, Section 7 Informal Consultation Call – discussion of approaches to evaluate effects on Southern Resident killer whale. Attendees included the Renewal Corporation, NMFS, USFWS, and USGS.
- November 15, 2019, Section 7 Informal Consultation Call – discussion on changes in the design of the J.C. Boyle powerhouse access road relocation in designated NSO critical habitat. Attendees included the Renewal Corporation and USFWS.
- February 14, 2020, Section 7 Informal Consultation Call – discussion regarding tree clearing in designated NSO critical habitat. Attendees included the Renewal Corporation and USFWS.
- March 20, 2020, Section 7 Informal Consultation Call - discussion regarding drafting of the BA, change in project regulatory lead, and drawdown engineering design advancement. Attendees included the Renewal Corporation, USFWS, and NMFS. NMFS recommended that a Technical Work Group (TWG) be established for review, coordination, and input on the reservoir drawdown effects analysis.
- Between April 4 through July 2, 2020, TWG meetings –nine meetings were held with a TWG to review engineering design advancements associated with reservoir drawdown. The TWG included members of NMFS, USFWS, ODFW, CDFW, USBR, Yurok Tribe, Karuk Tribe, and the Renewal Corporation. Meetings reviewed hydraulic modeling results, updated suspended sediment modeling results, reviewed the approach to the effects analysis for the BA, results, and the planned Aquatic Resource Measures to minimize and reduce impacts.
- April 24, 2020, TWG meeting – TWG meeting with the SWRCB and Stillwater Sciences to review the California Clean Water Act Section 401 Certification and Final Environmental Impact Report drawdown and suspended sediment analysis approach and assumptions. The TWG included

members of NMFS, USFWS, ODFW, CDFW, USBR, Yurok Tribe, Karuk Tribe, and the Renewal Corporation.

- Between April 24 through June 23, 2020, Section 7 Informal Consultation Coordination Calls – five Section 7 Informal Consultation coordination calls were held to coordinate on the TWG agenda and development of the BA, including discussion and guidance on the approach to the effects analysis, results, document format, and project description. Attendees included NMFS and the Renewal Corporation.
- July 9, 2020, Section 7 Informal Consultation Call – discussion of the results of sucker sampling, population estimate, and coordination points on the development of the sucker rescue and relocation plan (i.e., salvage plan). Attendees included USFWS and the Renewal Corporation.
- July 23, 2020, Section 7 Informal Consultation Call – discussion of sucker genetics analysis status, Abernathy lab funding and schedule, PacifiCorp access, and timeline for federal permitting. Attendees included USFWS and the Renewal Corporation.
- August 13, 2020, Section 7 Informal Consultation – update for NMFS on the status of the BA, document organization, and NMFS comment resolution. Attendees included NMFS and the Renewal Corporation.
- August 21, 2020, Draft BA Coordination Call – update agencies on status of the BA, discussion of areas of overlap between the agencies. Attendees included NMFS, USFWS, and the Renewal Corporation.
- August 26, 2020, Pacific Lamprey Passage and Salvage Discussion – meeting with USFWS to discuss Pacific lamprey passage. Attendees included USFWS and the Renewal Corporation.
- August 27, 2020, TWG Meeting – meeting to discuss juvenile salmonid and Pacific lamprey rescue and relocation plan. Attendees included NMFS, USFWS, CDFW, Yurok Tribe, Karuk Tribe, SWRCB, ODFW, SWRCB, and the Renewal Corporation.
- September 16, 2020, Fish Passage Criteria Meeting – discussion about criteria for fish passage following dam removal. Attendees included ODFW, CDFW, NMFS, and the Renewal Corporation.
- October 7, 2020, Section 7 Informal Consultation – update for agencies on the project description section of the BA. Attendees included NMFS, USFWS, and the Renewal Corporation.
- October 8, 2020, TWG Meeting – discussed fish passage monitoring approach taken in the BA. Attendees included NMFS, USFWS, ODFW, CDFW, Karuk Tribe, Yurok Tribe, and the Renewal Corporation.
- October 20, 2020, Section 7 Informal Consultation – updated for agencies on the bull trout effects analysis section of the BA. Attendees included USFWS, NMFS, and the Renewal Corporation.
- January 7, 2021, Technical Working Group Meeting – established timeline for finalizing the BA, as well as the process for moving the document forward. Attendees included NMFS, USFWS, CDFW, ODFW, Yurok Tribe, Karuk Tribe, and the Renewal Corporation.
- Between January 15 and March 19, 2021, TWG Meetings –eleven TWG weekly meetings were held to work toward finalization of the BA. Attendees included NMFS, USFWS, CDFW, ODFW, Yurok Tribe, Karuk Tribe, Klamath Tribe, and the Renewal Corporation. Between each weekly meeting, technical

calls were held with USFWS and NMFS to review and address comments for the species and effects analysis covered in the Biological Assessment.

USBR consulted with NMFS and USFWS on the ongoing operation of USBR's Klamath Project as described in the 2019 NMFS and USFWS BOs. Those BOs reviewed variable flow targets for the Klamath River based on Williamson River flows, with minimum daily flows, as discussed further in Section 4.2. Although it is understood that USBR consultation for flow management is underway and scheduled for completion in 2023, the Proposed Action evaluated herein assumes flows consistent with those reviewed in the 2019 BOs for the mainstem Klamath River from Iron Gate Dam to the Klamath River mouth for analysis purposes. This is because it is uncertain what flows will result from consultation.

As described further in Section 4.2, the hydrological conditions reviewed in the 2019 BOs are not anticipated to have an effect on the Proposed Action. Furthermore, achieving a free-flowing river condition under the Proposed Action will not have an effect on meeting minimum flow conditions as reviewed in the 2019 BOs.

1.6 Compliance with the Magnuson-Stevens Act

Pursuant to Section 305(b) of the Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. 1801 et seq.; Magnuson-Stevens Act), federal agencies must consult with NMFS regarding any of their actions authorized, funded, or undertaken, or proposed to be authorized, funded, or undertaken that may adversely affect EFH. EFH is defined in the Magnuson-Stevens Act as "those waters and substrates necessary to fish for spawning, breeding, feeding, or growth to maturity." If such an action would adversely affect any EFH, Section 305(b) of the Magnuson-Stevens Act also requires NMFS to recommend measures that can be taken by the action agency to conserve EFH (i.e., conservation recommendations). Such recommendations may include measures to avoid, minimize, mitigate, or otherwise offset the adverse effects of the action on EFH (50 CFR 600.905(b)). Freshwater EFH for Pacific salmonids includes those streams, lakes, ponds, wetlands, and other water bodies currently, or historically, accessible to salmon in Washington, Oregon, Idaho, and California, except areas upstream of certain impassable manmade barriers, and long-standing impassable natural barriers. EFH for Pacific coast groundfish includes waters from the mean higher high-water line, and the upriver extent of saltwater intrusion in river mouths, along the coasts of Washington, Oregon, and California seaward to the boundary of the U.S. exclusive economic zone. EFH for coastal pelagic species includes marine and estuarine waters from the shoreline along the coasts of California, Oregon, and Washington offshore to the limits of the exclusive economic zone. An EFH evaluation is presented in Appendix K.

Chapter 2: Proposed Action Description

2. PROPOSED ACTION DESCRIPTION

The Proposed Action, including reservoir drawdown and diversion, dam and facilities removal, and restoration of the reservoir areas and other areas within the limits of work, is fully described herein as it relates to the potential take of ESA-listed species. Additional details are provided in the 100% Design Report Rev C (Kiewit 2020). The 100% Design Report is a final draft document under review by FERC and the California Division of Safety of Dams. The Renewal Corporation expects that the revisions of the final draft based on such review will be completed in late 2021.

The Proposed Action is to produce a free-flowing river at all four hydroelectric development sites (J.C. Boyle, Copco No. 1, Copco No. 2, and Iron Gate). Depending on the river hydrologic conditions and flows of the drawdown water year, the target is to achieve free-flowing river conditions by early October, with the facility removal completed by December 31. Broadly defined, the Proposed Action is comprised of preparing the facilities for dam removal, including road improvements, dam and gate improvements, and general infrastructure. When that work has been completed, the reservoirs can be drawn down in preparation for the removal of the dams themselves. Once the reservoirs are drawn down, the restoration of the former reservoir footprints and tributary reconnections will commence.

This section is organized by initially describing the reservoir drawdown, diversion, and sediment evacuation at all four facilities (Section 2.1, 2.2), followed by a description of each dam facility and its removal process (Section 2.3). The restoration of the now exposed reservoir areas and tributary reconnections are then described (Section 2.4), followed by a description of other necessary project components such as roads, bridges, infrastructure improvements, hatchery disposition and development, and other proposed measures (Section 2.5). The Proposed Action also includes the conservation, avoidance, and mitigation measures to offset impacts from the drawdown and dam removal (Section 2.6). To best comprehend the actions previously described, Section 2.7 provides a summary and schedule of the proposed in-water work activities associated with the Proposed Action.

The Renewal Corporation will begin pre-drawdown construction activities starting in April 2022, considered the “pre-drawdown year.” Reservoir drawdown will begin in January 2023, considered Year 1. The Construction Period, including dam removal and restoration construction, begins in the year prior to drawdown, includes drawdown (Year 1), and extends through the following year (Year 2). The restoration, maintenance, and monitoring period begins in Year 3 and extends for a total of 5 years following the Construction Period (Years 3-7). As part of the effort to optimize the drawdown process, the Renewal Corporation, working with agency and tribal stakeholders, is refining operating scenarios to best establish the reservoir drawdown and construction timeline. The target date for volitional fish passage is early October of the drawdown year. The actual date for the reconnection of the Klamath River will be in response to the water year and river flow conditions experienced during the drawdown process. At the time this BA was prepared, the Renewal Corporation established a start date for construction at Iron Gate Dam based on probable 100-year flood conditions. This conservative approach allows for the removal of the dams themselves once the reservoirs are drawn down and stable, meaning the outflow capacity of the diversion tunnel exceeds the projected inflow caused by a 1 percent probability flood. Final timing of volitional fish passage at Iron Gate dam is reliant upon the start date of the dam removal and is thus heavily dependent on the water year type at the time of dam removal. Many variables can alter the water year forecast such as snowpack, status of the Upper Klamath Lake flood control curve, and the USBR Annual Operations Plan and its BO flows. The Renewal Corporation will continue to work with the tribal and agency stakeholders in refining assumptions and removing variables that could result in extending the schedule for final river connection. In addition, the Renewal Corporation will continue to work with these parties to establish contingency measures in the event unforeseen events occur during the construction that result in schedule delays.

2.1 Reservoir Drawdown and Diversion

Prior to drawdown, PacifiCorp will use the facilities' existing structures to bring the reservoirs at or near their minimum allowable operating levels. Then, starting January 1 of the drawdown year (Year 1), reservoir drawdown and associated sediment release will be accomplished through regulated releases to draw down the reservoirs in a controlled manner. At each development, drawdown will continue until the reservoir level stabilizes at the elevation of the historical cofferdam. The next step will be connecting the river to its historic channel by removing the cofferdam.

The reservoir drawdown and diversion approach described in this section is from the Renewal Corporation's 100% Design Report Rev C and the Reservoir Drawdown and Diversion Plan (Kiewit 2020 – Final Draft Document). The major drawdown facilities at J.C. Boyle are the spillway and diversion culverts beneath the dam. At Copco No. 1, drawdown facilities are the power generation facilities, the spillway, one constructed outlet tunnel through the base of the dam, and re-establishment of the historical diversion tunnel after the reservoir is substantially drawn down. At Iron Gate, the drawdown will occur initially through the power facilities and via a modified diversion tunnel. The penstocks at Copco No. 1 and Iron Gate provide only a minor amount of potential additional diversion. PacifiCorp will initially use the penstocks to bring the reservoirs to the minimum operating level, and then will only use the power facilities as needed to keep reservoir water levels lowered until their use is no longer feasible. The drawdown facilities for each development are listed in Table 2-1.

The Renewal Corporation will coordinate closely with USBR as that agency refills Klamath Lake during the months prior to and during drawdown to maintain compliance with the Klamath Project BOs (NMFS 2019a and USFWS 2019a). The process of refilling Klamath Lake affects the rates of discharge from Keno Dam to the J.C. Boyle Reservoir. The basin freshet from spring runoff and precipitation would follow reservoir drawdown and, depending on actual river basin hydrology and reservoir inflows, partial reservoir refilling may result, followed by subsequent periods of drawdown. Historically, the freshet ends by early June. The ability to control the water surface level (WSL) rates of reservoir drawdown to a target of 5 feet per day are dictated by the actual river flows over the drawdown period being experienced at the time of drawdown except at Iron Gate, where flows may be controlled by the existing gate and downstream orifice in the diversion tunnel.

The Renewal Corporation is refining operating scenarios to optimize the reservoir drawdown and construction timeline in response to the water year and river flow conditions experienced during the drawdown process. These scenarios include alternative measures to be implemented if construction conditions and progress during the drawdown year foreshadow delays to the October target for free-flowing river conditions and volitional fish passage. For dam safety purposes, the Iron Gate Dam removal process can only begin once the reservoir is drawn down and stable, meaning the outflow capacity of the diversion tunnel exceeds the projected inflow caused by a 1 percent probability flood. Further modifications to the schedule could be made based on final design review by the California Division of Safety of Dams (DOSD) and FERC. Drawdown start timing, sequence, and rate will be optimized based on conditions during the drawdown year to achieve the goals of sediment evacuation and fish passage. Evaluated scenarios of river flow conditions that would facilitate, or hinder, the drawdown schedule will help steer optimization and the timeline for the reservoir drawdown. The Proposed Action involves a large multidimensional construction project that is subject to changing conditions that affect the timeline; therefore, alternative measures development will focus on methods to facilitate fish passage around the Iron Gate construction site. The projected water year, evaluated drawdown scenario, and projected schedule based on year of conditions will be communicated to resource agencies including FERC, DSOD, NMFS, USFWS, and other agencies.

Table 2-1: Facilities to Be Used for Reservoir Lowering and Diversion

Location	Diversion Facility
J.C. Boyle Dam	
	Spillway
	Power intake
	Diversion culvert – Bay 1
	Diversion culvert – Bay 2
Copco No. 1 Dam	
	Spillway
	New outlet tunnel 1
	Power intake
	Existing Diversion Tunnel
Iron Gate Dam	
	Power intake
	Existing diversion tunnel

2.1.1 J.C. Boyle Dam

Drawdown of J.C. Boyle Reservoir will not require the use of any new or special diversion structures. The Renewal Corporation will use the existing power intake, spillway, and two low-level diversion culverts through the concrete portion of the dam under the spillway for this purpose. The existing earth-fill dam embankment and historical cofferdam will act to divert water into the diversion culverts as the reservoir is drawn down. At the beginning of drawdown, the intake gates will be gradually opened all the way and then the low-level diversion culverts will be re-opened. The water conveyance system (pipeline and power canal) will be isolated from the reservoir as the water level drops, allowing for decommissioning and selective removal of the various components of the water conveyance system and powerhouse and substation (see Section 2.3.1 for more information).

The initial drawdown stages (Stages 1 and 2) will use the power facilities and spillway gates to bring the reservoir to the minimum operating levels, depending on river flow rates or conditions. The initial stages of drawdown will achieve a target WSL rate of 5 feet per day.

After the initial drawdown, the power intake will be used as needed to divert water until the diversion culvert is opened. During this phase, the anticipated drawdown WSL rate may be more than 10 feet per day for a short period of time.

The final stages of drawdown will be initiated by removing one of the two diversion-culvert concrete stoplogs (Stage 3), followed by the second stoplog (Stage 4). The Renewal Corporation will remove the stoplogs using controlled blasting. The drawdown process for J.C. Boyle Reservoir will be considered complete when both diversion culverts are fully open and operating. Reservoir water levels will continue to subside through the spring and summer months as Klamath River flow rates decrease. The diversion culverts will remain open and will pass all river flows until the embankment dam and historical cofferdam, located about 450 feet upstream of the embankment dam centerline, are deconstructed, channel restoration is complete, and volitional fish passage is established.

The Renewal Corporation's design analysis during development of the 100% Design Report Rev C (Kiewit 2020 – Final Draft Document) compared steady-state inflows to culvert rating curves to determine the maximum flow allowable for crews to safely access the downstream side of the diversion culverts. USBR controls Link River Dam releases, and therefore has the capacity to regulate flows into J.C. Boyle Reservoir. For the safety of working crews during Stage 2 and Stage 3, flow coordination with USBR will be finalized when climatic information is available and flow forecasts are prepared by USBR to keep J.C. Boyle Reservoir below the spillway crest.

2.1.2 Copco No. 1 Dam

The Copco No. 1 Reservoir drawdown will be accomplished primarily through a new low-level outlet tunnel constructed through the dam (see Section 2.3.2 for more information). Prior to drawdown, deposited sediment and debris in the reservoir just upstream of the dam will be dredged to ensure that the tunnel outlet remains unobstructed and to facilitate the passage of river flows and sediment during and after drawdown. The historical diversion tunnel approach channel will also be dredged to facilitate later use of the tunnel during dam demolition and removal. Excavated material will be placed on a barge and transported upstream to an approved in-reservoir disposal location, pending USACE permit approval. This dredging and other pre-drawdown construction activities will be completed during the in-water work period (June 15-October 15) in the year prior to drawdown.

The new outlet tunnel will serve as a low-level reservoir outlet through the approximate center of the dam. The Renewal Corporation will build the tunnel by drilling and blasting from the downstream side of the dam from the spillway plunge pool toward the upstream face of the dam. A new steel pipe will extend from the tunnel to the downstream plunge pool. The tunnel will not be connected to the reservoir during pre-drawdown; rather, a remaining concrete section called a tunnel plug will be left in place to separate the tunnel from the reservoir until drawdown is initiated. The Renewal Corporation will remove the final plug by blasting to initiate drawdown after January 1 of the drawdown year. Once the low-level outlet tunnel begins operation, power operations will cease and reservoir drawdown will continue to a level at which the historical diversion tunnel can be opened.

Once the concrete dam and historical cofferdam, located upstream of the dam, are deconstructed, the mainstem river will pass through the dam site and the Renewal Corporation will complete final volitional fish passage channel construction.

2.1.3 Copco No. 2 Dam

Pre-drawdown construction at the Copco No. 2 Reservoir includes modifications to the downstream side of the dam to pass river flows through a channel through the existing dam structure and avoid the use of cofferdams or other structures in the river channel. Pre-drawdown-year work will occur during the in-water work period (June 15-October 15) and involve removing a portion of the downstream face of the left-side spillway bay (Spillway Bay No. 1) and making a small downstream channel improvement.

Once drawdown commences on January 1 of Year 1, the Renewal Corporation will open the spillway gates, and flows will pass through the power conveyance system and over the spillways.

The pre-drawdown-year work will be conducted during the low-flow period, which coincides with the in-water work period. During this work, the spillway gates will be closed and all river water will be passed through the power intake under normal power operations. Diversion through the power intake during this low-flow period will allow a temporary construction work platform to be built on the downstream side of the existing dam from the right bank onto the spillway apron (see Section 2.3.3 for more information). The reservoir may be drawn down through the power intake for the final 17 feet of dam concrete removal by a controlled blast. The concrete rubble will be removed with a long-arm hydraulic excavator and disposed of in the Copco concrete disposal area. Once the river flows are routed through the opened Spillway Bay No. 1, the power intake gate will be closed permanently and the reservoir drawdown will be complete.

The Renewal Corporation is considering using the Copco No. 1 facility to fully dewater the Copco No. 2 head pond to allow for Copco No. 2 dam and historical cofferdam removal without the need for staged diversion. PacifiCorp's current operations for Copco No. 1, Copco No. 2, and Iron Gate allow for the river channel between Copco No. 1 and Copco No. 2 dams to be dewatered for short periods of time. Iron Gate Reservoir provides for the required downstream environmental flows during this period. The availability of this option to the Renewal Corporation will depend on timing of approvals from the relevant agencies. This alternate approach for drawdown would occur during the year prior to drawdown to dewater the reservoir between Copco No. 1 Dam and Copco No. 2 Dam for a 5- to 10-day period to deconstruct the Copco No. 2 diversion dam and historical cofferdam. If this option is approved, the Renewal Corporation will proceed directly to remove the entire concrete diversion dam and portion of the intake structure to the final excavation limits. The Renewal Corporation would also remove the historical cofferdam and would complete the final channel restoration at this time.

2.1.4 Iron Gate Dam

During the pre-drawdown phase, the Renewal Corporation will partially line the existing diversion tunnel as reinforcement for its use during controlled reservoir drawdown. The Renewal Corporation will construct a temporary access road across the spillway and tunnel outlet on the downstream side of the dam to provide access to the existing tunnel division outlet (see Section 2.3.4.2 for more information on construction of these work pads). The lower portion of this diversion tunnel will be partially concrete-lined, and the Renewal Corporation will add a horizontal vent.

Once drawdown of Iron Gate Reservoir begins after January 1, the Renewal Corporation will use the existing diversion tunnel gate and downstream orifice to control the target drawdown WSL rate of 5 feet per day. The objective for Iron Gate Reservoir drawdown is to safely achieve a reservoir level below the historical cofferdam at the upstream dam toe.

At the final stage of Iron Gate Dam deconstruction, the Renewal Corporation will conduct a controlled breach of the cofferdam to connect the mainstem river through the dam site. The controlled breach will regulate flows to the downstream river to avoid flood impacts and public risk. Prior to the final breach, the Renewal Corporation will construct the final river channel passing through the dam embankment area so that when the cofferdam is breached, the river will be free-flowing and volitional fish passage conditions will be met.

2.2 Drawdown Rates of All Reservoirs

The Renewal Corporation will control drawdown using gates and other designed controls (e.g., tunnel orifice size) to maintain a drawdown rate that provides for safe drawdown and embankment and reservoir rim stability. Reservoir water level simulations from January 1 through the freshet period have been developed based on the proposed controlled drawdown methodology. Drawdown at J.C. Boyle Dam and Copco No. 1 Dam will be restricted by the size of the openings through the dams, but there will be no gates to allow for modulation of drawdown at these dams. Drawdown of Iron Gate Reservoir will be controlled by the existing gate in the diversion tunnel. During drawdown of the reservoirs, the Renewal Corporation will monitor for signs of instability at the dams and critical portions of the reservoir rims.

Copco No. 2 Dam does not impound a significant volume of water or sediment, and the Renewal Corporation may remove this dam during the same year as the three larger dams. However, the preferred alternative is to remove the concrete diversion dam and historical cofferdam during the pre-drawdown year as described in Section 2.1.3, pending final agency approval.

Reservoir drawdown rates at J.C. Boyle, Copco No. 1, and Iron Gate will target a WSL of 5 feet per day. However, as the reservoirs approach their lower reservoir levels and there is very limited reservoir storage remaining, there may be short periods when the target rate is exceeded, depending on reservoir inflows and when more rapid lowering at the bottom of the reservoir is desired for sediment evacuation. The actual drawdown rates may be lower (or result in filling) during storms because of increased inflows to the reservoirs.

The time necessary for drawdown will vary depending on the hydrology during the drawdown year. The Renewal Corporation expects that drawdown to the initial elevation (defined as the top of the historical coffer dams) will be achieved between mid-January and mid-April in most water years. This elevation will then be held (and the reservoirs allowed to refill depending on inflows) until there is good confidence that high flows are over for the season. The Renewal Corporation will then connect the diversion tunnels at the historical cofferdams to reach the final drawdown to the historical river channel elevation. The Renewal Corporation expects that this will take place in June or July but it will depend on the hydrology in the year of drawdown. This approach will result in two peaks of suspended sediment concentrations in the Klamath River, one in winter/spring and one in summer.

During dry periods, the reservoirs can be drawn down more quickly, which would result in a larger percent increase in flow to the river; however, because these river flows are within or just above the traditional power operation flows or average freshet river flows, the magnitude of the drawdown-related flows is not necessarily greater. During wet periods, the reservoirs may partially refill and drain multiple times before the spring freshet ends. Each refilling and subsequent draining may mobilize additional sediment. Following the spring freshet, there will be a final flow and sediment release that occurs in summer, corresponding to the opening of the diversion tunnel at Copco No. 1.

2.3 Dam and Facilities Removal

The Proposed Action includes the removal of dams (except for buried features), power generation facilities and transmission lines, water intake structures, canals, pipelines, and ancillary buildings. The Renewal Corporation will remove hazardous materials from each dam site and from any structural components left in place, per the Abatement Specifications provided by Entek for each of the four developments (Entek 2020a, b, c, d). If hazardous materials are not friable and are attached to a structure that will be entombed, they will be buried in place. The Renewal Corporation will also follow these standard practices: detailed assessment of the material, identification of required abatement and special handling (if required) for each type of hazardous material, and compliance with legal disposal and transportation rules per local, state, and federal regulations. Any remaining structures will not impact flow characteristics below the 100-year flood elevation.

Quantity estimates for all features to be removed, including earth-fill volumes, concrete volumes, and weights of mechanical and electrical equipment, have been prepared using detailed engineering drawings provided by PacifiCorp, which are believed to represent current, as-built conditions. A Waste Disposal and Hazardous Materials Management Plan was prepared identifying the disposal sites, materials, and best management practices.

The equipment that will be used for the removal of the dams and other facilities and for restoration of the reservoir areas pre- and post-drawdown is shown in Table 2-2. An estimated average workforce of 150 people may be required for the pre- and post-reservoir drawdown construction activities. The peak workforce required during excavation of the dams may reach 45 people at J.C. Boyle, 55 people at Copco No. 1, 40 people at Copco No. 2, and 80 people at Iron Gate dams.

Table 2-2: Equipment List for the Proposed Action

Name of Equipment	J.C. Boyle	Copco No. 1	Copco No. 2	Iron Gate
Crawler-mounted lattice boom crane, 100 to 120 ton or 150 to 200 ton, 160- to 200-foot boom	X	X	X	X
Rough terrain hydraulic crane, 35 to 75 ton	X	X	X	X
Hitachi hydraulic excavator, 180,000 to 240,000 lb, 6- to 8-cubic yard (cy) bucket				X
Mid-size hydraulic excavator, 28,000 to 60,000 lb, 1- to 2-cy bucket		X	X	
Cat 336 hydraulic track excavator, 80,000-lb, 3.5-cy bucket		X	X	X
Hydraulic track excavators, 65,000 to 120,000 lb, with Cat H120 hoe-ram, thumb, and sheer attachments	X	X	X	X
Cat 966 (52,000-lb, 5-cy bucket) or Cat 988 (65,000-lb, 6-cy bucket) articulated wheel-loaders	X	X	X	X
Cat 725, Cat 730, or Cat 740 articulated rear dump trucks, 30 ton (22 cy)	X	X	X	X
D-6, D-7, D-8, or D-9 standard crawler dozers	X	X	X	X
Front-end wheel loader, integrated tool carrier, 25,000 lb	X	X	X	X
D-8 support and knockdown dozer				X
Cat TL943 rough terrain telescoping forklift	X	X	X	X
Rough terrain telescoping manlift	X	X	X	X
Cat 140, 14, or 16 motor-grader		X		X
Flexifloat sectional barges		X		
Truck-mounted seed sprayer, 2,500 gallons	X	X		X
On-highway, light duty diesel pickup trucks, ½-ton and 1-ton crew	X	X	X	X
On-highway flatbed truck with boom crane, 16,000 lb	X	X	X	X
On-highway truck tractors, 45,000 lb	X	X	X	X
Off-highway water tanker, 5,000 gallons	X	X	X	X
On-highway water truck, 4,000 gallons		X	X	
Wheel-mounted asphalt paver				X
Self-propelled rubber tire and drum vibratory compactor, 5 to 15 ton				X
Engine generators, 6.5 kW to 40 kW, diesel or gasoline	X	X	X	X
Air compressors, 100 psi, 185 to 600 cfm, diesel	X	X	X	X
Airtrack drill or hydraulic track drill		X	X	
Hand-held drilling, cutting, and demolition equipment	X	X	X	X
Portable welders and acetylene torches	X	X	X	X
4-inch submersible trash pumps, electric	X	X	X	X
Light plants, 2,000 to 6,000 watt, 10 to 25 hp, diesel		X		X

2.3.1 J.C. Boyle

2.3.1.1 Limits of Work

J.C. Boyle Dam is in a relatively narrow canyon on the Klamath River. Minimum requirements for a free-flowing condition and for volitional fish passage on the Klamath River through the J.C. Boyle Dam site include partial removal of the embankment section and concrete cutoff wall beneath the embankment to the bedrock foundation to ensure long-term stability of the site and to prevent the potential development of a fish barrier at the site in the future. Figure 2-1 (Overview and Sheets 1 through 9) shows the limits of work and access at the J.C. Boyle site. Table 2-3 summarizes the J.C. Boyle features the Renewal Corporation will remove or bury on site as part of the Proposed Action.

Table 2-3: Removal of J.C. Boyle Features

Feature	Action	Comments
Embankment dam, cutoff wall	Partially remove	
Spillway gates and crest structure	Partially remove	Gates will be removed and retained concrete buried with embankment material.
Concrete box diversion culverts	Retain	Bury retained concrete with embankment material.
Fish ladder and diffusion box	Remove	
Timber bridge	Remove	
Steel pipeline and supports	Remove	
Canal intake (screen) structure	Partially remove	
Left concrete gravity section	Partially remove	Bury retained concrete with embankment material.
Canal headgate structure	Partially remove	Bury retained concrete with local fill.
Power canal (fume)	Partially remove	Retain invert slab and inside walls.
Power canal access road	Retain	The decommissioned road will be left in place and converted to a hiking trail per BLM direction.
Shotcrete slope protection	Retain	Removal would destabilize excavated rock slopes and increase potential for rock falls.
Forebay spillway control structure and discharge chute	Partially remove	
Tunnel inlet portal structure	Partially remove	Bury and barricade tunnel.
Surge tank	Remove	
Penstocks, supports, anchors	Partially remove	Concrete anchors would be removed to the springline of the penstock and the remaining concrete portion buried.
Tunnel portals	Close	Downstream and upstream ends will be buried.
Powerhouse gantry crane	Remove	

Feature	Action	Comments
Powerhouse, including mechanical and electric equipment	Partially remove	All concrete below elevation 3,340 to be left in place and buried. All mechanical and electrical equipment to be removed, and substructure filled with soil.
Powerhouse hazardous materials (transformers, batteries, insulation, petroleum products)	Remove	Materials that are not frayed will be buried in place.
Tailrace flume walls	Partially remove	
Tailrace channel area	Backfill	
Canal spillway scour area	Backfill	Backfill to extent possible with concrete rubble from dam, canal, and powerhouse; capped with embankment material.
Spillway aprons	Partially remove	Grade to construct a temporary 20-ft- to 30-ft-wide access road from the embankment excavation to the left bank.
2.4 miles of 12-kV and 0.5 mile of 230-kV transmission lines	Remove	
Switchyard, including fencing, poles, and transformers	Remove	
Buildings: office building (the Red Barn), maintenance shop, fire protection building, communications building, 2 residences, storage shed, reservoir level gages house	Remove	
Historical cofferdam	Remove	Remove by excavating the small embankment back toward the right bank and allow natural erosion following breach.

2.3.1.2 Construction Access and Staging

Figure 2-1 (Sheets 1 through 9) shows construction access roads, staging areas, disposal sites, and associated improvements that will be required for removal of J.C. Boyle Dam and powerhouse. The Renewal Corporation observed the existing conditions of the highways, local roads, and structures in the field to identify deficiencies and determine if improvements are necessary for mobilization and/or hauling during construction and demolition activities. Table 2-14 lists all road improvements that may be required for the Proposed Action.

The Renewal Corporation will mobilize construction equipment to the site in April of the pre-drawdown year to construct road improvements, prepare staging areas, and remove recreation sites. Equipment staging areas will be located at the left abutment of the dam and near the forebay and downstream powerhouse. Identified staging areas include a 4.7-acre area and a 5.6-acre area on the left abutment of the dam, a 1.0-acre area at the forebay, and a 1.7-acre area at the powerhouse. The Renewal Corporation will prepare staging areas as needed by limited vegetation clearing and minor grading.

2.3.1.3 Disposal Sites

There are two primary disposal sites proposed for earth-fill and concrete rubble from the J.C. Boyle deconstruction. The Renewal Corporation will relocate most dam embankment fill material to the scour hole or along the canal alignment, or it will be graded to match the general terrain. The Renewal Corporation will infill the scour hole with demolished concrete, primarily from the intake and power canal in conjunction with earth fill from the embankment dam and forebay area, as shown on Figure 2-2. The Renewal Corporation will grade the fill slope to 1.7 Horizontal:1 Vertical (H:V), and the cut slopes to 1.5H:1V. The Renewal Corporation will contour the fill for drainage and erosion protection.

The Renewal Corporation will use the historical borrow area previously identified as a potential disposal area only if needed or directed. If the scour hole and power canal embankment materials are completely covered and there is additional embankment material to be removed, the Renewal Corporation will place the remaining embankment material in the powerhouse tailrace and on the left and right banks upstream of the dam location, as shown on Figures 2-3 and 2-4. The Renewal Corporation will place erosion protection on the left bank, as shown on Figure 2-5.

The Renewal Corporation will place powerhouse concrete rubble into the powerhouse tailrace and the powerhouse cavity, as shown on Figure 2-6. The Renewal Corporation will realign the powerhouse access road to set it back from the edge of the scour hole, as shown on Figure 2-1, Sheet 8. After final grading for drainage and aesthetics, the Renewal Corporation will provide erosion protection in the former scour hole and will grade disposal sites upstream of the dam for stability and erosion protection.

2.3.1.4 Dam Removal

Once the reservoir is drawn down, the Renewal Corporation will remove the spillway gates and hoisting equipment prior to the Oregon in-water work period (July 1 to September 31). The spillway bays will remain open and able to discharge flood flows. Active dam deconstruction will begin in June of the drawdown year, and a volitional fish passage channel will be complete by October 1 of the drawdown year, depending on river flows and conditions.

After drawdown, the Renewal Corporation will partially demolish the concrete spillway aprons and will grade the area to construct a 20-foot-wide access road from the embankment excavation to the left bank. The deconstruction plan allows for dam removal to occur in dry conditions (i.e., isolated from the river flow) by leaving the upstream portion of the embankment and historical cofferdam in place as work platforms and removing the downstream dam section. Embankment removal (cut area) is shown on Figure 2-1, Sheet 2).

The Renewal Corporation will demolish the remaining work platform and breach the historical cofferdam to establish volitional fish passage by the end of September, and additional channel restoration will take place afterward. The Renewal Corporation will complete the cofferdam removal by excavating the small embankment back towards the right bank. The Renewal Corporation anticipates that once the structure is breached, flow will naturally erode portions of the historical cofferdam during excavation. The Renewal Corporation will rehabilitate the left bank access road following embankment and historical cofferdam excavation. This will involve placing soil and grading this area to match the contours of the left bank disposal area. Embankment, work platform, historical cofferdam, and soft sediment removal will involve removing embankment soils to pre-dam channel elevations appropriate for volitional fish passage. The final work platform breach and fill removal process is planned to occur in August and September, when river levels are at seasonal lows. The Renewal Corporation will schedule the exact timing of the breach according to river flow conditions at the time and the breach may be delayed if high flows occur.

Once the embankment dam and the historical cofferdam are removed, the Renewal Corporation will establish the volitional fish passage channel. Some in-water work will be necessary immediately upstream of the historical cofferdam to establish the volitional fish passage channel. The completed channel will include fringe roughness (i.e., placement of boulders to aid fish passage) and grade slope protection to stabilize soils.

2.3.1.5 Power Canal Removal

The Renewal Corporation will begin removal and partial demolition of the power canal, forebay, penstocks, and powerhouse once the power intake gate is closed and the power canal is dewatered. Power canal removal is shown on Figure 2-1, Sheets 3 through 8.

The power canal is made up of three types of canal sections: single wall, double wall (backfilled), and double wall (free-standing). For all three section types, the Renewal Corporation will demolish the front wall and haul the material to the scour hole. For the single-wall shotcrete and double wall (backfilled) types of canal sections, the back wall and invert slab will remain in place and the Renewal Corporation will place fill over them because removal of the shotcrete may destabilize the rock slope, thereby increasing the potential for rock falls during and after construction. For the double wall (free-standing) portions of the power canal, the Renewal Corporation will place uphill concrete walls horizontally on the invert slab and bury them in place. The cover soil material will be free-draining and sourced locally or from the embankment fill with a grade sufficient for recreational use and drainage. Following deconstruction of the canal structure, the Renewal Corporation will leave the road unaltered for future use by stakeholders. The Renewal Corporation will construct three animal crossings at designated locations along the power canal alignment using earth fill.

The Renewal Corporation will bury the forebay tunnel portal and grade the forebay area for drainage and to blend it in with surrounding topography.

2.3.1.6 J.C. Boyle Powerhouse Removal

The Renewal Corporation will leave in place all powerhouse concrete below elevation 3,340 feet and will cover the concrete with a minimum 3 feet of graded fill with erosion protection. The Renewal Corporation will fill and grade the powerhouse tailrace. The final grade will slope toward the Klamath River to promote drainage. The fill source will be the soil material locally available from the regraded powerhouse and substation area.

2.3.1.7 Transmission Line and Switchyard Removal

The Renewal Corporation will demolish the J.C. Boyle switchyard; demolish overhead distribution lines and associated poles or towers, as applicable; and install new connections to maintain the power grid. The Renewal Corporation and/or PacifiCorp will remove portions of overhead transmission/distribution Line 50. PacifiCorp will provide two new 230-kV transmission structures outside J.C. Boyle substation that will be installed to tie together the existing 230-kV transmission line north and south of the J.C. Boyle substation.

2.3.1.8 Imported Materials

Construction materials that the Renewal Corporation may import to the J.C. Boyle facility include temporary aggregate base and final seed and mulch materials, as needed.

2.3.1.9 Waste Disposal

Table 2-4 shows estimated quantities of materials potentially generated during removal of J.C. Boyle Dam and powerhouse, numbers of truck trips, and approximate haul distances for waste disposal. The Renewal Corporation will place excavated embankment material and concrete in the scour hole below the emergency spillway or along the power canal alignment. The Renewal Corporation will place any remaining excavated embankment materials in the left abutment disposal area. The Renewal Corporation will haul all mechanical and electrical equipment to a suitable commercial landfill or salvage collection point. Large debris (e.g., metal penstock pipe) may be handled by a recycler in Portland, Oregon, because local facilities may not have appropriate off-loading equipment or the capacity to process large and/or heavy materials. The Klamath County landfill is a commercial landfill approximately 20 miles away. The landfill accepts construction and demolition waste, asbestos, contaminated soils, and recyclables. See Table 2-4 for a list of materials that the Renewal Corporation will take to landfills and those that the Renewal Corporation will bury in on-site disposal areas.

Table 2-4: Disposal of J.C. Boyle Waste Material

WASTE MATERIAL	In-Situ Quantity	Bulk Quantity[1]	Disposal Site	Quantity per Trip	Total Trips[2]
Dam embankment – earth	135,800 cy	163,000 cy	On-site – left and right banks upstream of the dam	40 cy/trip (unpaved road)	4,100 trips (1-mile round trip [RT])
Powerhouse tailrace – earth	11,000 cy	13,000 cy	On-site – powerhouse tailrace	N/A	On-site disposal
Dam – concrete	3,440 cy	4,470 cy	On-site – scour hole	40 cy/trip (unpaved road))	110 trips (4 miles RT to scour hole)
Power canal and forebay concrete (Option 1)	23,000 cy	29,900 cy	On-site – scour hole		750 trips (2 miles RT)
Powerhouse and miscellaneous foundation concrete	400 cy	520 cy	On-site – powerhouse tailrace		On site disposal
Dam mechanical/ electrical	440 tons		Salvaged, or landfill near Klamath Falls, or alternative permitted site	25 tons/trip (Highway 66)	20 trips (44 miles RT)
Power canal and forebay mech/elec	270 tons				10 trips (48 miles RT)
Powerhouse mech/elec	11,210 tons				50 trips (52 miles RT)
Timber bridge	60 cy		Rock disposed on site; sheet piles, treated wood disposed off-site at permitted site	40 cy/trip	2 trips (up to 52 miles RT)
Building material debris	10 buildings 17,300 square feet (sf)		Landfill near Klamath Falls or alternative permitted site	25 tons/trip (Highway 66)	20 trips (44 miles RT)
Power lines	2.9 miles of 12-kV and 230-kV lines		Landfill near Klamath Falls or alternative permitted site		

Notes:

1 Volumes are increased by 30 percent for concrete rubble, 20 percent for loose earth materials.

2 Total trips of earth fill and concrete assume off-highway articulated trucks with a nominal load capacity of 40 cy. Total trips for hauling mechanical and electrical items using truck tractor-trailers is based on 25 tons per trip. Total trips for building material debris using truck tractor-trailers are based on 25 tons per trip.

2.3.2 Copco No. 1

2.3.2.1 Limits of Work

Copco No. 1 Dam is in a narrow canyon on the Klamath River. The Copco No. 1 development consists of a dam and power plant. Minimum requirements for a free-flowing condition and volitional fish passage through the Copco No. 1 Dam site include the removal of the concrete gravity-arch dam between the left abutment rock contact and the concrete intake structure on the right abutment to an approximate elevation of 2,474.1 feet to ensure future scour and migration of the riverbed does not expose foundational concrete that could create a fish barrier. Figure 2-7 (Overview Sheet and Sheets 1 through 5) shows the limits of work and access at Copco No. 1 and No. 2. Table 2-5 summarizes the Copco No. 1 features the Proposed Action will remove or retain.

Table 2-5: Removal of Copco No. 1 Features

Feature	Action	Comments
Concrete dam	Remove	Remove to elevation 2,472.1.
Spillway gates, deck, piers	Remove	
Penstocks	Partially remove	Thrust blocks will remain at spring-line and buried in place; pipe will be dewatered and removed.
Powerhouse intake structure	Partially remove	Plug
Gate houses on right abutment	Remove	
Diversion control structure	Remove	
Diversion tunnel portals	Plug	Filled with slope protection rock. Upstream portal sealed tightly to prevent water from entering. Downstream portal filled loosely.
Penstock tunnel portal	Plug	
Powerhouse, including mechanical and electrical equipment	Partially remove	All concrete below elevation 2,489.4 will be left in place and buried. All mechanical and electrical equipment will be removed and substructure filled with soil.
Powerhouse hazardous materials (transformers, batteries, insulation)	Remove	Unless they are not frayed and will be buried in place.
Tailrace channel	Remove	Infill
0.9 mile of 12-kV and 1.8 miles of 69-kV transmission lines	Remove	
Switchyard	Remove	
Warehouse and residence	Remove	
Historical cofferdam	Remove	Used to divert flow into historical diversion tunnel, then removed as part of final grading.

2.3.2.2 Construction Access and Staging

Figure 2-7, Sheet 2, shows construction staging areas and a disposal site for removal of Copco No. 1 Dam and powerhouse within the limits of work. The Renewal Corporation will mobilize construction equipment to the site by May of the year before drawdown to prepare the staging areas and disposal site. The primary 2.3-acre staging area will be located on the right abutment near the existing switchyard, as shown on Figure 2-7, Sheet 2. Two smaller staging areas are in the same vicinity (0.6 acre across the road and 0.5 acre near the penstocks). The Renewal Corporation will demolish the portions of the roads that are on PacifiCorp property and will provide erosion protection during and post-construction.

The Renewal Corporation will build a new temporary access road by pushing coarse rockfill into the river from the powerhouse or dry river access to the spillway plunge pool for a work platform at the base of the spillway, as shown on Figure 2-8-a. Once the outlet pipe is installed, the Renewal Corporation will modify the work platform by placing fill over the steel outlet pipe to protect it from washing out during potential spillway operation (Figure 2-8-b).

2.3.2.3 Disposal Site

A single, approximately 5.3-acre disposal site will be located above the right abutment at the current location of a maintenance building and a vacant residence (see Figure 2-7, Sheet 2). The Renewal Corporation will use this area for concrete debris generated from the removal of the dam and powerhouse. The Renewal Corporation will pile concrete debris approximately 50 feet deep in the disposal area, cover the concrete with soil material, grade the area for drainage and to blend into the surrounding topography, and provide slope and surface protection.

In addition, the Renewal Corporation will use the following areas for localized concrete and earth-fill disposal:

- Plunge pool, filled with concrete rubble and or general fill covered by on-site riverbed rock fill material as shown on Figure2-9
- Powerhouse, filled and covered as shown on Figure 2-10
- Penstock No. 3 portal and diversion tunnel portals
- An open-water disposal site located in the reservoir near the right bank upstream of the dam for placement of dredge materials removed by pre-drawdown dredging operations, pending permit approval from USACE. The open water disposal site is shown on Figure 2-7, Sheet 1, and the excavation area upstream of the dam is shown on Figure 2-7, Sheet 2. The approach channel excavation areas are shown on Figure 2-8a (indicated by red box on figure).

2.3.2.4 Dam and Powerhouse Removal

The Renewal Corporation will remove the concrete dam to elevation 2,472.1 during the drawdown year. The Renewal Corporation will push the resulting concrete rubble onto the spillway work platform at the base of the dam and haul it to the right bank disposal area.

The Renewal Corporation targets removal of the concrete foundation for completion in August or September and would occur during the in-water work period of the drawdown year when the water surface level will be at its lowest. This work will depend on the river's hydrologic conditions and flows. The existing historical cofferdam will be left in place to direct flows into the diversion tunnel to allow work to remove the concrete dam foundation to proceed in dry conditions (see Figure 2-8-a for approximate location of the historical cofferdam). The Renewal Corporation will remove the concrete dam foundation to elevation 2,472.1 feet so that future scour and migration of the riverbed does not expose foundational concrete that could create a fish passage barrier.

Figure 2-9 shows the final volitional fish passage channel grading plan, including the placement of concrete rubble in the dam scour hole. After the dam foundation has been removed, the Renewal Corporation will remove the historical concrete cofferdam upstream of the main dam by drilling and blasting and by other means necessary. The Renewal Corporation will haul concrete and spoil from the cofferdam to the disposal area. The Renewal Corporation will grade the river channel to provide for volitional fish passage, as shown on Figure 2-9.

Finally, following the removal of the dam and historical cofferdam and the establishment of the river channel, the Renewal Corporation will block the diversion tunnel by backfilling and burying the inlets. The Renewal Corporation will install a grate at the outlet end to prevent human access while allowing for groundwater drainage.

2.3.2.5 Transmission Line and Switchyard Removal

The Renewal Corporation will demolish the Copco No. 1 switchyard, and the Renewal Corporation and/or PacifiCorp will demolish overhead distribution and transmission lines and associated poles or towers, as applicable, and install new connections to maintain the power grid. The Renewal Corporation will demolish approximately 2.7 miles of overhead transmission/distribution line.

2.3.2.6 Imported Materials

Construction materials that the Renewal Corporation may import to the Copco No. 1 facility include temporary and final seed and mulch materials.

2.3.2.7 Waste Disposal

Table 2-6 shows estimated quantities of materials that will be generated during the removal of Copco No. 1 Dam and powerhouse, approximate number of truck trips, and approximate haul distances for waste disposal. The Renewal Corporation will place deconstructed concrete in the on-site disposal site and will haul loose steel off site to a local recycling facility. The Renewal Corporation will haul all mechanical and electrical equipment to a suitable commercial landfill or salvage collection point. Large debris (e.g., metal penstock pipe) may be taken to a recycler in Portland, Oregon, because local facilities may not have appropriate off-loading equipment or the capacity to process large and/or heavy materials. The Yreka Transfer Station is the only waste disposal facility in the vicinity (approximately 30 miles away). The facility has a Class III sanitary landfill accepting construction and demolition waste and mixed municipal waste, and a medium-volume transfer station accepting metals and mixed municipal recyclable materials. See Table 2-6 for a list of materials that the Renewal Corporation will take to landfills and those that the Renewal Corporation will bury in on-site disposal areas.

Table 2-6: Disposal of Copco No. 1 Waste Material

Waste Material	In Situ Quantity	Bulk Quantity[1]	Disposal Site	Quantity Per Trip	Total Trips[2]
Dam and powerhouse concrete	53,000 cy	69,000 cy	On-site	40 cy/trip (unpaved road)	1,750 trips (2 miles RT)[3]
Dam and powerhouse mechanical/electrical	1,175 tons	--	Transfer station near Yreka, CA	25 ton/trip (Copco Road)	50 trips (62 miles RT)
Building material debris	2 buildings 5,000 sf		Transfer station near Yreka, CA	25 ton/trip (Copco Road)	5 trips (62 miles RT)
Power lines[2]	2.7 miles of 12-kV and 69-kV	--	Transfer station near Yreka, CA		

Notes:

1 Volumes are increased by 30 percent for concrete rubble from reinforced concrete and 40 percent from mass concrete.

2 Total trips of concrete assume off-highway articulated trucks with a nominal load capacity of 40 cy. Total trips for hauling mechanical and electrical items and building material debris using truck tractor-trailers is based on 25 tons per trip. Truck trips for concrete disposal will travel only on project lands and private roads.

3 These trips will not occur on public roads.

2.3.3 Copco No. 2

2.3.3.1 Limits of Work

Copco No. 2 Dam is in a narrow canyon on the Klamath River approximately 0.4 mile downstream of Copco No. 1 Dam. Figure 2-7 (Sheets 2 through 4) shows the limits of work and access at Copco No. 2. Table 2-7 summarizes the Copco No. 2 features to be completely or partially removed.

Table 2-7: Removal of Copco No. 2 Features

Feature	Action	Comments
Concrete dam	Partially remove	
Spillway gates, structures	Remove	
Power penstock intake structure and gate	Partially remove	Intake structure to be buried where possible. All concrete that is exposed beyond the backfilled area to be removed.
Tunnel 1 outlet portal, tunnel 2 inlet/outlet portal, overflow spillway portal, and surge vent orifice	Barricade	
Tunnel 1 inlet portal	Concrete plug	
Embankment section and right sidewall	Remove	Earth-fill embankment to be excavated to remove the right bank retaining wall. Wall to be excavated below adjacent final grade. Temporary slope required to remove right bank wall to be backfilled.
Basin apron and end sill	Remove to elevation 2,453.5	

Feature	Action	Comments
Historical cofferdam upstream of dam	Remove	
Wood-stave penstock – wood portion only	Remove	
Wood-stave penstock steel cradles and concrete footings	Bury	Wood-stave penstock steel cradles and concrete footings to be buried in place.
Steel penstock, supports, anchors	Partially remove	Steel penstock concrete anchors to be removed to spring-line of penstock and remaining concrete to be buried in place.
Powerhouse, including mechanical and electrical equipment	Partially remove	Concrete below excavation line to be buried in place. All mechanical and electrical equipment to be removed, and substructure filled with concrete rubble and soil.
Powerhouse hazardous materials (transformers, batteries, insulation)	Remove	Unless they are not frayed and will be buried in place.
Powerhouse control center building, maintenance building, oil and gas storage building	Remove	
0.3 mile of 12-kV and 1.3 miles of 69-kv transmission line	Remove	
Switchyard	Retain portions	Portions to remain in service with 230-kV switchyard on north side of the river.
Tailrace channel	Backfill	Protect from river erosion with E7 Erosion Protection Material.
Copco Village, including former cookhouse/bunkhouse, modern bunkhouse, garage/storage building, bungalow with garage, 3 modular houses, 4 ranch-style houses, and schoolhouse/community center	Remove	

2.3.3.2 Construction Access and Staging

Primary access to the Copco No. 2 diversion dam will be from the right bank, as shown on Figure 2-11. The Renewal Corporation will develop an optional access road to the left bank of the diversion dam as needed to mobilize minor amounts of equipment to help facilitate the dam removal.

The Renewal Corporation will use a temporary bridge located near the existing Daggett Road bridge for construction traffic only. The existing bridge will continue to operate as normal. Construction of the temporary bridge will include minor clearing of vegetation, realignment of the road approach to the temporary bridge, and construction of bridge abutments in the water. The Renewal Corporation will install the temporary bridge between July and August of the year before drawdown over the course of approximately 4 weeks. The temporary bridge will remain in place for the duration of construction, and the Renewal Corporation will remove the bridge and grade and mulch and seed the area at the end of construction. The Renewal Corporation will remove the temporary bridge between November and December of the drawdown year, depending on the river flows and hydrologic conditions; the bridge removal process will take approximately 4 weeks.

Staging areas for the removal of Copco No. 2 Dam are the same as for Copco No. 1 Dam and powerhouse, as shown on Figure 2-7, Sheet 2, and as discussed above. Figure 2-7, Sheet 4 shows the staging areas for removal of Copco No. 2 Powerhouse and the wood-stave penstock. A 0.9-acre staging area is located at the powerhouse, and three additional staging areas are located near the Daggett Road bridge on both sides of the reservoir, as shown on Figure 2-7, Sheet 4.

2.3.3.3 Disposal Site

The Renewal Corporation will permanently bury concrete rubble generated from removal of Copco No. 2 Dam in the disposal site described above for Copco No. 1. Excavated material may also be used to cover the intake structure.

2.3.3.4 Dam Removal

As described in Section 2.1.3, dam removal at Copco No. 2 will occur in two stages: pre- and post-drawdown. Pre-drawdown work will include Spillway Bay No. 1 concrete removal accessed from a temporary construction work platform downstream of the dam. The Renewal Corporation will remove concrete between the two piers of Spillway Bay No. 1 using blasting techniques or mechanical demolition. In addition, the Renewal Corporation may excavate a temporary channel to route flows through Spillway Bay No. 1 below the dam during this pre-drawdown period. The remainder of the Spillway Bay No. 1 demolition would occur after January 1 of the drawdown year.

Dam deconstruction will consist of demolition of the concrete structure and spillway apron. The Renewal Corporation will most likely begin deconstruction from the left bank and move toward the right bank. The Renewal Corporation will remove all concrete down to approximately elevation 2,453.5 feet. The Renewal Corporation will also remove the earth-fill embankment, historical diversion dam, and intake structure (Figure 2-7, Sheet 2). The Renewal Corporation will complete all dam removal work at Copco No. 2 during the in-water work period.

The Renewal Corporation will complete removal of the historical diversion dam upstream of the Copco No. 2 Dam during the in-water work period of the drawdown year. The Renewal Corporation will drive equipment across the river from the right bank and may remove a portion of the left historical diversion dam to provide an alternative flow path for the river and reduce the flows in the work zone. The Renewal Corporation may create a work pad to facilitate cofferdam removal, and it may be necessary to place fill in the channel to allow equipment to cross to the left-side cofferdam. However, the Renewal Corporation anticipates that the reservoir area can be drawn down sufficiently to allow equipment to be driven across without requiring fill. The cofferdam removal plan is shown on Figure 2-12.

The Renewal Corporation prefers an alternative drawdown approach to dewatering the reservoir between Copco No. 1 and 2 for a 5- to 10-day period to deconstruct the Copco No. 2 diversion dam and historical cofferdam, as well as completing the channel restoration in the pre-drawdown year. In this circumstance, the Renewal Corporation would coordinate with PacifiCorp to control water storage in Copco No. 1 Reservoir, manage flows at Link River Dam, and use Iron Gate Reservoir storage to provide downstream environmental flows.

The Renewal Corporation may partially remove the earth-fill embankment by removing the temporary 1.2H:1V excavation that is designed to remove the right abutment retaining wall. The Renewal Corporation will backfill this temporary excavation to the final channel grade. The final grading plan of the channel through the Copco No. 2 site is shown on Figure 2-13.

2.3.3.5 Powerhouse and Penstock Removal

Similar to the removal of the other powerhouses, the Renewal Corporation will demolish the Copco No. 2 Powerhouse down to the adjacent ground level after removing its mechanical and electrical equipment. The Renewal Corporation will remove powerhouse concrete to elevation 2,344.5 feet and backfill the void spaces below with concrete rubble and other fill material (see Figure 2-14). The Renewal Corporation will remove the powerhouse structure and backfill the tailrace during the in-water work period of the drawdown year.

The Renewal Corporation will partially deconstruct the power intake structure at the dam and bury it in place after permanently closing the gate.

The wood-stave penstock is composed of pressure-treated wood, steel bands, steel cradles, and concrete footings. The Renewal Corporation will deconstruct the pressure-treated wood and transport it to an approved landfill. The Renewal Corporation will lay down concrete footings and steel cradles with bands in place and bury them using fill sourced from a borrow source adjacent to the wood-stave penstock.

The Renewal Corporation will remove the steel penstock from the slope above the powerhouse and remove the concrete anchors to the spring-line of the penstock to remove the pipe. The Renewal Corporation will then bury the concrete anchors using soil material adjacent to the penstocks.

The Renewal Corporation will fill tunnels' portal openings with earth fill and close the spillway overflow outlet and surge vent with steel barriers.

2.3.3.6 Transmission Line and Switchyard Removal

The Renewal Corporation will demolish portions of the Copco No. 2 switchyard south of the river, and the Renewal Corporation and/or PacifiCorp will demolish overhead distribution and transmission lines and associated poles or towers, as applicable. The switchyard north of the river will remain. The Renewal Corporation will demolish approximately 0.3 mile of 12-kV and 1.3 miles of 69-kV transmission/distribution line.

2.3.3.7 Imported Materials

Construction materials that the Renewal Corporation may import to the Copco No. 2 facility include temporary and final seed and mulch materials.

2.3.3.8 Waste Disposal

Table 2-8 shows estimated quantities of materials that will be generated during removal of Copco No. 2 Dam and powerhouse, approximate number of truck trips, and approximate haul distances for waste disposal. The Renewal Corporation will place concrete rubble generated during dam removal in the same on-site disposal area on the right abutment (Figure 2-7, Sheet 2) used for Copco No. 1 Dam. The Renewal Corporation will bury concrete rubble resulting from demolition of the powerhouse in the existing tailrace channel. The Renewal Corporation will haul all mechanical and electrical equipment to a suitable commercial landfill or salvage collection point.

The Yreka Transfer Station is the only waste disposal facility in the vicinity (approximately 30 miles away). The facility has a Class III sanitary landfill that accepts construction and demolition waste and mixed municipal waste, and a medium-volume transfer station that accepts metals and mixed municipal recyclable materials. Treated wood from the wood-stave penstock will be hauled to the landfill near Anderson, California, or another approved landfill. Large debris (e.g., metal penstock pipe) may be taken to a recycler in Portland, Oregon, because local facilities may not have appropriate off-loading equipment or the capacity to process large and/or heavy materials. See Table 2-8 for a list of materials that the Renewal Corporation will take to landfills and those that the Renewal Corporation will bury in on-site disposal areas.

Table 2-8: Disposal of Copco No. 2 Waste Material

Waste Material	In Situ Quantity	Bulk Quantity[1]	Disposal Site	Quantity Per Trip	Total Trips[2]
Dam embankment earth	8,840 cy	9,650 cy	On-site disposal area	40 cy/trip (unpaved road)	240 trips (2 miles RT)[3]
Dam concrete	4,800 cy	6,240 cy	On-site disposal area	40 cy/trips (unpaved road)	160 trips (2 miles RT)[3]
Powerhouse concrete	1,850 cy	2,405 cy	On-site tailrace area	Dispose at site (no hauling)	0
Dam and powerhouse mechanical/ electrical	260 tons 1,120 tons		Transfer station near Yreka, CA	25 ton/trips (Copco Road)	6 trips (62 miles RT) 45 trips (56 miles RT)
Building material debris	9 residential buildings 26,400 sf		Transfer station near Yreka, CA	20 cy/trips (Copco Road)	20 trips (56 miles RT)
Treated wood (wood-stave penstock)	550 tons		Landfill near Anderson, CA	20 cy/trip (Interstate 5)	55 trips (140 miles RT)
Power lines[2]	1.6 miles of 12-kV and 69- kV lines		Transfer station near Yreka, CA		

Notes:

[1] Volumes are increased by 30 percent for concrete rubble, 20 percent for loose earth materials.

[2] Total trips of earth fill or concrete assume off-highway articulated trucks with a nominal load capacity of 40 cy. Total trips for hauling mechanical and electrical items using truck tractor-trailers is based on 25 tons per trip. Truck trips for earth and concrete disposal will travel only on project lands and private roads.

[3] These trips will not occur on public roads.

2.3.4 Iron Gate

2.3.4.1 Limits of Work

Iron Gate Dam is in a relatively narrow canyon on the Klamath River. Minimum requirements for a free-flowing condition and for volitional fish passage on the Klamath River through the Iron Gate Dam site require the removal of the earth-fill embankment, concrete cutoff walls, and fish trapping and holding facilities located on random fill downstream of the dam between the rock abutments to the bedrock foundation. Figure 2-15 (Sheets 1 and 2) shows the limits of work and access at Iron Gate. Table 2-9 summarizes the Iron Gate features to be removed or retained.

Table 2-9: Removal of Iron Gate Features

Feature	Action	Comments
Embankment dam, cutoff walls	Partially remove	
Penstock intake structure and footbridge	Remove	
Penstock	Remove	
Water supply pipes and aerator	Remove	
Spillway structure	Backfill	Bury to extent practicable.
Powerhouse, including mechanical and electrical equipment	Partially remove	Concrete below excavation line to be buried in place. All mechanical and electrical equipment to be removed.
Powerhouse hazardous materials (transformers, batteries, insulation)	Remove	Unless they are not frayed and will be buried in place.
Powerhouse tailrace area	Backfill	
Fish Facilities on dam (fish ladder and trapping and holding facilities)	Remove	
Switchyard	Partially remove	
0.7 mile of 12-kV and 6.5 miles of 69-kV Transmission Line	Remove	
Diversion tunnel intake structure	Partially remove	Retained concrete to be buried.
Diversion tunnel portals	Bury	Portals buried; tunnel closed with existing gate in tunnel to prevent river flows.
Diversion tunnel control tower, hoist, and footbridge	Remove	Gate remains in closed position.

2.3.4.2 Construction Access and Staging

Figure 2-15, Sheets 1 and 2, shows staging areas that the Renewal Corporation may use for equipment or material staging, including 7.7 acres above the left abutment of the dam, 1.4 acres southwest of the disposal site, and 1.4 acres northeast of the disposal site. Figure 2-15, Sheet 1, shows 1.9 acres near the right abutment downstream of the dam (currently occupied by two PacifiCorp residences and some outbuildings) that the Renewal Corporation could also use for staging or construction offices. The Renewal Corporation expects that most of the staging activities will occur at the upper left-bank staging area. The

Renewal Corporation will prepare the staging areas by clearing vegetation and minor grading and will restore the areas with minor grading per Best Management Practices (BMPs) design. The Renewal Corporation will likely stage mechanical and electrical debris near the downstream toe of the dam in the parking area and the area of the fish collection facilities.

During pre-drawdown construction, the Renewal Corporation will construct a temporary access road to allow work on the diversion tunnel and gate structure (Figure 2-15, Sheet 1). The temporary road will start on the right bank at the right bank staging area and extend below the spillway outlet and the diversion tunnel outlet to the fish collection facilities and the powerhouse on the left bank. Figure 2-16 shows the portions of the access road that will be constructed in-water. Seepage flows from the spillway will be passed through the road with drainage culverts. This road will be extended to the tunnel outlet using a small bridge to cross the existing fish ladder. Use of the temporary access road requires that at least three of the six fish collection ponds be decommissioned in the pre-drawdown construction year. If river flows are high and water is spilled through the spillway, the road will wash out and will need to be rebuilt.

The Renewal Corporation will construct the temporary access road starting July 15 of the year before drawdown and will complete the road in approximately 20 days. The Renewal Corporation will place approximately 1,500 cy of rock fill below the ordinary high-water mark (OHWM) to support the road. The Renewal Corporation will decommission the temporary road just prior to the start of drawdown. Starting on December 15 of the pre-drawdown year, the Renewal Corporation will remove the portion of the temporary access road that extends in front of the spillway by excavating back toward the right bank, and will remove the portion that extends across the diversion tunnel outlet by working back toward the left bank. The temporary access road will take approximately 10 days to remove and during this time fish will be excluded from the area of active road removal.

Lakeview Road bridge is a county-owned, nine-span, simply supported, rolled-steel-beam bridge across the Klamath River just downstream of Iron Gate Dam. Because the bridge has been posted with a reduced load limit that is less than the current legal/permit loads on bridges and the loads of vehicles needed for the project, the Renewal Corporation will use other (private and public) access. The existing bridge will operate as normal and remain open for public use.

2.3.4.3 Disposal Sites

The Renewal Corporation will place embankment fill primarily into the existing Iron Gate spillway and the upland disposal site. The upland disposal site is on the northeastern slope above the former reservoir from which material was borrowed for dam construction (see Figure 2-15, Sheets 1 and 2). The Renewal Corporation may also use two alternative disposal locations: a disposal site on the left bank of the new river channel upstream of the dam embankment (disposal site #1) and/or one upstream of the left-bank disposal site (disposal site #2).

The Renewal Corporation will place earth materials excavated from the dam in the existing concrete-lined side-channel spillway, chute, and flip-bucket terminal structure (on the right abutment of the dam) to the extent practicable for restoration (see Figure 2-17). Following backfilling, the uphill portion of the spillway excavation may still be visible. After final grading for drainage and aesthetics, the Renewal Corporation will provide slope and erosion protection.

The Renewal Corporation will use concrete rubble from the demolition of the powerhouse and other materials to infill the powerhouse excavation and tailrace area and will place and grade a protective layer of fill above the demolition materials.

2.3.4.4 Dam and Powerhouse Removal

Following drawdown, the gate in the diversion tunnel will be open while the Renewal Corporation is removing the dam embankment. At the conclusion of the dam removal and after breaching, the Renewal Corporation will close the gate and backfill the opening to conform to the final grade.

The Renewal Corporation will start excavation of the embankment section at Iron Gate Dam in early summer of the drawdown year and will complete excavation by early October. The Renewal Corporation will place earth-fill material from the dam embankment in one of the disposal areas as described above. The Renewal Corporation will remove the dam embankment so that the final portion is the upstream base of the dam near the diversion tunnel intake.

The Renewal Corporation anticipates flow rates in the Klamath River to decrease (normal hydrologic cycle) throughout the dam removal period, which will result in low river flows around the time of the final dam breach. The Renewal Corporation will notch the remaining embankment and will progressively downcut the embankment to provide a controlled release of the remaining reservoir. The Renewal Corporation expects that the peak release from the final dam breach will be less than 6,000 cfs if the water surface elevation at the time of the breach is at or below 2,183 feet. This process will restore natural flows in the Klamath River channel and allow for final embankment removal and closure of the diversion tunnel. The Renewal Corporation will bury and permanently block the inlet and outlet of the diversion tunnel using coarse rockfill or concrete rubble. The use of coarse material will facilitate drainage of any water accumulating in the tunnel after the project is complete.

The Renewal Corporation will remove features associated with the powerhouse penstock, including the steel pipe, support members, foundations, anchor blocks, and couplings. The Renewal Corporation will deconstruct most of the concrete thrust blocks but will bury the final thrust block nearest to the powerhouse. The Renewal Corporation will remove all mechanical and electrical equipment from the powerhouse and ancillary facilities and dispose of these materials off-site. The Renewal Corporation will decommission all oil lines and septic systems. Removal of the powerhouse hazardous waste material, transmission lines, and ancillary buildings around the powerhouse and operator residences will not require access to the river, and the Renewal Corporation will complete these removals during the drawdown year after the water conveyance system has been isolated anddrained. The Renewal Corporation will demolish the Iron Gate Powerhouse structure down to elevation 2186.3 after removing its mechanical and electrical equipment. The Renewal Corporation will cover remaining concrete and backfill the area with embankment material. The Renewal Corporation will fill the tailrace area with concrete rubble and rock, as shown on Figure 2-17. The Renewal

Corporation expects the in-water work to fill in the tailrace area to occur between August and the end of September and that this work will take approximately 10 days to complete.

The Renewal Corporation will deconstruct all remaining fish facilities, including collection ponds, the fish ladder, water supply lines, holding tanks, and the spawning building that were not removed during pre-drawdown construction. The volitional fish passage channel will be established by excavating and shaping the final riverbed contours (in water) (see Figure 2-17).

2.3.4.5 Transmission Line and Switchyard Removal

The Renewal Corporation and/or PacifiCorp will demolish overhead distribution and transmission lines and associated poles or towers, as applicable. The Renewal Corporation will demolish approximately 7.2 miles of overhead transmission/distribution line.

2.3.4.6 Imported Materials

Construction materials that the Renewal Corporation may import to the Iron Gate facility include temporary and final seed and mulch materials.

2.3.4.7 Waste Disposal

Table 2-10 shows estimated quantities of materials generated during removal of Iron Gate Dam and powerhouse, approximate numbers of truck trips, and approximate haul distances for waste disposal. The Renewal Corporation will place excavated earth and concrete in the on-site disposal areas. The Renewal Corporation will haul all mechanical and electrical equipment to a suitable commercial landfill or salvage collection point.

Table 2-10: Disposal of Iron Gate Waste Material

Waste Material	In-Situ Quantity	Bulk Quantity[1]	Disposal Site	Quantity Per Trip	Total Trips[2]
Dam embankment earth	193,000 cy	232,000 cy	On-site spillway	60 cy/trip (unpaved road)	3,900 trips (0.5 mile RT)[3]
Dam embankment earth	916,000 cy	1,100,000 cy	On-site disposal area	60 cy/trip (unpaved road)	18,300 trips (2 miles RT)[3]
Concrete	6,500 cy	7,800 cy	On-site disposal area	20 cy/trip (unpaved road)	390 trips (2 miles RT)
Mechanical/ electrical	1,200 tons		Transfer station near Yreka, CA	25 ton/trip (Copco Road)	50 trips (54 miles RT)
Building material debris	4 buildings 2,700 sf		Transfer station near Yreka, CA	25 ton/trip (Copco Road)	10 trips (54 miles RT)

Waste Material	In-Situ Quantity	Bulk Quantity[1]	Disposal Site	Quantity Per Trip	Total Trips[2]
Power lines	7.2 miles of 12-kV and 69-kV line		Transfer station near Yreka, CA		

Notes:

[1] Volumes are increased by 30 percent for concrete rubble, 20 percent for loose earth materials.
[2] Peak daily trips for each site are based on the number of vehicles (units) shown, operating in one 10-hour shift.
[3] Total trips of earth fill assume off-highway articulated trucks with a nominal load capacity of 60 cy. Total trips of concrete assume off-highway articulated trucks with a nominal load capacity of 20 cy. Total trips for hauling mechanical and electrical items using truck tractor-trailers is based on 25 tons per trip.

The Yreka Transfer Station is the only waste disposal facility in the vicinity (approximately 25 miles away). The facility has a Class III sanitary landfill accepting construction and demolition waste and mixed municipal waste, and a medium-volume transfer station accepting metals and mixed municipal recyclable materials. Large debris (e.g., metal penstock pipe) may be taken to a recycler in Portland, Oregon because local facilities may not have appropriate off-loading equipment or the capacity to process large and/or heavy materials. See Table 2-10 for a list of materials that the Renewal Corporation will take to landfills and those that the Renewal Corporation will bury in on-site disposal areas.

2.4 Reservoir Restoration

2.4.1 Expected Reservoir Conditions Following Dam Removal

The restoration actions within the reservoir footprints are stated in the Reservoir Area Management Plan (Appendix C) and updated with information from the 100% Design Report Rev C (Kiewit 2020 – Final Draft Document).

The Renewal Corporation will simultaneously draw down the J.C. Boyle, Copco No. 1, and Iron Gate reservoirs and allow the accumulated sediment to naturally erode and evacuate from the reservoir areas. The accumulated sediment is predominantly silt, clay, and organic material that is more than 80 percent water, and highly erodible. USBR used both one-dimensional (1D) and two-dimensional (2D) sediment transport models to predict likely sediment transport and river conditions in the reservoirs after dam removal. USBR estimated that approximately 50 percent of the stored sediment in the reservoirs will be eroded during drawdown for a median water year with a range of 41 percent to 65 percent for dry and wet years, respectively (USBR 2011a).

The Reservoir Area Management Plan summarizes the previous hydraulic modeling completed by USBR and the anticipated responses of the reservoir areas to drawdown. Anticipated responses include erosion of reservoir deposits; slumping of saturated sediment deposits toward the river channel due to limited shear strength and draining of water from the pore spaces of the deposits; and drying, consolidation, cracking, and hardening of remaining deposits. During development of the 100% design Rev C, the Renewal Corporation used updated (2018) topographic and reservoir bathymetric surveys to estimate post-drawdown topography. The Renewal Corporation also used findings of sediment testing conducted in 2018 to estimate post-drawdown residual sediment thickness in the restored Klamath River channel and in high-priority tributaries.

Each reservoir has distinct features and characteristics. For instance, Copco No. 1 Reservoir has a large floodplain and meandering historical river planform, while the historical channel in the lower reaches of J.C. Boyle Reservoir was confined to a narrow canyon. Table 2-11 summarizes historical water features in each of the reservoirs. Additional description of each reservoir and its likely response to drawdown and dam removal is discussed below.

Table 2-11: Summary of Mainstem River, Side Channel, and Tributaries Currently Inundated in Each Reservoir

Location	Mainstem River Length (miles)	Side Channel Length (miles)	Tributary Length (miles)	Number of Tributaries
J.C. Boyle	3.3	-	0.2	10
Copco No. 1	6.9	1.2	1.5	18
Iron Gate	6.8	-	2.5	52

2.4.2 J.C. Boyle

The accumulated reservoir sediments are contained primarily in the historical channel and are thickest in the confined Canyon Reach. Lacking alternative flow pathways in the confined lower reach, the Renewal Corporation expects that the river will readily scour the reservoir sediment down to the underlying bedrock in the historical river channel bed. Narrow, but potentially several-foot-thick deposits may persist outside the channel banks. In the upstream reach, the Renewal Corporation expects that the channel will preferentially erode its historical channel bed and leave broad (approximately 1,000 feet wide) deposits on the channel margins relatively intact. The Renewal Corporation estimates that these deposits are less than 2 feet thick and will reduce in height and volume by approximately 30 to 40 percent as the material dries and consolidates (see Appendix C, Section 4.1). There are few tributaries on these marginal deposits, so the Renewal Corporation expects little subsequent evacuation after initial drawdown. Given the low relief of the upstream reach, high-flow events will periodically inundate and modify the remnant reservoir surfaces. It is uncertain if pre-dam bedforms such as the large mid-channel bar will be reestablished post-drawdown.

Restoration actions in the former reservoir will be focused on the mainstem and along the Spencer Creek tributary (see Appendix C, Figures B-1 and B-2).

2.4.3 Copco No. 1

Sediment thicknesses vary with pre-existing valley geometry so that the lower-elevation historical channel contains thicker deposits than higher-elevation terraces and other historical surfaces. The pre-dam valley relief was high in the downstream reach, with elevation differences in excess of 50 feet between the channel bed and the higher-elevation low-gradient surface the channel was eroding into on the outsides of its meander bends. These steep outside banks and the material underlying the valley bottom are composed of erosion-resistant fine-grained material. The Renewal Corporation does not expect the Klamath River to incise appreciably into this material, but rather, expects that the river will reactivate its historical planform during drawdown and leave accumulated reservoir sediment on higher-elevation floodplain and upland surfaces.

These spatial patterns of erosion were generally predicted by 2D morphodynamic modeling of Copco No. 1 Reservoir during drawdown (USBR 2011d). The model predicts erosion of reservoir sediment in excess of 5 feet to be concentrated in the sinuous historical channel and in the downstream limb of the cut-off meander bend, which will likely be re-occupied by Beaver Creek following drawdown. The model predicts nearly zero erosion outside of the historical channel. The model does not simulate fluvial bank erosion or bank failure, nor does it incorporate erosion from tributaries, springs, or concentrated surface runoff from hillslopes. Therefore, the extent of modeled erosion is a minimum prediction, and more material will likely be naturally evacuated during drawdown.

Given the topographic variability and width of the low-relief upland surfaces of the pre-dam valley bottom, reservoir deposits 2 to 6 feet thick and hundreds of feet in lateral extent may persist at elevations tens of feet above the mainstem active channel post-drawdown. Tributaries and springs may erode these deposits in some places, and remaining sediments will undergo the physical changes associated with drying. The volume reduction during consolidation may lower the surfaces up to 40 percent of the deposit thickness, and cracks are expected to form. These cracks may concentrate flow from surface runoff in the future and become the foci of subsequent erosion of the deposits through rilling and gullying (The Renewal Corporation 2018).

In addition to the mainstem of the Klamath River, the Renewal Corporation will focus restoration efforts on the Beaver Creek complex (see Appendix C, Figures B-5 through B-7).

2.4.4 Iron Gate

At Iron Gate Reservoir, the Renewal Corporation expects that the Klamath River will efficiently evacuate the majority of the reservoir sediment because the reservoir deposit layers are thin, the reservoir is deep, drawdown will be more rapid, and the historical channel occupied a narrow pre-dam valley with steep adjacent hillslopes (USBR 2011d). Reservoir sediments do not exceed 5 feet in thickness, except at the Jenny Creek delta, so uneroded sediment persisting after drawdown will reduce in thickness to around 3 feet after drying.

Given the relatively more-rapid drawdown proposed at Iron Gate Reservoir, reservoir deposit erosion from slumping should be more efficient (USBR 2011d). There are several mapped low-relief terraces, fans, and historical floodplains in the valley bottom on which larger areal extents of sediment may persist. The greatest uncertainty relates to the erosion of deposits by tributaries, particularly the Camp-Scotch-Dutch Creek complex in Mirror Cove. The valley is wider in Mirror Cove relative to the size of the historical tributaries, and therefore a larger areal extent of sediment relative to the mainstem areas is expected to remain after drawdown. However, these deposits are only 2 to 3 feet thick, and the deposits will consolidate when dry.

The main restoration areas in the Iron Gate Reservoir footprint are the mainstem of the Klamath River, Jenny Creek, and the Camp Creek complex (Dutch, Camp, and Scotch Creeks) (see Appendix C, Figures B-9 through B-12).

Primary reservoir restoration actions for J.C. Boyle, Copco No. 1, and Iron Gate will be the following: (1) reservoir drawdown, (2) sediment evacuation, and (3) dam removal. The Renewal Corporation will perform additional restoration actions to provide volitional fish passage, selectively stabilize residual sediments, and encourage native plant establishment. In addition, the Renewal Corporation will take supplemental restoration actions to enhance aquatic habitat in prioritized locations. The Reservoir Area Management Plan (Appendix C) describes measures for restoration implementation, monitoring, and adaptive management of the exposed reservoir bottoms and surrounding areas disturbed as part of the Proposed Action. The Reservoir Area Management Plan defines the restoration elements, establishes restoration performance criteria, and specifies monitoring and adaptive management approaches for river geomorphology and associated riparian and upland revegetation. The sections below provide a summary of the reservoir restoration approach and actions.

Restoration actions described herein include a tool chest of options the Renewal Corporation will apply based on existing information, and during subsequent restoration design iterations that will be based on observed and measured post-drawdown conditions. These include the following:

- Implementing measures to encourage sediment evacuation during drawdown.
- Reconstructing a geomorphically appropriate channel through the former dam footprints.
- Selective post-drawdown grading of mainstem near-channel areas and priority tributaries as needed to provide volitional fish passage, remove large, unstable residual sediment deposits, and where cost-effective and feasible, improve hydrologic connectivity to off-channel and floodplain areas to establish and sustain native riparian vegetation and enhance aquatic habitat.
- Installing large wood and boulder clusters to enhance habitat.
- Installing willow baffles to provide floodplain roughness and to encourage vegetation establishment and selectively stabilize sediments.
- Revegetating formerly inundated areas primarily through seeding to slow erosion and re-establish native plant communities.
- Selectively planting and irrigating locally salvaged and/or nursery-sourced plants, including wetland sod, willow cuttings, bare root trees and shrubs, and acorns.
- Controlling high-priority IEV prior to, during, and following construction where cost-effective and feasible.
- Fencing select locations to protect restored reservoir areas from trampling and herbivory by cattle and wild horses.

The Renewal Corporation will focus restoration actions on the mainstem Klamath River and high-priority tributaries and natural springs. The main physical constraint limiting the extent of restoration actions is the presence of culturally sensitive resources. The Renewal Corporation will perform final cultural resource evaluations post-drawdown, which could further constrain restoration activities.

The application of most of the above restoration actions depends on the distribution and amount of residual sediment following drawdown in each of the reservoirs. However, both the location and thickness of residual sediment remaining in the reservoirs following drawdown is uncertain. Residual sediment will vary, primarily depending on river flows during drawdown and, to a lesser degree, by the effectiveness of supplemental sediment evacuation methods. See Appendix C Sections 5.4.1, 5.5.1, and 5.6.1 for information on the approach, methods, and timing of supplemental sediment evacuation in each reservoir.

The restoration measures within the reservoir footprints will follow a feedback loop centered around systematic adaptive design and implementation. The Renewal Corporation will review channel response within the mainstem Klamath River and priority tributaries following drawdown, and information obtained during the monitoring process will be used to inform decisions regarding design for active restoration (construction) or continued monitoring of channel response. This process is described in Appendix C, Section 6. Restoration priorities are driven by the primary project goals of volitional fish passage, residual sediment stabilization, native plant establishment, and the secondary goal of enhancing native fish habitat. Priorities also considered the challenging natural environment for plant establishment, including variable soil quality, low rainfall, high summer temperatures, and competition from invasive species. From this, the Renewal Corporation identified the following four restoration tiers:

- 1st Tier - Klamath River. The highest Project priority is providing volitional fish passage on the Klamath River. This will be achieved through the primary habitat restoration actions (drawdown, sediment evacuation, and dam removal). Mainstem habitat connectivity is important for re-establishing natural distributions of anadromous salmonids and Pacific lamprey in the Klamath River Basin. The Renewal Corporation will promote fish passage by reconstructing a fish-passable and geomorphically appropriate channel through the footprints of the former dams. In addition, any anthropogenic structures in the river channel, either known or uncovered post-drawdown, will be removed. Additional measures may be taken to opportunistically encourage floodplain benches and channel complexity where post-drawdown conditions, access, time, and budget allow. Generally, the restoration approach for the Klamath River is to restore natural processes so that the river and associated habitats can recover without significant intervention (process-based restoration).
- 2nd Tier - Perennial Tributaries. The secondary priority is perennial tributaries, particularly at the tributary confluences with the Klamath River and where tributaries have formed deltas around the reservoir rim. Tributaries and tributary mouths tend to be highly used habitats by anadromous salmonids and Pacific lamprey. Tributaries can support several life stages necessary for anadromous salmonids to complete their life history, including spawning, egg incubation, juvenile rearing, and overwintering. Tributary mouths provide habitat for anadromous salmonids originating in the tributary, as well as adults and juveniles during migration and rearing. Because tributaries are expected to have lower suspended sediment loads than the mainstem as it adjusts to its restored condition, tributary mouths may also be particularly important refugia habitat for salmonids and Pacific lamprey in the first few years following drawdown.
- 3rd Tier - Natural Springs. Natural springs and seeps are water sources that can be used to create wetlands, add channel complexity by supporting spring-fed alcoves or side channels, and widen riparian areas. Appropriate planting and focused, minor grading can add complexity and connectivity to ecosystems associated with the river and springs. Expanded and revegetated areas serve as seed sources for passive restoration in adjacent areas, provide critical functions in terms of refugia and

foraging for terrestrial species, and improve potential biological productivity for a range of species, including aquatic organisms.

- 4th Tier - Intermittent and Ephemeral Tributaries. Although perennial tributaries are the highest priority, there are selected intermittent tributaries that may provide non-natal juvenile rearing refuge habitat. If access and budget allow, restoration actions may address connectivity at the mainstem confluence of the larger intermittent tributaries to provide expanded habitat and/or increased biological productivity.

Table 2-12 provides the goals and objectives that are informed by the current and historic conditions in the reservoir footprints which are described in detail in Appendix D of the Reservoir Area Management Plan. The goals and objectives that are intended to support the overall goals of restoring volitional fish passage, stabilizing exposed sediment with native vegetation, and enhancing habitat are described earlier in this section. Multiple planning-phase goals have already been accomplished. Additional objectives are included based on recent design updates. These include, for example, additional restoration activities for fish passage monitoring per the ODEQ and SWRCB CWA 401 WQCs. The maintenance and monitoring period is expected to be 5 years, beginning in the year following drawdown.

Table 2-12: Goals, Objectives, and Restoration Activities for Reservoir Area Restoration

<table>
<tr><th>Period</th><th>Goal</th><th>Objective</th><th>Restoration Measures</th></tr>
<tr><td rowspan="12">Pre-Construction Period</td><td rowspan="5">Prepare native plant materials for revegetation.</td><td rowspan="5">Collect and propagate native plant seed and grow container plants.</td><td>In Process. Identify potential seed collection, seed propagation, pole harvest cutting areas, and container plant grow contractors.</td></tr>
<tr><td>In Process. Perform surveys to identify and map seed collection and pole harvest areas.</td></tr>
<tr><td>In process: Prepare seed collection, seed propagation, container plant growing, and pole harvest contract documents.</td></tr>
<tr><td>In Process. Award and monitor native plant and seed contracts.</td></tr>
<tr><td>In Process. Develop revegetation contract documents.</td></tr>
<tr><td rowspan="5">Reduce invasive exotic vegetation (IEV).</td><td rowspan="2">Reduce and minimize the local occurrences of IEV.</td><td>Complete. Gather existing IEV data and perform IEV surveys.</td></tr>
<tr><td>Complete. Review potential herbicides and potential impact on fish and water quality.</td></tr>
<tr><td rowspan="3">Implement an IEV management program.</td><td>The Reservoir Area Management Plan. Create management plan and review with stakeholders.</td></tr>
<tr><td>Complete. Procure local contractor to perform IEV removal.</td></tr>
<tr><td>Pending. Inspect and monitor IEV removal execution.</td></tr>
<tr><td rowspan="2">Understand likely evolution of reservoirs post-removal and responses to restoration and</td><td rowspan="2">Conduct studies to fill in data gaps from prior planning efforts.</td><td>Completed. Sample sediment and perform tests to investigate wetting and drying characteristics, plant nutrient availability, and natural revegetation potential.</td></tr>
<tr><td>Completed. Perform revegetation pilot tests for native seed mixes.</td></tr>
</table>

Period	Goal	Objective	Restoration Measures
	reservoir management.		*In Process.* Identify reference physical and ecological conditions in tributaries.
Dam removal period (0 to 1 year)	Maximize reservoir area restoration for ecological uplift.	Develop comprehensive restoration plan for post-removal reservoir conditions.	*During drawdown*. Actively promote erosion of reservoir deposits during drawdown; use available techniques such as barge mounted hydraulic monitors or boats (supplemental sediment evacuation).
			Post-drawdown. Modify and enhance site-specific restoration actions based on site conditions after drawdown.
			Identify culturally significant areas that are off limits to disturbance.
			Post-drawdown. Develop final engineering plans for implementation.
	Allow natural erosion and transport of reservoir deposits and dispersal in the ocean.	Maximize erosion of reservoir deposits during drawdown.	*Post-drawdown.* Implement supplemental sediment evacuation activities.
	Evaluate active restoration options (post-removal) for habitat development.	Define locations amenable to site-specific restoration actions.	*Post-drawdown.* Collect new topographic data for basis of restoration design progression
			Post-drawdown. Delineate planting zones.
			Post-drawdown. Install pole cuttings and bare-root trees and shrubs.
	Stabilize remaining reservoir sediments.	Initiate native plant revegetation.	*Post-drawdown*. Seeding and establishment of riparian and upland vegetation.
Dam removal period (0 to 1 year) (continued)	Restore volitional fish passage in mainstem and tributaries.	Monitor and rectify any non-natural fish passage barriers.	*Post-drawdown*. Conduct field monitoring of mainstem and tributaries; fix non-natural barriers
			Post-drawdown. Conduct field monitoring of mainstem and tributaries; fix identified non-natural barriers.
	Minimize IEV.	Implement and monitor IEV removal during revegetation.	*Post-drawdown*. Include criteria for IEV removal during revegetation implementation.
			Post-drawdown. Monthly inspections of revegetation areas to verify IEV compliance.
Short-term (1 to 5 years after removal)	Restore natural ecosystem processes.	Continue native plant revegetation, maintenance, and monitoring.	*Post-drawdown*. Monitor establishment and adaptively replace failed pole cuttings, acorns, and container plants.
			Post-drawdown. Maintain irrigation system.
			Re-seed poorly established areas.
	Implement process-based river and tributary restoration actions where applicable.	Work with the river, not against it.	*Post-drawdown*. Assess progress of channel evolution based on natural processes. Implement intervention or construction where is necessary per the adaptive management program described in Chapter 6 of this document.
	Minimize IEV.	Continue IEV monitoring and removal.	*Post-drawdown.* Include criteria for IEV removal during establishment.
			Post-drawdown. Perform monthly inspections to verify IEV removal compliance.

Period	Goal	Objective	Restoration Measures
	Restore volitional fish passage in mainstem and tributaries.	Monitor and rectify any non-natural fish passage barriers.	*Post-drawdown.* Conduct field monitoring of mainstem and tributaries, fix non-natural barriers.
	Secondary Goal: Promote fish habitat.	Secondary Objective: Increase quantity and quality of in-stream and off-channel habitat for aquatic species.	*Post-drawdown*. Construct in priority tributary areas, in-stream habitat features based on designs that are appropriate for the system.
			Post-drawdown. Construct off-channel wetlands, side channels, and alcoves where appropriate.
			Post-drawdown. Enhance mid-channel gravel bars in priority tributaries.

The Renewal Corporation expects long-term outcomes resulting from the Proposed Action will include the establishment of volitional fish passage and ultimately the restoration of natural ecosystems processes; however, once volitional fish passage and natural ecosystems processes are achieved, continued monitoring and adaptive management will not be necessary. Natural ecosystem processes are generally described as follows:

- Natural hydrology maintained – river flow unimpeded to artificial impoundments in the Hydroelectric Reach – responds to natural hydrologic conditions
- Sediment transport processes maintained – sediment aggradation and degradation occurs – sediment is transported through the Hydroelectric Reach, enabling sediment transport connection between the Hydroelectric Reach and mainstem Klamath below the former Iron Gate Dam location
- Vegetation recruitment and propagation – the natural recruitment and propagation of native plant species is occurring
- Aquatic fish and invertebrate species occur within the river and perennial tributary features

2.4.5 Perennial Tributary Restoration

The Renewal Corporation will conduct restoration activities in the priority tributary restoration sites primarily during the Construction Period (drawdown year and year following), depending on how site conditions evolve. Restoration work to be conducted at the priority tributary restoration sites will include regrading of tributary stream channels for volitional fish passage and placement of boulder clusters, willow baffles, and large wood structures with ground-based equipment and helicopters. Priority tributary restoration sites include the lower portions or confluence areas adjacent to the tributaries listed in Table 2-13. The anticipated lengths of restored tributaries are shown in Table 2-13; although the final tributary length depends on natural processes.

Table 2-13: Tributary Restoration Lengths

Tributary	Anticipated Length (feet)
Spencer Creek	106
Beaver Creek	501
Jenny Creek	885
Scotch Creek	1,204
Camp Creek	6,181

A summary of the priority tributary restoration sites is provided below:

- **Spencer Creek:** The Renewal Corporation will limit restoration of Spencer Creek to minor profile adjustment at or near its confluence with the Klamath River. Sediment composition at the confluence is expected to be coarser than other locations throughout the Spencer Creek restoration reach; thus, it is plausible that during a low-flow year, mechanical means of sediment removal may be necessary. Under normal water years, sediment might be self-evacuated by flow in Spencer Creek. Design considerations for Spencer Creek will focus on removing observed passage barriers and providing a restored channel with stable planform, profile, and cross-section while promoting frequent floodplain access commensurate with the geomorphometry of the portion of Spencer Creek just upstream of the reservoir footprint.
- **Beaver Creek:** As with other primary tributaries, the Renewal Corporation will focus restoration work at Beaver Creek on preserving fish passage from the confluence with the Klamath River upstream beyond the limits of the reservoir footprint. Historical topographic information suggests that the alignment of Beaver Creek has occupied one (1) segment or the other of an abandoned Klamath River meander. The strategy for Beaver Creek will be to allow geomorphic processes to create the preferred pathway for Beaver Creek; whichever direction the path follows will be monitored, and interventions to preserve fish passage will be initiated as needed. Furthermore, the lower extents of Beaver Creek may comprise single or multiple threads.
- **Jenny Creek:** The Renewal Corporation expects restoration activities for Jenny Creek will address volitional fish passage through deltaic sediments at the upstream limits of the reservoir footprint as well as passage continuity through reservoir sediments at the confluence with the Klamath River. Adaptive design strategy will follow the procedure described in the Reservoir Area Management Plan (Appendix C, Section 6.2), but there is a high likelihood that physical manipulation of sediments will be required in the upstream section of the reach.
- **Camp Creek:** Restoration for Camp Creek will be similar to the approach outlined for Jenny Creek. Sediments that do not evacuate during drawdown will be physically removed during the year following dam removal as part of the restoration activities. In Camp Creek there is a potential for a multi-thread channel at the downstream end based on bathymetric mapping. The channels will be monitored as described in in the Reservoir Area Management Plan (Appendix C, Section 6.2) and restoration activities will focus on establishing and maintaining volitional fish passage.
- **Scotch Creek:** Restoration for Scotch Creek will be similar to the approach outlined for Jenny Creek. The Renewal Corporation will physically remove sediments that do not evacuate during drawdown

during the year following dam removal as part of the restoration activities. At Scotch Creek it will be important to promote confluence stability with Camp Creek. The Renewal Corporation will monitor channels as described in in the Reservoir Area Management Plan (Appendix C, Section 6.2) and will focus restoration activities on establishing and maintaining volitional fish passage.

- **Long Gulch:** Though not listed as a Major Tributary, Long Gulch will require targeted work following dam removal. Several culverts believed to have been placed during original dam construction are submerged in Long Gulch. The Renewal Corporation expects restoration activities along Long Gulch to consist of the removal of these culverts, reconstruction of the banks to approximate adjacent contours, and revegetation.

After restoration work is complete at the end of the Construction Period, some additional grading work may be needed at these tributary locations during the maintenance period (anticipated over a five-year period following the Construction Period). Additional in-water work that may occur during the maintenance period could include maintenance actions focused on fish passage, headcut migration, and residual reservoir sediment. The Renewal Corporation expects in-water work to be minimized but could occur at different locations over time in accordance with the fish passage monitoring, maintenance activities, and adaptive management detailed in the Reservoir Area Management Plan (Appendix C, Section 6.0).

The Renewal Corporation will apply in-water work best management practices (BMPs) to work related to reservoir restoration activities. These BMPs are specific to the restoration activities conducted during the Construction Period and Maintenance and Monitoring Period of the project. These BMPs for in-water work are part of the overall adaptive management approach that includes proactive monitoring and surveys for fish passage and tributary connectivity blockages, as described in the Reservoir Area Management Plan (Appendix C) and Aquatic Resources Management Plan (Appendix D).

Significant adaptive management interventions involve in-water work and the need for work zone isolation measures. The Renewal Corporation will implement the following BMPs for significant interventions that require in-water work:

1. The Aquatic Technical Working Group (ATWG) will be notified a minimum of 48-hours before start of work.
2. Unless under the guidance of ATWG, in-water work activities will occur during the in-water work window, expected to be June 15 to October 31.
3. A biologist will evaluate the in-water habitat to determine if salmonids or protected fish occur in the limits of work.
    a) If salmonid or protected fish are or are assumed to be present in the in-water work area, fish rescue, relocation, and exclusion will occur under the direction of a qualified fisheries biologist.
        (1) General conditions for fish capture and relocation activities: Exclusion will include the use of block nets, or similar, to isolate the work area from fish access. The fisheries biologist will evaluate the upstream and downstream extent of the fish exclusion and relocation efforts, which will be based on the minimal amount of wetted channel where salmonids may experience potential injury or mortality from the in-water activity. Fish relocation will be

performed using seine nets, dip nets, and/or electrofishing as determined appropriate and effective by the fisheries biologist. The duration and extent of fish relocation actions will be determined by the fisheries biologist. Once the work area is determined to be cleared of salmonids, in-water work activities will be cleared to begin.

i. Electrofishing: All electrofishing will be conducted in accordance with the NMFS Guidelines for Electrofishing Waters Containing Salmonids Listed under the Endangered Species Act (NOAA and NMFS, 2000).
ii. Salmonid Handling and Relocation: National Oceanic and Atmospheric Administration (NOAA) Restoration Center's Programmatic Approach to ESA/EFH Consultation Streamlining for Fisheries Habitat Restoration Projects (NOAA and NMFS, 2017), Section 2.4.1.E – Guidelines for Relocation of Salmonids, will guide relocation work.

b) If no salmonids or protected fish occur in the work area, a biologist will monitor the in-water work actions to ensure that there is no change in conditions that would require fish exclusion or relocation. The biologist will document and report the completion of the in-water work activity to NMFS as described below.

4. The Renewal Corporation will minimize disturbance to existing riparian vegetation and channel banks to the extent feasible to complete the required restoration or maintenance action.
5. In the tributary restoration areas, the Renewal Corporation will use cofferdam and flow diversion around the work area if channel bed adjustments are required.
6. The Renewal Corporation will use and store petroleum-powered equipment in a manner to prevent the potential release of petroleum materials into waters of the state.
7. Areas for fuel storage, refueling, and servicing of construction equipment will be located in an upland location.
8. Oil absorbent and spill containment materials will be on site when mechanical equipment is in operation within 100 feet of the proposed watercourse crossings. If a spill occurs, no additional work shall commence in-channel until the following occurs: (1) the mechanical equipment is inspected by the Renewal Corporation, and the leak has been repaired; (2) the spill has been contained; and (3) ATWG is contacted and have evaluated the impacts of the spill.
9. The Renewal Corporation will follow invasive species control measures to minimize potential transport of aquatic invasive species.
10. Documentation and Reporting: The Renewal Corporation will provide photographs of the in-water work location, summary of actions including any fish relocation, and notification of completion of the in-water work to ATWG within one (1) week of the completion of in-water work.

2.4.6 Measures to Manage Remaining Sediment

Stabilization of remaining reservoir sediment will be achieved through revegetation at J.C. Boyle Reservoir, Copco No. 1 Reservoir, and Iron Gate Reservoir. Vegetation restoration focuses on control of invasive exotic vegetation (IEV) species and revegetation of the reservoir areas with native grasses, shrubs, and trees as the primary method for sediment stabilization and riparian, wetland, and upland restoration. To implement this plan and manage the remaining reservoir area sediments, the Renewal Corporation proposes a two-pronged approach that consists of revegetation and active habitat restoration with monitoring and adaptive management. As part of this approach, the Renewal Corporation will conduct selective grading to remove unnatural erosion-resistant deposits that create fish passage barriers and to stabilize un-evacuated sediment at vulnerable high-sediment yield locations. The following sequence describes the activities and restoration features that may be implemented in the reservoir areas to manage sediment that is not eroded during drawdown:

1. Pre-dam removal (1 to 2 years pre-drawdown): conduct pre-treatment of IEV species, collect seeds, and grow additional seed stock.
2. Reservoir drawdown (January to March, year of drawdown): perform reservoir drawdown with natural erosion and supplemental sediment evacuation of accumulated reservoir sediment deposits; stabilize sediments and exposed areas with mulch and pioneer seeding, as needed and possible.
3. Post-drawdown first summer/fall (dry season immediately after drawdown): conduct additional seeding application where needed for exposed areas and remaining reservoir deposits, potentially with grasses and ground cover; manual removal/treatment of IEV; install riparian trees and shrubs in selected locations; and potentially install helicopter-placed wood structures.
4. Post-removal (year after dam removal is complete): maintain vegetation; continue to remove and treat IEV; design and implement priority fish-bearing tributary restoration grading work; install habitat elements such as willow baffles, boulder clusters and large wood habitat features.
5. Establishment period (years 3 through 7 post-drawdown): continued monitoring and maintenance of vegetation, removal of IEV, fish passage monitoring, and enhancement and maintenance of habitat features, as needed.

The Renewal Corporation will implement a detailed revegetation plan (Appendix C, Section 5.3), that addresses plant collection, propagation, seed collection, native bare root plants, pole cuttings/live stakes, native plant salvage, seed mixtures, mulching, irrigation, woody species, fencing, and Invasive Exotic Vegetation (IEV) management. The revegetation plan includes the following elements:

- Develop an additive layering system within each broad vegetation community type that (1) sets a matrix condition with seed and then (2) builds upon the matrix condition with supplemental woody species plantings where appropriate.
- Provide flexibility to respond to unfolding field conditions and subtleties in the landscape such as remnant wetland/riparian vegetation, post-drawdown soil conditions, microtopography, soil moisture, seeps, rocky areas, and drainages within each planting zone.
- Create a tool that will support revegetation post-drawdown as well as short- and long-term adaptive management efforts.
- Use inexpensive and robust plant material in the form of seed, cuttings, and bare root stock that are easily transported, establish well in difficult restoration conditions, cost much less per plant than container plants, and reduce the likelihood of spreading pathogens such as phytophthora.
- Plant bare root woody species in dense clusters within the seeded matrix to concentrate resources, increase survival rates via facilitation mechanisms and create island patches of trees and shrubs that will accelerate vegetation structural diversity and community development.

- Use existing adjacent vegetation cover types and post-drawdown topography and soil conditions to guide revegetation efforts.
- Allow for modifications to planting densities within an area while adhering to the total quantity of plant material being installed and managed to better mimic the subtle changes in densities across communities and the strata (tree, shrub, groundcover) within those communities.
- Incorporate salvaged wetland vegetation (sod, plugs or woody vegetation) opportunistically.

The Renewal Corporation will achieve revegetation of the exposed reservoirs through a combination of IEV management, seeding native herbaceous and woody species, planting bare root trees and shrubs and natural recruitment of vegetation.

The Renewal Corporation plans to use irrigation in the Iron Gate and Copco No. 1 newly established riparian areas as needed, and strategically place fencing around high-priority restoration areas.

The Renewal Corporation will implement two primary strategies for IEV treatment: eradication and containment. Species to be contained are those that are ubiquitous on the landscape, those in close proximity to all restoration areas, and those that cannot be realistically eradicated or contained for long periods, including cheatgrass (*Bromus tectorum*), medusahead (*Elymus caput-medusae*), and yellow starthistle (*Centaurea solstitialis*). The Renewal Corporation determined strategies for each species based on abundance on the landscape and the cost-effectiveness of treatments. The Renewal Corporation will adaptively manage treatments through a robust quantitative monitoring program. Treatments will require a combination of methods including mechanical (grubbing, mowing) and chemical. The Renewal Corporation will minimize chemical treatments for use only on species that are not effectively treated mechanically. The Renewal Corporation will not use helicopter or other mechanical sprayers. It is anticipated that a 10 to 50 ft buffer along up to 49 miles of access roads that includes the area around Iron Gate to Copco Lake and J.C. Boyle Powerhouse to the upper extent of J.C. Boyle Reservoir will be treated for IEV. The Reservoir Area Management Plan (Appendix C, Section 5.3.3) describes the herbicide BMPs that will be followed.

The Renewal Corporation will make strategic use of temporary fencing at priority tributary restoration sites to prevent browsing of newly planted vegetation. This use of fencing is constrained by construction access, flooding, and cost-effectiveness. Fencing installation will need to be modified in some locations based on topography and obstructions (e.g., steep slopes, rocks, trees). Where feasible, the Renewal Corporation will create exclusion zones around each of the proposed restoration areas rather than protecting individual plants with tubes. Fencing is intended to exclude cows and horses. The only fencing currently contemplated is fencing of priority tributary sites; the Renewal Corporation will minimize fencing of stream crossing areas.

The Renewal Corporation will install taller fencing to protect against deer and other native herbivores if herbivory becomes a management problem. The Renewal Corporation is not proposing taller fencing at this time but will investigate such fencing as an adaptive management practice if it observes unacceptable levels of herbivory by deer.

2.4.7 Measures to Monitor Remaining Sediment

Monitoring associated with restoration of the reservoir areas is designed to measure progress toward achieving the project goals, inform potential adaptive management needs, and provide feedback into river and reservoir area conditions to evaluate whether sites are trending towards or away from achieving the goals of the Proposed Action. The Renewal Corporation has identified physical site characteristics as appropriate monitoring metrics using standard field techniques to produce data compatible with standard protocols derived from previously developed dam removal monitoring and adaptive management plans as described in the following sections.

After drawdown of the reservoirs and removal of the dams, the Renewal Corporation will take the following actions to establish "baseline" or "initial conditions." The initial conditions reference data will be used for monitoring and adaptive management related to reservoir restoration:

1. Permanent ground photo points may be established throughout the reservoir areas that enable sufficient vantage points of critical areas in the reservoirs. The Renewal Corporation will take photos to provide initial conditions for monitoring data to develop informed maintenance and corrective actions. Each photo ground point may be monumented with 5/8-inch rebar and aluminum cap for long-term stability and documented with a northing, easting, and elevation using a survey-grade global positioning system.
2. High-resolution vertical aerial photos, sub-meter accuracy, may be completed for the reservoir areas.
3. The Renewal Corporation anticipates collecting aerial topographic data capture using Light Detection and Ranging (LiDAR) data, photogrammetric topographic data, or similar for the reservoir areas after sediment evacuation and initial ground cover stabilization and use it to create initial conditions surface models.

The Reservoir Area Management Plan (Appendix C, Section 6.1) provides monitoring parameters that include stability of remaining reservoir sediments, fish passage, IEV, native plant revegetation, and restoration of natural ecosystem processes.

2.4.8 Measures to Restore the Klamath River in Reservoirs

The Renewal Corporation used historical photographs of the reservoir areas prior to dam construction and inundation to inform restoration planning. These pre-dam photos show that the Klamath River was predominantly a narrow, volcanic bedrock– dominated canyon with a single-thread river. Isolated areas in the canyon are wider, such as in Copco No. 1 Reservoir and the upper portion of J.C. Boyle Reservoir. In these wider valley sections, the gravel-bed river planform is controlled by the locally resistant topographic constraints and contains floodplains and off-channel features such as remnant channels and wetlands.

The Renewal Corporation expects that the Klamath River in the reservoir areas will re-occupy the historical channel alignment due to geological constraints and the erosion of fine sediments accumulated in the reservoir bottoms during and immediately following drawdown. This conclusion was reached from both a geomorphic evaluation and a two-dimensional hydraulic modeling analysis by USBR (2012b). Because the Klamath River channel has not been altered since construction of the dams, the Renewal Corporation expects that the river will return to a natural gravel/cobble-bed river and behave similarly to pre-dam conditions. One exception is that riparian vegetation, primarily willows, may not be established on the banks, but will be planted with the revegetation efforts. The Renewal Corporation will implement the detailed riparian revegetation plan in the Reservoir Area Management Plan (Appendix C) to restore the Klamath River in the reservoir areas and restart natural river processes.

Habitat restoration on the floodplains and tributaries that flow into the Klamath River in the reservoir areas is critical to restoring natural ecosystem processes to the Hydroelectric Reach. The Renewal Corporation will implement the following restoration techniques in the reservoir areas as appropriate:

1. **Tributary Connectivity**: The Renewal Corporation will use light equipment and manual labor to move materials and enhance access and longitudinal connectivity of the tributaries with the mainstem Klamath River. In addition, the Renewal Corporation will add large wood to tributaries either in the channel or on the floodplain/terrace to promote habitat and complexity and connectivity as further described below.
2. **Wetlands, Floodplain, and Off-Channel Habitat Features**: Incorporating floodplain features into exposed floodplains, including wetlands, floodplain swales, and side channels.
   a) Wetland restoration strategies for the reservoir areas include preservation of existing non-reservoir-dependent wetlands, hydrologic connection of off-channel wetlands with the river, or creation of new wetlands at lower elevations corresponding to the post-dam removal surfaces and hydrologic regime.
   b) Floodplain swale are small depressional areas incorporated into the floodplain that provide microsites where floodplain vegetation can establish at slightly lower elevations (closer to the water table) than adjacent floodplain surfaces. To maximize diversity, floodplain swales vary in size and depth, but do not extend below the anticipated baseflow elevation.
   c) Side channel restoration strategies include modifying inlet and outlet hydraulics, improving hydraulic complexity with structures or realignment, and delivery of water to higher floodplain surfaces.
3. **Floodplain Roughness**: The Renewal Corporation will apply floodplain roughness as a strategy to exposed areas where frequent interaction with the river channel is anticipated. Floodplain roughness is created using equipment to roughen the floodplain surface with microtopography and partially bury brush, limbs, and wood in the soil. Microtopography creates variation in the constructed floodplain surface ranging from 0.5 foot above to 0.5 foot below the existing or design floodplain surface. Brush, limbs, and wood in the soil will increase moisture retention, create protective microsites for establishing seed and plants, and promote soil development by introducing organic material. The Renewal Corporation anticipates using willow baffles and large wood to create floodplain flow obstructions that promote sediment re-working and reduce floodplain flow velocities. Willow baffles are proposed as short-term measures to help stabilize newly exposed channel overbank areas until riparian revegetation establishes. Willow baffles are ‘hedges’ of willow poles planted perpendicular to the flow direction. The poles are densely planted in trenches that are backfilled with soil and small rock to provide some initial resistance to flow.

4. **Riverbank Stability and Channel Fringe Complexity**: The Renewal Corporation will introduce channel fringe complexity through the riparian revegetation and strategic addition bankline complexity (i.e., vegetation, rootwads, etc.), large wood, and boulders to create velocity shadows, improve bank stability, and reduce unnatural erosion. Boulder clusters will be locally sourced, oversized boulders (approximately 2 to 6 feet in diameter) at select locations along high-priority tributaries to enhance habitat. The number and size of boulders will vary depending on location and function, and placement will be done using land-based equipment working in readily accessible areas.
5. **Large Wood Habitat Features**: Although historical photos do not show large wood as a predominant geomorphic feature, the Renewal Corporation anticipates using large wood to improve habitat and promote reservoir area conditions that restore natural ecosystem processes and protect vegetation during the initial years of establishment. Large wood feature design and implementation will emulate natural river processes to allow all wood to be dynamic and provide long-term complexity. The Renewal Corporation will strategically place each large wood feature based on post-drawdown topographic and hydraulic conditions. The Renewal Corporation will not use any artificial anchoring (duckbill anchors, cables, pins, bolts, etc.) to ballast wood elements. Cultural resources will be evaluated and considered by the Renewal Corporation for specific wood design locations, and any ground placement during implementation activities will be coordinated with cultural specialists or on-site tribal monitors. The primarily placement of large wood habitat features will be in tributaries and will consist of several rootwad logs or trees placed in strategic arrangements or complexes. The Renewal Corporation will implement large wood by using a combination of ground and aerial helicopter methods based on the specific location and post-drawdown conditions.

The Reservoir Area Management Plan (Appendix C) contains detailed descriptions of the restoration approach, design information, maps, and additional information on reservoir area restoration with these techniques and applicable locations for implementation.

2.4.9 Restoration Activities Outside of the Reservoirs

The restoration measures outside of the reservoirs are primarily associated with infrastructure removal or upgrades such as civil structure demolition and associated restoration, electric transmission and distribution line removal and site restoration, recreation area demolition and restoration, temporary staging area restoration, spoil pile restoration, Yreka pipeline replacement restoration, and access road culvert or bridge upgrades and associated restoration. Restoration measures outside the reservoir areas primarily entail regrading to appropriate contours and replanting with native seed mixes or adding hardscape where applicable and are generally categorized as upland restoration or stream crossing restoration. The Renewal Corporation will regrade upland areas, including recontouring to neighboring conditions as applicable. The locations of these areas are depicted in the dam demolition design drawings. The Renewal Corporation will install temporary and permanent sediment and erosion control BMPs per the site-specific SWPPP, including revegetation with regionally appropriate upland native seed mixes.

Specific measures that the Renewal Corporation will implement in upland areas are:

- **Disposal sites for placement of embankment or concrete material**: These areas typically include between 10 to 50 feet of fill and will be graded by the Renewal Corporation to match existing topographic features in the vicinity and will include a cover depth of topsoil material suitable for revegetation where available/appropriate. Some disposal sites will be covered by the Renewal Corporation with coarse rock fill material to provide erosion protection in areas not conducive to vegetation establishment. Native vegetation will be preserved and protected where feasible and will avoid ripping within a distance of twice the canopy diameter from protected tree trunks to protect existing roots.
- **Staging areas and temporary access road areas adjacent to demolition of other work areas**: The majority of these areas are at elevations appropriate for upland planting, although in some cases they include a variety of planting zones. Many of these areas are already compacted to a high degree due to their current use. The Renewal Corporation will loosen soil compacted by staging and temporary access road areas adjacent to demolition or other work areas by deep ripping and disking as needed to facilitate seed germination and plant establishment. The Renewal Corporation will preserve and protect native vegetation, where feasible, during active use and revegetation. Ripping, equipment and vehicle parking, and material storage will be avoided to the extent feasible within a distance of twice the canopy diameter from protected tree trunks to protect existing roots.
- **Hydropower infrastructure demolition areas**: The Renewal Corporation will demolish the majority of PacifiCorp buildings and other hydropower infrastructure to be removed. In each former development location, after removal of all demolition debris and man-made materials, the Renewal Corporation will loosen compacted soil in the remaining disturbed areas by deep ripping and disking as needed and restore them to native habitat. These areas occur in a variety of planting zones and will be restored accordingly as described in the Reservoir Area Management Plan (Appendix C). The Renewal Corporation will preserve and protect existing native vegetation as feasible and will avoid ripping within a distance of twice the canopy diameter from protected tree trunks to protect existing roots.
- **J.C. Boyle canal demolition area**: The Renewal Corporation will demolish the J.C. Boyle canal along its entire length. Soils in the former canal area will likely be heavily compacted from previous canal construction activities. The Renewal Corporation will loosen compacted soils or position topsoil as needed on top of the canal features to facilitate seed germination and plant establishment. The existing power canal access road on the downslope side of the canal will remain in place post-construction to be used as a hiking trail.
- **J.C. Boyle spillway scour hole**: The Renewal Corporation will fill the existing spillway and scour hole area with on-site materials. Final grading will be sloped to the adjacent existing grades that naturally drain. The top cover of fill (minimum of 6 feet) will consist of general fill (E9/E9b) designed to provide final stabilization treatment.
- **Former recreation areas**: The Renewal Corporation will remove some of the existing recreation areas around the reservoir rims completely or in part. The Renewal Corporation will restore demolished recreation areas to native habitats. Much of the land within these areas is heavily compacted

because of the respective areas' uses. The Renewal Corporation will loosen compacted soils in recreation areas associated with the project by deep ripping and disking as needed to facilitate seed germination and plant establishment and will preserve and protect existing native vegetation as feasible. Deep ripping will be avoided within a distance of twice the canopy diameter from protected tree trunks to protect existing roots.

2.5 Other Project Components

There are numerous project components that fall outside of the reservoir drawdown, dam removal, and reservoir restoration activities that are discussed above. The Renewal Corporation partially derived these additional project components from the previous list of mitigation measures found in the Detailed Plan (USBR 2012a) and the 2012 EIS/EIR. These components are incorporated into the Proposed Action as the most effective way to avoid or minimize effects. The Renewal Corporation will implement these components as part of the Proposed Action. Other project components include long-term improvements that are required as terms of the KHSA or are needed to facilitate construction activities and to mitigate for other potential effects of dam removal.

Other project components include the following categories. Additional information for most of these categories is provided in the following sections.

- **Road Improvements:** Road and bridge improvements to maintain a level of service comparable to existing conditions, as needed.
- **Yreka Water Supply Improvements:** Pipeline and diversion facility improvements to maintain a level of service comparable to existing conditions.
- **Recreation Facilities Removal and Development:** Recreation facility demolition and associated habitat restoration, as well as proposed recreation opportunity development.
- **Iron Gate Fish Hatchery and Fall Creek Fish Hatchery:** Facilities modifications, improvements, and operations at the Iron Gate Fish Hatchery and the Fall Creek Fish Hatchery.
- **Downstream Flood Proofing Improvements:** It is anticipated that some downstream property owners may decide to implement flood risk reduction improvements to downstream structures to maintain the current level of flood risk exposure. Improvements would be related to existing structures and existing developed areas. Preliminary assessments of the type of work that could be constructed indicates that the probability that a project would affect native vegetation or be conducted in the water is extremely low. If any proposed project would involve in-water work, the private landowner would be required to obtain the necessary state and federal permits. There are no existing plans for any downstream flood risk reduction improvements related to the Proposed Action.

2.5.1 Road Improvements

Several road, intersection, structure, and culvert improvements are required as part of the Proposed Action to:

- Facilitate access for project-related vehicles and equipment associated with dam removal.
- Provide safety measures for both public and project road users during the dam removals.
- Return roads used by project-related vehicles to the respective owners and users in a state that equals or exceeds existing condition/function.

The Renewal Corporation assessed which elements require improvement for either construction access or post-construction restoration. The Renewal Corporation will implement the improvements at various phases throughout the project. Some will require completion prior to the dam removals, and others will be contingent on a future assessment of road elements once reservoir drawdown or hauling activities are complete. There will also be some ongoing activities throughout the Proposed Action to maintain roads heavily trafficked by project construction vehicles. The following sections describe some of these transportation-related improvements, and others have been previously described in the sections on construction access for each dam area.

Table 2-14 provides a summary of the road segments, bridges, and culverts discussed and the proposed improvements. Table 2-14 also includes a group of potential improvements that would only be implemented if fish passage blockages develop at road crossings following reservoir drawdown. The Renewal Corporation considers these actions unlikely to be necessary, but the actions are included in the table as contingency actions.

2.5.1.1 Construction Access Improvements

The Renewal Corporation will undertake various improvements to provide adequate access and haul routes associated with construction activities. The Renewal Corporation will complete these improvements prior to drawdown. Access routes in the dam sites to access the dams for pre-drawdown improvements, dam removal, and channel restoration are described above for each facility. The following temporary access improvements will be necessary to provide access to multiple portions of the limits of work.

Dry Creek Bridge – the structural members of this single-span bridge are inadequate to support the current legal/permit loads, as well as project mobilization and hauling trucks. The Renewal Corporation will construct a temporary support structure under the existing bridge and use steel plates over the existing bridge roadway to allow mobilization and hauling truck access.

Fall Creek Bridge – the structural members of this single-span bridge are inadequate to support the current legal/permit loads, as well as project mobilization and hauling trucks. The Renewal Corporation will construct a temporary support structure under the existing bridge and use steel plates over the existing bridge roadway to allow mobilization and hauling truck access.

Table 2-14: Potential Roadway and Access Improvements

Location	Improvements	Purpose		
		Construction Access	Post-Drawdown Effects[1]	Road Rehabilitation
J.C. Boyle				
Spencer Bridge	Monitor post-drawdown for a 2-year period for potential erosion or scour at the bridge embankments and intermediate piers		X	
Keno Worden Road	Potential pavement rehabilitation during or post-project			X
Keno Access Road	None			
Culverts at unnamed creek off Keno Access Road at unnamed tributary #1	Monitor post-drawdown for a 2-year period for potential erosion and/or sediment accumulation. Potential sediment removal and downstream erosion protection		X	
Topsy Grade Road	Potential pavement rehabilitation during or post-project		X	X
Culvert at unnamed tributary #3 under Topsy Grade Road	Monitor post-drawdown for a 2-year period for potential erosion and/or sediment accumulation. Potential sediment removal and downstream erosion protection		X	
J.C. Boyle Dam Access Road from OR66	Regrade uneven or rutted areas	X		
Junction of OR66 and J.C. Boyle Dam Access Road	Intersection widening	X		
	Tree removal			
	Signage			
J.C. Boyle Powerhouse Road	Cut back of west slope to relocate the road away from scour hole	X		
Timber bridge	Remove post-project completion	X		
Power Canal Access Road	Periodic roadway maintenance grading during construction	X		
J.C. Boyle Disposal Access Road	Regrading	X		
	Minor widening			
J.C. Boyle Left Abutment Access Road	None			

Location	Improvements	Purpose		
		Construction Access	Post-Drawdown Effects[1]	Road Rehabilitation
Copco and Iron Gate				
Interstate 5 (I-5)	None			
Copco Road (I-5 to Ager Road)	Potential pavement rehabilitation during or post-project			X
Cottonwood Creek Bridge	None			
Copco Road (Ager Road to Lakeview Road)	Potential pavement rehabilitation during or post-project			X
Dry Creek Bridge	Install temporary support structure	X		
Copco Road (Lakeview Road to Daggett Road)	Pavement maintenance during construction Potential pavement rehabilitation during or post-project	X		X
Brush Creek Bridge	None			
Unnamed culverts between Brush Creek and Scotch Creek	Potential rehabilitation or replacement post-construction			X
Culverts on Copco Road at unnamed tributary #1 and #2 on Camp Creek Cove	Monitor post-drawdown for a 2-year period for potential erosion and/or sediment accumulation. Sediment removal and erosion protection as needed.		X	
Fall Creek at Daggett Road	Replace with arch culvert (Figure 2-18)		X	
Scotch Creek Culvert	Replace with box culvert (Figure 2-19)		X	
Camp Creek Culvert	Replace with box culvert (Figure 2-20)		X	
Jenny Creek Bridge	Potentially modify with scour protection, as needed		X	
Copco Road (Daggett Road to Copco Access Road)	Potential road surface maintenance during or post-project			X
Fall Creek Bridge	Install temporary support structure	X		
Copco Road (Copco Access Road to Copco Road Bridge)	None			

Location	Improvements	Purpose		
		Construction Access	Post-Drawdown Effects[1]	Road Rehabilitation
Beaver Creek and E.F. Beaver Creek Culverts	Monitor post-drawdown for a 2-year period for potential erosion and/or sediment accumulation. Sediment removal and erosion protection as needed.		X	
Culverts on Copco Road at unnamed tributary #2 on Beaver Creek Cove	Monitor post-drawdown for a 2-year period for potential erosion and/or sediment accumulation. Sediment removal and erosion protection as needed.		X	
Culverts on Copco Road at unnamed tributary #1	Monitor post-drawdown for a 2-year period for potential erosion and/or sediment accumulation. Sediment removal and erosion protection as needed.		X	
Raymond Gulch culvert	Monitor post-drawdown for a 2-year period for potential erosion and/or sediment accumulation. Sediment removal and erosion protection as needed.		X	
Culvert on Copco Road at Spannuas Creek	Monitor post-drawdown for a 2-year period for potential erosion and/or sediment accumulation. Sediment removal and erosion protection as needed.		X	
Copco Road bridge	Monitor post-drawdown for a 2-year period for potential erosion or scour at the bridge embankments and intermediate piers. Potential abutment erosion protection		X	
Copco Access Road	Clear, grub, and regrade Minor widening into hillside if possible	X		
Patricia Avenue	None			
Culverts at Indian Creek at Patricia Avenue (Copco Lake)	Monitor post-drawdown for a 2-year period for potential erosion and/or sediment accumulation. Sediment removal and erosion protection as needed.		X	
Culvert on Ager Beswick Road at Snackenbury Creek	Monitor post-drawdown for a 2-year period for potential erosion and/or sediment accumulation. Sediment removal and erosion protection as needed.		X	
Ager Beswick Road	Potential pavement rehabilitation during or post-project		X	X
Mallard Cove boat ramp access	Minor works to enable barge mobilization	X		

Location	Improvements	Purpose		
		Construction Access	Post-Drawdown Effects[1]	Road Rehabilitation
Daggett Road	Minor grading improvements Potential road surface maintenance during or post-project	X		X
Daggett Road bridge	Construct temporary bridge upstream of existing bridge. No change to existing bridge.	X		
Lakeview Road bridge	No change to existing bridge. Use alternative access.	X		
Iron Gate Powerhouse Access Road	Signage Potential road surface maintenance during construction	X		X
Iron Gate Left Abutment Access Road	Restore after construction is complete			
Iron Gate Upstream Left Abutment Access Road	Restore after construction is complete			

[1] Improvements that may occur due to post-drawdown effects are contingency items that would only be implemented if a fish passage or road integrity issue develops. The probability of these actions being required is generally considered to be low.

2.5.1.2 Ongoing and Post-Project Maintenance Activities

Some roads may require ongoing maintenance at various points throughout the project or post-project to repair damage caused by heavy loads during implementation of the Proposed Action. See Table 2-14 for a list of the road segments where the Renewal Corporation proposes pavement rehabilitation or road surface maintenance during or post-project. Pavement rehabilitation is for asphalt concrete–paved roads and includes overlay or localized pavement replacement. Road surface maintenance is for gravel and dirt roads and may include minor regrading and gravel placement.

The Renewal Corporation may conduct a baseline and post-project pavement condition assessment to determine the extent of maintenance required. The Renewal Corporation may provide temporary traffic control on public roads during roadway surface maintenance and will involve one-way traffic control with flaggers and/or construction area signs.

2.5.1.3 Long-Term Road Infrastructure Improvements

The Renewal Corporation proposes some improvements to existing roads following drawdown to repair damage caused by heavy loads during dam removal activities. The proposed improvements would restore functionality of road infrastructure caused by a reduction in embankment or culvert stability following the drawdown of the reservoirs and dam removal. The reservoir drawdown creates the potential for creek bed levels to readjust back down to their pre-dam state. In some areas, this may cause incision into fine sediments that have settled during the operation of the reservoirs. Where road infrastructure was constructed atop these sediments, the erosion of sediments from beneath or near road elements could result in damage or failure. These locations are noted in Table 2-14 and are not further described here.

The Renewal Corporation will complete the construction of improvements at various stages throughout the project depending on the timeline for completion requirements, but many will require implementation prior to drawdown. The following sections summarize permanent proposed improvements to roads and bridges included in the project, but not previously described under the relevant dam removal description sections.

Timber Bridge

A timber bridge spans the Klamath River immediately downstream of J.C. Boyle Dam. The Renewal Corporation will remove this structure after dam removal.

Jenny Creek Bridge

Jenny Creek bridge crosses the mouth of Jenny Creek at Iron Gate Reservoir. The bridge is suitable for the access and hauling requirements of the project. Although the bridge crosses an area that is backwatered by Iron Gate Reservoir, no work is proposed at this bridge. The Renewal Corporation has analyzed the bridge's abutment protection against scour and does not expect the need for additional scour protection at this bridge.

Daggett Road Culvert at Fall Creek

Daggett Road crosses the mouth of Fall Creek at Iron Gate Reservoir. The Renewal Corporation anticipates erosion in this area following drawdown of the reservoir due to incision into reservoir sediments, which could result in a perched culvert outlet and a potential non-passable fish barrier. Due to uncertainty in the extent of channel lowering, the Renewal Corporation will replace the culvert with an arch culvert and provide suitable erosion protection during summer of the drawdown year (Figure 2-18, Table 2-14). The arch culvert will be approved for fish passage per NMFS fish passage requirements.

Copco Road Culvert at Scotch Creek

A 120-inch-diameter CMP culvert passes beneath Copco Road at Scotch Creek, adjacent to Iron Gate Reservoir. The Renewal Corporation anticipates erosion in this area following drawdown of the reservoir due to incision into reservoir sediments, which could result in a perched culvert outlet and a potential non-passable fish barrier. Due to uncertainty in the extent of channel lowering, the Renewal Corporation will replace the culvert with a box culvert and provide suitable erosion protection prior to drawdown (Figure 2-19, Table 2-14). The box culvert will be approved for fish passage per NMFS fish passage requirements.

Copco Road Culvert at Camp Creek

A 120-inch-diameter CMP arch culvert passes beneath Copco Road at Camp Creek adjacent to Iron Gate Reservoir. The Renewal Corporation anticipates erosion in this area following drawdown of the reservoir due to channel incision into reservoir sediments, which could result in a perched culvert outlet and a potential non-passable fish barrier. Due to uncertainty in the extent of channel lowering, the Renewal Corporation will replace the culvert with a box culvert and provide suitable erosion protection prior to drawdown (Figure 2-20, Table 2-14). The box culvert will be approved for fish passage per NMFS fish passage requirements.

2.5.2 Yreka Water System Improvements

2.5.2.1 Water System Pipeline

The water system pipeline for the City of Yreka, California, crosses the Klamath River near the upstream end of the reservoir impounded behind Iron Gate Dam. The 24-inch-diameter steel pipeline is minimally buried in the reservoir bed. When the Renewal Corporation removes Iron Gate Dam, high-velocity river flows could expose the existing pipeline and leave it vulnerable to damage. The Renewal Corporation will replace the reservoir-bottom pipeline crossing with a more secure permanent crossing.

Prior to construction of the permanent pipeline and prior to reservoir drawdown, the Renewal Corporation will construct a temporary 24-inch-diameter pipeline to temporarily convey flow to meet the City of Yreka's water demand. The temporary pipeline will be routed across the Daggett Road bridge. After the temporary pipeline is in service, the Renewal Corporation will construct a new permanent 24-inch-diameter concrete encased pipeline within the volcanic breccia rock layer. The new section of the permanent pipeline will be located in the immediate vicinity of the existing waterline crossing and will connect to the existing buried pipeline at either end.

2.5.2.2 Water System Intake

Existing Conditions

Water is diverted to the City of Yreka's water system from Fall Creek, a tributary to the Klamath River. The primary diversion, called Dam A, is located in the tailrace of the PacifiCorp Fall Creek powerhouse, and consists of a low concrete dam with spillway notch and sluice gate. The dam provides head for diversion to a 24-inch-diameter pipe through a concrete headworks structure. The headworks structure has four 3-foot-wide bays. Up to three bays can be used for screening water into the intake with removable fish screen panels. The bays at the headworks structure connect into a common channel leading to the gated supply pipeline. The City's water right and diversion capacity at the site is 15 cfs.

A secondary diversion point on Fall Creek is used whenever the power plant is shut down. This diversion, called Dam B, supplies water through a pipeline to the headworks structure at Dam A and then to the Yreka water supply pipeline.

Proposed Modifications

The existing fish screens at the intake near Dam A do not meet current NMFS criteria for anadromous fish. Dam B does not have a fish screen and is approximately 80 feet downstream of the Fall Creek falls, which are not passable by salmonids. From Dam B upstream to the base of the falls, Fall Creek has a stream gradient of approximately 13 percent, consists of boulder-dominated substrate, and contains little to no viable spawning or rearing habitat for salmonids. Dam A is on an artificially created bypass reach serving the powerhouse. Currently, both Dam A and Dam B create partial barriers to juvenile and adult salmonids, depending on flow conditions and/or weir board configurations. As part of the Fall Creek Hatchery design, the Renewal Corporation will construct velocity fish barriers downstream of Dam A and Dam B to preclude adult and juvenile anadromous fish from passing over Dam A and Dam B. In addition, during spawning months at Fall Creek Hatchery, CDFW will install a removable temporary picket weir system to direct adult fish into the Fall Creek Hatchery fish ladder downstream of the Fall Creek bridge. The picket barrier system will consist of a set of aluminum pickets with 1-inch-maximum clear spacing that will be installed on a permanent concrete sill and removed each year at the beginning and end of the trapping season. The sill will have side walls that the picket panels will be able to seal against, forming a continuous barrier across the stream. The sill and removable pickets will be oriented at an angle of approximately 30 degrees to the stream transect, such that an anadromous fish moving upstream will encounter the barrier and be directed toward the stream's east bank, where the fish ladder entrance pool is situated.

2.5.3 Recreation Facilities

The existing recreation facilities to be removed are listed below. Following removal of recreation features at each facility (e.g., fire rings, fishing piers, floating docks, toilets, picnic tables, signage, trash receptacles, wooden fencing, walkways), the Renewal Corporation will regrade, seed, and plant the disturbed areas as appropriate.

- J.C. Boyle: Pioneer Park East and Pioneer Park West
- Copco: Mallard Cove and Copco Cove
- Iron Gate: Jenny Creek, Wanaka Springs, Camp Creek, Juniper Point, Mirror Cove, Overlook Point, Long Gulch, and Fall Creek Day Use Area

The Renewal Corporation will work with the States of California and Oregon to develop potential enhancement sites. These potential enhancement sites are conditionally part of the Proposed Action in that they will be developed only if the states commit to funding for construction, operation, and maintenance per implementing agreements. Potential enhancement sites are listed below.

- Moonshine Falls, in Oregon, would be created with amenities to include access road improvements, parking area, universally accessible vault toilet, garbage facilities, water spigot, kiosk with angler box, one picnic site, river viewpoint with benches, trail to the boat launch, boat launch staging area and vehicle turnaround, boat launch drop off/staging area, boat slide and accompanying ramp to river's edge, and gravel beach.
- Copco Valley, in California, would be created with amenities to include access improvements, including road and parking area; universally accessible vault toilet; garbage facilities; kiosk with angler box; water spigot; picnic tables; designated dispersed river access sites with gravel connector trail; paved boat ramp; boat launch staging area; and hand/launching area/beach. This location would be nearly 2 miles south of the California-Oregon border on the existing Copco No. 1 Reservoir and would comprise approximately 10 acres. The existing site for Copco Valley consists only of a gravel access road. The remainder of the site would be on land currently inundated by the reservoir.
- Copco No. 2 Powerhouse, in California, would be created with amenities to include widened access road, parking area, universally accessible vault toilet, garbage facilities, water spigot, picnic areas, viewpoint with bench, staging area with bench and kiosk with angler box, shoreline trail from boat slide to Daggett Road, boat slide to launch at river edge, and boat slide staging area.
- Iron Gate, in California, would be created with amenities to include a parking area for 18 vehicles (including two spaces for accessible parking compliant with the Americans with Disability Act) and five vehicles with trailers, universally accessible vault toilet, garbage facilities, kiosk with angler box, water spigot, five picnic sites, trails to picnic sites, re-graded river’s edge/beach, paved four-lane boat launch, launch staging area, and existing vegetation.

The potential recreation enhancement site locations were chosen based on the predicted results of Proposed Action implementation and return of the river system back to its historical alignment. Consideration was given to slope and gradient of the river channel, river accessibility as an emergency water supply for firefighting operations, the relationship of the site to potential whitewater boating runs, and the sites' potential to enhance recreation activities. Sites were also vetted for their viability by stakeholders and their ability to accommodate assumed levels of use.

2.5.4 Fish Hatcheries

The existing Iron Gate Hatchery facilities, operated by CDFW, are part of the Lower Klamath Project. With the removal of Iron Gate Dam, the Renewal Corporation will also remove the water intake and fish capture, holding, and spawning facilities at the hatchery. The Renewal Corporation will move the hatchery operations to the Fall Creek Fish Hatchery. Relevant obligations under the KHSA with respect to Iron Gate Hatchery and Fall Creek Hatchery, are summarized as follows:

- PacifiCorp will fund 100 percent of hatchery operations and maintenance necessary to fulfill annual mitigation goals developed by CDFW in consultation with NMFS to meet ongoing mitigation goals following facilities removal.
- PacifiCorp's funding will be provided for hatchery operations to meet mitigation requirements and will continue for 8 years following the decommissioning of Iron Gate Dam.

2.5.4.1 Existing Iron Gate Hatchery Facility and Operations

Iron Gate Hatchery was constructed in 1962 to mitigate for lost anadromous salmonid spawning and rearing habitat between Copco No. 2 Dam and Iron Gate Dam. The historical mitigation goals include a release of 6,000,000 Chinook salmon (5,100,000 fingerlings and 900,000 yearlings), 75,000 coho salmon yearlings, and 200,000 steelhead yearlings annually. The SONNC coho salmon ESU, which includes coho salmon produced at Iron Gate Hatchery, is listed as threatened under the California Endangered Species Act (CESA) and the ESA.

A Hatchery and Genetics Management Plan and Section 10(a)(1)(A) Enhancement of Survival Permit was issued to CDFW in 2014 for the Iron Gate Hatchery coho salmon artificial propagation program (Section 10(a)(1)(A) Permit 15755). Under the Hatchery and Genetics Management Plan, the purpose of the coho salmon program is to aid in the conservation and recovery of the Upper Klamath Population Unit of the SONCC coho salmon ESU by conserving genetic resources and reducing short-term extinction risks prior to future restoration of fish passage upstream of Iron Gate Dam. Adult steelhead returns declined dramatically during the 1990s for unknown reasons, and Iron Gate Hatchery has produced no steelhead since 2012. Chinook salmon returns continue to be variable, but generally sufficient broodstock returns to Iron Gate Hatchery produce the mitigation goals.

The Iron Gate Hatchery is approximately 0.5 mile downstream of Iron Gate Dam, adjacent to the Bogus Creek tributary. The main hatchery complex includes an office, incubator building, rearing/raceway ponds, fish ladder with trap, settling ponds, visitor information center, and four employee residences. The collection facility is at Iron Gate Dam and includes a fish ladder consisting of twenty 10-foot weir-pools that terminate in a trap, a spawning building, and six 30-foot circular holding ponds.

The Iron Gate Hatchery operates with a gravity-fed, flow-through system that has five discharge points into the Klamath River. The Iron Gate Hatchery obtains its water supply from Iron Gate Reservoir. Two subsurface influent points at a depth of approximately 17 feet and 70 feet, respectively, deliver water to Iron Gate Hatchery. Up to 50 cfs is diverted from the Iron Gate Reservoir to supply the 32 raceways and fish ladder.

The existing spawning facility discharges through the main ladder and steelhead return line. An overflow line drains excess water from the aeration tower. The hatchery facility also has a discharge at the tailrace that supplies the auxiliary ladder or fish discharge pipe and two flow-through settling ponds for hatchery effluent treatment that converge to a single discharge point.

As noted above, CDFW operates the Iron Gate Hatchery. Per the Klamath Hydroelectric Project license, PacifiCorp must fund at least 80 percent of operations and maintenance costs, but PacifiCorp currently funds 100 percent of those costs pursuant to the KHSA.

The Renewal Corporation will demolish the existing fish collection facility at the toe of Iron Gate Dam as part of the Proposed Action. The Renewal Corporation will demolish the water supply intake and associated infrastructure along with the dam and hydropower developments.

2.5.4.2 Existing Fall Creek Hatchery

California Oregon Power Company built the Fall Creek Hatchery in 1919 as compensation for the loss of spawning grounds due to the construction of Copco No. 1 Dam. Six of the original rearing ponds remain (two above Copco Road and four below the road). CDFW last used these ponds from 1979 through 2003 to raise approximately 180,000 Chinook salmon yearlings, which CDFW released into the Klamath River at Iron Gate Hatchery. Although the raceways remain and CDFW continues to run water through them, the raceways have not produced fish since 2003, when CDFW moved all mitigation fish production to Iron Gate Hatchery. The Fall Creek Hatchery has retained its water rights and the facility will be upgraded as described in the Hatcheries Management and Operations Plan (Appendix F).

2.5.4.3 Hatcheries Management and Operations Plan

The Renewal Corporation developed a Hatcheries Management and Operations Plan (Appendix F) in consultation with NMFS and CDFW to guide hatchery operations for the 8-year period following dam removal, as stated in the KHSA. The plan specifies transfer of ownership of the existing Iron Gate Hatchery to CDFW, and improvements and modifications for the re-opening of the Fall Creek Hatchery. NMFS and CDFW have determined the priorities for fish production under the proposed Hatcheries Management and Operations Plan. As a state- and federally listed species in the Klamath River, coho salmon production is the highest priority for NMFS and CDFW, followed by Chinook salmon, which support tribal, sport, and commercial fisheries. Steelhead production is the lowest priority. Due to limited water availability and rearing capacities at the two facilities and recent low hatchery steelhead returns, NMFS and CDFW have determined that steelhead production will be discontinued.

To implement the proposed Hatcheries Management and Operations Plan, hatchery operations must be functional prior to drawdown of Iron Gate Reservoir. The Hatcheries Management and Operations Plan may be implemented in a manner that is consistent with the NCRWQCB’s “Policy in Support of Restoration in the

North Coast Region." The plan also requires CDFW to employ BMPs to minimize discharges during hatchery operations. Table 2-15 summarizes the NMFS and CDFW goals for fish production.

Table 2-15: Comparison of Hatchery Mitigation Requirements and NMFS/CDFW Production Recommendation

Species / Life Stage	Current Production Goal (at Iron Gate Hatchery)	Production Goal Post-Dam Removal	Release Dates
Coho Yearlings	75,000	Minimum of 75,000 at Fall Creek Hatchery	March 15 – May 1
Chinook Yearlings	900,000	Minimum of 250,000 at Fall Creek Hatchery	Oct 15 – Nov 20
Chinook Smolts	5,100,000	Up to 3,000,000 at Fall Creek Hatchery	April 1 – June 15
Steelhead	200,000	0	NA

Source for Current Production: NMFS and CDFW (2018).
Source for Post-dam Removal Goals: McMillen-Jacobs Associates (2020).

2.5.4.4 Improvements at Iron Gate Hatchery

Per KHSA Section 7.6.6, CDFW has proposed that the Renewal Corporation close the Iron Gate Hatchery and reopen the Fall Creek Hatchery. The Renewal Corporation, in consultation with CDFW and NMFS, decided to transfer the production of Chinook salmon and coho salmon to the Fall Creek Hatchery due to the high quality of Fall Creek water. Therefore, once the improvements at Fall Creek Hatchery have been completed and production can be initiated prior to Iron Gate Reservoir drawdown, Iron Gate Hatchery will be shut down. No further production will occur at Iron Gate Hatchery once reservoir drawdown is initiated.

2.5.4.5 Improvements at Fall Creek Hatchery

To raise yearling coho salmon and subyearling and yearling Chinook salmon, the Renewal Corporation will upgrade the Fall Creek Hatchery facility by modifying its plumbing to accommodate the installation of rearing vessels (rearing ponds or raceways). The Renewal Corporation will construct the new hatchery facility within the existing Fall Creek Hatchery footprint (Figure 2-21), and it will be operated and maintained by CDFW. The intake structure, coho salmon rearing building, Chinook salmon raceways, Chinook salmon incubation building, spawning building, and adult holding will be located on the eastern side of the creek. Use of these spaces will require coordination and concurrence with PacifiCorp. Non-consumptive water diversion from Fall Creek will support hatchery operations using the existing CDFW water right on Fall Creek; the water will return to the creek at the fish ladder on the eastern side of Fall Creek, minimizing adverse effects to Fall Creek aquatic resources.

To protect the quality of the City of Yreka's water supply and prevent fish pathogen introduction into the hatchery, fish will not be allowed upstream of either Dam A (main diversion point) or Dam B (alternate diversion point). As described in Section 2.5.2.2, Dam A and Dam B will be modified to include a sloped apron downstream of each dam to create velocity barriers. The combined high-velocity apron and the jump required to pass upstream of Dam A and Dam B will effectively bar passage of both juvenile and adult anadromous fish for the Fall Creek flow range anticipated during juvenile fish release, adult migration, and larger flood events.

As described in Section 2.5.2.2, the Renewal Corporation will construct a removable fish exclusion picket barrier adjacent to the fish ladder that will guide fish to the fish ladder entrance pool and ultimately up to the trap.

To supply water to the Fall Creek Hatchery, CDFW may divert up to 10 cfs of water from PacifiCorp's hydro-generation tailrace canal supplied from the pool behind Dam A or from a supplemental supply location on Fall Creek above Dam B. Water will be gravity-fed and plumbed to each rearing location. During periods when the powerhouse tailrace is not flowing, hatchery water will be diverted from Dam B to Dam A.

Adult Collection and Holding

Salmon are not anticipated to return to Fall Creek in sufficient numbers for broodstock until at least 3 years following dam removal (the first fish raised at Fall Creek Hatchery will begin to return as 3-year-olds in Year 4). Between the drawdown year (Year 1) and Year 4, or until fish return to Fall Creek Hatchery, CDFW will collect adult broodstock at the Iron Gate Hatchery auxiliary fish ladder or elsewhere in the Klamath River system as identified by CDFW and NMFS and described in the Fall Creek Hatchery Off-site Broodstock Collection Options Final Version 3.0 memorandum, dated February 22, 2021. CDFW and NMFS will develop separate protocols to transfer adults to Fall Creek Hatchery from collection locations to reduce transportation mortality. Spawning of those collected adults will occur at Fall Creek Hatchery.

Once Fall Creek Hatchery salmon returns begin, collection will occur using the Denil fish ladder and adult holding ponds. CDFW will sort fish by species and transfer them to the holding ponds to await processing in the spawning building. The fish ladder and adult holding ponds will be supplied with single pass, flow-through water from the coho salmon and Chinook salmon rearing facilities, excluding during periods of cleaning and therapeutant use when water will be conveyed to the settling pond.

Spawning

CDFW will manage spawning at Fall Creek Hatchery to meet the program production goals shown in Table 2-15. When adult Chinook salmon and coho salmon are held or returned to Fall Creek, CDFW will sort the adults for ripeness, and spawn the fish according to production goals for Chinook salmon and conservation goals described in the Hatchery and Genetics Management Plan for coho salmon and any amendments to the associated permit.

A simple spawning facility will be designed and constructed within the lower site footprint for future spawning operations at Fall Creek Hatchery.

Egg Incubation

CDFW will incubate coho salmon in a new coho salmon building and Chinook salmon eggs in a new Chinook salmon incubation building using surplus vertical flow incubator stacks from Iron Gate Hatchery. The incubation building will be designed to use minimal flows (up to 5 gallons per minute [gpm] per stack) and all water used will be discharged as pass-through water to the fish ladder, excluding periods of cleaning and therapeutic use, when water will be discharged to the settling pond for appropriate effluent treatment.

Rearing Vessels

Rearing at Fall Creek Hatchery will occur in the existing footprint of the current site, and rearing vessels include rehabilitated existing upper raceways and both conventional (raceway) and rectangular aquaculture rearing vessels; maximum rearing space required for the final facility depends on final fish production recommendations (Table 2-15). The coho salmon and Chinook salmon incubation and spawning buildings will be sited in areas of previous facility use (minimal site impacts). CDFW will discharge water from the rearing vessels either to Fall Creek through the fish ladder or, if treatment is needed, to the settling pond as described below.

Proposed Facility Flows

Rearing strategies for cultured fish at the Fall Creek Hatchery will employ a single-pass, flow-through water supply for eggs/fish reared in the incubation, early rearing, and grow-out portions of the facility. With the exception of concentrated waste streams (tank/vessel cleaning using a vacuum cleaning system) diverted to the offline settling pond, all water used in the facility will be returned to Fall Creek after use. During periods of adult trapping and spawning (October-December), water from rearing tanks/vessels will be routed through the adult holding ponds and out through the fishway to attract migrating adult salmon; peak flows of 10.0 cfs are anticipated for these periods. Table 2-16 provides an overview of the annual water budget based on current modeling efforts.

Table 2-16: Proposed Fall Creek Hatchery Water Requirements – Full Production

Month:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total juvenile cfs	3.1	5.9	6.7	7.2	9.3	2.2	3.1	4.1	5.1	7.6	8.3	3.1
Total ladder cfs									10.0	10.0	10.0	10.0

Settling Pond and Wastewater Treatment

The Renewal Corporation will construct a settling pond using the existing Fall Creek Hatchery lower raceways for post-use water treatment from effluent flow discharged from a vacuum system. CDFW will use the final pond in the existing lower concrete raceway bank (eastern-most pond) as a settling pond to settle out any biosolids or other solid waste from cleaning of the upstream facilities discharged to a waste drain. The Renewal Corporation will refurbish this pond and will split it into two distinct bays such that solids can be dried and removed as necessary over the life of the facility, while the waste drain system remains in operation. The Renewal Corporation designed the vacuum system to divert effluent during cleaning cycles from the incubation and spawning building and from all rearing tanks/vessels during cleaning and use of therapeutants in the settling pond for treatment or drying of solids. The Renewal Corporation will equip the downstream end of each of the settling pond bays with an overflow structure that will divert flow-through water into the fish ladder for mixing with the adult holding pond flows and release it to Fall Creek. During non-cleaning times, CDFW will discharge water from the rearing tanks through the fish ladder located in the lower pond area. The discharges from the facility will meet the NCRWQCB discharge requirements.

When cleaning of the settling pond is required, a septic pump truck will access the pond from the adjacent pad so the solids can be vacuumed out of the pond.

2.6 Conservation, Avoidance, and Minimization Measures

The Renewal Corporation will implement conservation, avoidance, and minimization measures, along with numerous BMPs, during the Proposed Action to comply with federal and state permits, including the USACE CWA Section 404 permit, the SWRCB and ODEQ Clean Water Act Section 401 Water Quality Certifications (SWRCB 2020b and ODEQ 2018, respectively), National Pollutant Discharge Elimination System (NPDES) permits for Oregon and California, and others. Measures have been developed over years of consultation and coordination between the Renewal Corporation and state, federal, and Tribal resource agency staff, and are tailored to different components of this multi-year restoration project. Specific measures have been developed for pre-drawdown- and drawdown-associated impacts during the Construction Period and through the restoration work into the Maintenance and Monitoring Period.

Previous planning efforts have generated conservation measures in a numbered identification manner (e.g., AR-1). The planning efforts over time have adjusted these uniquely identified measures such that they are not consistent between the issued permits (e.g., CWA 401s) and former plans (2018 Definite Plan). Since conservation measures are inherently future Surrender Order conditions, the measures have been included in the FERC Amended License Surrender Application and Definite Decommissioning Plan. These measures, while not holding to their original nomenclature (e.g., AR-1), consist of the same actions as previously defined. To simplify the understanding of all parties, the FERC Amended License Surrender Application and Definite Decommissioning Plan have established specific Management Plans to address all conservation, avoidance and minimization measures. Placing all measures into a resource-specific management plan provides the USFWS and NMFS the opportunity to further refine the measures through the management plan consultation process. For purposes of this BA, the following management plans contain the conservation measures outlined in this BA to protect listed species.

2.6.1 Aquatic Resources Management Plan

The Aquatic Resources Management Plan (Appendix D) incorporates six subplans and associated measures to reduce the potential for, and severity of, short-term impacts on aquatic species (SWRCB 2020a) as a result of implementing the Proposed Action. Implementing the Proposed Action will ultimately result in a free-flowing river system and provide anadromous fish passage to the tributaries as well as the mainstem Klamath River above the existing dams. As a result, the Renewal Corporation will implement several measures to survey and monitor fish and new habitat.

The Aquatic Resources Management Plan encompasses aquatic resource-related plans, and includes the following subplans:

- Spawning Habitat Availability Report and Plan
- Adaptive Management Plan (suckers)
- Fish Presence Monitoring Plan
- Tributary–Mainstem Connectivity Plan
- Monitoring and Adaptive Management Plan
- Juvenile Salmonids and Pacific Lamprey Rescue and Relocation Plan

The Renewal Corporation developed this plan in consultation with ODFW, CDFW, USFWS, and NMFS. Coordination with the ATWG is continuing, and ongoing feedback will be used to refine and finalize the aquatic resource measures. These measures are subject to consultation with aquatic resource agencies and negotiation of the final BOs for the project. The Aquatic Resource Measures discussion below summarizes the measures proposed to reduce effects to the associated aquatic resources. These measures are also provided in the FERC Amended License Surrender Application and Definite Decommissioning Plan (The Renewal Corporation 2020a).

2.6.1.1 Aquatic Resource Measures

The 2012 EIS/EIR included aquatic resource measures to reduce the potential short-term (less than 2 years following dam removal) adverse effects of the Proposed Action. In 2017, the Renewal Corporation assembled an Aquatic Technical Work Group (ATWG) composed of state and federal resource agencies and tribal fisheries scientists. The ATWG includes fisheries scientists representing CDFW, ODFW, USFWS, NMFS, the Yurok Tribe, the Hoopa Valley Tribe, the Karuk Tribe, and the Klamath Tribes. Through a series of nine meetings with the ATWG between April 28 and August 15, 2017, the Renewal Corporation and the ATWG reviewed recent similar dam removal projects and new scientific information developed since the 2012 EIS/EIR to update the 2012 aquatic resource measures, as described below. These measures were retained in the SWRCB's 2020 Lower Klamath Project Final EIR (FEIR) (SWRCB 2020a) and included as applicable in the California and Oregon Section 401 Water Quality Certifications (SWRCB 2020b and ODEQ 2018, respectively).[3]

Aquatic Resource Measure - Mainstem Spawning

Background: The Renewal Corporation expects short-term effects of the Proposed Action (suspended sediment concentrations [SSCs] and bedload) to result in high mortality of fall Chinook salmon and coho salmon embryos and pre-emergent alevins in spawning redds. Additionally, steelhead and Pacific lamprey migrating in the mainstem Klamath River after January 1 of the drawdown year could be directly affected by high suspended sediment levels. This measure was formerly identified as AR-1 in the Definite Plan report (The Renewal Corporation 2018).

[3] Following discussions with the ATWG and an evaluation of new information available since 2011, AR-3 and AR-5 were removed because no action is required. Additionally, because AR-7 addresses freshwater mussels, which are not a listed species, it is not included in the conservation measures listed in this BA.

Project Measures: The Renewal Corporation will implement monitoring and adaptive management measures to reduce project effects on mainstem spawning. Two actions included in the Tributary–Mainstem Connectivity Plan (Aquatic Resources Management Plan, Appendix D) are summarized below:

- **Action 1:** The Renewal Corporation will evaluate tributary-mainstem confluences, including four sites in the Hydroelectric Reach and five sites in the 8-mile reach from Iron Gate Dam to Cottonwood Creek, for 2 years beginning with the start of reservoir drawdown. Monitoring frequency will be variable based on the season and year. Additionally, a 5-year flow event, or 10,895 cfs or greater, on the Klamath River, recorded at the USGS Klamath River Below Iron Gate Dam CA gage (#11516530), will trigger a monitoring effort. If tributary confluence blockages are identified during monitoring, necessary means will be employed during the 2-year monitoring period to remove the obstructions to ensure volitional passage for adult Chinook salmon, coho salmon, steelhead, and Pacific lamprey. The Renewal Corporation will meet with the ATWG periodically during the 2-year monitoring period to review monitoring frequency to ensure volitional passage is maintained between the Klamath River and selected tributaries.

  The Tributary–Mainstem Connectivity Plan (Aquatic Resources Management Plan, Appendix D) and the Reservoir Area Management Plan (Appendix C, Section 6.2) contain additional details on this measure.

- **Action 2:** The Renewal Corporation will complete a spawning habitat evaluation in the Hydroelectric Reach and newly accessible tributaries following reservoir drawdown. A target of 44,100 square yards (yd^2) of mainstem spawning gravel will be required to offset the effects to 2,100 mainstem-spawning fall Chinook salmon redds. If mainstem spawning gravel availability is less than the target values following reservoir drawdown, the Renewal Corporation and the ATWG will convene to design, and the Renewal Corporation will implement, a spawning gravel augmentation project in the former Klamath River reservoirs and Hydroelectric Reach. A target of 4,700 yd^2 of tributary spawning gravel is required to offset the effects to 179 tributary-spawning steelhead redds. If tributary spawning gravel habitat is less than the target values following reservoir drawdown, the Renewal Corporation and the ATWG will convene to prioritize additional habitat restoration actions (e.g., gravel augmentation, gravel retention treatments) that will be undertaken by the Renewal Corporation to increase the amount of tributary habitat available to compensate for the loss of steelhead redds.

  The Spawning Habitat Availability Report and Plan (Aquatic Resources Management Plan, Appendix D) contains additional details on this measure.

These actions are intended to ensure adult salmonid and Pacific lamprey have access to mainstem and tributary spawning habitat in the Hydroelectric Reach, and between Iron Gate Dam and Cottonwood Creek following dam removal.

Aquatic Resource Measure - Outmigrating Juveniles

Background: The Renewal Corporation expects short-term effects of the Proposed Action (SSCs and bedload deposition, dissolved oxygen levels) to result in mostly sublethal, and in some cases lethal, impacts to a portion of the juvenile Chinook salmon, coho salmon, steelhead, and Pacific lamprey that are outmigrating from tributary streams to the Klamath River upstream of Trinity River during late winter and early spring of the drawdown year. This measure was formerly identified as AR-2 in the Definite Plan report (The Renewal Corporation 2018).

Project Measures: The Renewal Corporation will undertake three actions to reduce the overall effect on outmigrating juveniles as summarized below:

- **Action 1:** The Renewal Corporation will complete sampling and salvage of overwintering juvenile coho salmon from the Klamath River between Iron Gate Dam and the Trinity River confluence prior to reservoir drawdown. Sampling and salvage sites will focus primarily on alcoves, side channels, and backwater floodplain features adjacent to the mainstem Klamath River. The Renewal Corporation expects up to 500 juvenile coho salmon to be caught and relocated to off-channel ponds by the Renewal Corporation to protect this small, but important, life history strategy in the ESA-listed coho salmon population.

  A technical memorandum identifying target capture locations and methods for salvage of overwintering juvenile coho salmon will be provided to NMFS 6 months prior to the salvage.

- **Action 2:** The Renewal Corporation prepared a Tributary–Mainstem Connectivity Plan (Aquatic Resources Management Plan, Appendix D) with input from the ATWG to monitor tributary-mainstem connectivity for 2 years following the start of reservoir drawdown. The Renewal Corporation will monitor tributary-mainstem confluences, four sites in the Hydroelectric Reach, and five sites in the 8-mile reach from Iron Gate Dam to Cottonwood Creek with a variable frequency based on the season and year. Based on hydraulic and sediment transport modeling completed by USBR (2011) and updated based on the SRH-1D model described in Appendix I, sediment deposition during reservoir drawdown is predicted from Bogus Creek downstream to Cottonwood Creek. The primary area of sediment deposition is from Bogus Creek downstream to Willow Creek, with sediment deposition in the reach from Willow Creek downstream to Cottonwood Creek. Areas downstream of Cottonwood Creek are expected to have only minor deposition (USBR 2011a). No additional deposition is predicted in the Bogus Creek to Cottonwood Creek reach following dam removal.

  Species that would potentially be affected by obstructed tributary connections include outmigrating Chinook salmon, coho salmon, steelhead, and Pacific lamprey during and following reservoir drawdown. Further, depending on the erosion rates of reservoir sediments, tributary confluences in the reservoir areas may not meet fish passage conditions following drawdown.

  Tributary confluences to be monitored in the 2-year period following dam removal include Bogus Creek, Dry Creek, Little Bogus Creek, Willow Creek, and Cottonwood Creek. Tributaries in the Bogus Creek to Cottonwood Creek reach were selected because they are recognized as influential tributaries (e.g., historical fisheries of importance or important freshwater sources) in the mid-Klamath River (Soto et al. 2008). Hydroelectric Reach tributaries to be monitored include Spencer Creek, Shovel Creek, Fall Creek, Jenny Creek, and Camp/Scotch Creek. These tributaries were selected based on having historical or potential habitat for adult salmonids (Huntington 2006).

  Additionally, a 5-year flow event of 10,895 cfs or greater on the Klamath River at the USGS Klamath River Below Iron Gate Dam CA stream gage (#11516530) will trigger a monitoring effort. If tributary confluence blockages are identified during monitoring, the Renewal Corporation will employ the necessary means to remove the obstructions to ensure volitional passage for juvenile Chinook salmon, coho salmon, steelhead, and Pacific lamprey. The Renewal Corporation expects juvenile salmonids to benefit from the Proposed Action by restoring access to at least 13.9 miles of key tributary rearing habitats in the Hydroelectric Reach and several recognized thermal refugia areas, including Jenny and Fall Creeks.

The Tributary–Mainstem Connectivity Plan (Aquatic Resources Management Plan, Appendix D) and in the Reservoir Area Management Plan (Appendix C, Section 6.2) contain additional details on this measure.

- **Action 3:** The Renewal Corporation prepared and will implement a Juvenile Salmonid and Pacific Lamprey Rescue and Relocation Plan (Aquatic Resources Management Plan, Appendix D) for 13 key tributary confluences between Iron Gate Dam and the Trinity River. Tributaries to be monitored include Bogus Creek, Dry Creek, Cottonwood Creek, Shasta River, Humbug Creek, Beaver Creek, Horse Creek, Scott River, Tom Martin Creek, O'Neil Creek, Walker Creek, Grider Creek, and Seiad Creek. Water temperatures in tributary streams will be monitored from March 1 to July 1 of the drawdown year. SSCs will be measured continuously following drawdown at water quality stations in the mainstem Klamath River, including Iron Gate Dam, Seiad Valley, and Orleans. If key tributary water temperatures reach 17 degrees Celsius (°C) (7-day average of the daily maximum values) and Klamath River SSCs remain elevated above 1,000 milligrams per liter (mg/L), the ATWG will convene to organize the logistics for juvenile salvage and relocation efforts. If the tributary water temperature trigger of 19°C (7-day average of the daily maximum values) and Klamath River SSC trigger of 1,000 mg/L (7-day sustained daily maximum) are met, the Renewal Corporation will complete a salvage effort.

  The salvage effort would include capturing fish using seines, dip nets, and other methods from confluence areas, loading them to aerated transport trucks, and relocating them to cool water tributaries or off-channel ponds including, but not limited to, the Seiad Creek complex. The Renewal Corporation may transport salmonids other than coho salmon, such as juvenile Chinook salmon and steelhead, to the mainstem Klamath River downstream of the confluence of the Trinity River if suitable tributary habitat is unavailable closer to the salvage sites. The Juvenile Salmonid and Pacific Lamprey Rescue and Relocation Plan (Aquatic Resources Management Plan, Appendix D) contains details on the implementation of this measure.

Aquatic Resource Measure - Hatchery Releases

Background: The Renewal Corporation expects the short-term effects of the Proposed Action to result in mostly sublethal, and in some cases lethal, impacts on a portion of the juvenile Chinook salmon, coho salmon, steelhead, and Pacific lamprey that are outmigrating from tributary streams to the Klamath River during late winter and early spring of the drawdown year. Deleterious short-term effects are anticipated to be caused by high suspended sediment levels and low dissolved oxygen levels in the Klamath River from Iron Gate Dam downstream to Orleans. Hatchery-produced Chinook salmon and coho salmon juveniles that are released from the Fall Creek Hatchery into the Klamath River could suffer high mortality if juveniles are released during periods of high suspended sediment levels.

Project Measures: Hatchery-reared yearling coho salmon to be released in spring of the drawdown year could be held by CDFW at the proposed Fall Creek Hatchery or at another facility until water quality conditions in the mainstem Klamath River improve to sublethal levels. Final release schedules and locations are to be determined by CDFW. Based on the current hatchery release schedules and suspended sediment prediction in the Klamath River following dam removal, yearling coho salmon releases could be delayed to avoid lethal water quality conditions. The Renewal Corporation does not expect that delaying the release of yearling coho salmon will require a substantial change in the typical hatchery release schedule and may only require a 2-week delay in the release schedule. Water quality monitoring stations operated by the Renewal Corporation will be used by CDFW to determine when conditions in the mainstem Klamath River are suitable for the release of hatchery-reared coho salmon. Whether this measure is ultimately adopted will be at the discretion of CDFW, and the Renewal Corporation will coordinate closely with CDFW on the potential implementation of this measure in relation to the planned cofferdam breach periods. This measure will reduce project effects on outmigrating hatchery-origin yearling coho salmon released from the Fall Creek Hatchery. This measure was formerly identified as AR-4 in the Definite Plan report (The Renewal Corporation 2018).

Aquatic Resource Measure - Sucker Adaptive Management Plan

Background: The Proposed Action is anticipated to result in mostly lethal impacts to Lost River and shortnose suckers in the Hydroelectric Reach reservoirs. Lost River and shortnose suckers are lake-type suckers and are therefore not anticipated to persist in the Klamath River following restoration of the Hydroelectric Reach reservoirs to free-flowing riverine conditions. Suckers in the Hydroelectric Reach are not anticipated to migrate to lake-type habitats upstream due to high-gradient channel reaches between Keno Dam and J.C. Boyle Reservoir as well as insufficient fish passage conditions at the J.C. Boyle Dam fish ladder and the Keno Dam fish ladder (FishPro 2000, PacifiCorp 2013b).

Project Measures: The Renewal Corporation will undertake two actions to reduce the overall effect on suckers present in the Hydroelectric Reach reservoirs.

- **Action 1:** The Renewal Corporation sampled Lost River and shortnose suckers in fall 2018, spring and fall 2019, and spring 2020. Each sampling included 5 to 7 days of effort and a total of 24 days of effort over the four sampling periods. The purpose of sampling was to understand Lost River and shortnose sucker demographics, genetic composition, and population sizes in J.C. Boyle, Copco No. 1, and Iron Gate reservoirs. For each captured listed sucker, field crews identified, measured, evaluated body condition, photographed, tagged, fin clipped, and then released the fish. Passive integrated transponder (PIT) tags were used to mark listed suckers with unique identifications. Fin clips were taken to process sucker genetic material to determine sucker genetics. The Renewal Corporation used recaptured suckers to prepare sucker population estimates for the three reservoirs. USFWS will complete genetic assays and use fin clips collected by the Renewal Corporation to determine the genetic composition of sampled suckers in the three reservoirs. Genetic results for sampled fish are expected to be available by March 2021. Sucker sampling results from all sampling periods are presented in Appendix G, Section G.2.1.6.

- **Action 2:** The Renewal Corporation will salvage adult Lost River and shortnose suckers in the Hydroelectric Reach reservoirs and translocate the suckers to the Klamath National Fish Hatchery near Klamath Falls, Oregon, the Klamath Tribes sucker rearing facility near Chiloquin, Oregon, and Tule Lake Sump 1A near Tulelake, California, during either spring or fall of the year prior to drawdown, as described in the California AR-6 Adaptive Management Plan–Suckers and the Oregon AR-6 Adaptive Management Plan–Suckers (Aquatic Resources Management Plan, Appendix D). Salvage and release efforts will be conducted for up to 14 days, and, based on sampling catch efficiencies, up to 600 listed suckers are anticipated to be captured. If the Renewal Corporation deems the effort feasible, suckers may also be salvaged during drawdown of J.C. Boyle Reservoir, the most accessible of the three reservoirs. The number of translocated fish will not exceed 3,100 fish, which is the capacity of the Klamath National Fish Hatchery (100 adult suckers) and Tule Lake Sump 1A (3,000 adult suckers).

Measure details are contained in the California AR-6 Adaptive Management Plan–Suckers and the Oregon AR-6 Adaptive Management Plan–Suckers (Aquatic Resources Management Plan, Appendix D).

2.6.2 Terrestrial and Wildlife Management Plan

The Terrestrial and Wildlife Management Plan (Appendix E) includes measures to avoid or minimize potential impacts to special-status wildlife and plants and their terrestrial habitats. Measures to protect any potential gray wolf in the area, avoid habitat for willow flycatcher, establish 20-foot buffers around delineated wetlands, avoid special-status plants, and BMPs for bats are included in the Terrestrial and Wildlife Management Plan. The Renewal Corporation expects impacts to special-status amphibians and reptiles, including the potential for stranding western pond turtles during the drawdown phase, and potential impacts from construction and alterations to habitat throughout all phases of the Proposed Action. The Terrestrial and Wildlife Management Plan addresses those impacts and includes surveys and relocation protocols that were developed for these species. Measures to minimize potential impacts to bald or golden eagles and their habitat are described in the Terrestrial and Wildlife Management Plan. Survey protocols, nesting buffers, and construction timing windows and methods to minimize potential noise-related impacts are described in the Terrestrial and Wildlife Management Plan. The Terrestrial and Wildlife Management Plan also includes biological resources education guidelines and awareness training by a trained and approved designated biologist for all on-site personnel and their supervisors.

2.6.3 Erosion and Sediment Control Plan

The Erosion and Sediment Control Plan is a best management approach to address potential impacts associated with implementing the Proposed Action. As described in the ODEQ 401 WQC as Condition 8 and Condition 10 of the SWRCB 401 WQC addressing Construction General Permit under National Pollution Discharge Elimination System (NPDES) the Renewal Corporation will establish erosion and sediment control BMPs to minimize pollution from sediment erosion caused by facilities removal and restoration activities.

2.6.4 Reservoir Area Management Plan

The Reservoir Area Management Plan (Appendix C) includes all components to be implemented for restoration activities, monitoring, and adaptive management. The Reservoir Area Management Plan provides a detailed description of proposed restoration activities and a preliminary map identifying proposed locations for those activities. A list of BMPs or other measures addressing invasive weed management, revegetation, floodplain connectivity, and procedures to stabilize and restore the former reservoir area(s) after removal of the dams is also included. This plan was developed in consultation with USFWS and NMFS.

2.6.4.1 Summary of Best Management Practices

The Reservoir Area Management Plan details BMPs related to upland restoration, infrastructure, invasive exotic vegetation (IEV), and in-water work for significant interventions (maintenance actions). BMPs at upland restoration sites include grading and recontouring slopes to match the natural neighboring slopes and implementing site-specific temporary and permanent sediment and erosion control BMPs per the Stormwater Pollution Prevention Plan (SWPPP), including revegetation with regionally appropriate upland native seed mixes. Infrastructure-related restoration associated with bridge sites, the City of Yreka pipeline, and culverts will include temporary and permanent sediment and erosion control BMPs per the site-specific SWPPP, including revegetation with regionally appropriate riparian native seed mixes.

To manage the spread of IEVs into disturbed areas, the Renewal Corporation will closely monitor the movement of people and equipment while restoration activities are being performed. IEV cleaning stations will be included at each staging area for vehicle washing and boot cleaning. Fencing can prevent seed from entering the reservoirs from cattle movements, but wildlife capable of jumping over fencing is expected to move seed into restoration areas. Additional BMPs related to IEV management include:

- Maintaining a 50-foot-wide buffer free of IEV species around access roads and trails.
- Thoroughly cleaning clothing and gear following site visits.
- Checking clothing and gear for soil, seeds, and plant materials.
- Inspecting and cleaning equipment upon entering and exiting the limits of work.
- Inspecting and cleaning vehicles upon entering and exiting the limits of work.
- Training staff, including contractors, on weed identification and methods to avoid the unintentional spread of invasive plants.
- Managing vegetation using methods that reduce the spread of invasive species and encourage desirable vegetation.

Significant adaptive management interventions involve in-water work and the need for work zone isolation measures. Specific BMPs for significant interventions requiring in-water work are detailed in Section 2.4.5.

2.6.5 Fish Passage Monitoring

Restoration of the Klamath River and associated fish-bearing tributaries from reservoir to riverine habitat will evolve as natural processes are restored and the area experiences variable flows. Monitoring will therefore be necessary to ensure fish passage objectives are achieved. The Renewal Corporation will conduct fish passage monitoring on the mainstem Klamath River and project-associated fish-bearing tributaries upstream of the former Iron Gate Dam site. The Reservoir Area Management Plan (Appendix C, Section 6.2) and the Tributary–Mainstem Connectivity Plan (Aquatic Resources Management Plan, Appendix D) describe the fish passage monitoring areas, timing, methods for evaluating residual dam sediment headcuts, and the steps that will be taken if knickpoints are deemed to be fish passage barriers. In addition to the California and Oregon areas specified in the Reservoir Area Management Plan and Aquatic Resources Management Plan, two additional reaches in Oregon will be monitored for fish passage: (1) in the drawdown year, monitoring between J.C. Boyle Dam and the Oregon/California state line; and (2) annually within the downstream extent delineated by the former J.C. Boyle Dam scour hole, approximately 2.5 miles downstream of the J.C. Boyle Dam location, and at the former J.C. Boyle Powerhouse.

2.6.6 NSO Measures

The Joint Preliminary Biological Opinion included several measures specifically addressing potential effects on northern spotted owl (NSO) (NMFS and USFWS 2012). In coordination with USFWS, CDFW, and ODFW, the Renewal Corporation has incorporated measures into the current project description for the Proposed Action, as summarized below.

The Renewal Corporation biologists conducted six protocol surveys consistent with the 2012 USFWS NSO Survey Protocol (USFWS 2012b) at 18 calling stations in the vicinity of the J.C. Boyle Reservoir and powerhouse during the 2018 breeding season. The Renewal Corporation biologists did not detect northern spotted owls, nests, or activity centers during the surveys. Modification of 0.4 acre of habitat, including tree removal and grading, is required for the relocation of the J.C. Boyle powerhouse access road at the location of the scour hole. This area is dominated by Douglas-fir with average canopy cover of 30 percent and provides dispersal habitat for NSO. The effects of this habitat modification are described in Section 5.7.

As described in Section 4.9, there is no nesting, roosting, or foraging habitat within 0.25 mile of where project activities would occur. Northern spotted owls would not be expected to establish new activity centers within these areas, which provide only dispersal habitat at best, before or during implementation of the Proposed Action. Therefore, no additional northern spotted owl surveys are proposed unless helicopter flight patterns cannot avoid nesting, roosting, or forgaging (NRF) habitat areas, as described below and in Section 5.7.2.

Based on input from USFWS, the Renewal Corporation will implement the following conservation measures specific to NSO:

- To prevent disturbance to the known NSO activity center approximately 1.3 miles southeast of the eastern end of Copco Lake (CNDDB Masterowl number SIS0301 and BLM Master Site Number

[MSNO] 2191), helicopter flight paths will stay at least 1 mile from the known NSO activity center. No new surveys will be conducted and occupancy by nesting birds will be assumed.

- To address the potential for NSO to move into other areas that support NRF habitat south of Copco Lake, helicopter flight paths will stay at least 1 mile from suitable NRF habitat, as identified in the USFWS Relative Habitat Suitability mapping layer (S. Galloway, Biologist, USFWS Yreka Office, pers. comm., May 24, 2017).
- If helicopter flight paths cannot avoid the areas that support NRF habitat south of Copco Lake, then the Renewal Corporation will conduct disturbance-only surveys.
- No nesting, roosting, or foraging habitat will be affected by the Proposed Action. Modification of critical habitat during relocation and widening of the J.C. Boyle powerhouse access road at the scour hole will be limited to areas of NSO dispersal habitat. Dispersal habitat will not be downgraded as a result of tree removal.

2.7 Summary and Schedule of Proposed In-Water Work Activities

As described in the previous sections, much of the dam removal work will occur in dry conditions following reservoir drawdown. Table 2-17 summarizes the proposed in-water work activities.

Table 2-17: Proposed In-Water Work

Location	Description of Work	Approximate Schedule[1]
J.C. Boyle		
Timber bridge	Remove bridge, sheet pile, and miscellaneous steel and fill at abutments.	October to November of the drawdown year (Year 1)
Powerhouse tailrace channel (Figure 2-6)	Backfill tailrace with powerhouse concrete rubble and existing fill from substation and warehouse base material.	June to September Year 1
Earth-fill dam and historical earthen cofferdam	Remove intake structure (starting in April); remove earth-fill dam (starting in July), remove work platform (starting in August); and breach historical earthen cofferdam upstream of dam (in September). Some material may be placed on either side of future river channel on banks (Figure 2-1, Sheet 2). Area is mostly currently underwater.	April to September Year 1
Foundations for 14-foot low-pressure pipeline from intake to power canal. Rocker bent footings. Just upstream of Timber bridge (Figure 2-1, Sheet 2).	Removal of rocker bent footings under pipeline.	April to June Year 1

Location	Description of Work	Approximate Schedule[1]
Dam site river channel roughness	Placement of rock for channel roughness along left-bank fringe to aid fish passage.	August to September Year 1
Bridge piers from former bridge downstream of Hwy 66 bridge; at Pioneer Park West	Remove historical bridge piers from river channel; construct and remove an access road across the river to facilitate the work.	October to November Year 1
Pioneer Park West recreation site – boat ramp	New boat ramp for retained recreation area at edge of new channel.	July to August of the year before drawdown
Spencer Creek Priority Restoration Site	Regrading of stream channel and confluence for volitional fish passage – includes channel, floodplain, delta, and sediment stabilization grading; placement of boulder clusters, willow baffles, and large wood structures with ground-based equipment and helicopters.	April to September Year 2 and 3
Copco No. 1		
Open water disposal site shown on Figure 2-7, Sheet 1.	Removal of sediment using clamshell or suction dredging from barge.	July to August of the year before drawdown
Downstream base of dam and powerhouse access road and work pad – install	Access road to base of dam and to exit of existing diversion tunnel (installation). Approximately 600 linear feet could wash out during drawdown or deconstruction, in which case additional material would be placed in the water to repair the access track.	July to August of the year before drawdown
Downstream base of dam and powerhouse access road and work pad – remove	Removal of access road to base of dam and to exit of existing diversion tunnel.	September to October of the drawdown year (Year 1)
Powerhouse	Placement of fill to cover powerhouse along river's edge (Figure 2-10).	June to October Year 1
Dam	Removal of last parts of dam in-water work; may include in water blasting.	August to September Year 1
Plunge pool at base of dam	Fill plunge pool at base of dam with concrete rubble and "riverbed material" – type E7 – as part of final channel shaping (Figure 2-9).	September to October Year 1
Install channel roughness features	Restore volitional fish passage channel by placing rock.	September to October Year 1
Copco Valley new recreation area boat ramp	Construction of new boat ramp at Copco Cove for new recreation area at new river channel edge.	April to September Year 2
Beaver Creek Priority Restoration Site	Regrading of stream channel and confluence for volitional fish passage – includes channel, floodplain, delta, and sediment stabilization grading; placement of boulder clusters, willow baffles, and large wood structures with ground-based equipment and helicopters.	April to September Year 2

Location	Description of Work	Approximate Schedule[1]
Copco No. 2		
Diversion Dam/Spillway Apron access track	Build access road on right bank downstream of dam. Build work pad on spillway sill for access to Bay 1 removal (Figure 2-11).	July to October of the year before drawdown
Removal of spillway access and work pad	Remove work pad after Bay 1 is removed (with plug left in place).	July to September of the year before drawdown
Diversion dam/spillway apron access track and work pad	Rebuild work pad on spillway sill for access to Bay 1 plug and removal of Bays 2 to 5 (Figure 2-11).	June to July Year 1
Removal of existing cofferdam upstream of dam	Build work pad to remove old cofferdams upstream of dam, immediately followed by fill and removal. Construct access road across river or operate equipment directly in river.	July to August Year 1
Dam	Removal of last portions of dam structure; in-water work (Figure 2-11).	June to July Year 1
Diversion tunnel intake structure	Place riprap and fish-friendly gravel to plug intake structure (Figure 2-13).	June to July Year 1
Powerhouse tailrace (Figure 2-14)	Bury concrete rubble generated from removal of the Copco No. 2 Powerhouse and right tailrace wing wall in the powerhouse tailrace, covering an area of about 1 acre.	August to September Year 1
Daggett Road bridge	Install bridge upstream of Daggett road bridge. Embank abutments.	July to August of the year before drawdown
Daggett Road bridge	Remove temporary bridge just upstream of Daggett Road bridge.	October to November Year 1
Iron Gate		
Camp Creek – downstream of existing culvert	Install new precast bridge culvert at existing culvert location. Embank abutments and set precast arch culverts on top.	September to October of the drawdown year (Year 1)
Camp Creek (41.97396758, –122.4358561)	Excavate and remove existing culvert.	September to October Year 1
Scotch Creek – downstream of existing culvert	Install new precast bridge culvert at existing culvert location. Embank abutments and set precast arch culverts on top.	September to October Year 1
Scotch Creek (41.97533607, –122.4400093)	Excavate and remove existing culvert.	September to October Year 1

Location	Description of Work	Approximate Schedule[1]
Fall Creek Hatchery improvements	Fall Creek Hatchery improvements – in water components include fish ladder landing, diversion dam modifications, and potentially settling tank outfall erosion control pad. Fall Creek culverts at Daggett Road crossing (41.97325, -122.36667) proposed to be 45 feet long, 112 inch X 75 inch CMP arch culverts entailing 1,800 cy of backfill each.	March to September of the year before drawdown
City of Yreka water supply temporary pipeline	Install temporary pipeline crossing Daggett Road Bridge.	June to October of the year before drawdown
City of Yreka water supply permanent pipeline	Install permanent pipeline underneath Klamath River in the location of the existing City of Yreka water supply pipeline.	July to October Year 1 or 2, when river is free flowing
Fall Creek at Daggett Road	Install new arch steel culvert structure.	August to September of the year before drawdown
In-water work pad downstream of dam (Figure 2-16)	Construct access road and work pad on downstream side of dam to allow access for crane and other equipment.	July to August of the year before drawdown
In-water work pad downstream of dam (Figure 2-16)	Removal of access road and work pad on downstream side of dam.	December of the year before drawdown
Spillway fill downstream toe slope	Erosion protection on the downstream end of the spillway fill toe slope.	July to August Year 1
Access track for tunnel modifications below spillway and dam. From residential area on right bank to fish-spawning facilities at base of dam.	Temporary causeway past end of diversion tunnel to base of dam to be removed during dam removal.	July to September of the year before drawdown
Dam removal – final breach and removal	Removal of last bit of dam; would be in-water work.	August to mid-October/mid-November Year 1
Powerhouse tailrace	Fill of tailrace area below powerhouse.	September to October Year 1
Jenny Creek Restoration Priority Restoration Site	Regrading of stream channel and confluence for volitional fish passage; includes channel, floodplain, delta, and sediment stabilization grading; placement of boulder clusters, willow baffles, and large wood structures with ground-based equipment and helicopters.	April to September Year 2

Location	Description of Work	Approximate Schedule[1]
Camp Creek Restoration Priority Restoration Site	Regrading of stream channel and confluence for volitional fish passage; includes channel, floodplain, delta, and sediment stabilization grading; placement of boulder clusters, willow baffles, and large wood structures with ground-based equipment and helicopters.	April to September Year 2
Long Prairie Creek Restoration	Removal of three historical crossing structures over Long Creek.	April to September Year 2

Note:

[1] Table shows the schedule in which the work may be conducted. However, the duration of the in-water work activities may be significantly shorter than the window in which the activity is scheduled.

Following dam removal, there is some potential for the river and its tributaries to scour bridge abutments or develop headcuts that may create a fish passage concern at culvert crossings. Although the likelihood of issues developing at these locations is low, the Renewal Corporation has identified potential locations and contingency actions. The Renewal Corporation will monitor these areas in Year 1 and Year 2 following reservoir drawdown and will implement corrective actions if necessary. Table 2-18 summarizes these potential contingency actions that may involve in-water work.

Table 2-18: Summary of Potential Contingency In-Water Work Activities

Location	Description of Work
J.C. Boyle	
Highway 66 Bridge	Scour protection at abutments. Potential for placement of riprap below ordinary high water mark (OHWM); unlikely, based on current information. Would be done during restoration phase if needed.
Culvert at unnamed tributary #3; Topsy Grade 7200 (near Topsy campground) (42.12183415, -122.0415819)	Remove existing 3ea 24" CMP, replace with 3ea 36" CMP. Contingency action, but more likely to occur than other contingency culvert replacements due to location relative to reservoir.
Culvert Replacement at Spencer Creek	Spencer Creek; unlikely to occur – road and culvert outside of restoration boundary.
Culvert replacement at unnamed tributary #1 (NW side of reservoir) (42.15, -122.039 and 42.14987168, -122.0392295) double culverts at same location.	45-foot; 60" X 46" CMP Arch; 990 cf backfill; each culvert; two culverts at this location. Low-gradient area; unlikely to occur.
Culvert replacement at unnamed tributary #2 (SE side of reservoir in Sportsman's Park) (42.14301736, -122.0251116)	40-foot 60" x 46" CMP Arch; 880 cf backfill. Set far back from reservoir; very unlikely to occur.
Copco No. 1	
Mallard Cove – Boat ramp modifications – not currently proposed	Extension of boat ramp at Mallard Cove.

Location	Description of Work
Klamath River mainstem upstream of former Copco No. 1 reservoir area – Spawning gravel augmentation.	Implementation of Aquatic Resource Measure Mainstem Spawning includes monitoring of available spawning habitat; if targets are not met, spawning gravel may be placed in the main channel upstream of the former Copco No. 1 reservoir area.
Ager Beswick-66500 - at intersection of Patricia Road and Ager Beswick – head of Mallard Cove (AKA Keaton Cove) (41.96833043, -122.3043609)	Culvert replacement; 60" X 46" CMP Arch, 50 feet long. Unlikely to occur; culvert should be approximately 1,100 feet upstream of nearest channel gradient adjustment due to drawdown.
Indian Creek-Ager Beswick – near intersection of Patricia Road and Ager Beswick - head of Mallard Cove (Keaton Cove) (41.9683656, -122.3037973)	Culvert replacement; 55 feet long, 60" X 46" CMP Arch. Unlikely to occur; culvert should be approximately 1,100 feet upstream of nearest channel gradient adjustment due to drawdown.
AgerBeswick-77750 - Snackenbury Creek on south side of reservoir at eastern end. Crossing under Ager Beswick Road. (41.96526226, -122.2729338).	Culvert replacement; 50 feet long; 36" diameter CMP. Low potential to occur; narrow part of reservoir, small length of tributary to be exposed.
Copco Road-114000 – unnamed tributary #2 (north side of reservoir, west side of Beaver Creek Cove) (41,99149777, -122.3162123)	Culvert replacement 45 feet long, 36" CMP. Low potential to occur; tributary channel is not well defined below reservoir elevation.
Copco Road-114060 – unnamed tributary #2 (north side of reservoir, west side of Beaver Creek Cove) (41.99200549, -122.315899)	Culvert replacement, 45 feet long, 60" X 46" CMP Arch. Low potential to occur; tributary channel is not well defined below reservoir elevation.
Copco Road-129000 – Copco unnamed tributary #1 – north side of reservoir, eastern half; approximately directly across from Mallard Cove (41.9789205, -122.2872763)	Culvert replacement, 45 feet long, 36" CMP. Low potential to occur; approximately 1,600-foot tributary length to future river channel confluence.
Copco Road-129010 – Copco unnamed tributary #1 – North side of reservoir, eastern half; approximately directly across from Mallard Cove (41.97881387, -122.2872008).	Culvert replacement, 45 feet long, 48" CMP. Low potential to occur; approximately 1,600-foot tributary length to future river channel confluence.
Copco Road-133000 – Spannaus Gulch – north side, eastern end (41.97271183, -122.2781954)	Culvert replacement, 45 feet long, 112" X 75" CMP Arch. Low potential to occur; approximately 1,000-foot tributary length to future river channel confluence.
East Fork Beaver Creek – Beaver Creek and Copco Road, east branch (41.99570429, -122.3092875).	Culvert replacement, 50 feet long, 112" X 75" CMP Arch. Low potential to occur; Beaver Creek profiles indicate low potential for head cutting close to culvert.
Raymond Gulch – north side of reservoir east of Beaver Creek (41.98466518, -122.2966572)	Culvert replacement, 45 feet long, 112" X 75" CMP Arch. Low potential to occur; Raymond Creek culvert approximately 2,000 feet from confluence with future river channel.
West Fork Beaver Creek – Beaver Creek and Copco Road, west branch (41.99580791, -122.3096994)	Culvert replacement, 45 feet long, 112" X 75" CMP Arch. Low potential; Beaver Creek profiles indicate low potential for head cutting close to culvert.
Iron Gate	
Copco Road-59000 – Camp Creek unnamed tributary #1 (west side of Camp Creek cove) (41.96136579, -122.4428509)	Culvert replacement – 50 feet long, 60" X 46" CMP Arch.

Location	Description of Work
Copco Road-60+300 – Camp Creek unnamed tributary #2 – (west side of Camp Creek Cove) (41.96357952, -122.4428309)	Culvert replacement – 45 feet long, 60" X 46" CMP Arch.
Removal of sediment below dam and above Lakeview bridge (potential action)	Removal of sediment below dam and above Lakeview bridge (potential action).
Jenny Creek – upstream of existing bridge	Riprap erosion embankment protection on bridge abutments and upstream and downstream of bridge.
Iron Gate Dam to Cottonwood Creek (8-mile stretch of the mainstem Klamath River)	Removal of reservoir-related sediment or debris blockages at tributary confluences; minor grading or sediment movement at the mainstem confluence using mechanical (excavator or equivalent) equipment and/or hand crews (hand tools). Criteria and approach to tributary connectivity maintenance will be done in accordance with the Aquatic Resource Management Plan.

Chapter 3: Action Area

3. ACTION AREA

An Action Area is identified for analysis of the potential effects of the Proposed Action on listed species. The Action Area is defined as "all areas to be affected directly or indirectly by the federal action and not merely the immediate area involved in the action" (50 Code of Federal Regulations [CFR] § 402.02). Thus, observable or measurable effects of the project are not expected beyond the boundaries of the identified project Action Area.

The Proposed Action is located in the Klamath River Basin of northern California and southern Oregon. For the purposes of this BA, the Klamath River Basin includes all headwaters of tributaries to the Klamath River (e.g., Williamson, Sprague, Lost, Trinity Rivers) downstream to the mouth of the Klamath River. The Klamath River Basin is typically divided into three geographic areas: Upper Klamath Basin, Middle Klamath Basin, and Lower Klamath Basin. The Upper Klamath Basin includes Upper Klamath Lake and its tributaries downstream to Keno Dam. The Middle Klamath Basin is defined as the portion of the Klamath River watershed between Keno Dam and the Trinity River confluence. The Lower Klamath Basin includes the Trinity River confluence to the confluence with the Pacific Ocean.

For the purposes of this BA, the Action Area consists of the geographic extent anticipated for potential effects of the removal activities and the resulting free-flowing river condition on all evaluated listed species. Effects in the Action Area would vary according to species, because the population distribution and the specific effects may vary among species.

The Action Area (Figure 3-1) includes:

- Upper Klamath Lake and its fish-bearing tributaries, up to the limit of anadromy as defined by ODFW (2020);
- The Klamath River from Upper Klamath Lake downstream to the mouth of the Klamath River estuary;
- All fish-bearing tributaries of the Klamath River upstream of Iron Gate Dam, up to the limit of anadromy. For those tributaries in Oregon, the limit of anadromy is defined by ODFW (2020)[4]. Anticipated limits of anadromy are based on current watershed conditions. Limits of anadromy do not reflect potential Pacific lamprey access, which may exceed potential salmonid access extents;
- The area within 1.5 miles of the overall project construction limits in the Hydroelectric Reach (four developments and their reservoirs), which contains the four dams proposed for removal and encompasses the extent of fish passage actions on the main tributaries as well as the entire construction footprint. This 1.5-mile buffer is a conservative buffer to encompass potential effects related to noise from all construction activities including blasting activities at the dams, restoration work in tributaries, work at disposal sites, road work, and hauling;
- The 100-year floodplain from Link River Dam to the mouth of the Klamath River;

[4] ODFW (2020) only includes Oregon tributaries.

- The Pacific Ocean 1.5 miles north, south, and west of the mouth of the Klamath River. This 1.5-mile buffer is a conservative estimate for the distance that sediment mobilized during the Proposed Action could extend; and
- Tule Lake Sump 1A and the Lost River from Anderson-Rose Dam to Tule Lake Sump 1A to account for the effects of translocated suckers on existing suckers in Tule Lake Sump 1A and the Lost River reach.

The Action Area also includes the Pacific Ocean where there is species overlap between Klamath River Chinook salmon and Southern Resident killer whale. The exact boundaries of this area cannot be precisely defined based on current information; however, it includes coastal waters ranging from northern California through central Oregon up to the mouth of the Columbia River.

Chapter 4: Environmental Baseline

4. ENVIRONMENTAL BASELINE

This chapter describes the physical environment of the Action Area. Components of the physical environment that affect the condition of listed species and designated critical habitat are described, including existing habitat conditions, sediment and water quality, and aquatic diseases. Table 1-2 lists the species and critical habitats considered in this BA; detailed accounts of each are provided in Appendix G.

4.1 Watershed Setting

The Klamath River originates just downstream of Upper Klamath Lake in Southern Oregon and flows 253 miles southwest through the Cascade Mountains of Southern Oregon and Northern California to the Pacific Ocean.

As described in Chapter 3, the Upper Klamath Basin includes Upper Klamath Lake and its tributaries downstream to Keno Dam, inclusive of the dam. The Middle Klamath Basin is defined as the portion of the Klamath River watershed between Keno Dam and the Trinity River confluence. The Lower Klamath Basin includes the Trinity River confluence to the confluence with the Pacific Ocean. The Klamath Basin is generally rural, with a total human population of approximately 120,000. Its largest communities are Klamath Falls, Oregon, and Yreka, California. The Upper and Middle Klamath Basins have broad valleys shaped by volcanoes and active faulting. The fault-bounded valleys contain all of the large, natural lakes and large wetlands of the Klamath Basin. In the Lower Basin, the Klamath River forms a deep canyon surrounded by the mountains of the Siskiyou and Coast ranges.

The Klamath is unlike most river systems in that the river is warmer and flatter in its headwaters while downstream portions, beginning near the dams, tend to be colder and steeper. The Klamath River flows through mountainous terrain from the J.C. Boyle reach to the reaches downstream of Iron Gate Dam. Downstream of Iron Gate Dam, and for most of the river's length to the Pacific Ocean, the river maintains a relatively steep, high-energy channel.

4.2 Climate and Hydrology

The Klamath Basin receives widely varying precipitation. The climate upstream of Iron Gate Dam is dry, with an annual precipitation of approximately 13 inches at the river's origin near Klamath Falls, Oregon. In contrast, the climate downstream of Iron Gate Dam is wet, with an annual precipitation of approximately 80 inches near the river's mouth at Requa, California. At its higher elevations (above 5,000 feet), the area upstream of Iron Gate Dam receives rain and snow during the late fall, winter, and spring. Peak stream flows generally occur during snowmelt runoff in late spring/early summer. After the runoff period, flows drop in the late summer and early fall. Downstream of Iron Gate Dam, Klamath River flows are influenced by dam operations, as explained in more detail below.

The Action Area is defined in Chapter 3 and encompasses nearly the entire Klamath River Basin. The basin upstream of Iron Gate Dam is intricately connected to the hydrologic conditions generated by the USBR's Klamath Project, a water management project that stores, diverts, and conveys waters of the Klamath and Lost rivers. Flows for the Klamath Project are described in the 2019 USBR Klamath Project BA (USBR 2018). Operation of the Klamath Project seeks to generate a hydrograph that resembles the shape of the natural river flow regime for the Hydroelectric Reach; however, the flow volume, spring peak magnitude and duration, deep flushing flows, and flow variability are reduced relative to the natural hydrograph due to storage in Upper Klamath Lake and consumptive water use.

NMFS (2019a) and USFWS (2019a) issued BOs for operation of the Klamath Project for the period of April 1, 2019, through March 31, 2024. The BOs reviewed flow management for USBR's Klamath Project, including specific criteria for flows at the compliance point at Iron Gate Dam. Flow management strategies are divided into fall/winter and spring/summer periods. For the fall/winter (October-February) operations, water management follows a formulaic approach focused on meeting the needs of ESA-listed species in the Klamath River, while increasing water storage in Upper Klamath Lake and providing sucker habitat in Upper Klamath Lake. Minimum Iron Gate Dam average daily minimum target flows are 1,000 cfs in October and November and 950 cfs in December, January, and February. Spring/summer flows must meet the minimum outflows from Iron Gate Dam as summarized in Table 4-1.

Table 4-1: Minimum Iron Gate Dam Target Flows (NMFS 2019a)

Month	Iron Gate Dam Average Daily Minimum Target Flow (cfs)
March	1,000 (28.3 m^3/sec)
April	1,325 (37.5 m^3/sec)
May	1,175 (33.3 m^3/sec)
June	1,025 (29.0 m^3/sec)
July	900 (25.5 m^3/sec)
August	900 (25.5. m^3/sec)
September	1,000 (28.3 m^3/sec)
October	1,000 (28.3 m^3/sec)
November	1,000 (28.3 m^3/sec)
December	950 (26.9 m^3/sec)
January	950 (26.9 m^3/sec)
February	950 (26.9 m^3/sec)

m^3/sec = cubic meters per second

Klamath River flow management for the Klamath Project contains further provisions for an Environmental Water Account, which is a volume of water used to meet Iron Gate Dam flow targets in spring/summer. The Environmental Water Account is distributed based on a spring/summer formulaic approach for calculating Iron Gate Dam target flows. Minimum Environmental Water Account is 400,000 acre/feet and includes approximately 50,000 acre-feet of water for disease mitigation and habitat flows in the spring/summer seasons.

Geomorphic and sediment flows are critical in creating and maintaining in-channel and riparian habitat by providing overbank flows, which remove accumulated fine sediment, maintain sediment balance, scour vegetation and remobilize gravel to form bars, and may augment floodplain development. Geomorphic flows (i.e., flows >15,000 cfs) are intended to maintain channel form and floodplains. Sediment maintenance flows (i.e., surface and deep flushing flows) are intended to remove sediment from a channel or otherwise modify substrate composition (NMFS 2019a). Surface flushing flows constitute an average release of at least 6,030 cfs from Iron Gate Dam for at least 72 consecutive hours and deep flushing flows constitute an average release of 11,250 cfs for 24 hours.

Generally, operation of the Klamath Project has no effect on the magnitude and frequency of geomorphic flows and flood flows. Klamath Basin Monitoring Program (KBMP) output indicates that surface flushing flow would occur in nearly all years, which is likely to be of similar frequency and magnitude relative to the natural flow regime. However, surface flushing flows likely did not occur under the natural flow regime in protracted drought conditions with consecutive dry years (NMFS 2019a). USBR attempts to implement deep flushing flows downstream of Iron Gate Dam when hydrologic conditions and public safety allow. KBMP output indicates that deep flushing flows are achieved in 4 out of 36 years. The Klamath Project does decrease the frequency of deep flushing flows, which in turn has contributed to a higher risk of disease in juvenile Chinook and coho salmon (NMFS 2019a). Furthermore, USBR retains sole discretion to determine when to initiate or cease flood control operations for the Klamath Project and will continue to manage floods and peak flow control as it has in the past.

4.3 Vegetation Cover

The Klamath Basin is in the Klamath Bioregion (California) and the East and West Slope Cascades (Oregon) eco-regions. Vegetation communities in the bioregion and the eco-regions include drier pine and fir forests in the mountain ranges of Siskiyou County, and wetter forests near the coast. Recognized for their biological diversity, the Klamath-Siskiyou mountain ranges contain more than 3,000 known plant species, including 30 temperate conifer tree species, more than any other ecosystem in the world (CDFW 2015a). Land cover in the basin consists of a combination of upland tree habitat, aquatic habitat, and wetland habitat. Sagebrush and interior valley vegetation communities also exist in lower-elevation areas. The Klamath River Canyon itself is a mosaic of mixed conifer forest communities and riparian habitats (FERC 2007). In addition to their ecological significance, many plants, especially wetland plants, in the Klamath Basin are culturally important to Indian Tribes in the Klamath River region for food, basketry, regalia, and medicine, and some have importance for ceremonial use as well (Larson and Brush 2010, FERC 2007).

Based on a review of historical aerial photography conducted by the Renewal Corporation, timber harvest has been conducted in several locations within 0.5 mile of the limits of work near the J.C. Boyle Dam and powerhouse. The analysis of historical imagery noted that logging and forest thinning occurred in late summer/fall of 2003 and between 2003 and 2005 in the vicinity of the J.C. Boyle Reservoir and east of the Klamath River canyon between the J.C. Boyle Dam and the powerhouse. Additional timber harvest activities have occurred to the north and west of the J.C. Boyle reservoir on private lands in 2017 and 2018. These habitat alterations have the potential to reduce habitat suitability for species such as northern spotted owl.

Several wildfires have impacted vegetation cover in and adjacent to the Action Area in recent years, including the Goff and Lick Fires in 2012; the Butler, Salmon Complex, and Corral Fires in 2013; the Beaver, Frying Pan, Log, Little Deer, Coffee, and Whites Fires in 2014; the Nickowitz, Peak, Bear, and Happy Fires in 2015; the Gap, Pony, Grade, and Tulley Fires in 2016; and the Oak, Wallow, Abney, and Cedar Fires in 2017 (C. Isbell, USFS Klamath National Forest, pers. comm, March 19, 2018). Fires near the Hydroelectric Reach include the Oregon Gulch fire in 2014, which burned around 35,000 acres immediately adjacent to Copco No. 1 Reservoir. The Klamathon fire in 2018 burned 38,000 acres adjacent to and west of Iron Gate Reservoir, including the Scotch Creek and Camp Creek area and the river reach downstream of the dam. Further downstream, the Natchez fire occurred near Happy Camp in 2018 and burned 38,134 acres. Most recently, the Slater and Devil fires occurred in the fall of 2020 and burned a combined 166,127 acres north and west of Happy Camp (CalTopo 2021). No other significant habitat alterations were identified in the Action Area since the PacifiCorp surveys in 2004.

4.4 Land Use

The major land uses categories in the Action Area are agriculture, open space, forestry, recreation, and rural communities. The main urban areas are Klamath Falls and Yreka. Most of the land in the Action Area consists of agriculture/grazing or open space and conservation. A small portion is developed as hydroelectric operations and recreation sites. Residential developments occur in and around the community of Keno and the Keno Recreation Area and along portions of Copco No. 1 Reservoir. See the Klamath Facilities Removal EIS/EIR (USBR and CDFW 2012) for more detailed information about land use.

4.5 Sediment Supply and Conditions

4.5.1 Upper Klamath Lake to Keno Dam

The Klamath River is supply-limited for fine material (sands and small gravels), but capacity-limited for large material (cobbles and boulders) (USBR 2011a). Almost no substantial sediment is supplied to the Klamath River from the watershed upstream of Keno Dam. This is because Upper Klamath Lake, with its large surface area, traps nearly all sediment delivered from upstream tributaries, although some fine material may be transported through the lake during high runoff events.

4.5.2 Hydroelectric Reach and Reservoirs

Between Keno Dam and Iron Gate Dam, coarse sediment inputs from tributary streams and other streamside sources are currently trapped within the Hydroelectric Reach reservoirs. Sources in this reach supply 24,160 tons/year of coarse sediment (1.3 percent of the cumulative average annual basin-wide coarse sediment delivery) (Stillwater Sciences 2010). The following sections contain a description of the quantity and quality of the sediments stored within the Hydroelectric Reach reservoirs.

4.5.2.1 Sediment Quantity

In 2009 and 2010, USBR conducted a sediment sampling study in the project reservoirs to describe sediment composition and determine sediment thickness throughout all major sections of the reservoirs (USBR 2010). The study found that fine-grained sediment in all of the reservoirs except Copco No. 2 Reservoir consisted primarily of elastic silt and clay, with lesser amounts of elastic silt with fine sand. USBR determined that the sediment was mostly an accumulation of silt-sized particles of organic material such as algae and diatoms, and silt-sized particles of rock. The average grain size decreases nearer to the dams because smaller particles settle more slowly than larger particles. Accordingly, the upper reaches of each reservoir contained a higher percentage of silt, sand, and gravel than the lower reaches, which contain more clay, sandy elastic silt, and elastic silt with trace sand. The elastic silt in all of the reservoirs had the consistency of pudding and had very high water content (more than double the mass). USBR also found that the fine-grained sediment had a low cohesion and to be erodible; where water flowed faster than 2.9 to 5.8 feet per second (fps), accumulations of sediment were less than a few inches (USBR 2011c).

USBR (2011a) estimated that there are approximately 13,150,000 cy of sediment stored in the Hydroelectric Reach (Table 4-2). The sediment stored in the reservoirs has a high water content, and 85 percent of the particles are silts and clays (less than 0.063 millimeter [mm]), while 15 percent are sand or coarser (larger than 0.063 mm) (GEC 2006, Stillwater Sciences 2008, USBR 2011a).

Table 4-2: Estimated Volume of Sediment Stored in Hydroelectric Reach Reservoirs and Tributary Mouths (USBR 2011d).

Reservoir	Location	Volume (cy)
J.C. Boyle	Upper Reservoir	380,000
	Lower Reservoir	620,000
Copco	Upper Reservoir	810,000
	Lower Reservoir	6,630,000
Iron Gate	Upper Reservoir	830,000
	Lower Reservoir	2,780,000
	Jenny Creek	300,000
	Scott/Camp creeks	800,000
Total		**13,150,000**

J.C. Boyle Reservoir

Sediment behind the J.C. Boyle Dam is fine-grained, a large fraction of which is dead algae and other organic material (USBR 2011c). Most of the sediment volume is stored in the Canyon Reach of the reservoir, which extends from the J.C. Boyle Dam upstream approximately 1 mile to the Highway 66 bridge. Sediment thickness increases from 0 to 2 feet at the Highway 66 bridge to maximum values of 20 feet near the dam. The sediment in this reach is, on average, 50 percent silt, 40 percent clay, and 10 percent sand. The accumulated reservoir sediment deposit in the Upstream Reach of the reservoir, which runs from the Highway 66 bridge upstream approximately 2 miles to the upstream extent of the J.C. Boyle Reservoir, is primarily confined to the historical channel. The reservoir sediment deposit is typically less than 4 feet thick in the historical channel, except for a 1,000-foot section approximately 1 mile upstream of the Highway 66 bridge, where thicknesses of 8 to 10 feet filled the local low topography. As expected, the Upstream Reach sediment is coarser than downstream and is approximately 55 percent sand, 25 percent silt, and 20 percent clay on average (USBR 2011c).

In the Upstream Reach, the reservoir sediments are underlain by a 0- to 2-foot-thick layer of coarser Quaternary alluvial gravel and sand, which is in turn underlain by fine-grained, but resistant, weathered Tertiary volcanics (USBR 2010). Intact organic fragments, such as roots, twigs, bark, and wood, were only found at the pre-reservoir contact in three core samples (USBR 2010). The accumulated in situ reservoir sediment in both reaches has high moisture content, over 100 percent, with low cohesion, low strength, and high erodibility (USBR 2011c). The measured friction angle for the reservoir sediments from a sediment core near the dam site is approximately 30 degrees. Reservoir sediment testing determined that, on drying, the sediments undergo significant changes in their physical properties. When dry, erosion resistance increases by an order of magnitude and the erodibility decreases. In dried samples from the Upstream Reach, average decreases in sediment thickness of 60 percent and in volume of 66 percent, along with considerable density increases, were measured.

Copco No. 1 Reservoir

Sediment behind the Copco No. 1 Dam is fine grained and contains a significant fraction of dead algae and other organic material (USBR 2011c). Sediment thicknesses decrease longitudinally with distance upstream from the dam and decrease laterally with increasing elevation above the historical channel. Maximum deposit depths are 10 to 12 feet immediately upstream from the dam. Deposit thicknesses are 6 to 10 feet in the historical valley bottom (i.e., location of mapped geomorphic features) in the Downstream Reach, which extends from Copco No. 1 Dam upstream approximately 6 miles to the upstream extent of the mapped historical floodplain near Beaver Creek. The reservoir sediment is, on average, 55 percent clay, 35 percent silt, and 10 percent sand (USBR 2011c) and is underlain at the pre-dam contact by varying concentrations of fluvial sand and trace gravels (USBR 2010), and a thick layer of fine-grained, but resistant, diatomite. In the Upstream Reach, which extends approximately 3 miles from Beaver Creek to the upstream extent of the reservoir, the coarser reservoir sediment is composed of approximately 30 percent clay, 45 percent silt, and 25 percent sand on average (USBR 2011c), and is similarly underlain by varying concentrations of fluvial sand and trace gravels (USBR 2010) and a thinner layer of diatomite. Intact organic fragments, such as roots, twigs, bark, and wood, were found only at the pre-reservoir contact in a single core (USBR 2010).

The in situ reservoir sediment in both reaches has high moisture contents of nearly 300 percent, with low cohesion, low strength, and high erodibility (USBR 2011c). The measured friction angle from a sediment core approximately 1 mile upstream from the dam is approximately 27 degrees. Reservoir sediment testing determined that, on drying, the sediments undergo significant changes in their physical properties. When dry, erosion resistance increases by an order of magnitude and the erodibility decreases.

Iron Gate Reservoir

Sediment behind the Iron Gate Dam has the highest clay content and thinnest deposits of the three reservoirs and a considerable amount of dead algae and organic matter (USBR 2011c). Sediment thicknesses are deepest in the historical channel and shallower on the historical floodplain and current reservoir margins, and decrease with distance upstream from the dam, with maximum values of 4 to 5 feet in the mile upstream of the dam. Mirror Cove has relatively uniform sediment thicknesses of 2 to 3 feet. The maximum sediment thicknesses of 5 to 6 feet are at the Jenny Creek confluence and indicate the relative significance of the creek as a sediment source.

Accumulated reservoir sediment is approximately 60 percent clay, 25 percent silt, and 15 percent sand in the Downstream Reach, which extends approximately 2 miles from Iron Gate Dam to upstream of the Camp Creek confluence/Mirror Cove arm of the reservoir; and approximately 35 percent clay, 45 percent silt, and 20 percent sand in the Upstream Reach, which extends approximately 4 miles to the upstream extent of the reservoir (USBR 2011c). Reservoir deposits are underlain by fine-grained, weathered Tertiary volcaniclastic material with varying concentrations of gravel and sand (USBR 2010). At the reservoir–pre-reservoir contact interface, six cores found a layer of decaying organic matter and intact organic fragments (e.g., vertical roots, grasses, twigs, bark) in the upper portion of the pre-reservoir material (USBR 2010). In locations of some mapped geomorphic features, such as the Jenny Creek confluence and alluvial terraces in the Downstream Reach, layers of Quaternary alluvial gravel and sand are interbedded between the reservoir sediments and Tertiary volcanics (USBR 2010).

The accumulated in situ reservoir sediment has high moisture contents of nearly 200 percent in the Upstream Reach and nearly 300 percent in the Downstream Reach, with low cohesion, low strength, and high erodibility (USBR 2011c). The measured friction angle from a sediment core collected approximately 0.5 mile upstream of the Mirror Cove arm of the reservoir is approximately 32 degrees (USBR 2011c). Reservoir sediment testing determined that, on drying, the sediments undergo significant changes in their physical properties. When dry, erosion resistance increases by an order of magnitude and the erodibility decreases.

4.5.2.2 Sediment Quality

USBR collected sediment samples from the J.C. Boyle, Copco No. 1, and Iron Gate reservoirs in 2009 and analyzed them for chemical constituents (USBR 2011c). A screening-level human health and ecological risk evaluation of the sediment data concluded that chemicals detected in reservoir sediments are at concentrations unlikely to cause adverse effects in exposed human and wildlife receptors (CDM 2011).

Additional sediment samples were collected from the J.C. Boyle Reservoir in December 2017, January 2018, and February 2018, and analyzed for arsenic (CDM Smith 2018). Arsenic concentrations found in the 2017 samples were consistent with those found in 2009 and consistent with regional background ranges for arsenic.

To evaluate the risk to biota from the release of reservoir sediments, arsenic sediment concentrations were compared to sediment and soil ecological screening levels. The range of arsenic sediment concentrations

(4.3 to 15 milligrams per kilogram [mg/kg]) found in the J.C. Boyle Reservoir in both 2009 and 2017 are lower than most soil and sediment screening levels. It should be noted that regional background studies suggest that the arsenic background concentration is around 12 mg/kg. Natural geologic sources of arsenic may contribute to the relatively high background arsenic levels in southern Oregon soils (Sturdevant 2011).

4.5.3 Iron Gate Dam to Estuary

Downstream of Iron Gate Dam, channel conditions reflect the interruption of sediment flux from upstream by reservoir capture and the eventual re-supply of sediment from tributaries entering the mainstem Klamath River (PacifiCorp 2004b, USBR 2011a). The reach from Iron Gate Dam to Cottonwood Creek is characterized by coarse, cobble-boulder bars immediately downstream of the dam, transitioning to a cobble bed with pool-riffle morphology farther downstream near Cottonwood Creek (Montgomery and Buffington 1997, PacifiCorp 2004b, Stillwater Sciences 2010). Cottonwood Creek to the Scott River is a confined channel with a cobble-gravel bed and pool-riffle morphology (PacifiCorp 2004b). The median bed material ranges from 45 to 50 mm, but bar substrates become finer in the downstream direction, with median sizes of 49 mm and 25 mm at the upstream and downstream ends, respectively. Downstream of the Scott River, including through the Seiad Valley, the Klamath River is cobble-gravel-bedded with pool-riffle morphology (PacifiCorp 2004b). PacifiCorp (2004b) also noted increasing quantities of sand and fine gravel on the bed surface with distance downstream, likely reflecting the resupply of finer material from tributaries to the Klamath River.

The Lower Klamath Project dams trap most of the finer sediment produced in the low-sediment-yielding, young volcanic terrain upstream of the dams, which results in coarsening of the channel bed downstream of the dams until tributaries resupply the channel with finer sediment. However, most of the supply from the portion of the watershed upstream of J.C. Boyle Reservoir is trapped in Upper Klamath Lake, which is a natural lake. Most (approximately 98 percent) of the sediment supplied to the mainstem Klamath River is delivered from tributaries downstream of Cottonwood Creek (Stillwater Sciences 2010). The effects of the reservoir-interrupted upstream sediment supply are ameliorated to a large degree downstream of Scott River.

4.6 Water Quality Conditions

This section describes water quality conditions in the Klamath Basin as part of the environmental baseline for the listed species covered in this BA. PacifiCorp has implemented Interim Measures (IMs) 11 and 15, which are focused on improving water quality conditions, as described in Section 4.6.8. Information from annual IM-15 monitoring reports and other sources such as historical datasets, USGS monitoring data, USBR quarterly monitoring, ODEQ and NCRWQCB monitoring data, and Karuk and Yurok Tribal monitoring data is presented in the following sections describing baseline conditions. In addition, PacifiCorp implements other measures including turbine venting at the Iron Gate Dam powerhouse (IM-3) to increase the dissolved oxygen of water passing through the powerhouse turbines, as further described in Section 4.6.4.

4.6.1 Total Maximum Daily Loads

Much of the Klamath Basin is currently listed as water quality impaired under Section 303(d) of the CWA. Therefore, total maximum daily loads (TMDLs) have been developed by Oregon, California, and the United States Environmental Protection Agency (USEPA) for specific impaired water bodies with the intent to protect and restore beneficial uses of water. TMDLs (1) estimate a water body's capacity to assimilate pollutants without exceeding water quality standards and set limits on the amount of pollutants that can be added to a water body while still protecting identified beneficial uses. Table 4-3 lists the status of TMDLs in the Klamath River Basin. Additional information regarding the Oregon TMDLs can be found on ODEQ's website (http://www.oregon.gov/deq/wq/tmdls/Pages/TMDLs-Klamath-Basin.aspx), and, for the California TMDLs, on the NCRWQCB website (https://www.waterboards.ca.gov/northcoast/water_issues/programs/tmdls/).

Table 4-3: Status of TMDLs in the Klamath River Basin

Water body	Pollutant/Stressor	Agency	Original listing date	TMDL completion date[1]
Oregon				
Upper Klamath Lake Drainage	Temperature, dissolved oxygen, chlorophyll-*a* and pH	ODEQ	1998	2002
Upper Klamath and Lost River Subbasins[2]	Dissolved oxygen, pH, ammonia toxicity, and chlorophyll-*a*	ODEQ	1998	2019
Upper Klamath and Lost River Subbasins	Temperature	ODEQ	2010	2019
California				
Lower Lost River	pH and nutrients	USEPA	1992	2008
Klamath River	Temperature, dissolved oxygen, nutrient, and microcystins	NCRWQCB	1996, 1998, 2006, and 2008	2010
Shasta River	Temperature and dissolved oxygen	NCRWQCB	1998 and 2008	2007
Scott River	Temperature and sediment	NCRWQCB	1992, 1996, and 1998	2006
Salmon River	Temperature	NCRWQCB	1996	2005
Trinity River	Sediment	USEPA	1994 and 2006	2001
South Fork Trinity River	Sediment	USEPA	1994 and 2002	1998

Notes:

[1] The TMDL completion date is the year USEPA approved or is expected to approve the TMDL.
The Upper Klamath and Lost rivers TMDL (approved 2018) was modified to the Upper Klamath and Lost River Subbasins Nutrient TMDL and approved in 2019.

The strategic approach to the multiple Klamath Basin TMDLs includes a formal partnership between ODEQ and the NCRWQCB to treat the Klamath Basin as an integrated aquatic ecosystem with a comprehensive program of TMDL implementation. In addition, a network of Indian tribes, other federal, state, and local agencies, non-governmental organizations, and private organizations throughout the Klamath Basin are implementing water quality improvement projects and a wide range of restoration projects.

In addition, KBMP focuses on the coordination and sharing of data between more than 45 organizations that conduct water quality monitoring from the headwaters near Crater Lake in Oregon to the estuary at the Pacific Ocean in California. KBMP provides an adaptive management framework for participating organizations, which allows for an evaluation of water quality improvement progress throughout the basin over time.

Recent water quality trend analyses completed for tributaries to Upper Klamath Lake and at the lake's outlet at Link River suggest declining phosphorus concentration trends in the tributaries to Upper Klamath Lake (Walker et al. 2012, Walker et al. 2015). Extensive modeling by USGS indicates that lake algal biomass, and therefore outflow algal biomass, will decline in response to reductions in phosphorus loading to Upper Klamath Lake (Wherry et al. 2015). This suggests that Upper Klamath Lake is responding to upper-basin water quality improvements that are then translated to the Klamath River downstream of Upper Klamath Lake. The Upper Klamath Basin (i.e., Upper Klamath Lake and its tributaries downstream to Keno Dam) has been a focus for water quality improvement projects to meet TMDL objectives. However, Upper Klamath Lake's response to water quality improvements is uncertain. According to Wherry et al. (2015), "the quantitative predictions (from the modeling) have a high degree of uncertainty because they depend on calibration parameters that vary greatly with changes in assumptions or the calibration dataset." Furthermore, these predictions are based on qualitative, not quantitative, data.

Recommendations developed at the Klamath Hydroelectric Settlement Agreement (KHSA) Interim Measure 10 Water Quality Improvement Techniques Workshop called for a focus on controlling phosphorus inputs to Upper Klamath Lake from watershed sources in the upper basin (40 percent reduction target consistent with ODEQ's Upper Klamath Lake TMDL). These recommendations have been identified by the Interim Measure Implementation Committee and incorporated into a priority list of projects funded by PacifiCorp as part of the KHSA. This priority list of projects refers to currently identified categories, not projects themselves, which will be funded and implemented after dam removal. Implementation of the Interim Measure 11 water quality improvement projects began just after the KHSA was signed in 2010.

In summary, there are many water quality improvement projects planned by state and federal agencies and Indian tribes throughout the Klamath Basin to achieve the TMDL objectives as well as other restoration objectives. Although progress has been made, it is uncertain when these combined efforts will result in improved biostimulatory conditions in critical reaches (e.g., Keno Reservoir, Upper Klamath Lake), but there is substantial commitment from state and federal agencies and Indian tribes to ensure that the critical water quality improvements are completed to support restoration of passage for salmonids upstream of Iron Gate Dam.

4.6.2 Water Temperatures

Water temperatures in the Klamath Basin vary seasonally and by location. Upstream of Iron Gate Dam, water temperatures are typically very warm in summer months as meteorological conditions heat surface waters.

Water temperatures (measured as the 7-day average of the daily maximum temperatures) in Upper Klamath Lake and much of the reach from Link River Dam to the Oregon-California border exceed 20°C (68 degrees Fahrenheit [°F]) in June through August (Kirk et al. 2010). Both Upper Klamath Lake and Keno Reservoir undergo periods of intermittent, weak summertime stratification, but water temperatures in these water bodies are generally similar throughout the water column, and are among the warmest in the Klamath Basin (peak values >25°C [>77°F]). Upper basin locations influenced by groundwater springs, such as the Wood River and the mainstem Klamath River downstream of J.C. Boyle Dam, have relatively constant water temperatures year-round, and can be 5 to 15°C (41 to 59°F) cooler than other local water bodies during summer months, depending on the location.

Water temperatures in the Klamath Hydroelectric Reach are influenced by the facilities for the four hydroelectric projects. The relatively shallow depth and short hydraulic residence time in J.C. Boyle Reservoir do not support thermal stratification (FERC 2007; Raymond 2008, 2009, 2010), and this reservoir does not directly provide a source of cold water to downstream reaches during summer (NRC 2004). However, current power-peaking operations at the J.C. Boyle Powerhouse contribute to the availability of cold water in the river just downstream of the dam, where cold groundwater springs enter the river. During daily peaking operations at J.C. Boyle Powerhouse, warm reservoir discharges are diverted from the bypass reach, allowing cold groundwater to dominate flows in the river (PacifiCorp 2006). Water temperatures in the bypass reach can decrease by 5 to 15°C (9 to 27°F) when peaking operations are underway (Kirk et al. 2010). When flows are not diverted to the J.C. Boyle Powerhouse, warm water discharge dilutes cold groundwater spring inputs to the Klamath River.

Copco No. 1 and Iron Gate reservoirs are the two deepest reservoirs in the Klamath Hydroelectric Reach. These reservoirs thermally stratify beginning in April/May, and the surface and bottom waters do not mix again until October/November (Raymond 2008, 2009, 2010). The large thermal mass of the stored water in the reservoirs delays the natural warming and cooling of riverine water temperatures on a seasonal basis so that spring water temperatures in the Klamath Hydroelectric Reach are generally cooler than would be expected under natural conditions and summer and fall water temperatures are generally warmer (NCRWQCB 2010a). In the Hydroelectric Reach, maximum weekly maximum temperatures (MWMTs), which generally occur in late July, regularly exceed the range of chronic effects temperature thresholds (13 to 20°C [55.4 to 68°F]) for salmonid support in California (NCRWQCB 2010a).

The temporal water temperature pattern of the Hydroelectric Reach is repeated in the Klamath River immediately downstream of Iron Gate Dam, where water released from the reservoirs is 1 to 2.5°C (1.8 to 4.5°F) cooler in the spring and 2 to 10°C (3.6 to 18°F) warmer in the summer and fall, as compared with modeled conditions without the dams (PacifiCorp 2004b, Dunsmoor and Huntington 2006, NCRWQCB 2010a). Immediately downstream of Iron Gate Dam, daily water temperatures are also less variable than those documented farther downstream in the Klamath River (Karuk Tribe of California 2009, 2010, 2013).

Farther downstream, the presence of the four dams exerts less influence; water temperatures are more influenced by the natural heating and cooling regime of ambient air temperatures and tributary inputs of surface water. During summer, meteorological control of water temperatures results in increasing temperature with distance downstream of Iron Gate Dam. For example, daily average temperatures between

June and September are approximately 1 to 4°C (1.8 to 7.2°F) higher near Seiad Valley than those just downstream of the dam (Asarian and Kann 2013; Karuk Tribe of California 2009, 2010, 2013). Near the Salmon River confluence, the effects of the dams on water temperature are not discernible.

Downstream of the Salmon River, summer water temperatures begin to decrease slightly with distance as coastal meteorology (i.e., fog and lower air temperatures) reduces longitudinal warming (Scheiff and Zedonis 2011) and cool water tributary inputs increase the overall flow volume in the river. In general, however, the slight decrease in water temperatures in this reach is not sufficient to support cold water fish habitat during summer months. Daily maximum summer water temperatures have been measured at values greater than 26°C (78.8°F) just upstream of the confluence with the Trinity River (Weitchpec [RM 43.5]), decreasing to around 22°C to 24°C near Terwer Creek (Asarian and Kann 2013; Sinnott 2010; YTEP 2005, 2014). As is the case farther upstream, MWMTs in the Klamath River downstream of Iron Gate Dam to the Klamath River estuary regularly exceed the range of chronic effects temperature thresholds (13 to 20°C [55.4 to 68°F]) for salmonid support in California (NCRWQCB 2010a).

Water temperatures in the Klamath River estuary are linked to temperatures and flows entering the estuary, salinity of the estuary and resulting density stratification, and the timing and duration of the formation of a sand berm across the estuary mouth. When the estuary mouth is open, denser saltwater from the ocean sinks below the less dense fresh river water, resulting in a saltwater wedge that moves upstream and downstream in the estuary with the daily tides (Horne and Goldman 1994, Wallace 1998, Hiner 2006). The saltwater wedge results in persistent seasonal density stratification of the estuary with cooler, high-salinity ocean waters remaining near the estuary bottom and warmer, low-salinity river water near the surface. Under low-flow summertime conditions, when the mouth is often closed, surface water temperatures in the estuary have been observed at 18°C to 24°C (64.4 to 75.2°F) and greater (Wallace 1998; Hiner 2006; Watercourse Engineering, Inc. 2011; YTEP 2015). Input of cool ocean water and fog along the coast minimizes extreme water temperatures much of the time (Scheiff and Zedonis 2011). Water temperatures in wetlands and tributaries near the estuary ranged from 10°C to 16°C (50.0°F to 60.8°F) during March to November of 2013 through 2015 (YTEP 2015).

4.6.3 Suspended Sediment

For the purposes of this BA, suspended sediment refers to settleable suspended material in the water column. Bed materials, such as sand, gravel, and larger substrates, are considered bedload, and are discussed in Section 4.5. Two types of suspended material are important to water quality in the Klamath Basin and are discussed below: algal-derived (organic) suspended material and mineral (inorganic) suspended material. Sources of each type of suspended material differ, as do spatial and temporal trends for each, in the Upper, Middle, and Lower Klamath basins.

Suspended sediments in the tributaries to Upper Klamath Lake are generally derived from mineral (inorganic) materials, with peak values associated with winter and spring high flows. Of the three main tributaries to Upper Klamath Lake, the Sprague River has been identified as a primary source of sediment. Because phosphorus is naturally high in Klamath Basin sediments, the Sprague River is also an important source of this nutrient to the lake (Gearheart et al. 1995, ODEQ 2002, Connelly and Lyons 2007). Sources of sediment inputs in the Sprague River drainage include agriculture, livestock grazing and forestry activities, and road-related erosion as well as streambed and bank erosion, floodplain contributions, and upland processes (ODEQ 2002, Connelly and Lyons 2007, Rabe and Calonje 2009).

Between Link River at Klamath Falls and the upstream end of J.C. Boyle Reservoir, algal-derived (organic) suspended material is the predominant form of suspended material affecting water quality. Summer and fall algal-derived (organic) suspended materials decrease with distance downstream, as algae are exported from Upper Klamath Lake and into Lake Ewauna and Keno Reservoir, where they largely settle out of the water column (Sullivan et al. 2011). Data from June through November from 2000 through 2005 indicate that the largest relative decrease in mean total suspended solids (TSS) in the upper Klamath River occurs between Link River Dam and Keno Dam. Suspended materials generally continue to decrease through the Hydroelectric Reach (PacifiCorp 2004c), where further interception, decomposition, and retention of algal-derived (organic) suspended materials originating from Upper Klamath Lake occurs, as well as dilution from the springs downstream of J.C. Boyle Dam. However, increases in suspended material can occur in Copco No. 1 and Iron Gate reservoirs due to in situ summertime algal blooms, which can adversely affect beneficial uses. In the winter months, suspended material in the Hydroelectric Reach is dominated by mineral sediment loads transported during high-flow events, which can also settle out in the reservoirs as water carries relatively heavy sediment loads during high-flow events (see Appendix C of the Klamath Facilities Removal EIS/EIR for more detail).

Just downstream of Iron Gate Dam, summer and fall SSCs become relatively low. Between Iron Gate Dam and Seiad Valley, suspended materials can increase due to the transport of in-reservoir algal blooms during summer as well as riverbed scour and resuspension of previously settled materials during high flows in winter and spring (YTEP 2005, Armstrong and Ward 2008, Watercourse Engineering, Inc. 2011). Further downstream, near the confluence with the Scott River, concentrations of suspended materials tend to decrease with distance as suspended materials gradually settle out of the water column farther downstream or are diluted by tributary inputs (see Appendix C of the Klamath Facilities Removal EIS/EIR for more detail).

Mineral suspended sediments begin to have prominence again in the Klamath River downstream of Iron Gate Dam, as major tributaries to the mainstem contribute large amounts of mineral suspended sediments to the river during winter and spring (Armstrong and Ward 2008). In general, the data indicate that suspended sediment concentrations (SSCs) in the middle and lower Klamath River range from less than 5 milligrams per liter (mg/L) during summer low flows to greater than 500 mg/L during winter high flows. During large winter storms or following landslides in the Klamath Basin, extremely high SSCs have been observed in the Klamath River mainstem and tributaries. SSC generally increases in a downstream direction from the contribution of tributaries and because Iron Gate Dam currently effectively traps most suspended sediment. Under existing conditions, SSCs in the Klamath River estuary are relatively high. Suspended sediment measurements collected at the Klamath River estuary by the Yurok Tribe Environmental Program from 2009-2014 documented peak TSS values between 42 to 136 mg/L, typically occurring during winter (YTEP 2009, 2011, 2012, 2014).

Steeper terrain and land use activities such as timber harvest and road construction result in high sediment loads during high-flow periods. The three tributaries that contribute the largest amount of sediment to the Klamath River are the Scott River (607,300 tons per year or 10 percent of the cumulative average annual delivery from the basin), the Salmon River (320,600 tons per year or 5.5 percent of the cumulative average annual delivery from the basin), and the Trinity River (3,317,300 tons per year of sediment to the Klamath River or 57 percent of the cumulative average annual delivery from the basin) (Stillwater Sciences 2010) (see Appendix C of the 2012 EIS/EIR for more detail).

Wildfires are associated with elevated sediment loading. Wildfires reduce vegetative cover and alter soil properties and hydrological conditions, resulting in levels of erosion and sediment transport that may be orders of magnitude greater than pre-fire conditions (Neary et al. 2005). Post-fire sediment transport depends on factors such as fire frequency and severity, the timing and intensity of precipitation, and local soil properties, terrain, and hydrological conditions (Wondzell and King 2003, Neary et al. 2005, Moody and Martin 2009, Bladon et al. 2014). Increased sediment loading following wildfires is also associated with other water quality impairments, such as elevated loading of nutrients, heavy metals, and other contaminants (Bladon et al. 2014).

As noted in Section 4.3, several wildfires have impacted areas in and adjacent to the Action Area in recent years, including the Oregon Gulch fire in 2014, which impacted around 35,000 acres immediately adjacent to Copco No. 1 Reservoir (C. Isbell, USFS Klamath National Forest, pers. comm, March 19, 2018). The Klamathon fire in 2018 impacted 38,000 acres around Iron Gate Reservoir, including the Camp Creek area and the river reach downstream of the dam. Since 2008, many large wildfires (i.e., wildfires greater than 10,000 acres) occurred downstream of the hydroelectric dams, including the Siskiyou Complex in 2008, Fort Complex in 2012, Beaver and Happy Camp Complex in 2014, Bear in 2015, Gap in 2016, Prescott and Abney in 2017, Natchez in 2018, and Slater/Devil fires in 2020 (CalTopo 2021).

4.6.4 Dissolved Oxygen

Dissolved oxygen concentrations in the Klamath Basin depend on several factors, including water temperature (colder water absorbs more oxygen), water depth and volume, stream velocity (as related to mixing and re-aeration), atmospheric pressure (e.g., elevation), salinity, photosynthesis, and the activity of organisms that depend on dissolved oxygen for respiration. This last factor (respiratory consumption) is strongly influenced by the availability of nitrogen and phosphorus for supporting algal and aquatic plant growth.

In tributaries to Upper Klamath Lake, limited data indicate that dissolved oxygen varies from <7 to 13 mg/L (Kann 1993, ODEQ 2002). Concentrations in the lake itself exhibit high seasonal and spatial variability, ranging from near zero to supersaturation. High nutrient loading is the primary cause of eutrophication and subsequent low dissolved oxygen levels in Upper Klamath Lake. Water quality datasets collected by the Klamath Tribes include periods of weeks during the summer months when dissolved oxygen levels in the lake are continuously less than the ODEQ criterion of 5.5 mg/L for support of warm water aquatic life (Kann 2010, Kann 2017). Low (0 to 4 mg/L) dissolved oxygen concentrations occur most frequently in August, the period of declining algal blooms in the lake and warm water temperatures (Kann 2017, ODEQ 2002, Walker 2001) (see Appendix C of the Klamath Facilities Removal EIS/EIR for additional details).

Downstream in Keno Reservoir (including Lake Ewauna), dissolved oxygen reaches very low levels (<1 to 2 mg/L) during July through October as algae and particulate organic matter are transported from Upper Klamath Lake and subsequently decay. Four water treatment facilities discharge treated wastewater to Keno Reservoir; however, these facilities contribute a very small amount (<1.5 percent of the organic material loading) to the overall oxygen demand in the Keno Reach. Decomposition of algae transported from Upper Klamath Lake appears to be the primary driver of low oxygen in Keno Reservoir (including Lake Ewauna) (Sullivan et al. 2009, 2011; Kirk et al. 2010).

During summer, the reservoirs in the Hydroelectric Reach exhibit varying degrees of dissolved oxygen super-saturation (i.e., >100 percent saturation) in surface waters (due to high rates of internal photosynthesis by algae) and hypolimnetic oxygen depletion in bottom waters (due to microbial decomposition of dead algae). Although J.C. Boyle Reservoir, a relatively long, shallow reservoir, experiences weak intermittent stratification, seasonal variations in dissolved oxygen are observed at its discharge due to conditions in the upstream reach from Link River Dam through Keno Reservoir (including Lake Ewauna), and in Upper Klamath Lake. Copco No. 1 and Iron Gate reservoirs thermally stratify beginning in April/May and do not mix again until October/November (FERC 2007). Dissolved oxygen in Copco No. 1 and Iron Gate reservoirs and surface waters during summer months is generally at, or in some cases greater than, saturation, while levels in hypolimnetic waters reach minimum values near 0 mg/L by July (Raymond 2008, 2009, 2010).

Based on measurements collected immediately downstream of Iron Gate Dam, dissolved oxygen concentrations regularly fall below 8 mg/L (the Basin Plan minimum dissolved oxygen criterion is now based on percent saturation [NCRWQCB 2010a]) (Karuk Tribe of California 2001, 2002, 2007, 2009, 2013).

Continuous sonde measurements were collected immediately downstream of Iron Gate Dam by the Karuk Tribe, Yurok Tribe, USFWS, and Quartz Valley Indian Reservation during the summers (June-October) from 2001 through 2011. These data show that 20 percent to 62 percent of dissolved oxygen measurements immediately downstream of Iron Gate Dam fell below 8 mg/L. Low dissolved oxygen concentrations were most severe in October, when 62 percent of measurements fell below 8 mg/L and 11 percent of measurements fell below 6 mg/L (Asarian and Kann 2013). Daily fluctuations of up to 1 to 2 mg/L measured in the Klamath River downstream of Iron Gate Dam have been attributed to daytime algal photosynthesis and nighttime bacterial respiration (Karuk Tribe of California 2002, 2003; YTEP 2005; NCRWQCB 2010a).

PacifiCorp engages in turbine venting at the Iron Gate Dam powerhouse, which involves forced aeration to increase the dissolved oxygen of water passing through the powerhouse turbines. Preliminary data from pilot testing indicate that turbine venting can increase downstream dissolved oxygen by around 2 mg/L (PacifiCorp 2008, 2010). Since completion of the pilot tests, PacifiCorp has initiated turbine venting at the Iron Gate Dam powerhouse whenever dissolved oxygen levels fall to 87 percent or lower in the Klamath River downstream of the dam.

Farther downstream in the mainstem Klamath River, near Seiad Valley, dissolved oxygen concentrations increase relative to the reach immediately downstream of Iron Gate Dam, but continue to exhibit variability, with mean daily values ranging from approximately 6.5 mg/L to supersaturated concentrations of approximately 11.0 mg/L, from June through November (Karuk Tribe of California 2001, 2002, 2007, 2009, 2013). Discrete sampling measurements at Seiad Valley indicate that dissolved oxygen values fluctuate between around 8 mg/L and 12 mg/L from March through December, with the lowest values occurring in summer (Watercourse Engineering, Inc. 2015, 2016, 2017). Continuous sonde sampling collected at Seiad Valley from 2001 to 2011 indicate that around 50 percent of measurements fell below 8 mg/L during July and August of those years (Asarian and Kann 2013).

Measured concentrations of dissolved oxygen in the mainstem Klamath River downstream of Seiad Valley continue to increase with increasing distance from Iron Gate Dam. Dissolved oxygen concentrations near Orleans continue to be variable, with typical daily values ranging from approximately 6.5 mg/L to supersaturated concentrations of 11.5 mg/L (Asarian and Kann 2013; Karuk Tribe of California 2013; NCRWQCB 2010a; Watercourse Engineering, Inc. 2015, 2016, 2017). Farther downstream, near the confluence with the Trinity River and at the Terwer gage, minimum dissolved oxygen concentrations below 8 mg/L (the Basin Plan minimum dissolved oxygen criterion prior to 2010) have been observed for extended periods of time during late summer/early fall (YTEP 2005, 2011, 2013; Sinnott 2010). In 2010, minimum dissolved oxygen concentrations remained above 2010 amended Basin Plan minimum dissolved oxygen concentration criteria based on percent saturation (see Appendix C of the Klamath Facilities Removal EIS/EIR for additional details).

Dissolved oxygen concentrations in the Klamath River estuary vary both temporally and spatially; concentrations in the deeper main channel of the estuary are generally greater than 6 to 7 mg/L throughout the year (Hiner 2006, YTEP 2005). Discrete dissolved oxygen measurements taken monthly from 2009-2014 by the Yurok Tribe in the lower estuary generally range from 7.5 mg/L to 11.5 mg/L (YTEP 2009, 2012, 2014). Low dissolved oxygen concentrations (<1 to 5 mg/L) have been observed during summer months in the relatively shallow, heavily vegetated south slough (Hiner 2006, Wallace 1998). The low levels of dissolved oxygen observed in the slough are likely due to high rates of growth and subsequent decomposition of algae and macrophytes, which are not abundant elsewhere in the estuary.

4.6.5 Nutrients

Primary nutrients, including nitrogen and phosphorus, are affected by the geology of the surrounding watershed of the Klamath River, upland productivity and land uses, and a number of physical processes affecting aquatic productivity in reservoir and riverine reaches. Nitrogen arriving in Upper Klamath Lake has been attributed to upland soil erosion, runoff, and irrigation return flows from agriculture, as well as in situ nitrogen fixation by cyanobacteria (ODEQ 2002). Although the relatively high levels of phosphorus present in the Upper Klamath Basin's volcanic rocks and soils have been identified as a major contributing factor to phosphorus loading to the lake (ODEQ 2002), land use activities in the Upper Klamath Basin have also been linked to increased nutrient loading (Kann and Walker 1999, Snyder and Morace 1997), subsequent changes in its trophic status, and associated degradation of water quality. Extensive monitoring and research have been conducted for development of the Upper Klamath Lake TMDLs (ODEQ 2002) that show that the lake is a major source of nitrogen and phosphorus loading to the Klamath River (see the 2012 EIS/EIR for additional details).

Allowing for seasonal reservoir dynamics in the Hydroelectric Reach, nutrient levels in the Klamath River generally decrease with distance downstream of Upper Klamath Lake due to particulate trapping in reservoirs, dilution, and uptake along the river channel. In a 2005 to 2008 study of nutrient dynamics in the Klamath River during May through December, nutrients followed a decreasing longitudinal pattern, with the highest concentrations (approximately 0.1 to 0.5 mg/L total phosphorous [TP] and 1 to 4 mg/L total nitrogen [TN]) measured in the Klamath River downstream of Keno Dam (Asarian et al. 2010). On an annual basis, nutrients typically decrease through the Hydroelectric Reach due to dilution from the springs downstream of J.C. Boyle Reservoir and settling of particulate matter and associated nutrients in Copco No. 1 and Iron Gate reservoirs. On a seasonal basis, TP, and to a lesser degree TN, can increase in this reach due to the release (export) of dissolved forms of phosphorus (orthophosphate) and nitrogen (ammonium) from reservoir sediments during periods of summer and fall hypolimnetic anoxia (see Appendix C of the Klamath Facilities Removal EIS/EIR for additional details). The seasonal nutrient releases can occur during periods of in-reservoir algal growth or can be transported downstream to the lower Klamath River, where they may stimulate periphyton growth.

Downstream of the four facilities, TP values typically range from 0.1 to 0.25 mg/L in the Klamath River between Iron Gate Dam and Seiad Valley, with the highest values occurring just downstream of the dam (Asarian and Kann 2013). TN concentrations in the river downstream of Iron Gate Dam generally range from <0.1 to 2.0 mg/L and are generally lower than those in upstream reaches due to reservoir retention and dilution from springs in the Hydroelectric Reach (Asarian et al. 2009, Asarian and Kann 2013). Further decreases in TN occur in the mainstem river due to a combination of tributary dilution, alluviation on river banks following high water in spring and early summer, and in-river nitrogen removal processes such as denitrification and/or storage related to biomass uptake (Asarian et al. 2010). Ratios of nitrogen to phosphorus measured in the Klamath River downstream of Iron Gate Dam suggest the potential for nitrogen limitation of primary productivity, with some limited periods of co-limitation by both nitrogen and phosphorus. However, concentrations of both nutrients are high enough that other factors (i.e., light, water velocity, or available substrate) may be more limiting to primary productivity than nutrients, particularly in the vicinity of Iron Gate Dam (FERC 2007, Hoopa Valley Tribal Environmental Protection Agency 2008, Asarian et al. 2010) (see Appendix C of the 2012 EIS/EIR for additional details). This is particularly important with regard to factors controlling periphyton growth in the Klamath River between Iron Gate Dam and the Scott River.

Downstream of the confluence with the Salmon River, nutrient concentrations continue to decrease in the Klamath River compared with those measured farther upstream due to tributary dilution and seasonal nutrient retention in upstream reaches. Data collected by various tribes and agencies from 2001 to 2011 indicate that TP concentrations are generally 0.01 to 0.2 mg/L from the mouth of the Salmon River to the mouth of the Trinity River, with peak values occurring in September and October (Asarian et al. 2010, Asarian and Kann 2013). For TN, reports indicate that on a seasonal basis, TN increases from May through November, with peak concentrations (<0.5 mg/L) typically observed during September and October (Asarian et al. 2010, Asarian and Kann 2013). Relative to the higher concentrations measured near Iron Gate Dam, these lower nutrient concentrations may be limiting periphyton growth in this portion of the river.

Nutrient levels in the Klamath River estuary experience inter-annual and seasonal variability. Measured levels of TP in the estuary are typically below 0.1 mg/L during summer and fall (June to September), and TN levels are consistently below 0.6 mg/L (June to September) (Sinnott 2011, YTEP 2012, 2014); however, as with the upstream reaches, these levels do not meet the narrative California North Coast Basin Plan water quality objective for biostimulatory substances due to the promotion of algal growth at levels that cause nuisance effects or adversely affect beneficial uses (see the 2012 EIS/EIR for additional details).

4.6.6 pH

Levels of pH in the Klamath Basin vary daily, seasonally, and by location. Upstream of the Hydroelectric Reach, summertime pH levels are elevated above neutral (i.e., up to 8.2 in the Wood River subbasin and 8.5 to 9.5 in the Sprague River). These elevated pH levels have been linked primarily to high rates of photosynthesis by periphyton (i.e., benthic or attached algae) (ODEQ 2002, Kann 2017). The Klamath River is naturally low in alkalinity (i.e., weakly buffered), predisposing the system to elevated pH in response to algal photosynthesis (Horne and Goldman 1994). During November through April, pH levels in Upper Klamath Lake are near neutral (ASR 2005) but increase to very high levels (>10) in summer (ODEQ maximum pH is 9.0). Extended periods of pH greater than 9 have been associated with large summer algal blooms in Upper Klamath Lake (Kann 2010). On a daily basis, algal photosynthesis can elevate pH levels by up to 2 pH units over a 24-hour period. Generally, pH in the reach from Link River Dam through Keno Reservoir increases from spring to early summer and decreases in the fall (Watercourse Engineering, Inc. 2015, 2016, 2017). However, there are site-dependent variations in the observed trend. Peak values can exceed the ODEQ maximum of 9.0 (see Appendix C of the Klamath Facilities Removal EIS/EIR for additional details).

In the Hydroelectric Reach, pH is seasonally variable, with levels near neutral during the winter, increasing in the spring and summer. Peak values (8 to 9.2) have been recorded during the months of May and September, with lower values documented for June through August (7.5 to 8) (Raymond 2010), where the ODEQ pH maximum is 9 units (for the Klamath River upstream of the Oregon-California state line) and the California pH maximum is 8.5 units (for the river downstream of state line). Longitudinally, the lowest pH values were recorded downstream of J.C. Boyle Reservoir, and the highest values in Copco No. 1 and Iron Gate reservoirs (Raymond 2008, 2009, 2010). High pH levels typically coincide with high algal photosynthesis rates at or near the water surface during periods of thermal stratification and high nutrient concentrations in the KHP reservoirs (Raymond 2008).

Downstream of the Hydroelectric Reach, seasonally high pH values continue to occur, with the highest pH values generally occurring during late-summer and early-fall months (August through September). Daily cycles in pH also occur in this reach, with pH usually peaking in mid-day during the period of maximum photosynthesis (NCRWQCB 2010a). The California North Coast Basin Plan pH maximum of 8.5 units is regularly exceeded in the Klamath River downstream of Iron Gate Dam from May to September (Karuk Tribe of California 2007, 2009, 2010, 2013; Watercourse Engineering, Inc. 2015, 2016, 2017). The most extreme pH exceedances typically occur just upstream of Shasta River; values generally decrease with distance downstream (FERC 2007; Karuk Tribe of California 2007, 2009, 2010, 2013). During the summer months, pH values also are elevated in the lower Klamath River from Weitchpec downstream to approximately Terwer Creek (Watercourse Engineering, Inc. 2015, 2016, 2017). Refer to Appendix C of the Klamath Facilities Removal EIS/EIR for more detail.

In the Klamath River estuary, pH ranges between approximately 7.5 and 9, with peak values also occurring during the summer months (YTEP 2005, 2009, 2012, 2014). Daily variations in pH are typically on the order of 0.5 pH units, and fluctuations tend to be somewhat larger in the late summer and early fall. When large daily fluctuations are observed, they are likely caused by algal blooms that are transported into the estuary.

4.6.7 Algae

As primary producers, algae are critical components of riverine and lacustrine ecosystems. Their presence and abundance affect food web dynamics, as well as physical water quality parameters (e.g., dissolved oxygen, pH, turbidity, and nutrients), the latter through rates of photosynthesis, respiration, and decay of dead algal cells (Horne and Goldman 1994). Cyanobacteria are also photosynthetic, and can often be a nuisance aquatic species, occurring as large seasonal blooms that alter surrounding water quality. Some cyanobacteria species, such as *Microcystis aeruginosa*, produce cyanotoxins (e.g., cyclic peptide toxins that act on the liver, such as microcystins, alkaloid toxins such as anatoxin-a and saxitoxin that act on the nervous system) that can cause irritation, sickness, or, in extreme cases, death to exposed organisms, including humans (WHO 1999).

Chlorophyll-*a*, a pigment produced by photosynthetic organisms, including algae and cyanobacteria, is often used as a surrogate measure of algal biomass. Algae suspended in the water column (phytoplankton) can be represented as a concentration of chlorophyll-*a* (mg/L), while algae attached to bottom sediments or channel substrate (periphyton) can be represented as an areal biomass (mg chlorophyll-a/m^2).

In the tributaries to Upper Klamath Lake, algae are generally present as periphyton (i.e., benthic or attached algae) species. Periphyton in these streams can cause water quality impairments for dissolved oxygen and pH (see Appendix C of the Klamath Facilities Removal EIS/EIR for more detail). In Upper Klamath Lake, algae are dominated by phytoplankton or suspended algae. Large summertime blooms of cyanobacteria are typically dominated by *Aphanizomenon flos-aquae* (AFA), with smaller amounts of *M. aeruginosa* present. *M. aeruginosa* is believed to be responsible for the production of microcystins in the lake. Algal blooms in the PacifiCorp impoundments and downstream Klamath River are also dominated by cyanobacteria from summer into early fall (Watercourse Engineering, Inc. 2015, 2016, 2017).

Microcystin sampling in 2016 documented numerous exceedances of the World Health Organization (WHO) limit for drinking water (1 microgram per liter [µg/L]) and the Oregon Health Authority (OHA) Recreational Advisory Level (10 µg/L) within Upper Klamath Lake (Kann 2017, Watercourse Engineering, Inc. 2017).

Microcystin levels in 2016 increased from June to early July, exceeding 1 µg/L at several locations. Concentrations then dramatically increased in mid-August; measurements taken near the Agency Lake boat launch consistently exceeded 10 µg/L from August to early October, reaching a peak of over 100,000 µg/L in mid-August, far exceeding advisory levels. Microcystin levels elsewhere in Upper Klamath Lake ranged from around 0.5 to 100 µg/L during August to October (Kann 2017, Watercourse Engineering, Inc. 2017).

Additional microcystin data collection in Upper Klamath Lake is ongoing, including measurement of toxin levels in native suckers (Vanderkooi et al. 2010, Kann 2017). See Section 3.3 of the Klamath Facilities Removal EIS/EIR for more detail).

High (i.e., near 300 μg/L) summer chlorophyll-*a* concentrations in Keno Reservoir (including Lake Ewauna) are due to large populations of algae, predominantly *A. flos-aquae*, entering the Klamath River from Upper Klamath Lake in summer (Kann 2006; Sullivan et al. 2008, 2009, 2010, 2011; FERC 2007). Such high concentrations do not persist farther downstream in J.C. Boyle Reservoir. However, in Copco No. 1 and Iron Gate reservoirs, high chlorophyll-*a* concentrations are known to recur. Levels in Copco No. 1 and Iron Gate reservoirs can be 2 to 10 times greater than those documented in the mainstem river, although they are not as high as those found in Keno Reservoir (NCRWQCB 2010a, Watercourse Engineering, Inc. 2016, 2017) (see Appendix C of the Klamath Facilities Removal EIS/EIR for more detail).

Throughout the Klamath River, high chlorophyll-*a* concentrations have been shown to correlate with the toxigenic cyanobacteria blooms where *M. aeruginosa* was present in high concentrations, and with sharp increases in microcystin levels above WHO numeric targets (Kann and Corum 2009) and SWRCB, California Department of Public Health, and Office of Environmental Health and Hazard Assessment (OEHHA) guidelines (*Draft Voluntary Statewide Guidance for Blue-Green Algae Blooms* [SWRCB 2010]). High levels of microcystins occur during summer months in Copco No. 1 and Iron Gate reservoirs. Peak measured concentrations exceeded the SWRCB/OEHHA public health threshold of 8 μg/L by over 1,000 times in Copco No. 1 Reservoir from 2006 through 2009, and extremely high concentrations (1,000 to 73,000 μg/L) were measured during summer algal blooms in both Copco No. 1 and Iron Gate reservoirs during 2009 (Watercourse Engineering, Inc. 2011). Similarly, during the summer months in 2015 and 2016, high microcystin concentrations were observed in Copco No. 1 Reservoir (10 to 50,000 μg/L) and Iron Gate Reservoir (10 to 1,000 μg/L) (Watercourse Engineering, Inc. 2016, 2017). In J.C. Boyle Reservoir, microcystin concentrations peak at around 4 μg/L in August but remain below 1 μg/L for the rest of the summer months according to sampling done near Topsy Campground (Watercourse Engineering, Inc. 2017).

Microcystin concentrations in the Klamath River generally decrease with distance from Iron Gate Dam, with lower peak values occurring in the river than in Upper Klamath Lake and the PacifiCorp reservoirs. In 2016 and 2017, microcystin concentrations in the Klamath River from Iron Gate Dam to Seiad Valley ranged from <0.1 to 8 μg/L; concentrations from Seiad Valley to the estuary ranged from <0.1 to 4 μg/L (Watercourse Engineering, Inc. 2016, 2017). Since 2007, high levels of microcystins have prompted the posting of public health advisories around the reservoirs and along the length of the Klamath River during summer months. In 2015 and 2016, various agencies posted temporary advisories for Upper Klamath Lake, the Hydroelectric Reach, Copco No. 1 Reservoir, Iron Gate Reservoir, and some sections of the Klamath River near Iron Gate Dam in response to elevated cyanobacterial cell counts and cyanotoxin readings (Watercourse Engineering, Inc. 2016, 2017).

Microcystins can also bioaccumulate in aquatic biota (Kann 2008, Kann et al. 2011); 85 percent of fish and mussel tissue samples collected during July through September 2007 in the Klamath River, including Copco No. 1 and Iron Gate reservoirs, exhibited microcystin bioaccumulation (Kann 2008) (see Appendix C of the Klamath Facilities Removal EIS/EIR for more detail). Estuarine and marine nearshore effects (e.g., sea otter deaths) from cyanobacteria exposure have been reported in other California waters; however, none have been documented to date for the Klamath River estuary or marine nearshore (Miller et al. 2010).

4.6.8 PacifiCorp Interim Measures 11 and 15

The amended KHSA includes provisions for the interim operation of the Lower Klamath Project by PacifiCorp prior to implementation of the Proposed Action, and specifically includes several existing and ongoing Interim Measures (IMs) undertaken by PacifiCorp to improve water quality and fish habitat conditions, support and improve hatchery operations, and benefit environmental resources in the wider Klamath Basin prior to implementation of the Proposed Action. Several IMs focus on the conservation of coho salmon and are included in the PacifiCorp KHP Interim Operations HCP for Coho Salmon (PacifiCorp 2020b), discussed in Section 4.8.2.1. Two of the IMs, IM-11 and IM-15, focus on water quality, as described below.

4.6.8.1 Interim Measure 11

The KHSA includes IM-11, which is intended to improve water quality through nutrient reduction projects in the watershed. PacifiCorp has implemented many studies and pilot projects as part of IM-11, as described in the KHSA Implementation Report (PacifiCorp 2020b). Working with the Interim Measures Implementation Committee, PacifiCorp developed a list of priority project categories for water quality improvement, including diffuse source treatment wetlands, natural wetlands restoration, riparian fencing and grazing management, and irrigation efficiency and water management. While specific projects are in development, PacifiCorp continues to carry out studies under IM-11, including several studies on cyanobacteria (PacifiCorp 2020a). Examples of these studies include evaluating the ability of physical mixing to reduce cyanobacteria growth within Mirror Cove in Iron Gate Reservoir and genetic analysis of *Microcystis* populations in Copco No. 1 and Iron Gate reservoirs (PacifiCorp 2016a).

4.6.8.2 Interim Measure 15

The KHSA also includes IM-15, which requires PacifiCorp to fund baseline water quality monitoring from Upper Klamath Lake to the Klamath River estuary at the Pacific Ocean. The water quality monitoring under IM-15 entered its twelfth year in 2020, and PacifiCorp has an obligation to continue IM-15 monitoring until the Proposed Action begins.

IM-15 contains the following water quality monitoring elements:

- Cyanobacteria and cyanotoxin grab sampling for public health protection at 18 locations from Upper Klamath Lake to the estuary, including nine locations downstream of Iron Gate Dam in the Klamath River.
- Baseline water quality monitoring at 18 sites on the Klamath River from Link River Dam to the estuary. Additional water quality monitoring is conducted at the mouth of the four major Klamath River tributaries (Shasta, Scott, Salmon, and Trinity).
- Hourly data collection at 11 locations between Iron Gate Dam and the community of Klamath for temperature, dissolved oxygen, pH, and electrical conductivity.

- Seasonal (May-October), monthly, and bimonthly (excluding January and February) discrete grab sampling conducted for nutrients, including total nitrogen and phosphorus, nitrate and nitrite, ammonia, particulate and organic phosphorus, and dissolved carbon.

This monitoring is conducted by USBR, PacifiCorp, and the Yurok and Karuk tribes, and is funded by PacifiCorp.

The Renewal Corporation used water quality monitoring data collected as part of IM-15 to inform the Water Quality Monitoring and Management Plan that will be implemented during and following implementation of the Proposed Action.

4.7 Aquatic Diseases

The following analysis was in part taken from *Synthesis of the Effects to Fish Species of Two Management Scenarios for the Secretarial Determination on Removal of the Lower Four Dams on the Klamath River* (Hamilton et al. 2011). Supplemental information developed after the completion of Hamilton et al. (2011) is referenced accordingly.

Klamath River salmonids are exposed to various pathogens that cause infection, reduced immunity, and mortality. Existing information indicates that the most common pathogens of concern can be grouped into four categories: (1) viral pathogens such as infectious haematopoietic necrosis; (2) the bacterial pathogens *R. salmoniranrum* (bacterial kidney disease [BKD]), *Flavobacterium columnare (columnaris*), and *Aeromonas hydrophila*; (3) external protozoan parasites *Ichthyophthirius* (Ich), *Ichthyobodo*, and *Trichodina*; and (4) the myxozoan parasites *C.shasta* and *Parvicapsula minibicornis*. Infection and disease proliferation are primarily dependent on water temperature, although streamflow can be a major contributing factor that affects both water temperature and disease transmission (Stocking and Bartholomew 2007, Som and Hetrick 2016).

Columnaris is common worldwide and present at all times in the aquatic environment. *Columnaris* disease in coldwater fishes is generally seen at water temperatures above 15°C. In natural infections, the disease is often chronic to subacute, affecting skin and gills (CDFG 2003). Ich infestation of gill tissue results in hyperplasia, a condition that reduces the ability of the fish to obtain oxygen. Death is by asphyxiation. Ich can be found on any fish at any temperature, but typically only cause disease and mortality at water temperatures above 14°C and in crowded conditions (CDFG 2003). Other common pathogens are likely present in the Klamath River, but are reported rarely.

The life cycles of both *P. minibicornis* and *C. shasta* involve an invertebrate host and a fish host, where these parasites complete different parts of their life cycle. In the Klamath River, *P. minibicornis* and *C. shasta* share the same invertebrate host: an annelid worm, *Manayunkia occidentalis* sp. *no.* (Atkinson et al. 2020). Once the annelids are infected, they release *C. shasta* actinospores into the water column. Temperature and actinospore longevity are inversely related, but actinospore states have been detected in the Upper Klamath Basin between 10°C and 22°C and peak production occurs at approximately 17°C (Hurst et al. 2011).

Actinospores are generally released when temperatures are above 10°C in late March to early April (Bartholomew and Foott 2010).

Actinospores are buoyant and remain viable (able to infect salmon) from 3 to 7 days at temperatures ranging from 11°C to 18°C (Foott et al. 2006). Actinospores are viable for shorter periods of time when temperatures are outside of this range. As actinospores viability increases, actinospore distribution may increase, raising the infectious dose for salmon over a larger area of the river (Bjork and Bartholomew 2010). Actinospore abundance is controlled by the number of infected annelids and their infection levels (prevalence and severity), and actinospore abundance is a primary determinant of infectious dose (Bjork and Bartholomew 2009, Robinson et al. 2020).

Although actinospores die unless they encounter a fish host within the viability period, salmon become infected when actinospores enter the gills and the spores travel through the bloodstream, eventually reaching the intestines. Actinospores infect the intestine and can cause enteronecrosis of intestinal tissue that can be accompanied by a severe inflammatory reaction and mortality (Bartholomew et al. 1989, Bartholomew et al. 2017). The parasite replicates and matures to the myxospore stage over the course of 18 to 25 days (Benson 2014). Myxospores shed by the dying and dead salmon are consumed by annelids residing on the surface of the channel bed. The cycle continues with infection of annelid worms by the myxospores (Bartholomew and Foott 2010). Transmission of the *C. shasta* and *P. minibicornis* parasites is limited to areas where the invertebrate host is present.

4.7.1 Juvenile Salmonid Infection

Annual prevalence of the myxozoan parasite *C. shasta* has been documented in emigrating juvenile salmon populations during spring and early summer in the Klamath River (True et al. 2016). *C. shasta* in out-migrating juvenile salmonids has been well studied (True 2013, True et al. 2013, Som et al. 2019, Robinson et al. 2020), and the processes that influence *C. shasta* impacts on Klamath River salmon are increasingly understood (Robinson et al. 2020).

C. shasta infection of juvenile salmonids is a significant contributor to mortality in juvenile salmonids that migrate through the Klamath River (Bartholomew et al. 1997). Although juvenile salmonids infected by *C. shasta* may experience enteronecrosis mortality, infected juvenile salmonids that do not die from *C. shasta* are also prone to mortality caused by other pathogens such as *P. minibicornis*. Enteronecrosis may also weaken juvenile salmonids, making them more susceptible to predation, and the condition may compromise osmoregulatory systems that are essential for successful ocean entry. *C. shasta*-related mortality has been linked to population declines in fall Chinook salmon in the Klamath River (Fujiwara et al. 2011, True et al. 2013).

C. shasta infection rates of juvenile Chinook salmon are influenced by *C. shasta* spore densities, water temperature, flow rate, and juvenile salmonid residence time in areas of high spore densities (Figure 4-1) (Foott et al. 2011, Ray et al. 2014). Recent studies have also found a linkage between spore densities at the time of hatchery juvenile Chinook salmon release from Iron Gate Hatchery and subsequent prevalence of infection the following fall and subsequent spring (Robinson et al. 2020). *C. shasta* infections generally progress to clinical enteronecrosis over a 7- to 18-day period, depending on exposure and the time period fish spend in the infectious zone during their outmigration (True 2013). Mortality may occur between 13 days and 25 days post-exposure to *C. shasta* (Bartholomew et al. 2017).

Table 4-4 includes a summary of juvenile Chinook salmon prevalence of infection over 10 years at the Kinsman rotary screw trap location, 45 river miles downstream of Iron Gate Dam. The Kinsman trap is situated between the Shasta River and the Scott River, a reach of the Klamath River often referenced as the “infectious zone” (True et al. 2015). The general pattern of annual parasite abundance in the Klamath River downstream of Iron Gate Dam remains relatively consistent from year-to-year, although the extent of the infectious zone and the magnitude of parasite densities change seasonally and annually (Bartholomew and Foott 2010, Bartholomew et al. 2017). Depending on river conditions (e.g., flow and water temperature), the infectious zone may extend from Iron Gate Dam to downstream of Seiad Valley (True 2013, Bartholomew et al. 2017), although areas of high infection prevalence can extend to the lower Klamath River. Although high run-off years may reduce annelid densities downstream of Iron Gate Dam, the redistribution of annelids by high flows may result in the downstream relocation of *C. shasta* “hot spots” (Som and Hetrick 2016b). Estimates of the annual proportion of infected Chinook salmon range from 2 percent to 66 percent (Som and Hetrick 2016a). Because the release of Iron Gate Hatchery juvenile Chinook salmon overlaps with the period of high infection potential, studies suggest that a high proportion of the Iron Gate Hatchery Chinook salmon stock can become infected with *C. shasta* (Som et al. 2016a). For example, the USGS recently used the Stream Salmonid Simulator (S3) model to estimate the prevalence of mortality for outmigrating natural and hatchery-origin juvenile Chinook salmon. The S3 model simulated an overall prevalence of mortality of 34.8 percent of naturally produced juvenile Chinook salmon and 87.0 percent of hatchery-origin juvenile Chinook salmon caused by *C. shasta* during the 2020 outmigration at the Kinsman trap on the Klamath River downstream of Iron Gate Dam (USGS 2021). These fish would be expected to eventually succumb to the ceratomyxosis (USGS 2021). USFWS (2021) completed similar modeling for coho salmon outmigrating from the Shasta River into the Klamath River in spring 2020. USFWS estimated that 11.8 percent of juvenile coho salmon would experience ceratomyxosis mortality associated with *C. shasta* infection (USFWS 2021).

Table 4-4: Annual-Level *C. shasta* Infection Prevalence Estimates for Wild and/or Unknown Origin Juvenile Chinook Salmon Passing the Kinsman Rotary Screw Trap Site

Year	Origin	Prevalence of Infection	Infected Population Estimate Lower Confidence Limit[1]	Infected Population Estimate	Infected Population Estimate Upper Confidence Limit[1]
2005	All	0.41	0.26	0.38	0.47
2007	All	0.28	0.07	0.10	0.15
2008	All	0.6	0.43	0.51	0.58
2009	All	0.5	0.50	0.58	0.66
2010	Wild/Unknown	0.12/0.15	0.02	0.04	0.07
2011	Wild	0.2	0.07	0.11	0.17
2012	Wild/Unknown	0.06/0.00	0.04	0.08	0.14
2013	Wild	0.18	0.03	0.06	0.09
2014	Wild	0.67	0.12	0.18	0.26

Year	Origin	Prevalence of Infection	Infected Population Estimate Lower Confidence Limit[1]	Infected Population Estimate	Infected Population Estimate Upper Confidence Limit[1]
2015	Wild/Unknown	0.66/0.96	0.20	0.29	0.39
2016	Wild/Unknown		0.01	0.03	0.08
2018	Wild/Unknown		0.06	0.10	0.15
2019	Wild/Unknown		0.06	0.09	0.14

[1] The lower and upper confidence limits account for the estimation uncertainty in abundance and weekly prevalence of infection rates. Data for 2005 through 2015 from Som and Hetrick (2016a); data for 2016 through 2019 from N. Som; USFWS, unpublished data. No data for 2006 and 2017 due to high flows on the Klamath River

4.7.2 Spawner Influence on Prevalence of *C. shasta*

Returning adult salmon are exposed to myxospores when fish enter the Klamath River in the fall. Disease progression in adult fish is likely a function of water temperature and infectious dose (Bartholomew and Foott 2010). Because adult fish have a low infection threshold, the prevalence of infection is high, and infection rates may be high even in years of reduced infectious zone prevalence.

Adult salmonid carcasses play an important role in the lifecycle and prevalence of *C. shasta* (Som et al. 2016a). Fall Chinook salmon returns to Iron Gate Hatchery and the blockage created by Iron Gate Dam concentrate spawners and post-spawn carcass densities between Iron Gate Dam and the Shasta River confluence. Myxospore development occurs predominantly in decomposed carcasses rather than in recent post-spawned adults (Som et al. 2016a). Myxospore detection from carcasses ranges from 22 percent to 52 percent; however, less than 13 percent of carcasses are significant contributors to myxospores production (produce >500,000 spores). Based on average adult returns to the Shasta River to Iron Gate Dam reach, Chinook salmon carcasses potentially produce billions of myxospores. Myxospores remain viable in the channel bed sediments through the winter and early spring and re-enter the water column over the winter when juvenile salmonids begin to emerge from the gravels.

4.7.3 *C. shasta* Genetics

Susceptibility to *C. shasta* is also influenced by the genetic type of *C. shasta* that a fish encounters. Atkinson and Bartholomew (2010a, 2010b) conducted analyses of the genotypes of *C. shasta* and the association of these genotypes with different salmonid species, including Chinook and coho salmon, steelhead, rainbow trout, and redband trout. In the Williamson River, although parasite densities had been found to be high, Chinook salmon were resistant to infection because the genotype specific to Chinook salmon was absent. In a genetic analysis, the *C. shasta* genotypes were characterized as Type 0, Type I, Type II, and Type III:

- The Type 0 genotype occurs throughout the Klamath Basin, and native rainbow/redband trout and steelhead are susceptible to infection with Type 0. However, in most situations, this genotype occurs in low densities and is not very virulent. Infection generally leads to minimal or no mortality.
- The Type I genotype of *C. shasta* affects Chinook salmon. This genotype causes significant mortality to Chinook salmon downstream of Iron Gate Dam. The probability of the Type I genotype moving

upstream of Iron Gate Dam is high because some infected adult Chinook will spawn upstream of Iron Gate Dam and release myxospores that will infect annelid worms that inhabit these reaches. However, if this genotype were to move upstream of Iron Gate Dam due to project implementation, it would affect only Chinook salmon.

- The Type II genotype occurs in and upstream of Upper Klamath Lake and downstream of Iron Gate Dam, and at low levels between the dams, and affects non-native rainbow trout. However, it appears that the biotype of this parasite in the upper basin does not affect coho salmon. Risks to native rainbow/redband trout from this genotype are low (J. Bartholomew, Oregon State University, pers. comm.).
- Type III appears widespread based on fish infections but was not detected in water samples. Type III appears to infect all salmonid species (Atkinson and Bartholomew 2010b). Prevalence of this genotype is low, and it infects fish but does not appear to cause mortality.

The invertebrate host for *C. shasta* (the annelid worm) is present in a variety of habitat types, including runs, pools, riffles, edge-water, and reservoir inflow zones, as well as sand, gravel, boulders, bedrock, and aquatic vegetation, and is frequently present with a periphyton species, *Cladophora* (a type of algae) (Bartholomew and Foott 2010). Slow-flowing habitats may have higher densities of annelids, and areas that are more resistant to disturbance, such as eddies and pools with sand and *Cladophora*, may support increased densities of annelid populations (Bartholomew and Foott 2010), especially if flow disturbance events are reduced or attenuated. The reservoirs do not provide habitat for the annelid worm and removal of the reservoirs will increase the amount of habitat available to this species.

Observations downstream of Iron Gate Dam indicate that *C. shasta* has the potential to infect large portions of salmonid populations and cause significant mortality. If salmon spawning migrations were to occur upstream of Iron Gate Dam, an upriver infectious zone for *C. shasta* may be created similar to the one that currently occurs downstream of Iron Gate Dam where spawning occurs. However, removing Iron Gate, Copco No. 1, Copco No. 2, and J.C. Boyle dams will allow salmon to distribute over a larger area and remove the spawning bottleneck that currently occurs downstream of Iron Gate Dam. Although *C. shasta* was detected upstream of Iron Gate Dam in the lower Williamson River (a tributary of Upper Klamath Lake) and in areas downstream of Iron Gate Dam in nearly equal levels, the effects on fish have differed between these two areas. Results from the pathogen exposure portion of a study (Maule et al. 2009) demonstrated that *C. shasta* was abundant in the Williamson River. Historically, *C. shasta* occurred and continues to be present in the upper basin, and resident fish upstream of the dams evolved with these parasites. Historically, anadromous fish and their associated pathogens migrated to the Upper Klamath Basin, and available information suggests that the likelihood of introducing new pathogens that would affect existing populations is minimal (Bartholomew 1998, Stocking and Bartholomew 2007). *Columnaris* and Ich are ubiquitous in freshwater systems, and both are present throughout the Klamath River system upstream and downstream of Iron Gate Dam.

4.8 Aquatic Habitat Conditions

4.8.1 Upper Klamath Lake and Tributaries

This section summarizes the physical conditions in Upper Klamath Lake and its tributaries, which is pertinent to the analysis of effects on Lost River and shortnose suckers, bull trout, and Oregon spotted frog (OSF) from the Proposed Action. Detailed information on species status, critical habitat, life history, geographic distribution, threats, and population trends for these species is provided in Appendix G.

Upper Klamath Lake has a surface area of 92,000 acres. Major tributaries include the Williamson and Wood rivers. Most of the drainage tributaries of the Upper Klamath Basin funnel through Upper Klamath Lake, elevation 4,140 feet, before emptying into the Link River and Lake Ewauna at the head of the Klamath River (Buchanan et al. 1997). The surface elevation of Upper Klamath Lake fluctuates an average of 4.21 feet annually. Peak elevations, which occur in the spring, seasonally inundate lakeshore wetlands. The elevation declines from approximately early April to early October because of agricultural diversions, releases to the Klamath River, and decreases in tributary inflow (Buchanan et al. 2011).

The following text is excerpted from USBR 2018: Although Upper Klamath Lake was historically eutrophic, large-scale watershed development from the late 1800s through the 1900s has likely contributed to the current hypereutrophic condition in Upper Klamath Lake. This legacy, combined with current nutrient loading from the watershed and lake sediment, facilitates extensive cyanobacteria blooms that typically result in large diel fluctuations in dissolved oxygen and pH, high concentrations of the hepatotoxin microcystin, and toxic levels of un-ionized ammonia during bloom decomposition. Together, these conditions create a suboptimal environment for native aquatic biota. Indeed, in recent decades, Upper Klamath Lake has experienced serious water quality issues that have resulted in fish die-offs, as well as re-distribution of fish in response to changes in water quality.

The following text is excerpted from USBR 2018: In 1998, the ODEQ identified Upper Klamath Lake and its tributaries on the 303(d) list of Oregon waters with impaired beneficial uses (ODEQ 1998). Subsequently, the Upper Klamath Lake Drainage TMDL identified phosphorus as the key pollutant and recommended total phosphorus loading targets as the primary method to improve Upper Klamath Lake water quality. Phosphorus occurs in relatively high levels in the local geology of the Upper Klamath Basin, but has been, and continues to be, produced through past and current land use activities in the watershed. Specifically, the TMDL calls for a 40 percent reduction in external total phosphorus loading to limit the underlying causes of adverse water quality conditions. Recent work has indicated that a reduction in external phosphorus loading of this magnitude is likely to result in reduced water column phosphorus concentrations and thereby an improvement in water quality over a period of years to decades.

4.8.1.1 Lost River and Shortnose Sucker

Designated critical habitat for Lost River suckers and shortnose suckers includes, but is not limited to, Upper Klamath Lake and its tributaries. Upper Klamath Lake likely contains the largest remaining populations of both Lost River suckers and shortnose suckers, although the shortnose sucker population in Clear Lake may be similar in size. Both species are endemic to the Upper Klamath Basin, including Upper Klamath Lake and its tributaries and the Lost River and its tributaries.

The historical range of Lost River suckers and shortnose suckers has been severely impacted by the drainage of Lower Klamath and Tule lakes, wetland loss around Upper Klamath Lake, and alteration of river and spring habitats in the Upper Klamath Basin. Primary threats to listed suckers are past and continued loss of spawning and rearing habitats, water diversions, entrainment into irrigation systems, competition and predation by introduced species, disease and parasites, hybridization with other sucker species, isolation of remaining habitat due to barriers, and effects of climate change such as increased frequency and intensity of droughts (USFWS 1988, CDFG 2005, USFWS 2013c, USFWS 2019a). Water quality impairment related to nutrient-rich basin soils, wetland conversion, timber harvest, dredging and filling activities, removal of riparian vegetation, and livestock grazing is also a stressor to these species (USFWS 1988).

Most water bodies currently occupied by Lost River suckers and shortnose suckers do not meet water quality standards for nutrients, dissolved oxygen, temperature, and pH set by Oregon and California (Boyd et al. 2002, Kirk et al. 2010). These conditions (primarily in summer) have been associated with several incidents of mass adult mortality, which appears to be a consequence of inadequate amounts of dissolved oxygen (Perkins et al. 2000b). The occurrence of mass mortality of fish in Upper Klamath Lake is not new; however, it is believed that the increased dominance of the blue-green algae AFA in the system leads to increased regularity of extreme events (NRC 2004). Conditions are most severe in Upper Klamath Lake and Keno Reservoir (USFWS 2007b, 2007c). Degraded water quality conditions may also weaken fish and increase their susceptibility to disease, parasites, and predation (Holt 1997, Perkins et al. 2000b, ISRP 2005).

PacifiCorp finalized a Habitat Conservation Plan (HCP) for Lost River suckers and shortnose suckers in 2013 (PacifiCorp 2013b) in accordance with Section 10(a)(1)(B) of the ESA. This plan is described in more detail in Section 4.8.4.4.

4.8.1.2 Bull Trout

The Upper Klamath Lake core area, as defined in the 2015 Recovery Plan for Bull Trout (USFWS 2015b), comprises the northern portion of Upper Klamath Lake and its immediate major and minor tributaries. This core area includes two existing local bull trout populations: Threemile Creek and Sun Creek. Bull trout in the Klamath Recovery Unit have been isolated from other bull trout populations for the past 10,000 years and are recognized as evolutionarily and genetically distinct (USFWS 2015b). Therefore, there is no opportunity for bull trout in another recovery unit to naturally re-colonize the Klamath Recovery Unit if it were to become extirpated (USFWS 2015b).

In the Klamath Basin, bull trout abundance and distribution have likely been greatly reduced from historical levels due to habitat degradation and fragmentation, past and present land use practices, agricultural water diversions, and past fisheries management practices (USFWS 2015b). The Klamath Recovery Unit is also at the southern extent of the species' range and is likely susceptible to climate change effects characterized by warming temperatures, decreasing snowpack, and more variable hydrologic conditions. Further discussion of threats to bull trout populations in the Klamath Recovery Unit is provided in Appendix G.

Efforts to reduce hybridization and competition with non-native fish, replacement or removal of passage barriers, changes in fishing regulations, and habitat restoration projects have improved populations including the Threemile Creek and Sun Creek populations (Hamilton et al. 2010). However, the overall status of Klamath River bull trout continues to be depressed. Conservation recommendations in USFWS 2015b also included the reintroduction of anadromous species, such as Chinook salmon and steelhead, that were historically present in the upper Klamath River basin. Reintroduction of anadromous species is expected to support bull trout recovery by increasing the prey base and providing marine-derived nutrients (USFWS 2015b).

4.8.1.3 Oregon Spotted Frog

According to information available at the time Oregon spotted frog (OSF) was listed in 2014, OSF occupy two watersheds that flow into Upper Klamath Lake: Klamath Lake and Wood River (79 FR 51666–51667). These watersheds support four OSF populations that occur in both riverine and wetland habitats: Crane Creek, Fourmile Creek, Sevenmile Creek, and the Wood River channel in addition to the adjacent but separate BLM Wood River canal. Surveys completed in 2013 found occupied habitat in Sun Creek, Annie Creek, and more locations of Crane Creek and Sevenmile Creek (79 FR 51657).

Historically, these two watersheds were hydrologically connected. Survey efforts on Fourmile Creek, Sevenmile Creek, and the Wood River channel have been sporadic while Crane Creek and the BLM Wood River canal have been surveyed annually. Accordingly, there is still insufficient information to obtain population trends for all but the BLM Wood River canal population, which is declining. Private lands surrounding the known populations appear to have suitable habitat and likely contain additional breeding complexes and individuals. At the time of listing, the USFWS identified multiple threats to OSF, including human activities that result in the loss of wetlands to land conversions, hydrological changes, and changes in vegetation; predation by nonnative species, including nonnative trout and bullfrogs; inadequate existing regulatory mechanisms that result in significant negative impacts such as habitat loss and modification; and other natural or manmade factors including small and isolated breeding locations, low connectivity, low genetic diversity within occupied sub-basins, and genetic differentiation between sub-basins.

4.8.2 Klamath River

This section summarizes aquatic habitat conditions in the mainstem Klamath River from the mouth of Portuguese Creek upstream to Iron Gate Dam and tributaries excluding the Shasta and Scott Rivers. This information is pertinent to the coho salmon effects analysis for the Proposed Action. Detailed information on coho salmon populations and life stages and habitat conditions for each is provided in Appendix G. Appendix G also provides a detailed discussion of the status of coho salmon critical habitat within the Action Area, based on information presented in the 2019 NMFS Biological Opinion on the continued operation of the Klamath Project (NMFS 2019a).

Coho salmon are distributed throughout the Klamath River downstream of Iron Gate Dam and use the mainstem Klamath River for some or all their life history stages (spawning, rearing, and migration). Low numbers of adult coho salmon annually spawn in the Upper Klamath River mainstem. However, upstream dams block the transport of sediment into this reach of river, and the lack of clean and loose gravel diminishes the quality of salmonid spawning habitat downstream of the dams. Gravel augmentation implemented under the PacifiCorp HCP has improved spawning habitat in the Upper Klamath River reach, particularly between Iron Gate Dam and the confluence with the Shasta River (PacifiCorp 2012).

Coho salmon in the upstream extent of their distribution in the Klamath River spawn and rear primarily in several of the larger tributaries between Portuguese Creek and Iron Gate Dam, namely, Bogus, Horse, Beaver, and Seiad creeks (NMFS 2016a). Juvenile summer rearing areas in the mainstem Klamath River have been compromised by low-flow conditions, high water temperatures, insufficient dissolved oxygen levels, excessive nutrient loads, habitat loss, disease effects, pH fluctuations, non-recruitment of large woody debris (LWD), and loss of geomorphological processes that create habitat complexity. The period of time when fry and juvenile rearing, as well as smolt migration, is possible along the mainstem has been shortened by these conditions and is therefore a temporal limitation. Most tributaries with summer rearing potential are highly impacted by agriculture, past timber harvest, road building, legacy mining, cannabis activities, and wildfires. Very few remaining areas exist downstream of Iron Gate Dam with the potential and opportunity for summer rearing.

Unlike many of the other tributary streams in the Upper Klamath River reach, Bogus Creek and its largest tributary, Cold Creek, contain several cold-water springs that provide favorable conditions for rearing coho salmon during the summer (Hampton 2010). These springs are upstream of a waterfall that prevented anadromous fish access to these locations historically. In 1965, a fish ladder was constructed over this migration barrier, and adult salmon and steelhead have had access to another 6 miles of habitat upstream of the barrier since that time. There are several habitat and water conservation projects that have been completed recently or are currently underway to further improve rearing habitat conditions for juvenile coho salmon in the reach upstream of the ladder. These projects include installation of cattle exclusion fencing, riparian plantings, piping of irrigation ditches, construction of tailwater capture systems, and direct infusion of cold spring water to the channel. The mouth of Bogus Creek is adjacent to Iron Gate Hatchery, and hatchery-origin coho salmon are known to stray and spawn in Bogus Creek. The CDFW has been monitoring emigration of smolts from Bogus Creek since 2015. Results of this effort indicate that age 1+ coho salmon emigrate from late February through May, and fry coho salmon have been observed from April through mid-June (Knechtle and Giudice 2018).

Overwinter rearing habitat may also be a limiting factor for juvenile coho salmon in the Upper Klamath River reach. Human activities such as mining and agriculture have significantly altered the mainstem and tributaries into a more simplified channel with limited access to the floodplain. Additionally, much of the Upper Klamath River reach parallels Highway 96, leaving little room for floodplain complexity. As a result, slow-velocity water, such as side channels, off-channel ponds, and alcoves, have been eliminated, decreasing the ability for juvenile coho salmon to persist during high-velocity flows in the winter (NMFS 2014).

Over approximately the last 10 years, there has been a large effort to improve over-winter habitat for juvenile coho salmon in the Upper Klamath River reach. In particular, the Mid Klamath Watershed Council and Karuk Tribe have been constructing off-channel pond features in key locations to provide slow-velocity water. Over a dozen ponds have been constructed in locations such as Seiad Creek, Horse Creek, Tom Martin Creek, West Grider Creek, and O'Neil Creek. Monitoring efforts have shown that both natal and non-natal juvenile coho salmon are using these sites in large numbers (Witmore 2014).

As described in the following sections, PacifiCorp has implemented an extensive program of restoration actions to improve coho salmon habitat in the Action Area.

4.8.2.1 PacifiCorp Habitat Conservation Plan for Coho Salmon

The PacifiCorp KHP Interim Operations HCP for Coho Salmon (PacifiCorp 2012 and associated incidental take permit under ESA Section 10(a)(1)(B) include covered activities that are necessary to operate and maintain the Klamath hydroelectric facilities prior to the potential removal of four mainstem hydroelectric facilities, or prior to implementation of mandatory fishways that would be required under any new license for the KHP if the KHSA is terminated for any reason. NMFS issued the incidental take permit in 2012 for a term of 10 years (NMFS 2019a).

The PacifiCorp Coho Habitat Conservation Plan (HCP) identifies a process to implement measures that will avoid, minimize, and mitigate the effects of the Klamath Project's operations on coho salmon, and includes seven goals and objectives that were developed with technical assistance from NMFS, including:

- Offset biological effects of blocked habitat upstream of Iron Gate Dam by enhancing the viability of the Upper Klamath coho salmon population;
- Enhance coho salmon spawning habitat downstream of Iron Gate Dam;
- Improve instream flow conditions for coho salmon downstream of Iron Gate Dam;
- Improve water quality for coho salmon downstream of Iron Gate Dam;
- Reduce disease incidence and mortality in juvenile coho salmon downstream of Iron Gate Dam;
- Enhance migratory and rearing habitat for coho salmon in the Klamath River mainstem corridor; and
- Enhance and expand rearing habitat for coho salmon in key tributaries.

Continued implementation of the PacifiCorp HCP has benefited the conservation of the Klamath River coho salmon populations. Protection of the very limited thermal refugia sites in the Klamath River mainstem is understood to have improved juvenile-to-smolt survival rates, which has aided in improving viability for coho salmon and other salmonids during the ESA Section 10(a)(1)(B) permit duration (NMFS 2012).

The PacifiCorp HCP includes six conservation measure categories that compose the coho salmon conservation program and include the following:

- Habitat restoration projects designed to enhance the survival and recovery of listed coho salmon, funded through the Coho Enhancement Fund (CEF), and conducted by third parties;
- Implementation of turbine venting at Iron Gate Dam to enhance dissolved oxygen concentrations in surface waters downstream of Iron Gate Dam;

- Implementation of measures to provide instream flow, flow variability, and flow ramping rate measures to benefit listed coho salmon downstream of Iron Gate Dam, consistent with NMFS's 2010 opinion on USBR's Klamath Project, as well as future instream flow-related consultations between USBR and NMFS;
- Retrieving LWD trapped at or near the four facilities (Iron Gate, Copco No. 1 and Copco No. 2, and J.C. Boyle) and placing it in mainstem or tributary waters downstream of Iron Gate Dam;
- Research studies on fish disease conditions and causal factors downstream of Iron Gate Dam, funded through the Klamath River fish disease research fund, and conducted by third parties; and
- Funding and participation in Iron Gate Hatchery measures developed to support a Hatchery Genetic Management Plan (HGMP) to maximize conservation benefits of the hatchery program to coho salmon.

Coho Habitat Enhancement Measures

These conservation measures include habitat restoration and improvement projects and activities in the Klamath River and its tributaries downstream of Iron Gate Dam. These measures contribute to improving the viability of the affected populations of the SONCC coho salmon ESU by creating, maintaining, or improving access to suitable coho salmon habitat downstream of Iron Gate Dam.

<u>Coho Enhancement Fund Activities:</u> As of the end of 2019, PacifiCorp has provided funding of over $5,400,000 into the CEF. Starting in 2009 and running through the 2019 grant cycle, 51 grants have been selected to receive funding for projects that benefit coho salmon downstream of Iron Gate Dam (PacifiCorp 2019). When the projects are considered collectively, the CEF has resulted in (PacifiCorp 2019):

- Over 11,820 linear feet of channel restoration;
- Creation of over 163,320 square feet of off-channel ponds;
- Installation of five fish screens;
- Removal of 91 passage barriers;
- Improved access to over 111 miles of coho salmon habitat;
- Installation of over 7 miles of riparian fencing;
- Implementation of 31 separate water leases providing improved flows in almost 38 miles of stream; and
- Implementation of 111,643 square feet of other types of habitat enhancement projects, including large wood enhancement.

For a detailed description of the status of projects funded under the CEF by year, see PacifiCorp 2020c.

<u>Gravel Augmentation Planning and Implementation</u>**:** In 2013, PacifiCorp developed a Gravel Augmentation Plan as required by its HCP. The Gravel Augmentation Plan describes: (1) preliminary locations of sites for gravel augmentation; (2) the objectives for specific gravel placement projects; (3) the appropriate make-up and amounts of gravel to be placed (i.e., composition of sediment sizes and proportions in the mix); and (4)

procedures to be implemented to ensure gravel has been placed according to project plans and specifications (PacifiCorp 2013a). Gravel augmentation immediately downstream of Iron Gate Dam took place in 2014, 2016, and 2017. The material placed has subsequently been moved downstream by high flows (PacifiCorp 2020c). To date, PacifiCorp has placed 5,500 cy of gravel downstream of Iron Gate Dam, exceeding the 3,500 cy requirement in the gravel augmentation program for the mainstem Klamath River as described in the HCP. Additional gravel augmentation projects are being funded by the CEF in tributaries to the Klamath River. Gravel augmentation downstream of Iron Gate Dam has helped improve spawning conditions for the small numbers of coho salmon that do spawn in the mainstem Klamath River during fall. Properly functioning spawning substrate provides ample interstitial flow through redds and is of suitable size to permit efficient redd excavation by spawning adults. The benefits of gravel augmentation have been largely restricted to the uppermost several miles of the upper Klamath River reach downstream of Iron Gate Dam. Overall, implementation of the gravel augmentation measures has improved the functionality and conservation value of critical habitat for adult spawning downstream of Iron Gate Dam as compared to previous conditions (NMFS 2012).

At the time of the Coho HCP Biological Opinion in 2012, restoration actions implemented under the coho salmon conservation strategy throughout the duration of the ESA Section 10(a)(1)(B) permit were expected to increase over-summer survival for juvenile coho salmon. Projects that create, maintain, or improve access by coho salmon to habitats downstream of Iron Gate Dam were expected to increase the distribution of coho salmon and improve the spatial structure of the population. Increasing available habitat downstream of Iron Gate Dam would help ensure that coho salmon populations remain stable and improve while parallel actions are taken to address volitional fish passage issues in the longer term (NMFS 2019a).

Large Wood Retrieval

This conservation measure under the HCP includes retrieval of LWD pieces (greater than 16 inches in diameter and 15 feet in length) trapped at project dams. To accomplish Objective I for this measure, PacifiCorp checks for the presence of LWD trapped at or near Iron Gate, Copco No. 1, Copco No. 2, J.C. Boyle, and Keno dams on a quarterly basis. If present, these LWD pieces are to be retrieved and released to the river channel downstream of Iron Gate Dam to contribute to the river's habitat-forming features (PacifiCorp 2019). The quarterly LWD retrieval and replacement in the Upper Klamath River reach will add to the habitat complexity downstream of Iron Gate Dam, resulting in improvements to the conservation value of critical habitat for rearing juveniles. The transport of trapped LWD on a quarterly basis either to the Klamath mainstem directly, or for use in constructed habitat features, will improve habitat complexity, or in some cases, provide localized thermal refugia in the form of shade. Both of these habitat features enhance survival of juvenile coho by affording protection from predators and cooling water during critical periods in the late summer and fall (NMFS 2019a).

Iron Gate Flow Releases

USBR and PacifiCorp projects are intertwined, and as described in PacifiCorp's HCP and corresponding incidental take permit, Goal III commits PacifiCorp to improving instream flow conditions downstream of Iron Gate Dam. As a result, in September 2015, PacifiCorp began implementing a diurnal flow fluctuation program (PacifiCorp 2015). The program was designed to enhance flow variability downstream of Iron Gate Dam consistent with existing flow requirements during periods of relatively low, stable flows. The diurnal flow program was designed to mimic the changes in flow that naturally occur on a diurnal cycle due to natural hydrologic fluctuations (e.g., snowmelt, evapotranspiration). PacifiCorp created the flow program at the Iron Gate Powerhouse to automatically ramp up flows starting in the early morning, reaching a peak at 6 percent greater than the targeted daily release around mid-day. Flows then gradually ramp down to a minimum value of 3 percent less than the targeted daily release in the early evening (PacifiCorp 2015). This pattern repeats on a daily cycle, and all ramp rates were followed in accordance with the 2013 Opinion. From 2015 to the present, PacifiCorp has implemented this diurnal flow fluctuation program during the drier months of the year for Iron Gate Dam flows of 1,650 cfs or less. This flow program cannot be implemented for Iron Gate Dam flows greater than 1,650 cfs due to Iron Gate Powerhouse facility constraints. NMFS expects that the diurnal flow fluctuation program has provided benefits to coho salmon.

Fish Disease Research

The fish disease research projects are aimed at enhancing understanding and filling knowledge gaps related to factors and conditions causing disease in coho salmon in the Klamath River. PacifiCorp worked with NMFS and the Klamath River Fish Health Workgroup to identify research projects that address key scientific questions concerning fish disease, and the survival and recovery of coho salmon in the Klamath River Basin. Six projects have been funded by the Fish Disease Research Fund, all of which have been completed (PacifiCorp 2019).

4.8.2.2 PacifiCorp Interim Measures 7, 8 and 16

Since 2004, PacifiCorp has worked collaboratively with NMFS to develop conservation measures for listed coho salmon and with USFWS to develop such measures for the Lost River and shortnose sucker (PacifiCorp 2012). These measures are to be implemented in the interim period until issuance of a new FERC license or project dam removal as specified in the KHSA.

Several IMs pertaining to coho salmon formed the basis for the PacifiCorp Coho HCP discussed in Section 4.8.2.1. Several IMs have been implemented, including the development of fish disease and genetic studies, management plans, flow and diversion studies, and a continuation of current agreed-upon reservoir and power management operations. The following three IMs were implemented upstream of Iron Gate Dam to improve habitat conditions and passage for coho salmon in the J.C. Boyle reach (NMFS and USFWS 2012).

- IM-7: J.C. Boyle gravel placement and/or habitat enhancement
- IM-8: J.C. Boyle bypass barrier removal
- IM-16 Water diversions

IM-7

Under IM-7, PacifiCorp implemented gravel placement in several locations within the J.C. Boyle reach of the Klamath River to enhance fish spawning habitat, macroinvertebrate habitat, and channel geomorphic processes throughout the reach (PacifiCorp 2018a). This action was the subject of a separate ESA consultation with United States Army Corps of Engineers as the Action Agency. Proposed sites were selected based on their accessibility for gravel placement and aquatic habitat type (e.g., riffle, run, or pool tailout locations). Preference was also given to upstream locations that would facilitate gravel seeding to downstream habitat types during peak flows (NMFS and USFWS 2012). As of October 2017, about 3,500 cy of gravel has been added to nine sites, enhancing aquatic habitat in the Klamath River below J.C. Boyle Dam (PacifiCorp 2018a).

IM-8

IM-8 targeted removal of a high-gradient riffle in the J.C. Boyle bypass reach that was identified as a potential barrier for migrating adult fish. The riffle had large, side-cast boulders in the river channel that effectively covered all surface flow at low-flow levels. IM-8 involved the removal of some of these boulders to improve passage for resident redband trout and future migrating adult anadromous salmonids.

This project was subject to consultation between NMFS, USFWS, DOI, and ODFW, and was completed on October 13, 2012 (D. Ebert, Principal Environmental Scientist, PacifiCorp, pers. Comm., January 22, 2018). The boulders that formed the barrier were removed from the reach via winch and placed above the high water line. Following removal of the barrier, the area was determined to meet fish passage criteria based on water depth and velocity measurements. NMFS and ODFW agreed that fish passage had been adequately improved (D. Ebert, Principal Environmental Scientist, PacifiCorp, pers. Comm., January 22, 2018).

IM-16

Under IM-16, PacifiCorp will remove the screened diversions from Shovel and Negro creeks prior to the time that anadromous fish are likely to be present upstream of Copco No. 1 Reservoir. As this IM has not yet been implemented, it is discussed in the effects analysis in Chapter 5.

4.8.3 Estuarine and Near-shore Marine Environment

This section summarizes aquatic habitat conditions in the Klamath River estuary and near-shore marine environment, which is pertinent to the effects analysis for listed species that may occur in this portion of the Action Area and be affected by the Proposed Action.

The Klamath River estuary provides migratory and rearing habitat for all anadromous salmonids occurring in the Klamath River, including Chinook salmon, coho salmon, steelhead, and Pacific lamprey. The estuary also supports a wide array of other fish species and may serve as breeding and foraging habitat for marine and estuarine species, including, but not limited to green sturgeon, Pacific herring, surf smelt, longfin smelt, eulachon, top smelt, starry flounder and other flatfish, Klamath speckled dace, Klamath smallscale sucker, prickly and Pacific staghorn sculpin, northern anchovy, saddleback gunnel, and bay pipefish.

Bricker et al. (2007) reported the Klamath River estuary to be 6 square kilometers (km^2) (2.3 square miles) in size. Wallace (1998) surveyed the Klamath River estuary and noted the formation of a sand berm at the river mouth each year in the late summer or early fall, raising the water level in the estuary, reducing tidal fluctuation, and restricting saltwater inflow. The resulting "perching" and closure of the river mouth are driven by the estuary's natural forces of river discharge, wind and wave power, and tides, so it is reasonable to assume that ecosystems of the Klamath River estuary evolved under the conditions of a dynamic river mouth. Inundation events associated with perching of the river mouth can greatly exceed estuarine high tides and have likely been important in structuring the plant and animal communities that formed in and around the estuary (Lowe et al. 2018).

Surveys conducted by Wallace (1998) found that the brackish water layer along the bottom of the estuary may be important to rearing juvenile salmonids, because they appeared to be more abundant near the freshwater/saltwater interface. Over time, this available rearing habitat has been reduced due to levee construction and channel realignment occurring in the Klamath River estuary and in the lower reaches of off-estuary tributaries (e.g., Hunter-Salt Creek slough, Mynot Creek, Hoppaw Creek, and Waukell Creek slough) (NMFS 2014). Coastal wetlands along the lower Klamath River have been converted into pastures for cattle or farming, and the ability of streams to breach their banks and access floodplain habitats during flood events has been severely minimized, especially on the northern side of the estuary (Gale and Randolph 2000, Beesley and Fiori 2008). A large levee that extends along lower Terwer Creek was also constructed around the Klamath Glen community after the 1964 flood. This levee and others have eliminated juvenile access to floodplains, wetlands, and estuarine and tidally influenced sloughs that provide refugia and food resources for rapid growth and increased survival (NMFS 2014). Patterson (2009) concluded that floodplains and wetlands in the Klamath River estuary were degraded by various factors ranging from invasive species to cattle grazing, and the impacted areas are measured in the hundreds of acres.

Some tributary streams in the vicinity of the estuary (e.g., Junior, Waukell, Salt, and Spruce creeks) are currently overgrown with non-native invasive plant species, which impact water quality, inhibit the establishment of native riparian species, and dramatically reduce rearing capacity (Trebitz and Taylor 2007). The most prevalent invasive species are reed canary grass (*Phalaris arundinacea*), Himalayan blackberry (*Rubus procerns*, *Rubus discolor*), common reed (*Phragmites australis*), and the yellow pond lily (*Nuphar lutea*) (Patterson 2009).

Water temperatures in the Klamath River estuary are linked to temperatures and flows entering the estuary. The salinity of the estuary and resulting density stratification are related to the timing and duration of the formation of a sand berm across the estuary mouth. When the estuary mouth is open, denser saltwater from the ocean sinks below the lighter fresh river water, resulting in a salt wedge that moves up and down the estuary with the daily tides (Horne and Goldman 1994, Wallace 1998, Hiner 2006). The saltwater wedge results in thermal stratification of the estuary with cooler, high-salinity ocean waters remaining near the estuary bottom; and warmer, low-salinity river water near the surface. Under low-flow summertime conditions, when the mouth is closed, surface water temperatures in the estuary have been observed to be 18 to 24°C (64.4 to 75.2°F) and greater (Wallace 1998, Hiner 2006, Watercourse Engineering, Inc. 2011). Although temperatures in the estuary have been recorded as being above lethal thresholds for salmonids, thermal refugia in tidal areas may exist (Wallace 1998, Bartholow 2005). Input of cool ocean water and fog along the coast minimizes extreme water temperatures much of the time (Scheiff and Zedonis 2011).

Dissolved oxygen concentrations in the Klamath River estuary vary both temporally and spatially; concentrations in the deeper, main channel of the estuary are generally greater than 6 to 7 mg/L throughout the year (Hiner 2006, YTEP 2005). Low dissolved oxygen concentrations (<1 to 5 mg/L) have been observed during summer months in the relatively shallow, heavily vegetated south slough (Hiner 2006, Wallace 1998). The low levels of dissolved oxygen observed in the slough are likely due to high rates of growth and subsequent decomposition of algae and macrophytes, which are not abundant elsewhere in the estuary.

In the Klamath River estuary, pH ranges between approximately 7.5 and 9, with peak values also occurring during the summer months (YTEP 2005). Daily variations in pH are typically on the order of 0.5 pH units, and fluctuations tend to be somewhat larger in the late summer and early fall. When large daily fluctuations are observed, they are likely caused by algal blooms that are transported into the estuary. Nutrient levels in the estuary also experience inter-annual and seasonal variability. Measured levels of total phosphorus in the estuary are typically below 0.1 mg/L during summer and fall (June through September), and total nitrogen levels are consistently below 0.6 mg/L (June through September) (Sinnott 2011).

Under existing conditions, a freshwater plume exists in the nearshore environment in the vicinity of the Klamath River mouth. This freshwater plume is affected by winter runoff events. These effects include low-salinity, high levels of suspended particles, high sedimentation, and low light (and potential exposure to land-derived contaminants). The extent and shape of the plume are variable, and influenced by wind patterns, upwelling effects, shoreline topography (especially at Point Saint George), and longshore currents. High SSC events contribute to the plume, especially during floods. In a recent study of the Eel River nearshore sediment plume, approximately 80 miles south of the Klamath River, in situ measurements of plume characteristics indicated no relationship with SSCs, turbulent-kinetic-energy, time from river mouth, wind speed, wave height, or discharge. A relationship apparently did exist between effective settling velocity (bulk mean settling velocity) of plume sediments and wind speed/direction, as well as with tides (Curran et al. 2002).

4.8.4 Reservoirs

This section summarizes the physical conditions in J.C. Boyle, Copco No. 1, and Iron Gate reservoirs, which is pertinent to the analysis of effects on Lost River and shortnose suckers from the Proposed Action. Detailed information on sucker populations and critical habitat is provided in Appendix G.

Sediment quantity and quality in the reservoirs is described in Section 4.5.2. Water quality conditions in the reservoirs, including water temperatures, suspended sediment, dissolved oxygen, nutrients, pH, and algae are described in Section 4.6.

4.8.4.1 J.C. Boyle Reservoir

J.C. Boyle Reservoir is approximately 350 acres and has been described as two sections based on valley morphology and geomorphic features mapped prior to dam construction in 1958. The Canyon Reach extends from J.C. Boyle Dam upstream approximately 1 mile to the Highway 66 bridge, and the Upstream

Reach runs from the Highway 66 bridge upstream approximately 2 miles to the upstream extent of the J.C. Boyle Reservoir.

The reservoir is narrow and linear in the Canyon Reach, with water depths increasing from approximately 10 feet at the Highway 66 bridge to maximum values around 35 feet at the unnamed tributary junction 1,000 feet upstream from the dam. In the Upstream Reach, water depths are near zero for all but the historical channel location, where depths are typically 10 to 15 feet, with maximum values of 20 feet in the deep pool at the river right bedrock control. Wetland conditions support an extensive bulrush marsh in the wide, shallow reservoir margins of the Upstream Reach that experience seasonal fluctuations in water level.

4.8.4.2 Copco No. 1 Reservoir

Copco No. 1 Reservoir is approximately 972 acres and has been described as two sections based on valley morphology and geomorphic features mapped prior to dam construction in 1918. The Downstream Reach extends from Copco No. 1 Dam approximately 6 miles to the upstream extent of the mapped historical floodplain upstream of Beaver Creek. The Upstream Reach extends approximately 3 miles from upstream of the mapped historical floodplain to the upstream extent of the reservoir.

Physical conditions in Copco No. 1 Reservoir generally vary with distance upstream from the dam, and additional cross-sectional variability is due to the historical meandering valley geometry. Reservoir width and maximum water depths decrease with distance upstream from the dam, with maximum depths in the historical channel at the dam site. In the Downstream Reach, shallower depths are present on the dammed ancestral lakebed surfaces and terraces on the insides of meander bends. In the Upstream Reach, depths are relatively uniform and are 10 feet or less. Bedrock cliffs, some formed by post-dam erosion of volcaniclastic rocks, line portions of the reservoir. Small patches of emergent wetland and riparian vegetation are scattered around the reservoir shoreline. Larger patches of wetland and riparian habitat occur primarily at tributary confluences.

4.8.4.3 Iron Gate Reservoir

Iron Gate Reservoir is approximately 942 acres and has been described as two sections based on the location of primary tributaries and geomorphic features mapped prior to dam construction in 1962. The Downstream Reach extends approximately 2 miles from Iron Gate Dam to upstream of the Camp Creek confluence/Mirror Cove arm of the reservoir, where it transitions to the Upstream Reach, which extends approximately 4 miles to the upstream extent of the reservoir.

The Iron Gate Reservoir geometry is consistent with inundation of a relative uniform, deep, and narrow canyon, whereby reservoir width and water depth decrease with distance upstream from the dam, except at tributary valleys where the reservoir widens into coves. Iron Gate Reservoir is the deepest of the three reservoirs, with maximum water depths of 150 feet near the dam. Similar to Copco No. 1 Reservoir, small patches of willows and emergent vegetation occur along the shoreline of Iron Gate Reservoir, with larger areas of willow riparian habitat associated with tributary confluences.

4.8.4.4 PacifiCorp Habitat Conservation Plan for Lost River and Shortnose Suckers

PacifiCorp finalized an HCP for Lost River suckers (LRS) and shortnose suckers (SNS) in November 2013 (PacifiCorp 2013b) in accordance with Section 10(a)(1)(B) of the ESA. In response to this plan, the USFWS conducted an intra-service consultation (08EKLA00-2013-F-0043) on the effects to suckers of the authorization of the plan.

The HCP addressed direct effects to suckers, including entrainment at project diversions, false attraction at project tailraces, ramp rates, lake level fluctuations, migration barriers, loss of habitat, and water quality, as well as effects to sucker critical habitat (PacifiCorp 2013b pp. 43–58). Additionally, the Plan proposed the shutdown of the East Side and West Side facilities to reduce sucker mortality resulting from entrainment into the canals (PacifiCorp 2013b pp. 64–66). PacifiCorp established a Sucker Conservation Fund to support sucker conservation goals and objectives and committed to continue support of The Nature Conservancy's Williamson River Delta Restoration Project (PacifiCorp 2013b, p. 67). These commitments included $100,000 to the fund, and annual funding of about $4,000 to the Nature Conservancy over the 10-year period (termination date of February 20, 2024) of its incidental take permit (ITP). PacifiCorp contributed just over $14,233 to The Nature Conservancy for use on the Williamson River Delta property (PacifiCorp 2019). PacifiCorp contributed a total of $107,170 to the Williamson River Delta Restoration Project through 2018 (PacifiCorp 2019). PacifiCorp is also responsible for in-kind costs to implement management actions and monitoring (PacifiCorp 2013b pp. 79–80).

Implementation of the HCP required an ITP from USFWS under the ESA. PacifiCorp operations at numerous facilities along the Link and Klamath Rivers were covered. The permit called for authorization of lethal take of both species over the next 10 years, including 10,000 eggs, 66,000 larvae, 500 juveniles, and five adults. Additionally, harassment of 1,400,000 larvae, 6,700 juveniles, and 25 adults was included. However, much of the take was eliminated when PacifiCorp ceased operation of the East Side and West Side facilities. The USFWS determined that issuance of the ITP for the HCP was not likely to jeopardize the continued existence of the LRS or SNS and was not likely to destroy or adversely modify critical habitat for the species.

PacifiCorp continues to monitor operations at project facilities to estimate sucker take through project turbines and spillways at East Side and West Side power canals, J.C. Boyle, Copco No. 1, Copco No. 2, and Iron Gate dams. PacifiCorp shut down the East Side and West Side developments, and no longer routinely diverts water through the turbines or discharges water at the tailraces of the two facilities (PacifiCorp 2019). Therefore, all potential take attributable to the operation of the turbines at the East Side and West Side developments has been eliminated, and routine monitoring is not necessary. Monitoring results suggest PacifiCorp operations have less take of listed suckers than is authorized by the ITP (PacifiCorp 2019).

4.9 Terrestrial Habitat Conditions

This section summarizes terrestrial habitat conditions in the Hydroelectric Reach which is pertinent to the effects analysis for northern spotted owl. Detailed information on northern spotted owl occurrence and critical habitat in the Action Area is provided in Appendix G.

Northern spotted owls depend primarily on old-growth or mature forests with high canopy closure. There is no nesting, roosting, or foraging habitat within 0.25 mile of where project activities would occur. The Ponderosa pine forests in the vicinity of the J.C. Boyle Dam are generally younger and have low to moderate canopy closure, making them unsuitable for northern spotted owl nesting, roosting, or foraging. Larger trees with more canopy closure and diverse structure are present in small, isolated patches near the J.C. Boyle powerhouse; however, these small, isolated patches would not be expected to support a future nesting pair given the lack of nesting, roosting, and foraging habitat available in the surrounding vicinity.

At Copco No. 1 Reservoir, forested areas are dominated by oak, juniper, and pine. Older mixed forest habitat with higher canopy closer is located at higher elevations southeast of Copco No. 1 Reservoir. As described in Appendix G, a northern spotted owl activity center is located approximately 1.3 miles southeast of the upstream end of Copco No. 1 Reservoir. Terrestrial habitat in the vicinity of the Iron Gate Reservoir consists of grass-covered land with oaks and junipers; there is no forested habitat suitable for northern spotted owls.

4.10 Climate Change

4.10.1 Terrestrial Ecosystem

Recent scientific research on climate change has focused on the effects of changing temperature and annual precipitation records, extreme weather events, wildfire events, and insect and disease outbreaks on forest ecosystems. In the Pacific Northwest, an increase in average annual temperature of 3.3°F to 9.7°F is projected by 2070 to 2099 (Mote et al. 2014). Climate change is predicted to result in warmer, drier summers; warmer, wetter autumns and winters; and an increase in extreme precipitation events and heat waves (USFWS 2011b). Also, recent evidence supports that as summer temperatures are rising, the elevation of the tree line in high-elevation Pacific Northwest forests may be increasing (Lawler and Mathias 2007), while the productivity of tree growth in lower elevations is likely to decrease due to the prolonged warmer summer season.

In the Pacific Northwest, an increase in fire activity is expected to occur over all major forest types, with the total area burned projected to double by the 2040s and triple by the 2080s (USFWS 2011b; Mote et al. 2014). In northern California, areas burned by wildfire are expected to double by the end of the century (Garfin et al. 2014). Impacts of wildfires on surface waters are described in Section 4.10.2. The interaction between multiple disturbances (insect or disease outbreaks and wildfires) will heighten impacts on forests (Dalton et al. 2013). A loss of pine species is projected in the eastern Cascades as early as the 2040s due to a combination of mountain pine beetle outbreaks and increased tree susceptibility resulting from an increase in hot and dry weather conditions. Warmer winters have exacerbated beetle outbreaks by allowing more beetles, which normally die in cold weather, to survive and reproduce (Garfin et al. 2014). Other pests and diseases, including sudden oak death, have been spreading northward from California into southwestern Oregon (USFWS 2011b). For many tree species, the most climatically suited areas will shift from their current locations, increasing vulnerability to insects, disease, and fire. Eighty-five percent of the current range of three species that are host to pine beetles is projected to be climatically unsuitable for one or more of those species by the 2060s, while 21 to 38 currently existing plant species may no longer find climatically appropriate habitat in the Northwest by late in this century (Mote et al. 2014).

Invasive plant species are also predicted to increase due to climate change, because invasive species have a broader climate tolerance and larger geographic ranges (USFWS 2011b). An increase in extreme climatic events and disturbance facilitates biological invasions through increased movements of non-native species and decreased biotic resistance of native communities to invader establishment (Dietz et al. 2012).

Changes in forest composition may alter existing habitat conditions and initiate a change in the composition of species that use the habitat. The change in forest composition would likely occur over a time span of 100 to 500 years, where events such as fire and insect outbreaks have a shorter time scale of 25 to 100 years (USFWS 2011b).

4.10.2 Aquatic Ecosystem

Climate change has some general long-term implications for the Klamath Basin, including warming of air and water temperatures, changes in precipitation (i.e., amount of rain versus snow, and frequency of rain-on-snow events), the amount of snowpack, water quantity (e.g., more frequent, high-intensity storms, and lower summer flows), and overall seasonal streamflow patterns (NRC 2004, Halofsky et al. 2018). General climate trends identified for Oregon suggest that historical 20th-century warming is projected to continue with estimates varying from roughly 4 to 9°F by 2100 (May et al. 2018, Mote et al. 2019).

Earth's climate is now changing faster than at any point in the history of modern civilization, primarily due to human activities, especially emissions of greenhouse gases (USGCRP 2018). The range of anadromous salmonids is restricted in large part by climate. Pacific salmon populations in the Pacific Northwest are affected by climate stressors, including low snowpack, decreasing summer streamflow, habitat loss and modification caused by severe storm events, warming freshwater and marine temperatures, and conversion of riparian plant communities (USGCRP 2018).

Climatic conditions affect salmonid abundance, productivity, spatial structure, and diversity through direct and indirect impacts at all life stages (e.g., ISAB 2007; Lindley et al. 2007; Crozier et al. 2008; Moyle et al. 2013; Wainwright and Weitkamp 2013). The effects of climate change on coldwater fishes are likely to be especially severe in the southern part of their ranges. Chinook salmon, coho salmon, steelhead, and bull trout populations in the Klamath Basin are in the southern portion of their ranges, and these populations are anticipated to be affected by increasing water temperatures in both freshwater and marine habitats. In rivers, climate change is expected to alter flow patterns, including the seasonality and magnitude of droughts and floods. Although average winter precipitation is anticipated to increase over the longterm, year-to-year variation in precipitation is expected to increase. Additionally, extended droughts punctuated by extreme events such as heavy rainfall associated with atmospheric rivers and rain-on-snow events are likely to increase stressors on aquatic habitats and species (May et al. 2018).

Water temperatures in the Pacific Northwest warmed by approximately 0.72°C in the 20th century (Eaton and Scheller 1996; Mote et al. 2003). Anadromous salmonids, depending on the species and location, tolerate water temperatures in the range of 0 to 25°C (Brett 1971; Richter and Kolmes 2005). However, salmonid survival and reproduction may become impaired by water temperatures higher than 18°C (USEPA 2003). Therefore, even small increases in water temperatures can result in conditions that are suboptimal or lethal to salmonids already residing in rivers where summer temperatures often exceed 20°C (McCullough 1999).

Streams are also expected to be warmer and drier during the summer and fall months due to a reduction in snowpack levels and seasonal retention (May et al. 2018; Mote et al. 2019). Elevations below 9,900 feet will experience the greatest (approximately 80 percent) reduction in snow pack (Hayhoe et al. 2004). In California, losses are expected to be most significant in the southern Sierra and Cascade Mountains (Mote et al. 2005), the source of snowmelt for most streams in the lower Klamath River Basin. Increased temperatures also will increase the incidence of winter floods, summer droughts, and forest fire frequency (Edwards 1991; Field et al. 1999; Mote et al. 2019). Peak flows have already shifted to earlier in the year by 10 to 30 days in much of the western U.S. (Stewart et al. 2004). Predictions are that future peak flows may shift even earlier in the year by 30 to 40 days (Stewart et al. 2004). In the Klamath River Basin, these impacts will be more pronounced in streams that are primarily fed by snow-melt (i.e., Salmon and Scott rivers) than those fed by springs (the Williamson and Wood rivers in the upper basin, and the Shasta River downstream of Iron Gate Dam).

The hydrologic characteristics of the Klamath River mainstem and its major tributaries are dominated by seasonal melt of snowpack (NRC 2004; Halofsky et al. 2018). Van Kirk and Naman (2008) found statistically significant declines in April 1 Snow Water Equivalent since the 1950s at several snow measurement stations throughout the Klamath River Basin, particularly those stations at lower elevations (<6,000 feet). There is strong evidence that winter precipitation in the upper Klamath River Basin has declined (Mayer and Naman 2011). Climatic factors are likely responsible for much of the decline in long-term Upper Klamath Lake net inflows that occurred between 1961 and 2007 (Mayer 2008).

Bartholow (2005) found that the Klamath River water temperatures are increasing by 0.5°C/decade, which may be related to warming trends in the region (Bartholow 2005) and/or alterations of the hydrologic regime resulting from the USBR Klamath Project, logging, and water use in Klamath River tributary basins. Particularly, changes in the timing of peak spring discharge, and decreases in water quantity in the spring and summer may affect salmonids of the Klamath River. Rain-on-snow events may increase the frequency of late winter and early spring flooding, causing destruction of salmonid redds, and thereby reducing salmonid survival.

The Klamath River estuary will likely be impacted by more frequent and extreme tides and storms (Cayan et al. 2008) and will likely experience altered salinity concentrations as sea level rises (Scavia et al. 2002). These changes, in combination with increasing temperatures, can result in seasonally anoxic conditions (Moore et al. 1997) and altered food availability in at least some parts of the estuary. Impacts to salmonids using the Klamath River estuary may be modulated by their rearing strategy. For example, Chinook salmon in the Klamath River may not be significantly affected by anticipated conditions, because juvenile Chinook salmon do not appear to use the estuary extensively for rearing (Sullivan 1989).

In the Pacific Ocean, localized increases in California Current primary productivity may favor growth for some salmonids but benefits to populations will largely depend on movement patterns dictated by currents (Brodeur et al. 2007; Huyer et al. 2007; Wells et al. 2008). The California Current is a Pacific Ocean current that moves south along the western coast of North America, beginning off southern British Columbia, and ending off southern Baja California. The movement of northern waters southward makes the coastal waters cooler than the coastal areas of comparable latitude on the east coast of North America. The cold water is highly productive due to the upwelling, which brings nutrient-rich waters to the surface, thereby supporting coastal marine life and important fisheries. Furthermore, recent research suggests that the warming ocean may be disrupting upwelling, delaying upwelling processes by as much as 1 month. This delay may result in disrupted predator-prey relationships and adversely impact food availability to juvenile salmonids at ocean entry (Di Lorenzo et al. 2008; Scheuerell et al. 2009).

A connection between salmon abundance and a North Pacific climate variation, named the Pacific Decadal Oscillation (PDO), has been demonstrated (Mantua and Hare 2002). Warm-phase PDO is generally associated with reduced abundance of coho and Chinook salmon in the Pacific Northwest, while cool phase PDO is linked to above-average abundance of these fish. The El Niño Southern Oscillation (ENSO) and North Pacific Gyre Oscillation (NPGO) (Di Lorenzo et al. 2008) also influence habitat quality in the Pacific Ocean (Garcia-Reyes and Largier 2010), as well as inland aquatic habitats by influencing precipitation events. Unfavorable ocean conditions (e.g., warm phase PDO) are believed to be partially responsible for the poor survival of salmon stocks in California in 2006 (NMFS 2007a) and 2008 (Lindley et al. 2009).

Climate change models indicate that a changing climate will have a large negative effect on freshwater salmon habitat, and salmon recovery targets will be more difficult to attain (Battin et al. 2007). These changing conditions have profound implications for restoration of anadromous fish populations over the next 50 years. Summer baseflows in core bull trout streams in the Upper Klamath Basin are anticipated to decline by 15 percent by 2040, and 18 percent by 2080, with the Upper Sprague, Sycan, and Upper Klamath projected to experience the largest declines (Halofsky et al. 2018). As summer flows decrease, headwater streams may become intermittent more frequently, and may go dry especially during prolonged droughts.

Water temperature in all habitats is predicted to steadily increase throughout the 21st century, perhaps beyond salmonid tolerances. According to modeling studies as described in Chatters et al. (1992), the abundance of some salmonid populations in the Klamath River Basin may decrease by as much as 60 percent by 2100 due to warming, unless climate change is actively incorporated into conservation efforts. Equilibrium flow modeling of water temperatures conducted by USBR in the mainstem Klamath River at Klamath, CA projected that maximum average weekly temperatures may increase by 2.2°C to 4.4°C (4°F to 8°F) by 2070. According to this model, the simulated maximum average weekly temperatures at Klamath, CA during summer was 24.4°C (76°F). Juvenile coho salmon and other salmonids rely on cold water refugia during the summer. If suitable refugia are unavailable, the water temperature increases projected by the USBR model could preclude coho salmon and other salmonids from the Klamath River (USBR 2016).

As adverse as climate change predictions appear for the future of anadromous fish habitat, there are mitigating circumstances associated with the Upper Klamath Basin. Contrary to the commonly accepted view that snowpack storage is the dominant source of late summer water, research has revealed that the source of late summer water in western and central Oregon and northern California is almost exclusively immense groundwater storage in the Cascade Range. The volume of water stored as groundwater in permeable lava flows in the Cascade Range is seven times that stored as snow (Thompson 2007). Under climate change scenarios, streams fed by groundwater are predicted to continue to flow in the summer, due to an extended storage effect, but at a reduced volume (Thompson 2007; Tague et al. 2008). The hydrograph of groundwater-fed systems is expected to reflect higher winter flows and decreased spring and summer flows as snowmelt peaks earlier in the year, and flows are mediated by geologic drainage rates (Jefferson et al. 2007; Thompson 2007; Tague et al. 2008). Flow in streams fed by springs should continue to be more stable (less interannual variability) than streams dominated by surface runoff (Jefferson et al. 2007; Halofsky et al. 2018).

Although the hydrology and temperature regime of the Klamath River generally is dominated by surface water runoff, the Upper Klamath Basin and the Shasta River have substantial regional groundwater flow. Much of the inflow to Upper Klamath Lake can be attributed to groundwater discharge to streams and major spring complexes within a dozen or so miles from the lake. This large component of groundwater buffers the lake somewhat from climate cycles (Gannett et al. 2007), and with climate change, these groundwater basins, such as the Upper Klamath, will have more streamflow in late summer than those basins with little subsurface flow (Thompson 2007, Halofsky et al. 2018).

With respect to water temperature, groundwater is generally cooler in the summer and warmer in the winter than surface water. Because of the groundwater influence, stream water temperatures in the Upper Klamath Basin are less likely to be altered than those in the lower basin in response to climate change over the next 50 years. Water temperatures of springs generally reflect the temperature of their water source (aquifer). Consequently, spring water in the summer is farther from equilibrium with air temperature than ambient stream water, taking it longer (in time and distance) to warm (Tague et al. 2007).

Groundwater temperatures respond to climate change to a lesser degree than groundwater flows. Although hydraulic pulses can move through a groundwater system relatively rapidly, on the time scale of months or years, the actual advective travel time of water is much longer (Gannett 2010). Large-scale springs, such as in the Cascades, with travel times on the order of decades to centuries, can be expected to damp climatic temperature variations on the order of decades (Manga 1999). Large amounts of groundwater discharge into the Wood River subbasin, the lower Williamson River area, and along the margin of the Cascade Range (Gannett et al. 2007). Water temperature benefits to the mainstem Klamath River downstream of Upper Klamath Lake from Upper Klamath Basin groundwater inputs would continue to be diminished as water passes through Upper Klamath Lake, where it can warm before flowing downstream. However, a large spring complex provides significant high-quality water downstream of J.C. Boyle Dam, creating thermal diversity in the form of intermittently-spaced patches of thermal refugia (Hetrick et al 2009), and the Shasta River was historically a groundwater-dominated system (NRC 2004) with considerable potential to provide groundwater benefits currently and in the future.

The extent to which groundwater mitigates the effects of warming water temperatures is contingent on the long-term availability of groundwater supplies in California and Oregon. Legislative efforts have recently been directed at managing groundwater supplies. In 2014, the California State Legislature enacted the Sustainable Groundwater Management Act, which was intended to promote sustainable use of groundwater by requiring local and regional agencies to jointly develop management plans that outline sustainable groundwater management strategies for each basin in the state (CDWR 2018).

Under climate change, late-summer drought conditions will likely increase in frequency, further restricting the suitable rearing habitat of juvenile salmonids and the holding waters of adult spring Chinook salmon, reducing the spatial distribution of thermal refugia. These late-summer drought conditions may further restrict the distribution and abundance of salmonids in currently marginal habitats near the southern limit of their range. Climate change is likely to have deleterious effects on salmonid populations, and consequently an undesirable effect on harvest of salmonids during the next 50 years.

As described in Section 4.10.1, climate change is resulting, and will continue to result, in increased wildfire activity. Several wildfires have recently occurred in the vicinity of the Action Area, as described in Section 4.3 and 4.6.3. Wildfires contribute to a loss of vegetation, which is associated with increased soil erosion and sedimentation and increased temperatures from the loss of shade along riparian zones. Intense lasting heat from major wildfires can cause plants to release a gas into the soil that cools and solidifies into a water-repelling substance that coats soil particles and causes hydrophobicity. Hydrophobic layers decrease infiltration of stormwater and aquifer recharge while increasing runoff, erosion, sedimentation, and stream discharges (USDA Forest Service 2005). Increased sediment loading may be associated with elevated loading of nutrients, heavy metals, and other contaminants, which further degrade aquatic habitat (Bladon et al. 2014)

Chapter 5: Effects of the Proposed Action on Listed Species and Critical Habitat

5. EFFECTS OF THE PROPOSED ACTION ON LISTED SPECIES AND CRITICAL HABITAT

As described in Section 1.4, nine federally listed species and their critical habitat are evaluated in this BA due to their occurrence in the Action Area, proximity to the activities, or potential to be affected by the project. Table 5-1 lists the portion of the Action Area where each species may occur. To aid NMFS and USFWS in their review, the effects analysis for species under the jurisdiction of NMFS, including coho salmon, Southern Distinct Population Segment (sDPS) green sturgeon, sDPS eulachon, and Southern Resident DPS killer whale, are grouped together and described in Sections 5.1 to 5.4. The effects analysis for species under the jurisdiction of USFWS, including Lost River and shortnose sucker, bull trout, Oregon spotted frog, and northern spotted owl, are described in Sections 5.5 to 5.8.

Table 5-1: Federally Listed Species Evaluated in This BA

Scientific Name	Common Name	Listing[1]	Critical Habitat[2]	Portion of Action Area
NMFS Species				
Oncorhynchus kisutch	SONCC coho salmon	T	Y	Upper, middle, and lower Klamath Basin
Acipenser medirostris	Southern DPS green sturgeon	T	Y	Klamath estuary
Thaleichthys pacificus	Southern DPS eulachon	T	Y	Lower Klamath River
Orcinus orca	Southern Resident killer whale	E	Y, Proposed Revision[3]	Marine
USFWS Species				
Deltistes luxatus	Lost River sucker	E	Y	Upper Klamath Basin
Chasmistes brevirostris	Shortnose sucker	E	Y	Upper Klamath Basin
Salvelinus confluentus	Bull trout	T	Y	Upper Klamath Basin
Strix occidentalis caurina	Northern spotted owl	T	Y	May occur within 1.5 miles of project limits of work
Rana pretiosa	Oregon spotted frog	T	Y	Upper Klamath Basin in tributaries to Upper Klamath Lake; Middle Klamath Basin in upper reaches of Spencer Creek

[1] Listing
E Federally Endangered
T Federally Threatened

[2] Critical Habitat
Y Yes - designated critical habitat occurs in Action Area

[3] FERC intends to conference with NMFS on potential effects of the Proposed Action on proposed critical habitat for Southern Resident killer whale, as evaluated in this BA.

Revised regulations (84 Federal Register [FR] 44976) define effects as all consequences to listed species or critical habitat that are caused by the proposed action, including the consequences of other activities that are caused by the proposed action. A consequence is caused by the proposed action if it will not occur but for the proposed action, and it is reasonably certain to occur. Effects of the action may occur later in time and may include consequences occurring outside the immediate area involved in the action.

To determine the effects of an action, the potentially affected listed resources (endangered and threatened species and designated critical habitat) need to be identified, then the potential stressors associated with the action and the nature of that exposure need to be determined. The next step requires an examination of the best available scientific and commercial information to determine whether and how those listed resources are likely to respond (effects) given their exposure. The final step of the analysis is making a determination of risk that the project effects pose to listed resources.

A “no effect” determination is the appropriate conclusion when the Action Agency determines that the Proposed Action will not affect listed species or critical habitat (USFWS and NMFS 1998). A “may affect, not likely to adversely affect” determination is the appropriate conclusion when effects on listed species are expected to be discountable, insignificant, or completely beneficial. Beneficial effects are contemporaneous positive effects without any adverse effects on the species. Insignificant effects relate to the size of the impact and should never reach the scale where take occurs. Discountable effects are those extremely unlikely to occur. Based on best judgment, a person will not (1) be able to meaningfully measure and detect or evaluate insignificant effects; or (2) expect discountable effects to occur.

A “may affect, likely to adversely affect” determination is the appropriate conclusion if any adverse effect to listed species may occur as a consequence of the proposed action or other activities that are caused by the proposed action. Further, a “may affect, likely to adversely affect” determination is appropriate when the effect is not discountable, insignificant, or beneficial (USFWS and NMFS 1998). In the event the overall effect of the proposed action is beneficial to the listed species, but also is likely to cause some adverse effects, then the proposed action "is likely to adversely affect" the listed species. A "may affect, likely to adversely affect" determination requires formal Section 7 consultation.

Past designations of critical habitat have used the terms Primary Constituent Elements (PCEs), physical and biological features (PBFs) or “essential features” to characterize the key components of critical habitat that provide for the conservation of the listed species. New critical habitat regulations (81 FR 7214) discontinue use of the terms “PCEs” or “essential features” and rely exclusively on use of the term PBFs because this term is specifically discussed in the ESA. The terms PBFs, PCEs, and essential habitat features are synonymous in meaning and the approach for the evaluation of effects on critical habitat is the same regardless of whether the original designation identified PCEs, PBFs, or essential features.

The BA also assesses impacts of the Proposed Action on a “short-term” and “long-term” basis. Short-term effects are those taking place for less than 2 years following dam removal. Long-term effects are those taking place for more than 2 years following dam removal. Either short- or long-term impacts may affect listed species. For the purposes of this BA, impacts will be considered “likely to adversely affect” a species if they will result in the following:

Short term:

- Disturb any life history stage of a species such that it causes a disruption of breeding, feeding or sheltering in the short term.
- Take any individuals of any life history stage in the short term.
- Decrease the quality of any PBF of critical habitat for any life history stage of a listed species in the short term.
- Decrease the quality of a large proportion of critical habitat under the ESA or adversely affect EFH under the Magnuson-Stevens Act in the short term.

Long term:

- Take any federally listed fish or terrestrial species for more than two generations after removal of all dams.
- Decrease the quality and quantity of any PBF of critical habitat for federally listed fish species; decrease foraging, nesting, and roosting habitat for northern spotted owl; or decrease the habitat community in the long term.
- Decrease the quality and quantity of any PBF of critical habitat for federally listed fish species or terrestrial foraging, nesting, and roosting habitat for northern spotted owl over a large proportion of the habitat available to it in the long term.
- Decrease the quality or amount EFH under the Magnuson-Stevens Act in the long term.
- Worsen conditions that are currently causing a federally listed species to decline in the long term.
- Eliminate a year class of salmon or steelhead, thereby jeopardizing the long-term viability in the Klamath Basin. Because of the fixed, 3-year timing of the coho salmon life cycle, which has little to no plasticity, this criterion was added for the protection of coho salmon in particular.

The Proposed Action has the potential to affect one or more of the listed species discussed in this BA. However, not all of the proposed activities will affect all species. Therefore, the following “Effects” sections assess each species individually for only those project actions that have the potential to affect one or more individuals of that species. Although the majority of the species evaluated are found in the aquatic environment, effects are also analyzed for one terrestrial species, the northern spotted owl. In addition, the effects on the PBFs of each species’ critical habitat are evaluated.

The potential short-term and long-term effects of the Proposed Action on listed species are listed in Table 5-2, and include the following:

- <u>In-water construction activities</u>: In-water construction activities at Iron Gate Dam have the potential to affect listed fish species. Prior to drawdown, there is potential for effects to suckers during construction activities in the Copco and Iron Gate reservoirs. Salvage of listed suckers will occur at J.C. Boyle, Copco No. 1, and Iron Gate reservoirs prior to the onset of reservoir drawdown; however, not all listed suckers will be salvaged from the reservoirs. There is also potential for effects to coho salmon during construction on the downstream side of Iron Gate Dam and at Lakeview Road bridge.

During restoration actions and monitoring and maintenance for fish passage, there is potential for effects to coho salmon. These in-water activities could cause direct harm and short-term increased SSCs.

- Increased suspended sediment concentrations: Suspended sediment released during the Proposed Action will affect species based not only on the species' abundance, distribution, and life stages present, but also on the timing, duration, frequency, characteristics, and concentration of the suspended sediment in the Hydroelectric Reach and downstream to the mouth of the Klamath River in the short term. Therefore, suspended sediment concentrations have the potential to affect listed suckers in Copco No. 1 and Iron Gate reservoirs and listed coho salmon downstream of Iron Gate Dam.
- Decreased dissolved oxygen concentrations: Dissolved oxygen concentrations during the Proposed Action will affect species based not only on the species' abundance, distribution, and life stages present, but also on the timing, duration, frequency, and characteristics of suspended sediment concentrations, dissolved oxygen concentrations, and water temperatures and flows in the Hydroelectric Reach and downstream to the mouth of the Klamath River in the short term. Therefore, dissolved oxygen concentrations have the potential to affect listed fish species downstream of Iron Gate Dam.
- Altered hydrology of the Klamath River: Removing the four Klamath River dams will alter the hydrology of the Klamath River downstream of Keno Dam. Dam removals will restore natural river flows downstream of Keno Dam, and the extended residence time created by the existing dams will be replaced by a free-flowing river. Therefore, altered hydrology has the potential to affect coho salmon, listed suckers, and the Chinook salmon food base for Southern Resident killer whales.
- Habitat modification: Removing the four Klamath River dams will modify existing aquatic habitat in the hydroelectric reach by converting the reservoir pools of the four dams to a free-flowing river. Aquatic habitat will also be modified temporarily downstream of Iron Gate to the extent of where released sediment is anticipated to deposit, and in the long term through a return to more natural sediment transport and hydrological regime. Terrestrial habitat will be modified in areas associated with hydroelectric facilities and in temporary construction areas, which will be restored following construction. Therefore, habitat alteration has the potential to affect coho salmon, listed suckers, and northern spotted owl.
- Noise: Demolition of the dams and their associated structures will entail the use of heavy equipment and blasting as necessary. Noise may result in adverse effects on listed suckers, coho salmon, and northern spotted owl.
- Restoring passage for anadromous salmonids in the Upper Klamath Basin: Anadromous salmonids will have the opportunity to access historical habitat in Upper Klamath Lake tributaries once the dams are removed, potentially resulting in effects on bull trout, Oregon spotted frog, and listed suckers related to predation, competition for resources, and disease transmission.
- Changes in salmonid prey base: The Proposed Action will affect Chinook salmon, the primary prey base for Southern Resident killer whales due to increased suspended sediment concentrations and decreased dissolved oxygen concentrations during drawdown as well as the reduction of future

hatchery Chinook salmon production. In the long term, the Proposed Action is expected to benefit Chinook salmon, and Southern Resident killer whale food resources, based on Chinook salmon access to expanded spawning and rearing habitats, flow and water quality improvements, and reduced incidence of disease-related mortality.

The use of herbicides to control IEV in the Hydroelectric Reach may result in adverse effects on non-target organisms if not properly applied. All herbicides will be federal USEPA-approved formulations and used according to appropriate state guidelines for pesticides. In coordination with NMFS and USFWS, BMPs for herbicide application were developed for the Proposed Action, as described in the Reservoir Area Management Plan (see Appendix C). With implementation of these BMPs, the use of herbicides is not expected to result in adverse effects on aquatic or terrestrial species. Therefore, herbicide effects are not discussed further in this BA.

Table 5-2: Potential Effects of the Proposed Action on Listed Species

Species/Critical Habitat Potentially Affected	In-Water Activities	Increased Suspended Sediment Concentrations/ Decreased Dissolved Oxygen Concentrations	Altered Hydrology	Habitat Modification	Noise	Effects of Restored Passage for Upper Klamath Salmonids	Changes in Salmonid Prey Base
NMFS Species							
SONCC coho salmon ESU and critical habitat	X	X	X	X	X		
Southern DPS green sturgeon and critical habitat		X					
Southern DPS eulachon and critical habitat		X					
Southern Resident killer whale and proposed critical habitat							X
USFWS Species							
Shortnose sucker and critical habitat	X	X	X	X	X	X	
Lost River sucker and critical habitat	X	X	X	X	X	X	
Bull trout and critical habitat						X	
Northern spotted owl and critical habitat				X	X		
Oregon spotted frog and critical habitat						X	

The Proposed Action is also expected to result in a range of benefits to listed species, including a net ecological benefit and improved long-term water quality. The removal of the four dams will provide a free-flowing river with volitional fish passage from downstream of Keno Dam to the Pacific Ocean. Dam removal is expected to aid in the recovery of anadromous fish by:

- Providing access to historical anadromous fish habitat in the reach upstream of the Iron Gate Dam site to the headwaters of the Klamath Basin via the existing fish passage facilities at Keno Dam and Link River Dam[5]. This will increase the geographic distribution and genetic diversity of anadromous fish in the Klamath, thus improving the long-term viability and recovery of imperiled salmonid species like coho salmon.
- Restoring the recruitment of gravel (i.e., the natural process of gravel transport and deposition) in the Hydroelectric Reach and downstream of Iron Gate Dam, which will benefit fish spawning, food production, and provide habitat for juvenile Pacific lamprey.
- Creating a more mobile streambed. This is expected to reduce fish disease by decreasing the population of annelid worms that serve as an alternate host for *Ceratonova shasta* (*C. shasta*), a deadly fish disease that causes significant juvenile coho salmon and Chinook salmon mortality in some years.
- Improving water quality.

The process of reservoir drawdown and dam removal will have acute short-term impacts, but similar efforts in other rivers (Elwha, Condit, Marmot) demonstrate that the river system and its fish resources are capable of recovering quickly after the short-term impacts have subsided. Benefits of the Proposed Action are described in the effects analysis for each species below.

5.1 Coho Salmon

This section presents the effects analysis approach and findings. A detailed account of the species, including regulatory status, critical habitat, life history, geographic distribution, population trends, threats, and status of populations and critical habitat in the Action Area is provided in Appendix G.

5.1.1 Effects Analysis Approach

The Proposed Action will have result in many benefits to coho salmon through restoration and access to historic habitat, improvement in water quality conditions, and reestablishment of sediment transport below through the former reservoir and dam sites. While the Proposed Action will result in restored salmonid habitat, the process to change lentic to lotic habitat will result in impacts to coho salmon. The majority of anticipated adverse impacts on SONCC coho salmon populations in the Action Area are related to short-term increases in SSCs during and following the drawdown of the Hydroelectric Reach reservoirs. The suspended sediment effects analysis approach is described in detail below.

[5] The Proposed Action does not include improvements at Keno Dam or Link River Dam.

Coho salmon could also be affected in the short term by in-water construction activities at the base of and downstream of Iron Gate Dam prior to drawdown, as well as by dam deconstruction itself. These construction activities have the potential to result in direct harm, noise, and water quality and sedimentation effects. Potential impacts from other associated construction activities, including fish rescue and relocation and restoration activities, in the newly restored habitats upstream of Iron Gate Dam are also considered in the effects analysis. Long-term effects of the Proposed Action on coho salmon include effects related to habitat connectivity, water quality, and hatchery modification and operations.

The analysis of effects on coho salmon critical habitat is a habitat-based assessment that estimates the effect of the Proposed Action on substrate and sediment levels, water quality conditions, and other general conditions of watersheds that support the biological and ecological requirements of the species. The effects of the Proposed Action are overlaid on the environmental baseline (Chapter 4 describes the physical and chemical environment and Appendix G describes the biological environment) and combined with cumulative effects (Chapter 6) to determine if the Proposed Action is or is not reasonably likely to destroy or adversely modify the value of constituent elements essential to the conservation of SONCC coho salmon in the Action Area. Different areas and features of critical habitat will have varying roles in the recovery of natural, self-sustaining salmon populations. For example, tributary streams provide a significantly greater amount of juvenile coho summer and winter areas and adult spawning habitat than do mainstem rivers. However, mainstem rivers are critical as migratory routes for coho smolts migrating to the ocean and for adults moving upstream to spawn. Therefore, the final step in the critical habitat effects analysis is whether, with implementation of the Proposed Action, critical habitat will remain functional to serve the intended conservation role for the SONCC coho salmon ESU, or retain its current ability to establish those features and functions essential to the conservation of the species.

5.1.1.1 Suspended Sediment Effects Analysis Approach

The suspended sediment effects analyses completed by the Renewal Corporation are based on sediment modeling output provided by USBR (2011b). The updated modeling represents a revised drawdown scenario proposed by the Renewal Corporation (Appendix I), which was then incorporated into the USBR's previously developed SRH-1D 2.4 sediment transport model (Sedimentation and River Hydraulics, One Dimension Version 2.4) (Huang and Greimann 2010, USBR 2011b), hereafter referred to as "the model." The model assesses the predicted SSCs associated with background conditions and the Proposed Action reservoir drawdown and dam removal. Historical suspended sediment data for the Klamath River upstream and downstream of Iron Gate Dam (summarized in 2012 EIS/EIR, Section 3.2.3 [Water Quality]) were determined to be insufficient for conducting an analysis of suspended sediment effects under existing and proposed conditions. To compensate for this limitation, USBR developed the model using suspended sediment data collected by the USGS at the (1) Shasta River near Yreka, (2) Klamath River near Orleans, and (3) Klamath River at Klamath gages to estimate daily SSCs (in milligrams per liter [mg/L]) as a function of discharge (cfs) recoded at various gages on the Klamath River. Daily SSCs were modeled for water years 1961 through 2008 to represent background conditions, as well as for the year following removal of the dams under multiple drawdown scenarios (USBR 2011b). In 2020, USBR ran an additional drawdown scenario as an update to the model, which included Renewal Corporation's updated proposed reservoir drawdown plan (Appendix I). Suspended sediment modeling results were reported for four USGS gaging stations, including Iron Gate, Seiad Valley, Orleans, and Klamath (see Figure 5-1). SSC data are reported in reference to each of the four stations.

SSCs were modeled for each day between November 1, 2019 and September 30, 2021, for all water years between 1961 and 2008 for both the dams-in-place scenario (background conditions) and the reservoir drawdown and dam removal scenario (Proposed Action). Figure 5-2 through Figure 5-4 show the SSC modeling results for the Iron Gate, Seiad Valley, and Orleans streamflow gages, respectively. This 48-year hydroperiod is representative of current conditions for peak flows and yearly floods because the operation of the Klamath Project (see Section 4.2) does not impact high flow conditions. Furthermore, a comparison of the 1961 to 2018 hydroperiod was developed from the USGS gaging stations, which shows that the magnitude, shape, and timing of the hydroperiods have been generally consistent during the selected hydroperiod (Figure 5-5).

The results of modeling all potential years from the 1961 to 2008 hydroperiod were summarized by day for each life-stage period of focal fish species in the Klamath River. Because SSCs vary with hydrology, the Renewal Corporation used an SSC exposure–duration analysis to predict the potential impacts of reservoir drawdown on the focal species for each year within the 48-year hydroperiod. The Renewal Corporation's analysis bracketed the range of anticipated SSC impacts to focal species from the Proposed Action. The Renewal Corporation then prepared a more detailed description and analysis for two representative years within the 48-year record that include the calculated median and most severe impact years for the focal species.

Determining the representative impact years and assessing the potential effects of suspended sediment on anadromous fish species required identifying the spatial and temporal distribution of each life stage in the Klamath Basin relative to expected areas of elevated suspended sediment. For each life stage of the focal species, potential effects were determined by evaluating the magnitude and duration of SSCs predicted by the model for the mainstem Klamath River at times and locations where each life stage is likely to be present. To determine the potential effects of suspended sediment exposure to coho salmon life stages, the Renewal Corporation reviewed recent fisheries literature and data for Klamath Basin coho salmon. Coho salmon life stages, period of use, and presence in the mainstem Klamath River are presented in Table 5-3.

Table 5-3: Coho Salmon Period of Use by Life Stage, Date, and Duration in the Mainstem Klamath River

Period of Use	Life Stage Analyzed	Date Window	Duration
Upstream Migration	Adults	9/1 – 1/1	14 days
Spawning and Incubation	Adults, Eggs	11/1 – 3/14	60 days
Summer Rearing	Age-0+ juveniles	3/15 – 11/15	20 days
Winter Rearing	Age-1+ juveniles	11/15 – 2/14	20 days
Spring Outmigration	Age-1+ juveniles	2/15 – 6/30	14 days

Because upstream migration rate data for adult coho salmon in the Klamath River is limited, upstream migration rates of adult salmonids from other basins were examined. Jepson et al. (2015) found that in the mainstem Willamette River, two separate groups of tributary spawning coho salmon had median migration rates of 13.7 and 15.5 miles/day while ascending the mainstem river. Based on 2,463 calculated migration rates for Chinook salmon, median upstream migration rates in riverine habitats of the Columbia Basin ranged from 6.2 to 18.6 miles/day depending on river and reach (Keefer et al. 2004). Based on an upstream migration rate of 12.4 miles/day, upstream migrating coho salmon could ascend the 149 river miles from the Trinity River confluence to Iron Gate Dam in 12 days. Because most coho salmon are distributed in the lower Klamath Basin, the Renewal Corporation expects adult coho will spend less than 2 weeks in the mainstem Klamath River to reach their preferred spawning tributaries. For the purpose of this analysis, the Renewal Corporation assumed that upstream migrating adult coho salmon will be exposed to elevated SSCs under the Proposed Action for 14 days based on typical upstream migration rates for anadromous salmonids in other systems.

If adult coho salmon encounter adverse water quality conditions during their upstream spawning migration, fish may use clear water tributaries as refugia, minimizing exposure to turbid water. In some cases, adult coho salmon may enter and spawn in non-natal tributaries, as occurred with some Chinook salmon during the Elwha River dam removals (Liermann et al. 2017). Additionally, 14-day exposure periods may be a conservative estimate, because modeled SSCs are predicted to cause impaired homing or major stress from mid-November to January, when most adult coho salmon will likely be in close proximity to spawning sites.

The Renewal Corporation completed a review of literature related to SSC exposure duration for spawning, incubation, and emergence life stages. Coho salmon eggs deposited in mainstem Klamath River redds will be subjected to elevated SSCs for approximately 38 to 48 days. Subsequently, hatched alevin and developed fry will be subjected to elevated SSCs for several more weeks to months. Therefore, coho salmon redds constructed prior to reservoir drawdown will be subjected to SSCs that are expected to result in nearly 100 percent mortality of eggs, alevin, and fry.

To determine the duration of time in which juvenile coho salmon may need to rear in the mainstem Klamath River or use the Klamath River as a migration corridor, the Renewal Corporation reviewed the passive integrated transponder (PIT) tag detections of juvenile coho salmon at monitoring sites during summer (May 1 to August 31) and winter (November 1 to January 31), as described in Manhard et al. (2018). The Renewal Corporation calculated mainstem travel/residency times for age-0+ coho salmon (Table 5-4). Based on median travel times from Iron Gate Dam to the Klamath River estuary of 11.7 days in the summer and 18.9 days in the winter, the Renewal Corporation used a conservative mainstem exposure duration time of 20 days for both summer and winter age-0+ coho salmon. One PIT-tagged age-0+ coho salmon traveled 176.4 river miles between the Shasta River and Waukell Creek in 24.5 days during summer. During this migration, there will likely be other tributaries, confluence areas, or off-channel habitats with acceptable water quality for juvenile coho salmon to use to avoid poor mainstem water quality conditions.

Table 5-4: Klamath River Mainstem Residence Times (Days) and Distance Traveled (Miles) by PIT-Tagged Juvenile Coho Salmon During Summer and Winter Redistribution Periods

Statistic	Summer Redistribution (May 1 – August 31)	Winter Redistribution (November 1 – January 31)
(n)	41	161
Min (days)	2.0	1.8
Max (days)	62.9	53.3
Median (days)	11.7	18.9
Min (distance – miles)	7.3	4.0
Max (distance – miles)	176.4	148.4
Median (distance – miles)	48.0	71.8

To describe the potential effects of elevated SSCs on outmigrating juvenile salmonids, the Renewal Corporation reviewed past studies to analyze Klamath River juvenile salmonid outmigration rates and timing. Past Klamath River studies found juvenile salmonid outmigration rates are influenced by tributary and Klamath River water temperatures, smolt growth rates, and other environmental cues. Wallace (2004) reported coho salmon smolts in the Klamath River estuary peaked in May, the same month as peak juvenile coho salmon outmigration from Klamath River tributaries (Stillwater Sciences 2010). Radio telemetry studies conducted on wild and hatchery coho salmon smolts in the Klamath River between 2006 and 2009 found a wide range of travel times for coho salmon smolts outmigrating from Iron Gate Dam to the gaging station near the Klamath River estuary (Beeman et al. 2012). The minimum and maximum travel times were 3.8 and 54.4 days, respectively, with median values over the 4-year study ranging between 15.1 and 25.9 days. However, the longest residence time for any single reach was from the Iron Gate Dam release site to the Shasta River, as tagged fish remained near the release site until they were ready to begin the downstream migration to the Klamath River estuary. Once fish passed the Shasta River, travel times in any individual reach were less than 2 days, and coho salmon smolts usually took less than 1 week to migrate to the Klamath River estuary (Beeman et al. 2012). Courter et al. (2008) estimated that all fish from a given cohort will migrate to the estuary in 2 weeks. This prediction is consistent with coho salmon smolt travel rates documented by Stutzer et al. (2006). Based on the literature review, a 14-day outmigration period is believed to be a conservative estimate for juvenile salmon outmigration on the Klamath River. Although outmigrating age-1+ coho salmon will be exposed to elevated SSCs, outmigrants will also have access to clean water sources such as clear water tributary confluences, off-channel ponds and tributaries, and spring seeps, reducing exposure times. Additionally, SSCs will be substantially diluted in a downstream direction by tributary accretion, including the Trinity River (RM 43.4).

To determine SSC exposure, the Renewal Corporation used USBR's daily SSC modeling results to calculate the median SSC value for each duration period during the windows of use for each life stage for each of the 48 years within the modeled hydroperiod. For example, for each 14-day period during the adult upstream migration period (September 1 to January 1), the median SSC was calculated to represent the sustained exposure concentration for that 14-day period. The range of SSCs over the period of use window represents all of the concentrations to which adult coho could be exposed under different river entry timing. For example, an adult coho salmon that enters the Klamath River during the middle of October, prior to reservoir drawdown, will be exposed to a median SSC of 2 mg/L for a duration of 14 days, whereas an adult coho salmon that enters the river in the middle of December will be exposed to an SSC of 86 mg/L for a duration of 14 days. Using the median SSC for the 14-day exposure period likely represents a moderate condition because the median SSC value represents the midpoint SSC for that exposure period. Using the median SSC value may overestimate the anticipated SSC effects on salmonids because, with the exception of extremely high concentrations of suspended sediment, the exposure duration appears to influence the severity of the effects more than the SSC concentration.

To refine the evaluation of potential effects of SSC exposure on the different populations of listed coho salmon residing in the Klamath Basin, the Renewal Corporation used the modeled SSC values from stations at Iron Gate, Seiad Valley, and Orleans. Figure 5-6 illustrates the geographic designations of the nine populations of coho salmon in the Klamath Basin, the location of USGS stations for which modeled SSC results are available, and the locations of select screw traps used to determine the outmigration timing for juvenile coho salmon from each population. Table 5-5 contains the location of SSC model results used to determine the exposure concentration for each population of listed coho salmon and the corresponding exposure duration in days for each life stage.

Table 5-5: Coho Populations with Corresponding SSC Stations and Exposure Times (days) by Life Stage

SONCC Population(s)	Modeled SSC Station	Life Stage / History	# of Exposure Days
Upper Klamath River, Shasta River	Iron Gate Dam	Adult Migration	14
		Summer Rearing	20
		Winter Rearing	20
		Juvenile Outmigration	14
Scott River, Middle Klamath River	Seiad Valley	Adult Migration	14
		Summer Rearing	20
		Winter Rearing	20
		Juvenile Outmigration	14
Salmon River, Lower Klamath River, Lower Trinity River, Upper Trinity River, South Fork Trinity River	Orleans	Adult Migration	14
		Summer Rearing	20
		Winter Rearing	20
		Juvenile Outmigration	14

Based on a literature review, the most commonly observed effects of suspended sediment on fish include (1) avoidance of turbid waters in homing adult anadromous salmonids; (2) avoidance or alarm reactions by juvenile salmonids; (3) displacement of juvenile salmonids; (4) reduced feeding and growth; (5) physiological stress and respiratory impairment; (6) damage to gills; (7) reduced tolerance to disease and toxicants; (8) reduced survival; and (9) direct mortality (Newcombe and Jensen 1996). Information on both concentration and exposure duration is necessary to understand the potential severity of suspended sediment effects on salmonids (Newcombe and MacDonald 1991).

With an understanding of anticipated SSCs in the Klamath River and coho salmon life-stage travel times and concomitant SSC exposure durations, the Newcombe and Jensen (1996) method was used to assess impacts of SSC on coho salmon. Newcombe and Jensen (1996) reviewed and synthesized 80 published reports of fish responses to suspended sediment in streams and estuaries, and established a set of equations to calculate “severity of ill effect” indices (Table 5-6) for various species and life stages based on the duration of exposure and concentration of suspended sediment present. The severity of ill effects provides a ranking of the effects of SSC on salmonid species, as calculated by any of six equations that address various taxonomic groups of fishes, life stages of species in those groups, and particle sizes of suspended sediments.

For coho salmon, the Renewal Corporation used the equations derived for adult and juvenile salmonids to predict the SEV (severity) indices (0 to 14) for each combination of median SSC value and exposure duration. Newcombe and Jensen’s severity of ill effects was used to rate the severity of exposure to suspended sediment.

Table 5-6: Scale of the Severity of Ill Effects Associated with Elevated SSCs Based on Newcombe and Jensen (1996)

<table>
<tr><th>Severity</th><th>Category of Effect</th><th>Description of Effect</th></tr>
<tr><td>0</td><td>Nil effect</td><td>No behavioral effects</td></tr>
<tr><td>1</td><td rowspan="3">Behavioral effects</td><td>Alarm reaction</td></tr>
<tr><td>2</td><td>Abandonment of cover</td></tr>
<tr><td>3</td><td>Avoidance response</td></tr>
<tr><td>4</td><td rowspan="5">Sublethal effects</td><td>Short-term reduction in feeding rate; short-term reduction in feeding success</td></tr>
<tr><td>5</td><td>Minor physiological stress: increase in rate of coughing, increased respiration rate</td></tr>
<tr><td>6</td><td>Moderate physiological stress</td></tr>
<tr><td>7</td><td>Moderate habitat degradation, impaired homing</td></tr>
<tr><td>8</td><td>Indications of major physiological stress: long-term reduction in feeding rate, Long-term reduction in feeding success, poor condition</td></tr>
<tr><td>9</td><td rowspan="6">Lethal effects</td><td>Reduced growth rate: delayed hatching, reduced fish density</td></tr>
<tr><td>10</td><td>0–20% mortality
Increased predation of affected fish</td></tr>
<tr><td>11</td><td>>20–40% mortality</td></tr>
<tr><td>12</td><td>>40–60% mortality</td></tr>
<tr><td>13</td><td>>60–80% mortality</td></tr>
<tr><td>14</td><td>>80–100% mortality</td></tr>
</table>

The indices used by Newcombe and Jensen have become a standard for selecting management-related turbidity and suspended sediment criteria (e.g., Walters et al. 2001), and the Newcombe and Jensen study remains the best available source for estimating SSC effects on salmonids (Berry et al. 2003). However, there are inherent sources of uncertainty in this application of the model. Newcombe and Jensen base much of their analysis on laboratory studies that were conducted in controlled environments over short durations, mostly examining acute lethal impacts of non-fluctuating SSCs. The current analysis is a relatively complex application of the Newcombe and Jensen (1996) model in that temporal variation in SSC within periods is captured by summing continuous days of exposure in various concentration categories of suspended sediment. How coho salmon will actually respond to elevated SSCs is uncertain. In addition, Newcombe and Jensen do not explicitly address the translation of sublethal severity levels into population-level effects. The model also assumes that all suspended sediment effects are negative. This framework exaggerates the effects of suspended sediment on aquatic organisms, particularly for lower SSCs and exposure durations.

Predictions of mortality at high SSCs and exposure durations are considered more certain than the predictions of sublethal effects. For the current application of the Newcombe and Jensen framework, sublethal effects resulting from exposure to lower concentrations are also important to consider because sublethal SSC impacts may be magnified when sublethal concentrations occur in conjunction with the already stressed condition of some species and life stages from water temperature (Bozek and Young 1994) and disease.

To determine the range of expected impacts related to high SSCs and to identify the representative impact years chosen for further detailed analysis, the Renewal Corporation used the daily modeled SSCs from the Seiad Valley station to determine the median SSC value for each coho salmon life stage time block and then calculated the resulting SEV score by applying the specified exposure duration to each median SSC value based on the life stage period of use (summer rearing, juvenile outmigration, etc.). The calculated SEV indices were then considered to result in potential mortality to the species when the value equals or exceeds a score of 9.5. Calculated SEVs of less than 9.5 are expected to result in only sublethal effects for the purpose of this analysis.

To evaluate the level of impacts that may occur in a given water year under the Proposed Action, each SEV score of 9.5 or greater that occurred within the defined life stage period for coho salmon was summed to produce a total SEV score for each year within the modeled hydroperiod. The summed SEV scores were then ranked in order from smallest to largest, with the highest single total SEV score representing the most severe impact year within the 48-year hydroperiod. Because there are an even number of records in the hydroperiod, there are two median values. To account for this factor, the Renewal Corporation chose the year with the highest SEV score of the middle 2 years to represent the median impact year. For coho salmon, the median impact year is represented by the 1991 water year and the most severe impact year is represented by the 1970 water year.

5.1.1.2 Dissolved Oxygen Effects Analysis Approach

The Renewal Corporation analyzed the short-term effects of the Proposed Action on dissolved oxygen levels and applied the previous long-term effects analysis presented in the 2012 Biological Assessment (USBR

2012b). The Renewal Corporation updated an existing numerical model (Greimann 2010, Stillwater Sciences 2011) to predict short-term dissolved oxygen levels in the Klamath River downstream of Iron Gate Dam. Dissolved oxygen levels are expected to be impacted by the short-term immediate oxygen demand (IOD) associated with the rapid depletion of water column dissolved oxygen caused by the release or resuspension of anoxic sediments due to reduced metals and chemicals in the sediments (Stillwater Sciences 2011). Biological oxygen demand (BOD) refers to the amount of oxygen needed by aquatic microbes to metabolize organic matter and oxidize ammonia reduced nitrogen species, as well as to oxidize reduced mineral species such as ferrous iron (Stillwater Sciences 2011). While IOD exerts short-term pressure on dissolved oxygen concentrations, BOD is typically exerted more slowly over time.

The one-dimensional, steady-state spreadsheet model uses an approach similar in concept to the Streeter and Phelps (1925) dissolved oxygen-sag equation to incorporate the oxygen-demand offsets of tributary dilution and reaeration in evaluating the different short-term oxygen demand parameters (e.g., IOD and BOD). The dissolved oxygen spreadsheet model also includes chemical oxygen demand generated from the conversion of ammonium and other nitrogenous compounds in reservoir sediments to nitrate under anoxic conditions (i.e., when dissolved oxygen levels are 0 mg/L or greater). This is termed nitrogenous oxygen demand and is inherently included in the oxygen demand rate constants used in the dissolved oxygen spreadsheet model (Stillwater Sciences 2011).

The spreadsheet model input parameters are represented by boundary conditions at Iron Gate Dam as well as other inputs downstream of Iron Gate Dam. Boundary condition inputs include BOD and IOD, initial oxygen saturation, flow, SSCs, and water temperature. Flow, SSCs, and water temperature data are also included for other downstream model nodes to represent the influence of tributary dilution. Tributary dilution factors were updated based on HEC-RAS model output developed to simulate the Renewal Corporation's revised drawdown scenario (Appendix I). The dilution ratios for each month for each tributary are calculated as the total tributary inflow for the month divided by the total mainstream flow volume downstream of the tributary confluence during the first water year of dam removal.

BOD and IOD are predicted in the spreadsheet model using empirically derived oxygen depletion rates for a particular SSC based on laboratory incubations conducted under the Klamath Dam Removal Secretarial Determination oxygen demand study (Stillwater Sciences 2011). Initial oxygen concentrations are based on either high initial saturation conditions (80 percent saturation) or low initial saturation conditions (0 percent saturation). The Renewal Corporation used 80 percent saturation as a conservative but reasonable estimate for high saturation conditions based on PacifiCorp sonde data for existing conditions (PacifiCorp 2009, 2018b) and Karuk Tribe (https://waterquality.karuk.us:8080/) data collected downstream of Iron Gate Dam. Because the IOD/BOD model results are sensitive to initial dissolved oxygen concentrations (Stillwater Sciences 2011), and because initial percent saturation is uncertain during drawdown conditions where SSCs and IOD/BOD generated from J.C. Boyle and Copco drawdowns may reduce initial dissolved oxygen concentrations, the Renewal Corporation also simulated 0 percent saturation initial conditions in the model to represent worst-case initial conditions. The results bracket the range of dissolved oxygen conditions that could be expected in the Klamath River downstream of Iron Gate dam during the reservoir drawdown.

Flow and suspended sediment data are based on hydrology and sediment model outputs completed for the proposed reservoir drawdown scenario (Appendix I). SSC input to the model used the SRH-1D mean daily SSC at Iron Gate for the revised drawdown scenario and followed the methodology described in Stillwater Sciences (2011). For each month, the peak mean daily SSC value was identified and used to calculated initial IOD/BOD for the model. The mean daily discharge on the same day of each peak SSC was used as the mainstem discharge input to the model. Water temperatures were unchanged from the Stillwater Sciences (2011) model and are monthly averages derived from a HEC5Q water temperature model (Bartholow et al 2005).

Oxygen depletion rates are scaled to the level of suspended sediments expected under median impact year and severe impact year scenarios developed for juvenile coho salmon (1991 and 1970, respectively) and Chinook salmon (1991 and 1973, respectively) based on the USBR hydrology and sediment transport model updated for the revised drawdown (USBR 2011b, Appendix I). Model output was synthesized for the peak daily SSC value for each month from October prior to the drawdown year through September of the drawdown year. Summary output includes anticipated minimum dissolved oxygen levels and the location, extent, and duration of anoxic conditions.

The Renewal Corporation used dissolved oxygen thresholds of 7mg/L and 5 mg/ to determine the potential downstream distances of dissolved oxygen impairment that will be expected under each impact year scenario and for each initial dissolved oxygen saturation scenario. NMFS suggested 7 mg/L as a dissolved oxygen concentration that has minimal impairment on aquatic habitat for salmonids. Laboratory studies have demonstrated that dissolved oxygen concentrations of 7.0 mg/L or greater result in little to no population impairment for salmonids (Carter 2005, EPA 1986, Davis 1975). The Renewal Corporation also presented the 5 mg/L dissolved oxygen threshold to provide consistency with previous Klamath River dam removal dissolved oxygen analyses (Stillwater Sciences 2011, USBR 2012b, SWRCB 2020a) that used 5 mg/L as a minimum value below which short-term fish effects are likely to be acute and may cause mortality (Stillwater Sciences 2011).

5.1.1.3 Bedload Deposition Effects Analysis Approach

The Renewal Corporation analyzed SRH-1D bed sediment and bedload modeling output provided by USBR to assess bedload sediment transport and deposition associated with the Proposed Action. Updated modeling output reflects the Proposed Action’s drawdown approach and schedule, which results in a slower average drawdown rate and later reservoir sediment evacuation in the Hydroelectric Reach reservoirs then previously modeled by USBR (2012a).

In SRH-1D, USBR dam removal simulations were divided into two modeling domains: the Hydroelectric Reach or “US Reach” from Keno Dam to approximately 0.5 miles downstream of Iron Gate Dam, and the downstream reach or “DS Reach” from below Iron Gate Dam to the mouth of the Klamath River. The geometry for the SRH-1D models was from their respective HEC-RAS models (USBR 2011a). A full description of the model is provided in USBR (2011a). For some analyses, the Renewal Corporation analyzed the results by subreach, as defined by dam locations and the upstream limits of reservoirs in the US Reach, and by major tributary confluences in the DS Reach. The SRH-1D modeling output is in monthly and 28-day timesteps for the DS Reach and US Reach, respectively, both covering a period of two water years beginning on October 1 of the pre-drawdown year and ending on September 30 in the post-drawdown year.

The Renewal Corporation replicated the analyses presented in the 2020 Final EIR (SWRCB 2020a) and the Final Biological Assessment (USBR 2012b), which analyzed SRH-1D model output for Scenario 8, the selected dam removal scenario included in the Detailed Plan (USBR 2012a). The Renewal Corporation selected data from three representative water years (1976, 1984, 2001) to represent median, wet, and dry hydrologic conditions, respectively. The representative years are the same years analyzed by USBR (2012a) for the Detailed Plan and in the 2018 EIR (SWRCB 2018).

The Renewal Corporation analyzed SRH-1D bed elevation and sediment thickness as well as sediment texture output data for reference locations over monthly time steps for the three representative water years. Output data included reach-averaged changes in channel bed elevation and sediment thickness, and sediment texture.

5.1.2 Short-Term Effects

Reservoir drawdown and construction-related activities associated with dam removal are expected to result in take of coho salmon in the short term. Restoration actions will begin in the year dam removal occurs; however, minimization measures will be implemented, as described in the conservation measures and appended management plans that will help reduce the extent of take. Effects associated with reservoir drawdown (i.e., SSC and dissolved oxygen impacts) will affect all populations of coho salmon, while the other short-term effects associated with dam removal, construction, and restoration will primarily be limited to individuals from the Upper Klamath population. **Therefore, the Proposed Action is likely to adversely affect coho salmon from the Upper Klamath River, Shasta River, Scott River, Salmon River, Lower Klamath River, Upper Trinity River, Lower Trinity River, and South Fork Trinity River population units in the short term.**

The following sections describe short-term effects of the Proposed Action on coho salmon.

5.1.2.1 In-Water Construction Activities

In-water construction activities that have the potential to affect coho salmon include pre-drawdown construction on the downstream side of Iron Gate Dam and at Lakeview Road bridge. Replacement of the City of Yreka water supply pipeline will occur prior to drawdown upstream of Iron Gate Reservoir and will therefore not affect coho salmon.

Following drawdown, dam removal construction activities that have the potential to affect coho salmon include demolition and blasting activities associated with removal of Iron Gate Dam facilities; embankment removal, disposal, and final breach; and final channel grading. Because coho salmon will be excluded from work zones upstream of Iron Gate Dam until the final dam breach and because the other dams in the Hydroelectric Reach will be deconstructed during the same period as the work at Iron Gate Dam, this analysis focuses on effects of the work at Iron Gate Dam. Dam removal activities will conclude with the creation of a volitional fish passage channel at each dam site, allowing fish to access and use the historical habitat upstream of each dam.

Restoration actions and fish passage monitoring and maintenance activities, including those associated with management plans (see Appendix C and D) and conservation measures (Section 2.6), are described in BA sections that follow this discussion of initial in-water construction activities.

Pre-Drawdown Construction at Iron Gate Dam

Between July and December of the year before drawdown, the Renewal Corporation will undertake several pre-drawdown construction activities in the vicinity of Iron Gate Dam that are necessary to facilitate the controlled drawdown of Iron Gate Reservoir, scheduled to commence on January 1 of Year 1. These construction activities are described in Section 2.3.4.2 and include the following in-water work that could potentially affect coho salmon in the short term:

- Construction of an access road from the right bank across to the fish collection facilities could cause direct harm and short-term increased SSCs downstream of Iron Gate Dam.
- Construction of a work pad on the upstream side of Iron Gate Dam on the right bank of the reservoir to allow access to the gate house could cause short-term increased SSCs downstream of Iron Gate Dam.
- Construction of a temporary bridge adjacent to Lakeview Road could cause direct harm and short-term increased SSCs downstream of Iron Gate Dam.
- Installation of tunnel outlet erosion protection measures (e.g., armoring the existing left bank access road) could cause direct harm and short-term increased SSCs downstream of Iron Gate Dam.
- Removal of temporary access roads could cause direct harm and short-term increased SSCs downstream of Iron Gate Dam.

Access Road and Work Pad Construction

Pre-drawdown construction work is proposed to begin in July of the year before drawdown with the installation of a temporary work pad and two access roads at the base of Iron Gate Dam to complete required modifications to the dam diversion tunnel outlet. The left bank access road will use the existing access to the powerhouse and fish facilities and will require the decommissioning of three adult holding ponds and the installation of a small temporary bridge to cross the fish ladder. The right bank access road will provide access from the existing operator’s residences and extend upstream across the spillway outlet. The access road will be constructed during the low-flow months of the in-river work period. Approximately 1,500 cy of rock fill material will be placed in the wetted channel of the Klamath River over approximately 10 days in July of the year before drawdown. Fill material used for tunnel access will be removed from the river once tunnel modifications have been completed prior to reservoir drawdown. Material will be removed from the river between December 15 of the year before drawdown and January 1 of the drawdown year.

Due to high water temperatures that occur in the mainstem Klamath River in the vicinity of Iron Gate Dam during summer, no coho salmon adults, redds, or juveniles are expected to be present in the vicinity of Iron Gate Dam during July through September, and they therefore will not be affected by the construction of temporary access roads, work pad, and crane platform.

Temporary Lakeview Road Bridge Construction

Beginning in July, the Renewal Corporation will construct a temporary bridge downstream of the existing Lakeview Road bridge to facilitate heavy truck loads for construction-related activities. Temporary approaches to the bridge will extend approximately 25 feet into the river footprint as rockfill embankments, with a single-span steel bridge placed on slabs on the embankments. The temporary bridge abutments will be rock fill with pre-cast or cast-in-place concrete abutments supported by a cast-in-place dynamic slab and a rock fill bench. In-water placement of fill and cast-in-place concrete pours will take place within the in-water work window starting in July and take approximately 4 weeks to complete the bridge construction.

The temporary bridge will remain in place for the duration of construction; after construction is completed, the Renewal Corporation will remove the temporary bridge, leaving the existing bridge in place. Due to high water temperatures that occur in the mainstem Klamath River in the vicinity of Iron Gate dam in summer, no coho salmon adults, redds, or juveniles are expected to be present in the vicinity of the Lakeview Road bridge during July, and therefore, will not be affected by the construction of the temporary bridge.

Removal of Access Roads

Removal of temporary access roads downstream of Iron Gate Dam will take place beginning in mid-December and take approximately 10 days to complete. In mid-December, few juvenile coho salmon will be expected to be present in the mainstem Klamath River as increasing river discharge triggers overwintering coho salmon to migrate into off-channel habitats and tributary streams. Any juvenile coho remaining in the mainstem after December 15 are expected to be located downstream of Bogus Creek and other natal spawning tributaries. Additionally, the implementation of the Aquatic Resource Measure Outmigrating Juveniles Action 1 is intended to further reduce the number of juvenile coho salmon remaining in the mainstem prior to drawdown. The implementation of in-water work BMPs will minimize turbidity and will exclude any juvenile coho salmon that are within proximity to the work site prior to in-water excavation.

Any adult coho salmon or redds present near the base of Iron Gate Dam could be affected by direct harm from in-water excavation or from increased levels of SSCs generated by disturbances related to in-water work. Adult migrating coho salmon will likely volitionally move downstream and enter tributaries such as Bogus Creek prior to spawning, and any adult hatchery-produced coho salmon will be able to volitionally leave the work area and enter the hatchery facility through the auxiliary fish ladder. Any redds constructed in the immediate vicinity of Iron Gate Dam could also be affected, although the complete mortality of any coho salmon redds constructed in the mainstem immediately downstream of the dam is expected to occur following the beginning of reservoir drawdown on January 1.

Summary of Pre-Drawdown Construction Effects

During the summer, juvenile coho salmon, including age-1+ smolts and age-0+ fry and parr, are expected to be in tributary streams or limited to thermal refugia sites along the mainstem Klamath River located further downstream, and are not expected to be within the vicinity of the Iron Gate Dam work areas during July to September. In mid-late December, few juvenile coho salmon are expected to be in the mainstem Klamath River in the vicinity of Iron Gate Dam as increasing flows trigger the migration of overwintering fish into off-channel habitats and tributary streams. Additionally, the implementation of the Aquatic Resource Measure Outmigrating Juveniles Action 1 is intended to further reduce the number of juvenile coho salmon remaining in the mainstem prior to drawdown. Increased suspended sediment attributed to pre-drawdown in-water work is expected to be localized, short-term in duration, and minimized by the implementation of in-water work BMPs (i.e., from the SWRCB and ODEQ Clean Water Act Section 401 Water Quality Certifications [SWRCB 2020b and ODEQ 2018, respectively]).

Any adult coho salmon attempting to migrate to the Iron Gate fish ladder after mid-December of the year before drawdown and any redds constructed in the mainstem Klamath River immediately below the dam in the fall of the year before drawdown could be affected by pre-drawdown construction activities through direct harm and increases in SSCs downstream of the Iron Gate Dam work areas. These impacts are expected to be limited to a small number of adult coho salmon from the Upper Klamath River population that migrate and spawn near Iron Gate Dam and are likely to be hatchery-origin due to the proximity to the Iron Gate Fish Hatchery (USBR and CDFW 2012). Other populations of coho salmon are distributed in tributaries downstream of and including the Shasta River and will not be affected by pre-drawdown construction activities.

Post-Drawdown Construction at Iron Gate Dam

Following the completion of drawdown, activities necessary to remove Iron Gate Dam and associated infrastructure will take place primarily between March 15 and October 15 of the drawdown year. These activities will involve the decommissioning or removal of all facility components, as well as site restoration of the dam footprint to facilitate volitional fish passage upstream of Iron Gate Dam. Post-drawdown construction activities at Iron Gate Dam are described in detail in Section 2.3.4.4, and include the following in-water work components that have the potential to affect coho salmon in the short term:

- Powerhouse, penstock, and fish facility removal will be conducted in the dry but could cause direct harm due to noise and vibration.
- Embankment removal, disposal, and cofferdam breach could cause direct harm and short-term increased SSCs downstream of Iron Gate Dam.
- Volitional fish passage channel grading could cause direct harm and short-term increased SSCs downstream of Iron Gate Dam.

Powerhouse, Penstock, and Fish Facility Removal

Iron Gate Dam embankment excavation and fish facility, penstock, and powerhouse demolition are scheduled to occur following completion of drawdown. As described previously, the reservoir will be drawn down through the diversion tunnel, which will continue to direct the Klamath River around the embankment removal area until the final cofferdam breach, with a target of early October in the drawdown year.

The Renewal Corporation will begin out-of-water demolition to remove the powerhouse, penstock, and remaining fish facilities in April of the drawdown year, and these activities will be completed by the end of August of the drawdown year. During this time, the Renewal Corporation will excavate the reinforced concrete in deck, wall, and floor slabs in any structures to be removed by mechanical methods (including intake structures, control structures, fish handling facilities, and powerhouse). Blasting might be required to remove the fish-holding ponds at the base of the dam. If blasting is required at this location, it will likely occur in August, and it could take approximately 2 weeks to complete removal of the holding ponds. This work is expected to take place in the dry, and therefore will not directly impact any life stage of coho salmon. However, noise and vibration from demolition and blasting activities have the potential to affect life stages of coho salmon present in or near vicinity the Iron Gate Dam.

When demolition activities commence, SSCs in the Klamath River below Iron Gate Dam will still be elevated compared to background levels, especially directly below Iron Gate Dam, where tributary inputs and dilution are low (Figure 5-2). It is likely that juvenile coho salmon using the mainstem Klamath River in the spring and early summer of the drawdown year will avoid the area directly below Iron Gate Dam and will move rapidly downstream after entering the Klamath River from tributaries such as Bogus Creek. No adult coho salmon will be present near the base of Iron Gate Dam during the April-to-August timeframe.

Embankment Removal, Disposal, and Breach

The Renewal Corporation expects that dam embankment excavation will begin on or about July 1 of the drawdown year and will be completed by early October of that year. Excavation of the embankment fill will mostly occur in the dry, and fill will be spoiled primarily into two main locations: the Iron Gate spillway and a disposal site on the left bank of the new river channel upstream and downstream of the dam embankment (disposal site #1). Additional disposal sites, including one upstream of the left bank disposal site (disposal site #2) and an alternative upland disposal site, may be used if needed. The upland disposal site is on the northeastern slope above the former reservoir from which material was borrowed for dam construction. Additionally, the tailrace area will be filled with concrete rubble and rock. This in-water work to fill in the tailrace area is expected to occur between August and the end of September and will take approximately 10 days to complete.

Disposal site #2 is in a natural drainage landform that will be expected to continue to focus surface runoff toward the river. If the drainage is filled with material from the dam embankment, it could be expected to erode over time until the drainage channels reach a stable state. The input of sediment to the Klamath River from the erosion of this disposal site will be expected to occur over several years and will likely be most prevalent during storm events that already produce high levels of SSC in the Klamath River under existing conditions. As stated in Section 2.3.4.3, this disposal site will be sloped to match the adjacent topography and will be stabilized, minimizing the risk of surface runoff resulting in elevated levels of SSC in the mainstem Klamath River relative to background conditions.

During June, mean monthly SSCs under the background condition are typically around 1 mg/L at the USGS Iron Gate station. Under the Renewal Corporation's modeled drawdown scenario, the mean monthly SSC is 1,830 mg/L, which will likely discourage juvenile coho salmon from moving upstream and entering the work area. However, the excavation and placement of fill in the areas adjacent to the Klamath River near Iron Gate Dam are likely to cause increases in SSCs extending downstream of the dam and could affect juvenile coho that are emigrating downstream or redistributing into tributaries. Filling of the tailrace could also result in direct harm of any coho salmon present near the base of the dam in September of the drawdown year. Beginning in late September of that year, it is possible that adult coho salmon will be migrating upstream to spawn in tributaries of the Klamath River and could be affected by increased levels of SSC associated with the excavation and placement of fill near the base of Iron Gate Dam.

Final Grading and Volitional Fish Passage Channel Construction

Flow rates in the Klamath River are anticipated to decrease (in accordance with the normal hydrologic cycle) through the dam removal period, which will result in the lowest possible reservoir and river levels occurring around the time of the final cofferdam breach in early October of the drawdown year. The remaining embankment will be notched and progressively down-cut to provide a controlled release of the lower portion of the reservoir. A 10 feet to 20 feet-wide breach channel would sufficiently constrict the breach outflows such that the maximum peak outflows do not exceed 7,000 cfs if the final breach is initiated at reservoir water surface elevation at or below 2201 feet (Kiewit 2020). Throughout the final breach, a minimum of 1,000 cfs, or the flow in the Klamath River if it is less than 1,000 cfs at the time, will be maintained. The diversion tunnel will remain open throughout and continue to pass flows. As the water level drops and the capacity of the tunnel is reduced, those flows are augmented by the outflows resulting from the breach formation. At the completion of the final breach, natural flow in the Klamath River will be restored with all flows diverted through the breach channel while the remaining embankment materials in the extended cofferdam are removed (Kiewit 2020).

The final dam breach is expected to cause a rapid increase in SSCs downstream of Iron Gate Dam. Flows are expected to decline rapidly and return to minimum flows within 1 to 3 days of the final breach. During this work, the Renewal Corporation expects that it is less likely that juvenile coho salmon will be present in the reach directly below Iron Gate, but that adult coho salmon may be present. The breach timing is near the early end of the migration period for coho salmon in the mainstem below Iron Gate Dam, and while likely to be in low numbers, any adults present will experience periods of elevated SSCs that may impair homing, cause physiological stress, and potential mortality. If coho salmon redds have been constructed and eggs deposited prior to the breach, the eggs will likely be lost due to the elevated SSC and sediment deposition.

Following the final breach at Iron Gate Dam, the establishment of the volitional fish passage channel will involve riverbed excavation and shaping to ensure future scour and channel migration will not create a fish barrier at the former Iron Gate Dam site. Channel grading and shaping will commence in October following the final embankment breach once minimum flows are established through the project site; the channel work will take approximately 2 weeks to complete. The Renewal Corporation will conduct the grading in the wetted channel, which therefore will cause increased SSCs downstream of Iron Gate Dam, especially in the reach between the dam and the Shasta River, where dilution from tributary inputs is low.

The completed channel will also contain erosion protection material that will be installed prior to the final embankment breach. The rock fill will be placed in-water and could affect coho salmon downstream of Iron Gate Dam through increases in SSCs.

5.1.2.2 Suspended Sediment Concentrations and Dissolved Oxygen Effects Associated with Reservoir Drawdown

The Proposed Action is anticipated to release 1.2 to 2.9 million metric tons of fine sediment stored in the reservoirs into the Klamath River downstream of Iron Gate Dam (USBR 2011a), resulting in higher SSCs than normally occur under background conditions (Figure 5-2). From the beginning of drawdown (beyond normal reservoir elevating levels) on January 1 through October 1 of Year 2, SSCs will begin to increase during reservoir drawdown, prior to the deconstruction of the dams, and continue to rise through the spring runoff period as material behind the dams is mobilized downstream. The Renewal Corporation expects the drawdown of Copco Lake to begin on November 1 of the year before drawdown, in advance of the drawdown of the J.C. Boyle and Iron Gate reservoirs, which are expected to commence on January 1 of the drawdown year (Year 1). Based on the suspended sediment modeling conducted to analyze background conditions and the Proposed Action (USBR 2011b, Appendix I), the Renewal Corporation expects SSCs to exceed 1,000 mg/L for approximately 8 weeks in early Year 1, with the potential for peak concentrations exceeding 5,000 mg/L for several days to up to 2 weeks, depending on the water year. The transport of the suspended sediment load is expected to have lethal and sublethal effects on coho salmon and other native fish species inhabiting the Klamath River in the Hydroelectric Reach and downstream of Iron Gate Dam.

Appendix H presents the predicted effects for the median impact year and the severe impact year scenarios for SSCs on each coho salmon life history stage and cohort to evaluate the likely effects of the Proposed Action on coho salmon populations in the Action Area. Based on the methodology for determining focal species impact years described in Section 5.1.1.1, 1991 was determined to be the median impact year for coho salmon and 1970 was determined to be the severe impact year. In summary, although no single-year class is expected to be lost, all populations in the Action Area are expected to encounter concentrations of suspended sediment under the Proposed Action that are elevated when compared to background conditions and that are likely to cause varying levels of direct mortality, impaired homing, increases in physiological stress, and reduced feeding and growth, all of which could impact the overall fitness and survival of individuals. Table 5-7 includes a summary of anticipated effects to the different life stages and populations of coho salmon in the Action Area for the median and severe impact year scenarios.

Table 5-7: Proposed Action Median Impact Year (MIY) and Severe Impact Year (SIY) Effects Summary for Coho Salmon Life History Stages under Background Conditions, Year 1 (Drawdown Year) and Year 2

Coho Salmon				
Adult Migration (Sep 1– Jan 1)	Spawning Through Fry Emergence (Nov 1 – Mar 14)	Age-0+ Summer Rearing (Mar 15 – Nov 14)	Age-1+ Winter Rearing (Nov 15 – Feb 14)	Early Spring Outmigration (Feb 15 – Jun 30)
Background Conditions				
MIY: SEV 0 – 6 Sublethal effects for all populations **SIY:** SEV 1 – 8 Sublethal effects for all populations	**MIY**: Low survival of redds constructed in mainstem Klamath River **SIY:** Low survival of redds constructed in mainstem Klamath River	**MIY:** SEV 1 – 8 Sublethal effects for all individuals rearing in the mainstem during summer from all populations **SIY:** SEV 2 – 8 Sublethal effects for all individuals rearing in the mainstem during summer from all populations	**MIY:** SEV 3 – 7 Sublethal effects for all individuals rearing in the mainstem during winter from all populations **SIY:** SEV 3 – 9 Sublethal effects for all individuals rearing in the mainstem during winter from all populations	**MIY:** SEV 3 – 8 Sublethal effects for all populations **SIY:** SEV 3 – 8 Sublethal effects for all populations

Coho Salmon				
Adult Migration (Sep 1– Jan 1)	Spawning Through Fry Emergence (Nov 1 – Mar 14)	Age-0+ Summer Rearing (Mar 15 – Nov 14)	Age-1+ Winter Rearing (Nov 15 – Feb 14)	Early Spring Outmigration (Feb 15 – Jun 30)
Year 1 (Drawdown)				
MIY: SEV 7 – 8 Sublethal effects for all populations **SIY:** SEV 7 – 9 Sublethal effects for all populations	**MIY**: Up to 100% mortality of progeny of mainstem spawners (about 13 redds, or 0.7 to 26% of Upper Klamath River Population Unit natural coho run for drawdown year **SIY**: Up to 100% mortality of progeny of mainstem spawners (about 13 redds, or 0.7 to 26% of Upper Klamath River Population Unit natural coho run for drawdown year	**MIY:** SEV 8 – 10 Up to 20% mortality anticipated for juveniles from the UKR, SHR, SCR, and MKR populations rearing in the mainstem during summer and sublethal effects for the SMR, LKR, and TRR populations rearing in the mainstem during summer **SIY:** SEV 7 – 11 Up to 40% mortality anticipated for juveniles from the UKR and SHR populations, and up to 20% mortality of juveniles from the SCR, MKR SMR, LKR, and TRR populations rearing in the mainstem during summer	**MIY:** SEV 7 – 11 Up to 40% mortality anticipated for juveniles from the UKR and SHR populations, and up to 20% mortality of juveniles from the SCR, MKR SMR, LKR, and TRR populations rearing in the mainstem after mid-January **SIY:** SEV 7 – 9 Sublethal effects for all populations	**MIY:** SEV 7 – 10 Up to 20% mortality of juvenile coho salmon smolts outmigrating from all populations. See Appendix H, Table H-21 **SIY**: SEV 8 – 10 Up to 20% mortality of juvenile coho salmon smolts outmigrating from all populations. See Appendix H, Table H-21
Year 2				
MIY: SEV 6 Sublethal effects for all populations **SIY:** SEV 5 Sublethal effects for all populations	**MIY**: Similar to background conditions **SIY:** Similar to background conditions	**MIY:** SEV 6 – 8 Sublethal effects for all individuals rearing in the mainstem during summer from all populations **SIY:** SEV 5 – 8 Sublethal effects for all individuals rearing in the mainstem during summer from all populations	**MIY:** SEV 7 – 8 Sublethal effects for all individuals rearing in the mainstem during winter from all populations **SIY:** SEV 8 – 9 Sublethal effects for all individuals rearing in the mainstem during winter from all populations	**MIY**: SEV 6 – 8 Sublethal effects for all populations **SIY:** SEV 6 – 8 Sublethal effects for all populations

Population Codes: UKR = Upper Klamath River, SHR = Shasta River, SCR = Scott River, MKR = Middle Klamath River, SMR = Salmon River, LKR = Lower Klamath River, TRR = Trinity River populations (Upper Trinity River, Lower Trinity River, South Fork Trinity River)

Dissolved Oxygen

As described in Section 5.1.1.2, BOD and IOD are predicted in a spreadsheet model using empirically derived oxygen depletion rates for a particular SSC based on laboratory incubations conducted under the Klamath Dam Removal Secretarial Determination oxygen demand study (Stillwater Sciences 2011). The dissolved oxygen spreadsheet model was used to assess dissolved oxygen conditions downstream of Iron Gate Dam during reservoir drawdown. Because the model is sensitive to initial dissolved oxygen concentrations, the Renewal Corporation used two initial dissolved oxygen levels for the model boundary condition. Although dissolved oxygen levels may reach 100 percent saturation as flow passes through the Iron Gate Dam outlet tunnel, the Renewal Corporation used 80 percent saturation as a conservative estimate for the High Initial Dissolved Oxygen Scenario. For the Low Initial Dissolved Oxygen Scenario, the Renewal Corporation used 0 percent saturation to account for the unknown effects of high SSCs on flow entering Iron Gate Reservoir from the upstream Copco No. 1 Reservoir drawdown. The Low Initial Dissolved Oxygen Scenario is considered by the Renewal Corporation to be an extreme condition that, with the High Initial Dissolved Oxygen Scenario, provides the full range of impacts that may occur due to depleted dissolved oxygen levels as a result of reservoir drawdown. Results for the Low Dissolved Oxygen Scenario are presented in Appendix H.

Background Condition Model and Proposed Action Model Boundary Conditions

Under background conditions, dissolved oxygen concentrations remain above 7 mg/L under the coho salmon median impact year (1991) and severe impact year (1970) scenarios except in July and August, when background conditions average monthly water temperatures exceed 19 °C, resulting in low initial condition dissolved oxygen concentrations. Since background condition peak SSCs remain under 10 mg/L from October to September, SSCs have little effect on the initial dissolved oxygen levels and dissolved oxygen levels remain above the 5 mg/L threshold used to determine dissolved oxygen impacts to salmonids.

Table 5-8 includes the dissolved oxygen model input parameters for the Proposed Action model. The origin of the model parameters is provided in Section 5.1.1.2.

Table 5-8: Dissolved Oxygen Spreadsheet Model Boundary Condition Input Parameter Values for the Proposed Action Coho Salmon Median Impact Year and Coho Salmon Severe Impact Year at Iron Gate Dam by Month

Year[1]	Avg. Monthly Temperature (deg C)[2]	80% Dissolved Oxygen[3]	0% Dissolved Oxygen[4]	Flow (cfs)[5]	SSC (mg/L)[6]	IOD (mg/L)	BOD (mg/L)
Coho Median Impact Year (WY 1991 Conditions)							
10/27/2022	11.8	8.0	0.0	1,021	1	0.0	0.0
11/24/2022	7.0	8.9	0.0	964	64	0.0	0.2
12/31/2022	3.1	9.9	0.0	997	66	0.0	0.2
1/13/2023	1.7	10.3	0.0	3,166	16,226	10.2	57.1
2/1/2023	2.6	10.0	0.0	1,356	3,840	2.4	13.5
3/1/2023	5.0	9.4	0.0	921	478	0.3	1.7

Year[1]	Avg. Monthly Temperature (deg C)[2]	80% Dissolved Oxygen[3]	0% Dissolved Oxygen[4]	Flow (cfs)[5]	SSC (mg/L)[6]	IOD (mg/L)	BOD (mg/L)
4/2/2023	8.5	8.6	0.0	1,122	147	0.1	0.5
5/15/2023	12.2	7.9	0.0	943	625	0.4	2.2
6/17/2023	17.2	7.1	0.0	810	12,423	7.8	43.7
7/1/2023	20.1	6.7	0.0	701	1,334	0.8	4.7
8/2/2023	19.1	6.8	0.0	956	475	0.3	1.7
9/17/2023	16.3	7.2	0.0	966	263	0.2	0.9
Coho Severe Impact Year (WY 1970 Conditions)							
10/23/2022	11.8	8.0	0.0	1,255	2	0.0	0.0
11/14/2022	7.0	8.9	0.0	1,461	86	0.1	0.3
12/31/2022	3.1	9.9	0.0	1,105	68	0.0	0.2
1/7/2023	1.7	10.3	0.0	14,250	556	0.4	2.0
2/7/2023	2.6	10.0	0.0	5,796	620	0.4	2.2
3/16/2023	5.0	9.4	0.0	4,212	1,694	1.1	6.0
4/15/2023	8.5	8.6	0.0	3,569	4,968	3.1	17.5
5/5/2023	12.2	7.9	0.0	2,729	1,544	1.0	5.4
6/16/2023	17.2	7.1	0.0	1,636	13,205	8.3	46.5
7/4/2023	20.1	6.7	0.0	828	2,001	1.3	7.0
8/2/2023	19.1	6.8	0.0	879	314	0.2	1.1
9/1/2023	16.3	7.2	0.0	911	167	0.1	0.6

[1] Year values updated from 2012 BA to reflect the 2023 reservoir drawdown.
[2] Raw daily water temperature data from HEC5Q water temperature model.
[3] Initial dissolved oxygen downstream of Iron Gate Dam calculated for 80 percent saturation using average monthly water temperature, salinity = 0 ppt, and elevation = 707 meters (2,320 feet). An initial dissolved oxygen at 80 percent saturation was used to simulate normal existing conditions based on PacifiCorp 2018b water quality data downstream of Iron Gate Dam.
[4] Initial dissolved oxygen downstream of Iron Gate Dam calculated for 0 percent saturation to simulate worst case conditions based on uncertainty of water quality within Iron Gate Reservoir due to the early drawdown of Copco Reservoir.
[5] Predicted daily flow values from updated USBR hydrologic model output based on revised KRRC drawdown scenario (USBR 2011b, Appendix I). Daily flow values correspond to the peak SSC for each month.
[6] Predicted peak SSC by month from updated USBR hydrologic model output based on revised KRRC drawdown scenario (USBR 2011b, Appendix I).
WY = water year

Proposed Action Dissolved Oxygen Model

For the Proposed Action, the model includes Copco No. 1 Reservoir drawdown beginning in November prior to the drawdown year, and J.C. Boyle and Iron Gate reservoir drawdowns beginning on January 1 of the drawdown year. Under the median impact year (1991), two peak SSC events that result in dissolved oxygen levels less than 5 mg/L are anticipated to occur in mid-January and mid-June. The mid-January peak SSC event (16,226 mg/L) relates to reservoir drawdown as stored sediments are mobilized as reservoir outflow exceeds inflow. The mid-June peak SSC event (12,423 mg/L) is associated with the breach of the Copco No. 1 historical cofferdam and mobilization of stored sediments upstream of the cofferdam.

Under the severe impact year (1970), one peak SSC event that results in dissolved oxygen levels less than 5 mg/L is anticipated to occur in mid-June. The mid-June peak SSC event (13,205 mg/L) is associated with the breach of the Copco No. 1 historical cofferdam and mobilization of stored sediments upstream of the cofferdam. High stream flows earlier in the model domain reduce SSC levels below Iron Gate Dam as reservoir bed sediments will not be transported.

Coho Salmon High (80 Percent) Initial Dissolved Oxygen Saturation Scenario

Table 5-9 includes the dissolved oxygen model output for the median and severe impact year scenarios associated with an 80 percent initial dissolved oxygen saturation. Under the median impact year scenario, dissolved oxygen levels decline to 0.2 mg/L and 0.0 mg/L during the mid-January and mid-June peak SSC events. The mid-January event occurs as the reservoirs are drawn down, reservoir outflow exceeds inflow, and stored sediments are mobilized. During this event, minimum dissolved oxygen levels occur 1.2 miles downstream of Iron Gate Dam (RM 193.1) and recover to 7 mg/L and 5 mg/L at RM 131.8 and RM 148.6, respectively, due to reaeration and inputs from tributary streams. For reference, the Scott River confluence is located at RM 145.1. Depleted dissolved oxygen conditions at Iron Gate Dam persist for 6 consecutive days relative to the 7 mg/L threshold and 3 consecutive days relative to the 5 mg/L threshold. The distance and magnitude of depleted oxygen conditions downstream of Iron Gate Dam varies daily, depending on SSC concentrations, water temperatures, dissolved oxygen saturation, and tributary discharge. Juvenile coho salmon from the Upper Klamath River, Shasta River, and Scott River populations that overwinter in the mainstem Klamath River or that are emigrating from tributary streams in mid to late January may experience high SSCs and diminished dissolved oxygen conditions that may result in sublethal or lethal effects. Dissolved oxygen concentrations generally recover to levels greater than 7 mg/L in all reaches by late January under the median impact year scenario.

The mid-June event is caused by the Copco No. 1 historical cofferdam breach and the drawdown of high SSC water and sediment stored by the cofferdam. Minimum dissolved oxygen levels occur 0.6 miles downstream of Iron Gate Dam and recover to 7 mg/L and 5 mg/L at RM 161.6 and RM 177.8, respectively. Depleted dissolved oxygen conditions at Iron Gate Dam persist for 47 consecutive days relative to the 7 mg/L threshold, and 9 consecutive days relative to the 5 mg/L threshold. The distance of depleted oxygen conditions downstream of Iron Gate Dam varies daily, depending on SSC concentrations, water temperatures, dissolved oxygen saturation, and tributary discharge. Depleted dissolved oxygen conditions (less than 7 mg/L) in proximity to Iron Gate Dam may persist for 1-2 months, primarily due to elevated water temperatures and low initial dissolved oxygen background conditions coupled with elevated SSCs Iron Gate Reservoir.

Under the severe impact year (1970) scenario, reservoir inflows exceed the capacity of the Iron Gate Dam outlet tunnel and less stored sediment is mobilized during the initial drawdown. Dissolved oxygen levels decline to 0.0 mg/L during the mid-June SSC event. During this event, minimum dissolved oxygen levels occur 0.6 miles downstream of Iron Gate Dam and recover to 7 mg/L and 5 mg/L at RM 145.5 and RM

161.0, respectively. Depleted dissolved oxygen conditions at Iron Gate Dam persist for 109 consecutive days relative to the 7 mg/L threshold, and 8 consecutive days relative to the 5 mg/L threshold. The distance of depleted oxygen conditions downstream of Iron Gate Dam varies daily depending on SSC concentrations, water temperatures, dissolved oxygen saturation, and tributary discharge. Dissolved oxygen concentrations recover to 7 mg/L upstream of the Scott River under this scenario. Juvenile coho salmon in the upper mainstem Klamath River or emigrating from tributaries between Iron Gate Dam and the Shasta River confluence are expected to experience sublethal effects associated with diminished dissolved oxygen concentrations.

Table 5-9: Estimated Location of Minimum Dissolved Oxygen and Location at Which Dissolved Oxygen Will Return to 7 mg/L and 5 mg/L Downstream of Iron Gate Dam Due to High Short-Term SSC Under the Proposed Action Coho Salmon Median Impact Year and Severe Impact Year Scenarios With 80 Percent Initial Dissolved Oxygen Saturation

Date[1]	Boundary Conditions at Iron Gate Dam			Spreadsheet Model Output			
	Initial Dissolved Oxygen (at 80% Saturation)[2]	IOD	BOD	Minimum Dissolved Oxygen	Location of Minimum Dissolved Oxygen[3]	Location at Which Dissolved Oxygen Returns to 7 mg/L[4]	Location at Which Dissolved Oxygen Returns to 5 mg/L[4]
	(mg/L)	(mg/L)	(mg/L)	(mg/L)		RM	RM
Coho Median Impact Year (WY 1991 Conditions)							
10/27/2022	8.0	0.0	0.0	8.0	0.0	-	-
11/24/2022	8.9	0.0	0.2	8.9	0.0	-	-
12/31/2022	9.9	0.0	0.2	9.9	0.0	-	-
1/13/2023	10.3	10.2	57.1	0.2	1.2	131.8	148.6
2/1/2023	10.0	2.4	13.5	7.7	0.6	-	-
3/1/2023	9.4	0.3	1.7	9.2	0.6	-	-
4/2/2023	8.6	0.1	0.5	8.6	0.6	-	-
5/15/2023	7.9	0.4	2.2	7.6	0.6	-	-
6/17/2023	7.1	7.8	43.7	0.0	0.6	161.6	177.8
7/1/2023	6.7	0.8	4.7	5.9	0.6	186.5	-
8/2/2023	6.8	0.3	1.7	6.6	0.6	189.0	-
9/17/2023	7.2	0.2	0.9	7.1	0.6	-	-
Coho Severe Impact Year (WY 1970 Conditions)							
10/23/2022	8.0	0.0	0.0	8.0	0.0	-	-
11/14/2022	8.9	0.1	0.3	8.9	0.0	-	-
12/31/2022	9.9	0.0	0.2	9.9	0.0	-	-
1/7/2023	10.3	0.4	2.0	10.0	1.9	-	-

Date[1]	Boundary Conditions at Iron Gate Dam			Spreadsheet Model Output			
	Initial Dissolved Oxygen (at 80% Saturation)[2]	IOD	BOD	Minimum Dissolved Oxygen	Location of Minimum Dissolved Oxygen[3]	Location at Which Dissolved Oxygen Returns to 7 mg/L[4]	Location at Which Dissolved Oxygen Returns to 5 mg/L[4]
	(mg/L)	(mg/L)	(mg/L)	(mg/L)		RM	RM
2/7/2023	10.0	0.4	2.2	9.7	1.2	-	-
3/16/2023	9.4	1.1	6.0	8.4	1.2	-	-
4/15/2023	8.6	3.1	17.5	5.6	1.2	168.5	-
5/5/2023	7.9	1.0	5.4	7.0	1.2	-	-
6/16/2023	7.1	8.3	46.5	0.0	0.6	145.5	161.0
7/4/2023	6.7	1.3	7.0	5.5	0.6	184.0	-
8/2/2023	6.8	0.2	1.1	6.7	0.6	189.6	-
9/1/2023	7.2	0.1	0.6	7.2	0.6	-	-

[1] Year values updated from 2012 BA to reflect 2023 reservoir drawdown.
[2] Initial dissolved oxygen downstream of Iron Gate Dam calculated for 80 percent saturation using average monthly water temperature, salinity = 0 ppt, and elevation = 707 meters (2,320 feet). An initial dissolved oxygen at 80 percent saturation was used based on typical existing conditions below Iron Gate Dam.
[3] Location is in miles downstream of Iron Gate Dam.
[4] Minimum acceptable dissolved oxygen concentration for salmonids.
WY = water year

The Renewal Corporation used a High Dissolved Oxygen Scenario to represent the most likely background conditions, similar to those that occur under existing conditions, and a Low Dissolved Oxygen Scenario to represent an extreme condition scenario if poor water quality conditions in Iron Gate Reservoir result in initial condition dissolved oxygen concentrations to be considered anoxic (0 mg/L) before exiting the Iron Gate tunnel. The results for the Low Dissolved Oxygen Scenario are presented in Appendix H.

Under the most-likely scenario, diminished dissolved oxygen conditions will primarily affect the Klamath River from Iron Gate Dam downstream to Seiad Valley. Coho salmon from Upper Klamath River, Shasta River, and Scott River populations are most likely to be impacted by low dissolved oxygen concentrations. Middle Klamath River and other downstream populations are not expected to be impacted by diminished dissolved oxygen as dissolved oxygen levels return to 7 mg/L downstream of the Scott River. Since anticipated diminished dissolved oxygen conditions will occur early (median impact year) and late (median and severe impact year scenarios) in the coho salmon outmigration periods, outmigrants entering the Klamath River from natal tributaries in mid-January and mid-June will be most affected. Additionally, any age-0+ juvenile coho salmon that are rearing in the mainstem Klamath River during these time periods and within these geographic locations may suffer lethal or sublethal effects due to diminished dissolved oxygen conditions.

Rotary screw trap (RST) data from the I-5 RST, Shasta River RST, and Scott River RST were used to assess potential depleted dissolved oxygen effects to outmigrating coho salmon. Based on RST results, less than 1 percent of age-1+ Upper Klamath River and Shasta River coho salmon populations and approximately 6 precent of age-1+ Scott River coho salmon population will be exposed to depleted dissolved oxygen conditions. Therefore, if the final drawdown and Copco No. 1 cofferdam breach occurs in mid-June, only a small percentage of Upper Klamath River, Shasta River, and Scott River juvenile coho salmon populations will experience depleted dissolved oxygen conditions upon entering the Klamath River. Breaching the Copco No. 1 cofferdam earlier in the drawdown year could have broader impacts as more juvenile coho salmon are present in the mainstem Klamath River between February and June.

Under all scenarios, minimum dissolved oxygen concentrations are expected to occur within 2 miles of Iron Gate Dam, and diminished dissolved oxygen conditions improve with downstream distance due to reaeration and additional discharge from tributary streams. Therefore, juvenile coho salmon entering the mainstem Klamath River from tributaries closest to Iron Gate Dam such as Bogus Creek during times of low dissolved oxygen conditions are most likely to suffer direct mortality, whereas fish entering from tributaries further downstream in the effected reach such as the Scott River will likely be exposed to dissolved oxygen levels closer to the 7 mg/L threshold and may only experience sublethal effects.

Although 5 and 7 mg/L were used as thresholds to demonstrate the duration of time and length of affected reaches, salmonids persist in depleted dissolved oxygen conditions. For instance, the USEPA (1986) reported that salmonid mortality begins to occur when dissolved oxygen concentrations are below 3 mg/L for periods longer than 3.5 days. A summary of various field studies by Washington Department of Ecology (2002) reported that significant mortality occurs in natural waters when dissolved oxygen concentrations fluctuate in the range of 2.5 - 3 mg/L, and that long-term (20 - 30 days) constant exposure to mean dissolved oxygen concentrations below 3 - 3.3 mg/L is likely to result in 50 percent mortality of juvenile salmonids (WDOE 2002). Other studies indicate that water temperatures also play an important factor in the response of salmonids to dissolved oxygen conditions, as coho salmon have recently been found consistently using off-channel habitat with dissolved oxygen concentrations as low as 1 mg/l in the lower Klamath River Basin, but water temperatures were generally 15°C or less (Beesley and Fiori 2014). Juvenile fish rearing or emigrating from tributaries to the mainstem Klamath River during periods of poor water quality conditions are expected to employ behavioral responses, such as rapid downstream movement, or the use of clear, well-oxygenated tributary junctions to minimize the impacts of high SSC and low dissolved oxygen due to the Proposed Action. However, depleted dissolved oxygen levels and hypoxia will be an additive stressor to the high SSCs that coho salmon will encounter during outmigration, potentially increasing coho salmon mortality during the drawdown year.

Implementation of Aquatic Resource Measure Juvenile Outmigration Actions 1 and 3, described further in the section below, will reduce the impacts to fish rearing in the mainstem Klamath River prior to the onset of drawdown that will be impacted by the mid-January peak SSC event, or emigrating from tributaries to the mainstem Klamath between March 1 - July 1 of the drawdown year that could be impacted by the mid-June peak SSC event. However, any juvenile coho salmon present in the mainstem Klamath River upstream of Seiad Valley during the drawdown year could be impacted by diminished dissolved oxygen concentrations, especially during peak SSC events expected in mid-January and mid-June. Therefore, diminished dissolved oxygen concentrations resulting from the reservoir drawdown and sediment release activities of the

Proposed Action are likely to adversely affect juvenile coho salmon from the Upper Klamath River, Shasta River, and Scott River populations.

Aquatic Resource Measure - Outmigrating Juveniles

Short-term suspended sediment effects of the Proposed Action will result in mostly sublethal, and in some cases lethal, effects to a portion of the juvenile coho salmon rearing in, or outmigrating from, the mainstem Klamath River during late winter, spring, and summer of the drawdown year. Deleterious short-term effects on outmigrating juvenile coho salmon could be reduced by implementing three actions, including Action 1 – the capture and relocation of overwintering juvenile coho salmon from the mainstem Klamath River to off-channel habitats; Action 2 – monitoring mainstem-tributary connectivity to ensure juvenile salmonid access to clear water tributaries during reservoir drawdown; and Action 3 – monitoring and salvaging juvenile coho salmon from tributary confluences during reservoir drawdown. The implementation of these measures will reduce the exposure and magnitude of drawdown suspended sediment effects (i.e., SSCs and dissolved oxygen impacts) to juvenile coho salmon; however, implementation of the measures will have associated impacts related to capture, handling, and relocation of juvenile fish. Action 1 and Action 3 are described below as they relate to drawdown effects.

Action 1

Prior to drawdown, Action 1, a targeted capture and relocation of overwintering juvenile coho salmon from the mainstem Klamath River, will occur as close to the start of drawdown as possible, likely occurring in early to mid-December. Implementing Action 1 immediately prior to the initiation of drawdown will allow as many redistributing juvenile coho salmon as possible to find suitable winter rearing habitats within tributaries or off-channel features without intervention. The Renewal Corporation's rescue and relocation plan will be developed in coordination with NMFS, and will include trapping and active collection methods, including the use of seine nets, minnow traps, or other gear types. Fish capture efficiency will be contingent on habitat complexity, number of fish present, and hydraulic conditions. Fish captured during the 2-week effort will be transported and released in tributary or off-channel ponds as identified in the relocation plan and as described in Section 2.6.1.1. Based on a reconnaissance effort to be conducted in the winter 1 year prior to drawdown, the Renewal Corporation will provide an estimate of the number of juvenile coho that are anticipated to be captured during the implementation of Action 1. The Renewal Corporation expects that this number will not exceed 500 individuals and will represent less than 50 percent of juvenile coho salmon present in the mainstem Klamath River at the onset of drawdown.

Current predictions of SSC-related mortality to juvenile coho salmon overwintering in the mainstem Klamath River estimate an impact of 0 to approximately 40 percent of individual coho salmon population units, depending on the impact year scenario and the geographic location of the population unit at the time of elevated SSC levels (see Appendix H).

Anticipating 50 percent capture efficiency, this conservation measure could reduce mortality to 0 to 20 percent of overwintering juvenile coho salmon, depending on SSC levels associated with the given water year during reservoir drawdown.

Action 3

Monitoring of hydrologic conditions and suspended sediment during spring and summer of Year 1 will be conducted so that the implementation of Action 3 will be based on near real-time monitoring results. SSC monitoring results will be compared to the predicted values displayed on Figure 5-2. If SSCs are higher in concentration or longer in duration than those predicted under the severe impact year scenario, the Renewal Corporation will assume that there is an increased risk of impacts to coho salmon, and juvenile salmonid salvage from tributary confluences may need to be more intensive. Water temperatures in tributary confluence areas and juvenile salmonid behavior will also be monitored by the Renewal Corporation and used to inform implementation of Action 3.

If tributary and mainstem water quality conditions and juvenile salmonid abundance and behavior necessitate implementation of Action 3, the effectiveness of the action will depend on the need for and effectiveness of salvage efforts. The Renewal Corporation's tributary salvage plan (see the Juvenile Salmonid and Pacific Lamprey Rescue and Relocation Plan in Appendix D) developed in coordination with NMFS includes trapping and active collection methods, including the potential use of RSTs in tributaries where CDFW currently operates RSTs and fyke nets. In other tributaries, juvenile fish will be salvaged using seines and possibly electrofishing where seines cannot be used effectively due to debris, elevated water velocities, or other constraints.

Fish capture efficiency will be contingent on tributary habitat complexity, number of fish present, and hydraulic conditions. Fish that avoid salvage efforts or decide to leave their natal tributary prior to salvage efforts are expected to move in a downstream direction based on recent juvenile coho salmon migration studies (Manhard et al. 2018).

Individual fish will avoid traps and migrate to the mainstem (particularly during high flows). Overall, the Renewal Corporation anticipates 50 percent of juveniles outmigrating to the mainstem could be captured. Current predictions of SSC-related mortality estimate an impact of 0 to approximately 15 percent of individual coho salmon population units, depending on the impact year scenario and the geographic location of the population unit (see Appendix H).

Anticipating 50 percent capture efficiency, this conservation measure could reduce mortality to 0 to 7.5 percent of outmigrating juvenile coho salmon, depending on SSC levels associated with the given water year during reservoir drawdown. The implementation intensity of this measure will be adjusted as necessary to limit mortality.

The procedures for trapping, handling, trucking, and releasing outmigrating salmonids could result in injury or mortality to some individuals, and releasing fish at downstream locations could reduce natal cues and increase stray rates. For example, Chesney et al. (2007) reported coho salmon mortality rates associated with downstream migrant trapping on the Shasta and Scott rivers ranging from 3.6 to 7.9 percent for age-0+, 0.75 to 1 percent for age-1+, and 0 percent for age-2+ coho salmon. Trucking mortality rates may also be relatively low. Trucking mortality rates for rainbow trout that are hauled from the Mad River Hatchery to Shasta County are less than 0.5 percent (C. Layman, CDFG Mad River Hatchery, pers. comm., September 14, 2011).

Johnson et al. (1990) examined tag recovery rates in offshore fisheries for three groups of transported fish, as well as a control group. The fish in their study were transported for approximately 30 minutes by truck. As indexed by the recovery of tagged fish in ocean catch, the survival-to-harvest of fish that were released immediately following transport was 76 percent, 83 percent, and 84 percent relative to the untransported control group. Quinn (1997) reported that displacement studies indicate that maturing salmon tend to reverse the sequence of their outward migration as juveniles. This will lead them to the river or hatchery where they began life. Displaced salmon return first to the odors of their release site and will continue to the rearing site if its odors can be detected. If not, adults seem to seek the nearest river or hatchery.

Under Action 3, the Renewal Corporation will capture and transport fish only if conditions in the mainstem are as poor as predicted, and tributary water temperatures exceed threshold levels for juvenile coho salmon survival. Due to the uncertainties with suspended sediment modeling, water quality and fish behavior will be monitored by the Renewal Corporation during spring and summer of the drawdown year. Water quality conditions and detection of adverse fish behavior will trigger the initiation and cessation of the capture program and inform suitable release locations.

Even though these conservation measures are intended to minimize mortality of juvenile coho salmon resulting from reservoir drawdown, adverse effects to some individuals that survive through the high SSCs are anticipated during the process. However, the survival of those fish that will have otherwise suffered mortality due to high SSCs may recruit to the adult population and eventually spawn.

5.1.2.3 Bedload Deposition Effects Associated with Reservoir Drawdown and Dam Removal

The Renewal Corporation analyzed SRH-1D bed sediment and bedload modeling output provided by USBR to assess bedload sediment transport and deposition associated with the Proposed Action. The bedload deposition analysis approach and results are presented in Section 5.1.1.3. The following summary is based on the potential bedload deposition effects to coho salmon.

The reservoir drawdown and dam removal were simulated over a 2-year period beginning on October 1 of the pre-drawdown year. Modeling results predict reservoir sediments will coarsen over the 2 years as flows winnow fine sediments and the Klamath River channel erodes to its historical pre-dam elevation. Two sediment wedges, one upstream (Figure 5-14) and one downstream (Figure 5-15) from the Iron Gate Dam footprint, increase the channel bed elevation and affect channel morphology and habitat between the downstream end of Iron Gate Reservoir (approximately 1 mile upstream of Iron Gate Dam) and Willow Creek (Figure 5-16). Since the sediment wedges upstream and downstream of the Iron Gate Dam site are building at the end of the simulation period, sediment wedge longevity in the model run is unknown.

Over the 2-year simulation period and for some number of years past the simulation period (because the simulation period did not extend to sediment equilibrium), the two sediment wedges may affect coho salmon from the Upper Klamath River population through channel and pool filling, and redd scour or burial. The simulations indicate that the primary bedload deposition reach is located from approximately 1 mile upstream of Iron Gate Dam to 5.1 miles downstream to the Willow Creek confluence (Figure 5-16), for a total distance of 6.1 miles. Bedload deposition may affect a minimum of 2 years of adult coho salmon spawning within the depositional reach. Any coho salmon redds constructed in the depositional reach will likely suffer 100 percent mortality due to suspended sediment released in the drawdown year, as described in Section 5.1.2.2. Following final reservoir drawdown and coffer dam breach, a portion of the stored coarse sediment will mobilize and deposit downstream between Iron Gate Dam and Willow Creek. Depending on the channel bed material, hyporheic (intergravel) flow, and cover habitat, adult coho salmon could spawn in the recently deposited material. Due to the high sand content (Figure 5-17) of mobilized stored sediments, subsequent sediment mobilization during late fall and winter could either scour or bury redds. Based on the model simulations, a similar process could be repeated in the post-drawdown year. Further, because the sediment wedges are in an aggrading state at the end of the model simulations, redd scour or burial could also occur in subsequent years. However, because coho salmon are primarily tributary spawners and because channel bed adjustments are expected to occur during the fall spawning period when stream flow increases with fall precipitation, coho salmon are unlikely to use these dynamic transport areas as spawning sites.

Depending on the rate of sediment wedge erosion, the two sediment wedges could also impact upstream passage of coho salmon through the former Iron Gate Dam site. The sediment wedges, and the potential braided conditions associated with them, may impact fish passage and tributary connectivity in the short term. Braided channel conditions are typically associated with shallow water depths, which may hinder fish passage. This effect may persist until flows can reorganize bed sediments to form a deeper, single-thread flow path. The apex of the sediment wedge downstream of Iron Gate Dam is located around the Bogus Creek confluence, which may also create connectivity issues for fish attempting to access Bogus Creek for spawning or for the auxiliary fish ladder that may be used to collect adult fish for hatchery broodstock. The thickness of the wedge around Bogus Creek is approximately 1 foot to 3 feet in fall of year 2 and 2 feet to 7 feet in fall of year 3. Since the modeled simulation period ended during aggrading conditions, the persistence of the sediment wedge beyond the simulation period is unknown.

The results of the model have been used to identify locations where sediment aggradation may be of concern for fish passage, and therefore, corrective fish passage actions are anticipated to occur. Implementation of fish passage monitoring and corrective actions as described in the Reservoir Area Management Plan (Appendix C), the Tributary–Mainstem Connectivity Monitoring Plan (in Appendix D), and part of Aquatic Resource Measure Outmigrating Juveniles Action 2 will identify and remediate fish passage issues that may occur within the former reservoir and dam footprints for 6 years following the start of reservoir drawdown. Additional monitoring within the 8-mile reach of the mainstem Klamath River between Iron Gate Dam and Cottonwood Creek for a period of 3 years following the initiation of reservoir drawdown will also be completed.

Over time (5 years to 50 years), the sediment wedges will disperse and bed elevations will adjust to a new sediment equilibrium, which will include a restored sediment supply from upstream tributaries that was formerly trapped by the Hydroelectric Reach dams. Mobilized reservoir sediments will deposit over a bed that has been degraded over the past 60 years due to the elimination of bedload replenishment caused by sediment trapping upstream of Iron Gate Dam. As a result, bed elevations may remain elevated relative to current conditions as sediment processes return to pre-dam conditions.

5.1.2.4 Reservoir Restoration and Fish Passage Monitoring Actions

Restoration actions described in Section 2.4 and Appendix C will result in the establishment of herbaceous vegetation in drained reservoir areas and will accelerate the stabilization of the sediment and minimize erosion from exposed terrace surfaces following reservoir drawdown (O'Meara et al. 2010). Woody species will gradually establish on the river terraces as they propagate from the outer edges of the reservoir. Revegetation efforts will be initiated to support establishment of native wetland and riparian species on newly exposed reservoir sediment. Equipment access is expected to be limited immediately following drawdown due to terrain, slope, and sediment instability. The revegetation of the reservoir areas will reduce erosion, stabilize exposed surfaces, and eventually provide shade and food resources for fish in the new free-flowing river channel.

Restoration actions described in Section 2.4 and Appendix C will include regrading of tributary stream channels for volitional fish passage, placement of boulder clusters and willow baffles, and construction of large wood structures with ground-based equipment and helicopters. The Renewal Corporation will conduct these restoration actions in the drawdown year (Year 1) and Year 2, following reservoir drawdown and dam removal, with a monitoring and maintenance period extending for 5 years, ending in Year 7. Based on the goal of establishing volitional fish passage at Iron Gate Dam in early October in Year 1, there is potential for coho salmon to be present in the proposed work areas described in Section 2.4.4.

Following reservoir drawdown in Year 1, the Renewal Corporation will undertake complete mulching and seeding of the reservoir area footprints, installation of riparian trees and shrubs, placement of large wood by helicopter, and initial channel grading of tributaries to establish volitional fish passage. Restoration activities conducted in Year 1 are expected to occur prior to October and before volitional fish passage is established at each of the dam sites. Therefore, reservoir restoration activities conducted in Year 1 will not affect coho salmon. Beginning in Year 2, the Renewal Corporation will complete the installation of channel and floodplain habitat features as well as tributary and floodplain grading using excavators and other ground-based equipment. In Year 2, small numbers of age-0 juvenile coho salmon hatched from the initial recolonization of these tributaries in late fall and winter of Year 1 could potentially be found rearing in these lower reaches or redistributing to or from the Klamath River or other tributary streams.

Following drawdown and dam removal, several actions will be implemented to ensure fish passage for coho salmon to habitat in the former Hydroelectric Reach. As described in Appendix C and D, these actions include fish passage monitoring on the mainstem Klamath River and project-associated fish-bearing tributaries upstream of the former Iron Gate Dam to evaluate blockages and headcuts in residual dam sediment, and the steps to take if they are deemed to be fish passage barriers. Additional fish passage actions are associated with Aquatic Resource Measure Mainstem Spawning and Aquatic Resource Measure Outmigrating Juveniles (Actions 2 and 3), as described in Section 2.6.1.1.

In the years following, it is likely that age-0 and age-1 coho salmon could be found throughout the Hydroelectric Reach of the Klamath River and in natal and non-natal tributary streams. The Renewal Corporation will apply the in-water work BMPs that are described in Section 2.4.5 to any work that is conducted in fish-bearing tributaries in Year 2 and during the 5-year maintenance period ending in Year 7.

In-water work BMPs related to seasonal timing of instream work, work area isolation and/or dewatering, and fish rescue and relocation will likely minimize any effects to coho salmon and other aquatic species present. While these measures are expected to minimize the duration and extent of restoration and restoration maintenance activities, temporary exclusion from channel reaches, short-term elevated turbidity, and capture, handling, and relocation of coho salmon are expected to occur in localized sections of restored tributary or mainstem/confluence areas.

While the physical and mechanical components of restoration will affect coho salmon, the benefits of restoration action will greatly exceed the impacts. Reestablishment of vegetation along riparian corridors and uplands will stabilize sediments and shade tributary corridors, habitat complexity features will improve habitat heterogeneity and refugia under varied flow conditions, and fish passage monitoring and corrective actions will minimize the potential for blockages that would impede returning coho salmon from accessing historic habitat. These benefits will occur in the short term, but are also anticipated to persist and accelerate the long-term recovery of the former reservoir and dam footprints.

5.1.2.5 Hatchery Modifications

Iron Gate Hatchery

NMFS and CDFW continue to prioritize the production of coho salmon and Chinook salmon in the Klamath Basin. Because coho salmon are a state- and federally listed species in the Klamath River, coho salmon production is the highest priority for NMFS and CDFW, followed by Chinook salmon production, which supports tribal, sport, and commercial fisheries. Steelhead production is the lowest priority, in part due to the low numbers of steelhead that have returned to Iron Gate Hatchery in recent years and the limited water availability and rearing capacity of the existing and proposed hatchery facilities. With these constraints, NMFS and CDFW have determined that steelhead production will be discontinued.

Hatchery management guidelines following the removal of Iron Gate Dam have been developed based on NMFS and CDFW recommendations. Due to costs associated with filtration and UV treatment and limitations on the quantity of water available from Bogus Creek, the Iron Gate Hatchery will be closed prior to the initiation of the drawdown of Iron Gate Reservoir. Eggs and juvenile fish at Iron Gate Hatchery during the fall of the year before drawdown will be transferred to the Fall Creek Hatchery following protocols developed by CDFW and NMFS. Fall Creek Hatchery will be renovated as described in Section 2.5.4.5 to facilitate post-dam removal fish production.

Fall Creek Hatchery Improvements

Fall Creek Hatchery improvements as described in Section 2.5.4.5 will be completed by the Renewal Corporation prior to the removal of Iron Gate Dam and the return of adult coho salmon to the Hydroelectric Reach upstream from Iron Gate Dam. While the Renewal Corporation will construct the Fall Creek Hatchery, CDFW will operate the facility. Because Fall Creek Hatchery improvements will be completed before coho salmon have access to Fall Creek and the Klamath River upstream of Iron Gate Dam, construction of Fall Creek Hatchery improvements will not result in take of coho salmon.

Fall Creek Hatchery Fish Exclusion Barrier

To protect the quality of the City of Yreka's water supply and prevent fish pathogen introduction into the Fall Creek Hatchery, fish will be excluded from migrating into the water supplies at both Dam A and Dam B. The Renewal Corporation will construct three fish exclusion barriers prior to the removal of Iron Gate Dam and the return of anadromous fish into Fall Creek. The exclusion barriers (as described in Section 2.5.4.5) will include modifications to Dam A and Dam B and the installation of a removable picket weir that will be situated on Fall Creek downstream of the Copco Road bridge, adjacent to the existing lower raceways. Following the completion of operations at the Fall Creek Hatchery, the picket weir will be permanently removed and fish will be able to access the reach of Fall Creek between the picket weir and Dam B as well as the downstream portion of the Fall Creek Powerhouse tailrace up to Dam A.

Fall Creek Falls, also known as Barrier Falls, is approximately 1.1 miles (5,800 feet) upstream from the confluence of the Klamath River on Fall Creek. The falls consists of several steep cascades, is more than 125 feet in height, and is a total passage barrier to resident and anadromous fish species. The proposed exclusion picket weir barrier just upstream of the Fall Creek Hatchery fish ladder will exclude adult anadromous fish from approximately 1,000 feet of habitat downstream of the Fall Creek Falls, which equates to approximately 17 percent of the total length of anadromy on Fall Creek. A field visit by NMFS, CDFW, the Renewal Corporation, and PacifiCorp on February 5, 2018, to assess habitat conditions in Fall Creek noted the presence of low-gradient habitat from the Copco bridge upstream to the extent of anadromy near the base of Fall Creek Falls. The velocity-apron fish barriers at Dam A and Dam B will prevent all fish from passing the dams into the water intakes situated just upstream of each dam. Dam A is in the tailrace of the Fall Creek Powerhouse, and Dam B is on Fall Creek approximately 100 feet downstream of the base of Fall Creek Falls.

Fall Creek Hatchery Water Supply

Non-consumptive water diversion by CDFW from Fall Creek will support hatchery operations using a combination of the existing CDFW water right on Fall Creek and riparian rights. The SWRCB has confirmed that CDFW's non-consumptive water right permit of 10 cfs is valid for hatchery operations. CDFW may divert up to 10 cfs of water from PacifiCorp's hydro-generation tailrace canal supplied from the pool behind Dam A and from a supplemental supply location on Fall Creek above Dam B. Water will be gravity-fed and plumbed to each rearing vessel and the adult capture and hold facility, pending the Renewal Corporation's confirmatory site survey. During periods when the powerhouse tailrace is not flowing, Fall Creek water will be diverted from Dam B to Dam A to supply the hatchery.

CDFW will divert a minimum of 2.2 cfs during June and a maximum of 10 cfs in September to December for fish production and operations at Fall Creek Hatchery (Table 5-10). The Renewal Corporation calculated mean monthly discharges for Fall Creek based on a historical USGS stream gage (No. 11512000) that was operated from 1933 to 1959. Since 2002, PacifiCorp has maintained an additional water right that allows the diversion of up to 16.5 cfs to be diverted from Spring Creek in Oregon into Fall Creek for increased hydropower production. The estimated minimum flow in Spring Creek that may be diverted into Fall Creek is 5 cfs (PacifiCorp 2004b). Additionally, the City of Yreka maintains a water right to divert up to 15 cfs from Fall Creek for municipal purposes and is also required to maintain a minimum of 15 cfs in the Fall Creek channel, with the compliance measurement point located at the historical USGS gage located downstream of the Copco Road bridge. To evaluate the potential effects to coho salmon based on water use for the proposed Fall Creek Hatchery, the Renewal Corporation calculated the percentage of water used by month for the Fall Creek Hatchery as a proportion of both the historical monthly mean flow, minus the City of Yreka's maximum diversion, plus the minimum 5 cfs Spring Creek diversion and the monthly historical mean flow, minus the City of Yreka's minimum diversion, plus the maximum 16.5 cfs diversion rate (Table 5-10)

Table 5-10: Fall Creek Water Usage Budget

Month	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Fall Creek Mean Monthly Discharge (cfs)	46.5	50.6	49.2	45.3	37.8	35.1	33.7	33.3	34.0	34.9	37.3	42.8
Fall Creek with Maximum Yreka Diversion (-15 cfs)	31.5	35.6	34.2	30.3	22.8	20.1	18.7	18.3	19.0	19.9	22.3	27.8
Fall Creek with Maximum Yreka and Minimum Spring Creek Diversions (+ 5 cfs)	36.5	40.6	39.2	35.3	27.8	25.1	23.7	23.3	24.0	24.9	27.3	32.8
Fall Creek with Maximum Yreka and Maximum Spring Creek Diversions (+16.5 cfs)	48.0	52.1	50.7	46.8	39.3	36.6	35.2	34.8	35.5	36.4	38.8	44.3
Required Water for Fall Creek Hatchery (cfs)	2.5	5.3	6.7	7.2	9.3	2.2	3.1	4.1	10.0	10.0	10.0	10.0
Percent of Natural Flow Available with Maximum Diversion	7%	13%	17%	20%	33%	9%	13%	18%	42%	40%	37%	30%
Percent of Natural Flow Available with Minimum Diversion	5%	10%	13%	15%	24%	6%	9%	12%	28%	27%	26%	23%

Depending on the month and the amount of flow that is diverted from Spring Creek into Fall Creek, Fall Creek Hatchery may use 5 to 42 percent of the total streamflow for hatchery operations (Table 5-10). A majority of the water used at Fall Creek Hatchery will be returned to Fall Creek through the fish ladder proposed to be located adjacent to the lower rearing area. A portion of the diverted water used for hatchery operations such as spawning and incubation, or for rearing vessel cleaning cycles will return to Fall Creek downstream of a settling pond/raceway proposed to be constructed in the footprint of the existing lower raceways. The settling pond will remove solids from the water, reducing hatchery effects on Fall Creek's aquatic resources. Downstream of the settling pond and fish ladder, the total flow of Fall Creek plus Spring Creek diversions will be available for fish use.

Although natural streamflows in Fall Creek are artificially elevated by the addition of water diverted from Spring Creek, depending on the monthly Fall Creek Hatchery water use and minimum diversion rates, there may be up to a 20 cfs deficit of natural historical flows between the points of diversion at Dam A and Dam B downstream to the settling pond and fish ladder discharge points. Reductions in flow may potentially reduce the quantity of rearing, migration, and spawning habitat available in Fall Creek for coho salmon. However, based on the proposed location of the fish exclusion barrier as described previously, coho salmon will not be able to access the section of Fall Creek that has reduced streamflows due to Fall Creek Hatchery water use.

Based on the volume of available instream flows, hatchery operation water needs, and the return of diverted water to Fall Creek, the withdrawal of Fall Creek water to satisfy Fall Creek Hatchery water supply needs is not anticipated to result in adverse effects to coho salmon.

Fall Creek Hatchery Discharge

Wastewater flows generated at Fall Creek Hatchery will drain to the refurbished lower raceways of the existing hatchery for post-use water treatment. The settling pond will treat water discharged from the spawning building, the incubation building, and all rearing vessels during cleaning or during times of therapeutant use. Otherwise, CDFW will discharge water from the rearing vessels back to Fall Creek through the fish ladder at the lower raceway area. The NCRWQCB has indicated that discharges may not exceed 5mg/L total suspended solids. Discharges from the hatchery will be required to obtain a discharge permit from the NCRWQCB. Because water use at Fall Creek Hatchery is intended to be non-consumptive, a roughly equivalent amount will be discharged to Fall Creek either directly from the rearing vessels, the fish ladder, or via the settling pond. Based on the planned use of a settling pond to capture solids, returning diverted flow back to Fall Creek, and operating within the requirements of the NCRWQCB discharge permit, Fall Creek Hatchery discharge is not anticipated to result in adverse effects to coho salmon.

Fall Creek Hatchery Coho Salmon Production Practices

Between Year 1 and Year 4, or until adult Chinook and coho migrants begin to return to Fall Creek Hatchery in sufficient numbers to meet production goals, adult coho salmon used for hatchery broodstock will need to be collected in the Klamath River or tributaries, as identified by CDFW and NMFS. Prior to this collection phase, CDFW and NMFS will develop a separate protocol for the collection and transfer of adults to Fall Creek Hatchery from collection locations to reduce injury or mortality from transportation and handling. Spawning and incubation of coho salmon will occur at Fall Creek Hatchery. Coho salmon hatchery production at Fall Creek Hatchery will continue to follow the Hatchery and Genetic Management Plan for Iron Gate Hatchery Coho Salmon and any amendments to the associated permit (Iron Gate Hatchery HGMP) (CDFW and PacifiCorp 2014). The HGMP for coho salmon was developed for the Iron Gate Hatchery as part of CDFW's application for an ESA Section 10(a)(1)(A) permit for the Iron Gate Hatchery coho salmon program (CDFW and PacifiCorp 2014; 78 FR 1200 [January 8, 2013]; 78 FR 6298 [January 30, 2013]; 79 FR 69428 [November 21, 2014]). The HGMP is intended to guide hatchery practices toward the conservation and recovery of SONCC coho salmon, specifically through protecting and conserving the genetic resources of the upper Klamath River coho salmon population. Coho salmon hatchery production by CDFW at Fall Creek Hatchery will continue to follow the guidelines outlined in the Iron Gate Hatchery HGMP (CDFW and PacifiCorp 2014). Hatchery operations at Fall Creek Hatchery and associated changes as part of the Proposed Action will be described by the HGMP Section 10(a)(1)(A) Permit 15755, and any amendments, and covered by the associated Biological Opinion (NMFS 2014).

Aquatic Resource Measure Hatchery Releases

The objective of the hatchery release measure is to address reservoir drawdown and project-related effects on hatchery-produced coho salmon smolts that will be released from Fall Creek Hatchery during the spring of

Year 1, when high SSCs are potentially lethal to outmigrating juvenile salmonids. CDFW will determine the need and schedule for implementation of Aquatic Resource Measure Hatchery Releases. If necessary, hatchery-reared yearling coho salmon scheduled to be released in the spring of Year 1 may be held at Fall Creek Hatchery or another facility until water quality conditions in the mainstem Klamath River improve to sublethal levels.

As hatchery managers, CDFW will have the option to adjust the timing and location of hatchery releases during spring of Year 1. Although it may be out of sync with natural life history timing, if smolts are released later in the spring (e.g., mid-May), survival is anticipated to be higher than if juvenile coho salmon are released during suspended sediment conditions that may be lethal. Based on completed hydraulic and sediment modeling, a second peak in SSCs associated with coffer dam removal is expected to occur in approximately mid-June of the drawdown year (Appendix I). The Renewal Corporation will coordinate activities with hatchery managers to ensure that hatchery reared fish are not released immediately prior to coffer dam removal. Extending the spring holding period for juveniles will also avoid peak SSCs in Year 2, the year following dam removal. It is anticipated the increased holding period conservation measure will be beneficial for coho salmon.

5.1.3 Long-Term Effects

The Proposed Action will restore coho salmon access to at least 76 miles of additional habitat (DOI 2007, NMFS 2007b), including approximately 53 miles in the mainstem, and tributaries such as Fall, Jenny, Shovel, and Spencer creeks, and others; and approximately 22.4 miles currently inundated by the Hydroelectric Reach reservoirs (Cunanan 2009). Following dam removal, restoration maintenance and monitoring actions will run for several years and include minimization measures that will result in take of coho. The purpose of those actions is to minimize the impact of restoration maintenance and monitoring actions (i.e., removing tributary blockages and fish passage improvement actions) that are conducted for beneficial purposes. **Therefore, the effect of the Proposed Action will be beneficial for the coho salmon from the Upper Klamath River, Mid-Klamath River, Lower Klamath River, Shasta River, Scott River, and Salmon River population units in the long term. The effect of the Proposed Action on coho salmon from the three Trinity River population units will also likely be beneficial over the long term.**

The following sections describe the long-term effects of the Proposed Action on coho salmon.

5.1.3.1 Habitat Connectivity and Water Quality

The following paragraphs address long term benefits from habitat connectivity and water quality improvements from the Proposed Action. Further discussion of long-term benefits to anadromous salmonids, including coho salmon, is covered in section 5.4.3.3. The application of long-term benefits is expected to be expansive and dynamic, with species responses varying over time and location.

The Proposed Action will alter the hydrology in the Klamath River to establish a flow regime that more closely mimics natural conditions by increasing spring flow and by incorporating more variability in daily flows. Elimination of the reservoirs will allow tributaries such as Fall, Shovel, and Spencer Creeks, as well as natural groundwater springs, to flow directly into the mainstem Klamath River, creating patches of cooler water that could be used as temperature refugia by coho salmon (Hamilton et al. 2011). The Proposed Action will restore connectivity to habitat on the mainstem Klamath River, up to and including Spencer Creek, and will create additional habitat in the Hydroelectric Reach. The Renewal Corporation expects coho salmon to quickly recolonize habitat upstream of Iron Gate Dam following dam removal. This response has been observed after barrier removal on the Elwha River (McHenry et al. 2017; Liermann et al. 2017), White Salmon River (Hatten et al. 2015, Allen et al. 2016), and Cedar River (Burton et al. 2013, Anderson et al. 2014). Assuming coho salmon distribution will extend up to Spencer Creek following reestablishment of volitional fish passage, coho salmon from the Upper Klamath River population will have access to 76 miles of habitat, including approximately 53 miles in the mainstem Klamath River and tributaries (DOI 2007, NMFS 2007b), and approximately 22.4 miles currently inundated by the reservoirs (Cunanan 2009).

Free-flowing conditions created by the Proposed Action are expected to improve outmigration timing and increase concomitant adult escapement (Buchanan et al. 2011). The Proposed Action is expected to result in improvements to mainstem Klamath River hydrology, instream habitat, and water quality in the Hydroelectric Reach and downstream of the former Iron Gate Dam. Additionally, the Renewal Corporation expects the Proposed Action will reduce polychaete habitat and disease potential downstream of Iron Gate Dam. These improvements will benefit coho salmon populations throughout the Klamath River Basin, with populations closest to Iron Gate Dam expected to experience the most benefits from the Proposed Action.

The Renewal Corporation also anticipates age-0+ coho salmon will benefit from improved water quality conditions following the Proposed Action. Currently, degraded water quality conditions in the mainstem Klamath River exclude most summer rearing of juvenile coho salmon, with the exception of cool water refugia at the mouths of tributaries or in off-channel habitats. Age-0+ coho salmon may also redistribute in the fall in response to freshets that raise flows and decrease water temperatures. The Renewal Corporation expects the Proposed Action to decrease the residence time of water above Iron Gate Dam from several weeks to less than a day, resulting in improved water quality and a more natural temperature regime. Reservoir removal will also increase the benefits of tributaries such as Fall, Shovel, and Spencer creeks, as well as natural groundwater springs that will flow directly into the mainstem Klamath River, creating patches of cooler water that could be used as temperature refugia by age-0+ coho salmon during summer and fall, as well as providing slightly warmer winter water temperatures conducive to the growth of salmonids (Hamilton et al. 2011). The Proposed Action is expected to result in a 2 to 10°C decrease in water temperatures during the summer and fall months (PacifiCorp 2004a, Dunsmoor and Huntington 2006, NCRWQCB 2010b). The Renewal Corporation expects these Proposed Action benefits to increase the quantity and quality of summer rearing habitats and extend the duration of potential use of these habitats by coho salmon.

Investigations assessing the benefits and risks of the Proposed Action on coho salmon have resulted in a range of viewpoints. For example, a Coho Salmon and Steelhead Expert Panel (Dunne et al. 2011) concluded that coho will receive relatively modest improvements from dam removal, especially in the short term; however, the Panel concluded that larger (moderate) responses will be possible under the Proposed Action if watershed conditions in the Upper Klamath Basin improved and the Proposed Action resulted in the reduction of *C. shasta*–induced mortality on juvenile salmonids.

Coho salmon colonization of the Klamath River Hydroelectric Reach between Keno Dam and Iron Gate Dam will likely increase the abundance, diversity, and spatial distribution of the SONCC coho salmon ESU by some amount, which are key factors used by NMFS to assess viability of the ESU. Both the Coho and Steelhead Panel (Dunne et al. 2011) and Hamilton et al. (2011) concluded that benefits of dam removal for coho salmon go beyond increased abundance. Although noting uncertainties, the Panel acknowledged that colonization of the Klamath River between Keno Dam and Iron Gate Dam by the Upper Klamath River population will likely improve the viability of the SONCC ESU by increasing abundance, diversity, and spatial distribution. In general, as habitat availability and diversity increase for an ESU, so does the resilience of the population, reducing the risk of extinction (McElhany et al. 2000) and increasing chances for recovery.

Based on increased habitat availability and improved habitat quality, the effect of the Proposed Action will be beneficial for the coho salmon from the Upper Klamath River, Mid-Klamath River, Lower Klamath River, Shasta River, Scott River, and Salmon River population units in the long term. Based on improved habitat and water quality in the mainstem Klamath River, the effect of the Proposed Action on coho salmon from the three Trinity River population units will also likely be beneficial in the long term.

5.1.4 Critical Habitat Effects

Critical habitat features considered essential for the conservation of the SONCC coho salmon ESU (NMFS 1997) include (1) substrate, (2) water quality, (3) water quantity, (4) water temperature, (5) water velocity, (6) cover/shelter, (7) food, (8) riparian vegetation, (9) space, and (10) safe passage conditions. PBFs for coho salmon are described in NMFS (1999a) as follows: “In addition to these factors, NMFS also focuses on the known PBFs within the designated area that are essential to the conservation of the species and that may require special management considerations or protection. These essential features may include, but are not limited to, spawning sites, food resources, water quality and quantity, and riparian vegetation.”

The initial drawdown and release of sediment is likely to adversely affect the spawning sites, food resources, and water quality PBFs of mainstem Klamath River coho salmon’s critical habitat in the short-term. **Therefore, in the short term, the Proposed Action will have an adverse effect on Southern Oregon Northern California Coast (SONCC) coho salmon critical habitat.**

The Proposed Action will result in more natural sediment transport and hydrologic processes downstream of Iron Gate Dam, which will help create more natural substrate characteristics, increase the number and quality of spawning sites, enhance food resources, improve water quality, reduce disease prevalence, and expand the amount of riparian vegetation available for coho salmon. **Therefore, in the long term, the Proposed Action will have a beneficial effect on the SONCC coho salmon critical habitat.**

The effects of the Proposed Action on critical habitat described below are based on evaluation of the physical, chemical, and biological changes that are expected to occur to designated critical habitat in the area of analysis, and how those changes will affect the PBFs in the short term and long term.

5.1.4.1 Substrate

Nearly all of the coarse sediment supplied from upstream of the Hydroelectric Reach and downstream of Keno Dam is trapped in the reservoirs, and therefore, has not contributed to the bedload supply downstream of Iron Gate Dam since construction of the dams. The lack of clean and loose gravel diminishes the amount and quality of salmonid spawning habitat downstream of the dams. Channel substrate downstream of Iron Gate Dam is coarsely armored due to winnowing of sands and gravels.

SRH-1D modeling estimates 1 feet to 4 feet of reach-averaged sediment deposition will occur following reservoir drawdown as a sediment wedge is formed in a mile-long reach around Bogus Creek by summer of year 2 after drawdown. Downstream of the Willow Creek confluence, increases in width-averaged, reach-averaged bed elevation due to sediment deposition are expected to be less than 0.2 foot. After 2 years, the sediment wedge centered around Bogus Creek, if left unaltered, could potentially continue to increase in thickness as sediment from a 10-foot-thick sediment wedge located upstream of Iron Gate Dam provides additional sediment transported downstream. The application of the restoration actions (i.e., sediment stabilization) and fish passage maintenance and monitoring actions are expected to minimize the development and duration of problematic sediment wedges.

In the long term, the free-flowing Klamath River will process the sediment wedges upstream of Iron Gate Dam and at Bogus Creek, and channel bed elevations will adjust to a new equilibrium. The new equilibrium elevation downstream of Iron Gate Dam may be higher than existing conditions as a result of the scour and coarse sediment starvation that has occurred since the construction of Iron Gate Dam. Therefore, the streambed will regain some of its lost elevation and substrate characteristics with the return of a more natural sediment transport regime. The timeline of returning to a new equilibrium has not been modeled and will likely take years after drawdown.

Changes in sediment texture downstream of Iron Gate Dam are limited to the reach between Iron Gate Dam and Willow Creek. By the end of the simulated 2-year period, there is only a moderate increase in sand content in the surface sediments between Iron Gate Dam and Bogus Creek of slightly over 20 percent in a dry hydrologic scenario and below 10 percent in median and wet hydrologic scenarios. Changes in sand content downstream of Bogus Creek are negligible at the end of 2 years of simulation with all values below 5 percent. Changes to reach-averaged median grain sizes (D50) only occur upstream of Willow Creek during the 2 years of each hydrologic simulation. Downstream of Willow Creek, reaches have the same D50 at the end of simulation as their initial conditions. The greatest decreases in D50 occur in the reach from Iron Gate Dam to Bogus Creek, where an initial value of 74.5 mm decreases to 51.6 mm for dry hydrology and to 69 mm for wet and median hydrology. Sediment texture between Iron Gate Dam and Willow Creek could fine, and sand content could increase after the 2 years of simulation as a result of sediment supply upstream of Iron Gate Dam. Sand content in surface sediments in Iron Gate Reservoir at the end of 2 years of simulation is 27 percent to 43 percent, and there is still a sediment wedge just upstream of Iron Gate Dam Several years may be needed to flush sand from the bed and return sand content to equilibrium values.

SRH-1D model results indicate decreases in bed elevation and increases in median substrate size in the reservoirs during drawdown (January to July). The erosion of most of the fine reservoir sediments occurs during drawdown, so channel bed elevations are close to historical, pre-dam elevations except for at the downstream portions of each reservoir, where additional years may be required to flush the remaining sand and gravel from the reservoirs.

5.1.4.2 Spawning Sites

Bedload trapping by dams in the Hydroelectric Reach and winnowing of gravels below Iron Gate Dam have resulted in a coarse, armored channel bed that is unsuitable for spawning salmonids. The lack of loose spawning gravel is especially critical below Iron Gate Dam (FERC 2006). Spawning habitat quality improves in a downstream direction as tributary-supplied sediment and flow from Bogus, Willow, and Cottonwood creeks enter the Klamath River.

Based on spawning surveys conducted from 2001 to 2016 (Magneson and Gough 2006, USFWS 2017, unpublished data), there is average of six mainstem coho salmon redds in the reach downstream of Iron Gate Dam, and all will likely suffer 100 percent mortality as a result of the drawdown release of suspended sediment in the year of reservoir drawdown. This will result in total mortality of incubating eggs, alevin, and pre-emergent fry following drawdown. Following the final Iron Gate coffer dam breach and with increasing streamflow in the fall and winter of the year following reservoir drawdown, bedload movement may affect spawning sites within the newly accessible habitat within the former reservoir footprints and within the depositional reach between the former Iron Gate Dam site and Willow Creek. This cycling of bedload material from the former reservoir footprint into the depositional reach may persist for multiple years until a new channel equilibrium is reached. However, because coho salmon are primarily tributary spawners, and because channel bed adjustments are expected to occur during the fall spawning period when streamflows begin to elevate with the onset of fall precipitation, it’s unlikely that coho salmon will utilize these dynamic transport areas as spawning sites.

The proportion of sand in the bed downstream of Iron Gate Dam could increase to over 20 percent or more in the first few years after reservoir drawdown. The sand content may not reach equilibrium levels for several years depending on hydrology. The high sand content reduces spawning habitat quality and egg/alevin survival. The formation of a sediment wedge around Bogus Creek will bury preexisting substrate and fill in-channel holding and rearing habitat until channel organizing flows can erode the sediment wedge.

Once the sand is flushed from the riverbed following dam removal, an increase of suitable spawning gravel in the reach between Iron Gate Dam and Bogus Creek is expected. Improved spawning habitat is anticipated with the restored transport of spawning gravels from areas upstream of Iron Gate Dam (FERC 2007). Improved spawning gravel availability downstream of Iron Gate Dam will potentially improve critical habitat for coho salmon by reducing median substrate to a size more favorable for spawning (DOI 2011). The release of sediment from behind the dams will help create more natural substrate characteristics in the Hydroelectric Reach and increase the number of spawning sites available for coho salmon.

5.1.4.3 Food Resources

There will be a substantial increase in sand content immediately following reservoir drawdown in the Iron Gate Dam to Bogus Creek reach. The percent of sand in the bed is expected to increase up to 40 percent in the month immediately after reservoir drawdown. Increased sand concentrations will reduce the interstices in the substrate; and in turn, affect benthic macroinvertebrate (BMI) production.

Under the Proposed Action, increased SSCs will be expected to affect filter-feeding BMI in the short term. The high concentrations of suspended sediment released during winter are not predicted to have a severe effect on macroinvertebrates during their winter dormancy period. However, excessive SSCs and low dissolved oxygen levels during spring and summer of the drawdown year are expected to cause physiological stress, reduced growth, and mortality to filter-feeding BMIs. The scraper-grazers feeding guild among the BMIs are also expected to be deleteriously affected, but due to their increased mobility, will be affected less than the filter-feeders. SSC effects could impact BMI as far downstream as Orleans. During summer of the drawdown year, high SSCs associated with cofferdam breaching activities and drawdown completion will be expected to impact macroinvertebrates during the peak of their feeding and reproductive period. Recolonization of affected BMI populations will occur relatively quickly due to the shortened life cycle of BMIs and rapid dispersal through drift and/or the flying stages of many BMI adults. In addition, recolonization is expected to occur rapidly through drift or dispersal of adult life stages from established BMI populations in the many tributaries to the Klamath River.

Juvenile coho salmon feed primarily on drifting terrestrial insects, many of which are produced in the riparian canopy, and on aquatic invertebrates growing in the interstices of the channel bed and in the leaf litter in pools (NMFS 2003). The anticipated increase in sand composition in the channel will partially fill in interstitial spaces between gravel, cobble, and boulders, which will adversely affect BMI production and availability as a food source for coho salmon.

In the long term, the reformation of river channels in the Hydroelectric Reach reservoirs following the Proposed Action is expected to benefit BMIs by providing more suitable substrates than currently exist. As a result, suitable habitats formed in the Hydroelectric Reach will be opened to additional colonization by BMIs through rapid dispersal by drift from upstream populations in current riverine reaches and/or dispersion of adult life stages. Recolonization will also be expected to occur rapidly from established BMI populations in the many tributaries of the Klamath River. Increased habitat availability for BMI populations is anticipated to increase food availability for juvenile coho salmon downstream of Iron Gate Dam as BMI freely drift or migrate downstream of the Hydroelectric Reach. Increased habitat availability will result in a substantial increase in the amount of food resources available for coho salmon.

5.1.4.4 Water Quality and Quantity

High flows are critical for shaping river channels, creating diverse habitats, and connecting these habitats to riparian zones, terraces, and floodplains that provide nutrients to the riverine ecosystem and shelter for fish and other aquatic organisms when conditions in the river are unsuitable. Periodic springtime high-flow events also have the potential to scour the channel of fine-grained sediments and Cladaphora, which harbor intermediate hosts for disease organisms that produce high mortality in juvenile salmon. High flows mobilize the streambed, removing fine sediments and organic material that can reduce spawning success and macroinvertebrate production, as well as reduce interstitial habitat used as cover by small fish. High flows are also important drivers of riparian ecosystem functions, such as for dispersing and germinating seeds of riparian plants and creating new areas for vegetation colonization through erosion and deposition. Riparian ecosystems are important for filtering fine sediment from hillslope runoff, buffering streams from contaminants, and providing shade and temperature regulation, bank stability, and nutrients to the stream.

Suspended Sediment

The Proposed Action will result in high SSCs in the Klamath River in the short term. Elevated SSCs due to reservoir drawdown and construction activities in Year 1 will result in effects on juvenile coho salmon and redds that range from extreme stress to mortality.

The sediment released from the drawdown and dam removal will be a short-term effect of the Proposed Action, and high SSCs are not expected to persist for more than 2 years following reservoir drawdown. In the long term, SSCs will return to background levels.

Water temperature

Reservoir drawdown under the Proposed Action will occur from winter through summer, over a range of water temperatures. As the reservoirs will be drawn down from low elevation conduits, the reservoirs should remain mixed through the drawdown period. Additionally, due to the low expected residence time of water flowing through the reservoirs, background temperature characteristics of river reaches upstream of the reservoirs provide an indication of likely temperature patterns during drawdown. Therefore, there are no anticipated short-term effects of the Proposed Action on water temperature during the drawdown period.

In agreement with the Klamath River Water Quality Model (KRWQM) results, Klamath total maximum daily load (TMDL) model (see Appendix D of the Klamath Facilities Removal EIS/EIR) results indicate that under the Proposed Action, water temperatures in the Klamath River downstream of Iron Gate Dam (RM 193.1) will be 2 to 10°C (3.6 to 18°F) lower during August through December, and 2 to 5°C (3.6 to 9°F) higher during January through March than those under the existing condition (Figure 5-7) due to removal of the large thermal mass created by the Hydroelectric Reach reservoirs (NCRWQCB 2010a). There is a brief period in late April and early May where the model indicated that water temperatures may exceed those preferred by juvenile coho salmon. However, these late-April and early-May temperatures do not reach beyond stressful levels.

The Klamath TMDL model also predicts that daily fluctuations in water temperature downstream of Iron Gate Dam will be greater under the Proposed Action than the existing condition, because water temperatures will be in equilibrium with (and will reflect) daily fluctuations in ambient air temperatures. These impacts will decrease in magnitude with distance downstream of Iron Gate Dam, but still be felt near the Scott River (Figure 5-8) and will not be evident at the Salmon River confluence (Figure 5-9).

The thermal lag formerly caused by water storage in the Hydroelectric Reach reservoirs, and the associated thermal mass, will be eliminated in the Klamath River following the Proposed Action. Elimination of the thermal lag and thermal mass will restore water temperature diurnal variability, and water temperatures will be more in sync with historical migration and spawning periods for coho salmon. The Renewal Corporation expects water temperatures to warm earlier in the spring, and cool earlier in the fall compared with background conditions (Stillwater Sciences 2009b, Hamilton et al. 2011). Changes in water temperature will benefit migrating adult and juvenile coho salmon during fall upstream migration and juvenile redistribution to overwintering habitats by providing a broader window of suitable water quality during migration. Juvenile outmigrants may also outmigrate earlier during spring with slightly warmer water temperatures, potentially reducing their susceptibility to parasites and disease, and improving growth rates.

Simulations of water temperatures without the reservoirs (as discussed in Hamilton et al. 2011) show that the temperature difference with and without dams will be greatest downstream of Iron Gate Dam but could extend an additional 120 to 130 miles downstream of Iron Gate Dam. Estimated decreases in stream temperature with dam removal relative to current conditions are likely to be smaller with continued climate change; however, temperature conditions will be much improved under the Proposed Action as compared to existing conditions.

In summary, water temperatures in the Klamath River downstream of Iron Gate Dam will be 2 to 10°C (3.6 to 18°F) lower during August through December and 2 to 5°C (3.6 to 9°F) higher during January through July than those under the existing condition (Figure 5-7). Water temperatures in the reach upstream of the Scott River and downstream of the Salmon River appear to be slightly cooler overall relative to the baseline condition.

Under the Proposed Action, the cooler fall water temperatures will be beneficial for adult migration and juvenile rearing. The warmer winter temperatures are within the preferred range for coho salmon and may actually improve growth rates. However, water temperatures during late April through July (downstream of Iron Gate Dam to Scott River mouth) appear to be higher than the existing condition and may reach stressful levels for juvenile coho salmon.

Dissolved oxygen

Although predicted short-term increases in oxygen demand under the Proposed Action generally result in dissolved oxygen concentrations above the minimum acceptable level (5 mg/L) for salmonids, exceptions to this will occur in mid-January and mid-June when dissolved oxygen levels decline to less than 5 mg/L.

The Proposed Action could cause long-term overall increases in dissolved oxygen, as well as increased daily variability in dissolved oxygen, in the Klamath River, particularly for the reach immediately downstream of Iron Gate Dam. KRWQM (see 2012 EIS/EIR Section 3.2.1.1 for model background) results using 2001–2004 data indicate that substantial improvements in long-term dissolved oxygen may occur immediately downstream of Iron Gate Dam following implementation of the Proposed Action, with increases of 3 to 4 mg/L dissolved oxygen possible during summer and late fall (PacifiCorp 2004c).

The Klamath TMDL model (see Appendix C of the 2012 EIS/EIR) also indicates that under the Proposed Action (similar to the TMDL TCD2RN scenario), dissolved oxygen concentrations immediately downstream of

Iron Gate Dam during July through November will be greater than those under the existing condition (similar to the TMDL T4BSRN scenario), due to the lack of stratification and oxygen depletion in bottom waters in the upstream reservoirs as compared with a free-flowing river condition (Appendix C of the 2012 EIS/EIR; NCRWQCB 2010a).

Overall, the Proposed Action will cause long-term increases in summer and fall dissolved oxygen in the Klamath River immediately downstream of Iron Gate Dam, along with potentially increasing daily variability. Effects will diminish with distance downstream of Iron Gate Dam, so that there will be no measurable effects on dissolved oxygen by the confluence with the Trinity River.

Water velocity

The Renewal Corporation expects the Proposed Action to result in relatively minor changes to river flows downstream of Iron Gate Dam. Assuming changes in water velocities are proportional to changes in flow exceedances, then there will be relatively little change between existing and Proposed Action conditions downstream of the former Iron Gate Dam (Figure 5-10). Proposed Action water velocities downstream of the former Iron Gate Dam will be lower in the fall and slightly higher during the summer. However, Proposed Action flows and water velocities will be similar to the existing condition at Orleans (Figure 5-11). Some increased flow variability downstream of Keno Dam will be expected due to the loss of the detention effect of the four Hydroelectric Reach reservoirs.

Although not a part of existing designated critical habitat, the most significant difference in water velocities will occur in the Hydroelectric Reach. Following dam removal, the reservoir pools of the four dams will be converted to a free-flowing river. The average depths and velocities of the restored river in the former reservoir pools will be similar to the reaches upstream and downstream of the reservoirs (Figure 5-12) (USBR 2011b).

5.1.4.5 Space

The PBF "space" refers to the space needed for individual and population growth and normal behavior (64 FR 24049). The release of sediment associated with the Proposed Action will result in sediment deposition in the reaches downstream of Iron Gate Dam. Sediment deposition will result in some channel and pool filling in the reach between Iron Gate Dam and Cottonwood Creek. This will result in a loss of space for coho salmon. However, this reach has also been subject to interrupted sediment supply due to the presence of the Hydroelectric Reach dams. This interruption of sediment transport has likely resulted in some habitat simplification due to the river's reduced ability to establish and maintain the type of pool:riffle morphology that will occur with a normal sediment supply. Therefore, although sediment deposition that results from the Proposed Action will reduce overall habitat space, the reintroduction of coarse sediment will allow for increased habitat complexity in the post-dam channel downstream of Iron Gate.

The Proposed Action will increase coho salmon living space in at least 76 miles of additional habitat (DOI 2007, NMFS 2007b), including approximately 53 miles in the mainstem, and tributaries such as Fall, Jenny, Shovel, and Spencer creeks, and others; and approximately 22.4 miles currently inundated by the Hydroelectric Reach reservoirs (Cunanan 2009).

5.1.4.6 Safe passage

Adult coho

SSCs in the mainstem Klamath River will be high enough to cause major physiological stress and impaired homing in the fall of the year before drawdown, and immediately following removal of the dams in Year 1, depending on the amount of reservoir sediment that remains to be eroded. This reduction in water quality may result in the few adult coho salmon that typically spawn in the mainstem Klamath River to stray into cleaner-flowing tributary streams. However, the Proposed Action will also restore coho salmon migratory access to the Hydroelectric Reach, expanding coho salmon distribution to historical habitat along the mainstem Klamath River, and all tributaries upstream of Iron Gate Dam as far as Spencer Creek; including Jenny, Shovel, and Fall creeks (Hamilton et al. 2005). Adults could first access this reach in fall of Year 1. Once upstream of Iron Gate Dam, migrating coho salmon will encounter progressively improving water quality. In the long term, the Proposed Action will allow for coho salmon access to at least 76 miles of additional habitat (DOI 2007, NMFS 2007b).

Coho salmon smolts

Coho salmon smolts from the year before drawdown cohort are expected to outmigrate to the ocean beginning in late February of Year 1, although most natural origin smolts outmigrate to the mainstem Klamath during April and May (Wallace 2004). Under the Proposed Action, SSC will be higher during spring than under existing conditions, thereby reducing the quality of coho salmon smolt migration habitat. As a result, coho smolts outmigrating in early spring (prior to April 1) are likely to experience between 0 and 6 percent mortality depending on SSC level and the coho population (see Table 5-7).

In the long term, the return to a more natural hydrologic regime is expected to result in river flows that are either the same or higher than the current condition for the months of March through July (Figure 5-10). The higher flows will assist smolt migration.

5.1.4.7 Riparian vegetation

Riparian habitat occurs along the river and reservoir shorelines in some areas and consists of deciduous, shrub, and grassland vegetation. Downstream of Iron Gate Dam, riparian vegetation coverage is limited to the edge of the river channel and the surfaces of existing gravel bars. The Proposed Action does not include removal of riparian vegetation, and the proposed drawdown releases will not exceed flows currently experienced by the river channel.

Project dams prevent the downstream transport of sediment, which may result in a diminished supply of spawning gravel and other altered geomorphological processes (including sand and silt starvation) that may influence aquatic habitat and adversely influence the establishment of riparian vegetation (FERC 2007). In the long term, with the dams out, a return to sediment transport and hydrologic process will likely improve riparian establishment and succession patterns. The Proposed Action includes planting and re-establishment of riparian vegetation in the drained reservoir areas, which will result in several miles of riparian corridor along restored tributaries (that are currently under reservoir water). The reestablished riparian vegetation within the former reservoir footprints could be a source for riparian vegetation recruitment downstream of the former Iron Gate Dam. Additionally, the newly accessible riverine habitat of the Klamath River within the hydroelectric reach and associated tributaries support mature riparian vegetation that will become available to recolonizing coho salmon from the Upper Klamath River population.

5.2 Southern DPS Green Sturgeon

This section presents the effects analysis approach and findings. A detailed account of the species, including regulatory status, critical habitat, life history, geographic distribution, population trends, threats, and status in the Action Area is provided in Appendix G.

5.2.1 Effects Analysis Approach

SDPS green sturgeon are only known to occupy the Klamath River estuary and marine nearshore environment of the Action Area during summer and fall for feeding. Therefore, the effects analysis focuses on the potential for the Proposed Action to affect sDPS green sturgeon due to increased SSCs in the estuary during reservoir drawdown and dam removal, and potential effects of sediment-borne contaminants on critical habitat. Since sDPS green sturgeon are expected to migrate out of the Klamath River estuary with the onset of fall rains and subsequent elevated flows, the effects analysis focuses on project related effects of elevated suspended sediment that occur within June 1 - September 30 time period.

Designated critical habitat for sDPS green sturgeon is found approximately 1 mile offshore of the mouth of the Klamath River. Therefore, the effects analysis for critical habitat focuses on the potential for the Proposed Action to release fine sediments and/or sediment-borne contaminants resulting in degradation of water quality and reduced food resources for sDPS green sturgeon.

5.2.2 Short-Term Effects

Under background conditions, SSCs in the Klamath River estuary are relatively high. The lower Klamath River, from downstream of the Trinity River confluence to the estuary mouth, is currently listed as sediment-impaired under Section 303(d) of the CWA, as related to protection of the cold freshwater habitat (COLD) beneficial use associated with salmonids (SWRCB 2006, NCRWQCB 2010a).

Under the Proposed Action, sediment released from Iron Gate Dam will decline in concentration with distance from the dam due to tributary accretion. Therefore, the magnitude of SSCs from the Proposed Action relative to background conditions will be at its lowest level in the Klamath River estuary. However, modeling results (Appendix I) indicate that Proposed Action SSCs at Klamath Station (Figure 5-13) will exceed background conditions from June to September.

Little scientific literature exists regarding the effects of SSC on sDPS green sturgeon. Only the adult life stage could occur in the Action Area, and adult sturgeon species are typically considered to be more tolerant to turbid conditions than salmonids based on the fact that they regularly occur in turbid estuaries (Moser and Lindley 2007) and prefer turbid water for spawning (Gessner and Bartel 2000). Garakouei et al. (2009) conducted a laboratory analysis of fingerling sturgeons' response to SSCs. The species used in the study were *Acipenser persicus* and *A. stellatus*, both native to the Caspian Sea and found in Iran. The authors found that these sturgeon fingerlings were more sensitive than fingerling salmonids to elevated suspended sediment levels. Cherr and Clark (2005), as reported in Garakouei et al. (2009), stated that sturgeons require muddy water during spawning to prevent adhesion and deformation of eggs, which indicates that adult sturgeon may be more tolerant of suspended sediment than fingerlings. Adult sDPS green sturgeon will be the life stage that will enter the Klamath River estuary during the summer and fall. The nearest sDPS green sturgeon fingerlings will only be found in the Sacramento River, where they stay for 1 to 3 years before migrating. Further, during radio telemetry studies, McCovey (2010) found that adult green sturgeon did not respond to periods of poor water quality, including high water temperature, algal blooms, disease outbreaks, and pulses of suspended sediment.

Adult sDPS green sturgeon will not be in the estuary prior to the summer and fall following reservoir drawdown, and therefore will not be exposed to elevated SSCs resulting from the initial winter/spring period drawdown. During the summer foraging period of the drawdown year, monthly median SSC values for the 48-year modeling hydroperiod under the Proposed Action range from 20 to 496 mg/L, levels higher than under background conditions of 1 to 131 mg/L. However, green sturgeon are not sight feeders and generally feed on benthic organisms detected in fine sediments by their sensitive barbells. This trait will likely reduce the impacts of suspended sediment on the species in terms of feeding ability (EPIC et al. 2001). In addition, only a small proportion, if any, of the total sDPS green sturgeon population will be expected to use the Klamath River estuary during the summer and fall following initial reservoir drawdown, further minimizing the potential for short-term impacts related to the project. By the summer of Year 2, the Renewal Corporation expects SSC values at the Klamath Station to be within the range of background conditions. **Therefore, the Proposed Action may affect, but is not likely to adversely affect the sDPS green sturgeon in the short term.**

5.2.3 Long-Term Effects

In the long term, the Renewal Corporation does not expect conditions in the Klamath estuary to be substantially different than background conditions. The benefits of more natural water temperature, flow, and sediment transport regimes are expected to benefit sDPS green sturgeon, but those benefits are not expected to extend to the estuary, or at least will be greatly diminished due to accretion flow from the many tributaries between the former Iron Gate Dam and the estuary. **Therefore, the Proposed Action may affect, but is not likely to adversely affect sDPS green sturgeon in the long term.**

5.2.4 Critical Habitat Effects

The Klamath River estuary and 1 mile of the coastal marine area adjacent to Yurok Tribal land are excluded from the critical habitat designation. However, the nearshore area beyond a 1-mile area north, south, and offshore of the mouth of the river is considered critical habitat.

As stated in 74 FR 52300, the essential features for the conservation of the sDPS green sturgeon in coastal marine areas include:

1. Migratory corridor. A migratory pathway necessary for the safe and timely passage of all life stages in marine and between estuarine and marine habitats.
2. Water quality. Nearshore marine waters with adequate dissolved oxygen levels and low enough levels of contaminants (e.g., pesticides, organochlorines, elevated levels of heavy metals) to allow normal behavior, growth, and viability of subadult and adult green sturgeon.
3. Food resources. Abundant prey items for subadults and adults, which may include benthic invertebrates and fish.

The migratory pathway for sDPS green sturgeon is in the nearshore and deep offshore ocean environment. Because adult green sturgeon may be more tolerant of turbid water, and the expected suspended sediment levels in the estuary and nearshore environment are predicted to be only slightly elevated compared to the existing conditions, the effects of the Proposed Action will not hinder migration for this species in designated critical habitat areas.

Sediment release associated with the Proposed Action could cause short-term and long-term decreases in the water quality PBF of the sDPS green sturgeon's coastal marine critical habitat. Potential water quality effects will occur because the organic and inorganic contaminants that have been identified in the sediment deposits currently trapped behind the dams (USBR 2011d) will be mobilized during reservoir drawdown and transported to the nearshore marine environment. However, core samples of reservoir sediment deposits were collected and analyzed for organic and inorganic contaminants in 2004-2005, and again in 2009-2010, with the results indicating no positive exceedances of applicable screening levels (USBR and CDFW 2012). In addition, there were no positive exceedances of the applicable and available maximum marine screening levels (CDM 2011), with the exception of a small number of sediment samples from J.C. Boyle Reservoir, which exceeded the applicable marine screening level for dieldrin and 2,3,4,7,8-PECDF (CDM 2011). The marine screening levels are designed to be protective of direct toxicity to benthic and epibenthic organisms, which corresponds to a "no adverse effects level." The vast majority of 2009– 2010 samples indicate a low risk of toxicity to sediment-dwelling organisms.

With respect to bioaccumulation potential, there are no exceedances of applicable marine bioaccumulation screening levels (CDM 2011). Further, with the exception of four samples in J.C. Boyle Reservoir (CDM 2011), levels of other known bioaccumulative compounds did not exceed ODEQ bioaccumulation screening levels for marine fish. Note that ODEQ bioaccumulatory screening levels are not strictly applicable in the California marine offshore environment; however, they are indicative of potentially bioaccumulative compounds. The effect of the Proposed Action on the water quality PBF of critical habitat is expected to be insignificant due to the very low levels of contaminants in the reservoir sediments, low bioaccumulation potential, and the dilutive effects of the river water and ocean.

A considerable amount of fine sediment in the sediment plume is anticipated to initially deposit on the seafloor shoreward of the 60-meter isobath along the coast, with greater quantities depositing in close proximity to the mouth of the Klamath River (USBR and CDFW 2012). After this initial deposition, as described by Farnsworth and Warrick (2007), resuspension during the typical winter storms will likely occur before final deposition and burial. Much of this sediment will eventually be transported further offshore to the mid-shelf and into deeper water off-shelf through progressive resuspension and fluid-mud gravity flows. This sediment deposition and resuspension may affect benthic food resources of the sDPS green sturgeon. Food resources in the nearshore environment include crabs, shrimp, clams, annelid worms, and other invertebrates, as well as small fish like anchovies and sand lances (74 FR 52300). Many of these food resources are mobile and will not be affected by sediment deposition. Some organisms, like clams and annelid worms, may be affected by sediment deposition and resuspension. However, the area of impact will be relatively small when compared to the expanse of the critical habitat zone, and green sturgeon will be able to access other food resources if benthic food organisms become affected by the Proposed Action sediment deposition.

Green sturgeon will be able to substitute other food resources if nearshore sediment deposition affects benthic-dependent prey species. The effect of the Proposed Action on the water quality PBF of critical habitat is expected to be insignificant due to the very low levels of contaminants in the reservoir sediments, low bioaccumulation potential, and the dilutive effects of the river water and ocean.

In summary, there is no designated critical habitat in the Klamath River estuary. However, the nearshore area beyond about a 1-mile area north, south, and offshore of the mouth of the river is considered critical habitat. The Proposed Action is anticipated to have minimal to no effect on critical habitat due to the dilutive effects of the marine environment. **Therefore, the Proposed Action may affect, but is not likely to adversely affect sDPS green sturgeon critical habitat.**

5.3 Southern DPS Eulachon

This section presents the effects analysis approach and findings. A detailed account of the species, including regulatory status, critical habitat, life history, geographic distribution, population trends, threats, and status in the Action Area is provided in Appendix G.

5.3.1 Effects Analysis Approach

SDPS eulachon are only known to occupy the lower Klamath River, estuary, and nearshore environment area during the winter and spring for spawning, incubation, and early rearing. Therefore, the effects analysis focuses on short-term degradation of water quality due to increased SSCs in the lower Klamath River and estuary.

As with sDPS green sturgeon, little scientific literature exists regarding the effects of SSC on sDPS eulachon. Because of the potential for spawning eulachon to be present in the Action Area, it is likely that incubating eggs or larva will be sensitive to increases in SSC related to the Proposed Action during the drawdown year. To assess the potential effects on migrating and spawning adult sDPS eulachon, the Renewal Corporation calculated 7-day median SSC concentrations at Klamath Station and then utilized the Newcombe and Jensen (1996) models for assessing impacts on juvenile salmonids to evaluate the potential effects to sDPS eulachon.

SDPS eulachon critical habitat is designated in the lower 10.7 miles of the Klamath River from the river mouth upstream to Omogar Creek (critical habitat does not include reaches in Yurok Tribe and Resighini Rancheria lands). Therefore, the effects analysis focuses on the predicted short-term increase in SSC that could potentially affect the spawning and incubation sites, migration corridors, and nearshore and offshore foraging habitat PBFs of designated critical habitat. This analysis extends the predicted SSC effects analyzed for salmonids to eulachon, and then overlays the spatial and temporal increases in SSC with the expected use of critical habitat elements by sDPS eulachon. Although SSC effects on eulachon have not been studied, the species is believed to be similarly sensitive to impaired water quality.

The Renewal Corporation utilized the same approach as described in the coho salmon effects analysis (Appendix G) to determine the median and severe impact years to be assessed in more detail. By summing the SEVs within each period of use time block, the median impact year and severe impact year for sDPS eulachon were determined to be 1974 and 1977, respectively.

5.3.2 Short-Term Effects

Under the Proposed Action, sediment released from Iron Gate Dam will decline in concentration with distance from the dam due to tributary accretion. Adult eulachon entering the Klamath River in the late winter and spring following reservoir drawdown may be exposed to SSCs exceeding background levels for a portion of their migration period. Based on spawn timing and duration, the Renewal Corporation calculated 7-day median SSCs for both the median impact year (1974) and severe impact year (1977) scenarios at Klamath Station between January 1 and May 5 for both the dams in place scenario (background conditions) and the Proposed Action (Figure 5-13) to evaluate the potential effects of elevated SSCs on adult eulachon in the estuary and lower Klamath River for spawning (Table 5-11).

Table 5-11: 7-Day Median SSC, SEV Score, and Adult Eulachon Response Scenarios atthe USGS Klamath Station

	Year 1 (Drawdown)			Year 2		
Scenario	7-day Median SSC Range (mg/L)	SEV	Response	7-day Median SSC Range (mg/L)	SEV	Response
Background Median Impact Year	46 to 1119	7 to 9	Sublethal effects, including major stress	11 to 1237	6 to 9	Sublethal effects, including moderate stress
Background Severe Impact Year	1 to 18	4 to 6	Sublethal effects, including moderate stress	46 to 514	7 to 9	Sublethal effects, including major stress
Proposed Action Median Impact Year	34 to 958	7 to 9	Sublethal effects, including major stress	28 to 1241	7 to 9	Sublethal effects, including moderate stress
Proposed Action Severe Impact Year	30 to 3477	7 to 10	Major stress and up to 20% mortality for 10% of the migration and spawning period	38 to 496	7 to 9	Sublethal effects, including major stress

Although Newcombe and Jensen (1996) did not specifically assess SSC exposure risk to eulachon, based on juvenile salmonid effects, predicted background and Proposed Action median impact year SSCs may cause sublethal effects, including major stress. Eulachon present in the lower Klamath River during the earliest spawning migrations in mid- to late January of the drawdown year are likely to experience the most substantial effects, but the effects are likely to be similar to those under background conditions. Similar background and Proposed Action results are expected during the winter of Year 2.

For the severe impact year scenario, 7-day median SSC values for the Proposed Action in Year 1 are substantially higher than the background condition and are expected to result in up to 20 percent adult eulachon mortality for approximately 10 percent of the migration and spawning period (Table 5-11). Impacts to eggs and larval eulachon from elevated SSC are also expected to be higher during Year 1 for the Proposed Action compared to background conditions. In addition, increased SSCs may temporarily alter the quality of the sand and pea gravel substrate that eulachon rely on for spawning and incubation. **Therefore, elevated SSC levels in the lower Klamath River resulting from the Proposed Action are likely to adversely affect sDPS eulachon in the short term.**

5.3.3 Long-Term Effects

In the long term, conditions in the lower Klamath River and estuary are not expected to be substantially different than under background conditions. The Renewal Corporation expects a more natural water temperature, flow, and sediment transport regime will benefit eulachon, but those benefits are not expected to extend to the lower Klamath River or estuary, or they will be greatly diminished due to accretion flow from the many tributaries between the former Iron Gate Dam and the estuary. **Therefore, the Proposed Action may affect, but is not likely to adversely affect sDPS eulachon in the long term.**

5.3.4 Critical Habitat Effects

In the Klamath River, designated critical habitat extends from the mouth of the Klamath River upstream to Omogar Creek, a distance of 10.7 miles, and excludes tribal lands in the Yurok Reservation and Resighini Rancheria boundaries. As stated in 76 FR 65324, the specific physical or biological features essential for the conservation of the sDPS eulachon include:

- Freshwater spawning and incubation sites with water flow, quality, and temperature conditions, and substrate supporting spawning and incubation.
- Freshwater and estuarine migration corridors free of obstructions with water flow, quality, and temperature conditions supporting larval and adult mobility, and with abundant prey items supporting larval feeding after the yolk sac is depleted.
- Nearshore and offshore marine foraging habitat with water quality and available prey, supporting juvenile and adult survival.

Modeled daily SSC values at Klamath Station for the Proposed Action under the median impact year are expected to be similar to background conditions in Year 1 and Year 2. However, SSCs will be substantially higher under the Proposed Action severe impact year relative to background conditions in Year 1. Under the severe impact year scenario, temporary degradation of the available eulachon spawning and incubation habitat due to increased SSCs is expected. Additionally, some settling of fine sediment likely to occur in the lower Klamath River and estuary may temporarily impact the available spawning substrate for sDPS eulachon. SSCs under both scenarios are predicted to return to within the range of background levels in the lower Klamath River by the winter following drawdown, and any fine sediment that has settled will likely be resuspended and transported from the lower Klamath River by fall and winter freshets.

Increased SSCs in the lower Klamath River and estuary from January 1 through fall of the drawdown year are likely to cause degradation of water quality conditions for adult sDPS eulachon that are migrating to spawning sites in the lower Klamath River. SSCs should return to background levels at Klamath Station prior to the following year's adult and larval eulachon migration periods.

The Renewal Corporation also expects some short-term increases of SSCs in the nearshore and possibly offshore marine environment near the mouth of the Klamath River. However, these temporary increases are not expected to adversely affect sDPS eulachon forage species or be of sufficient magnitude to reduce the suitability of the water quality in the nearshore or offshore eulachon foraging.

In summary; the initial drawdown and release of sediment may adversely affect freshwater spawning and incubation sites and adult and larval migration habitat PBFs of sDPS eulachon critical habitat in the short term, but is not likely to adversely affect the nearshore and offshore marine foraging habitat PBF. **Therefore, the Proposed Action is likely to adversely affect sDPS eulachon critical habitat in the short term. The Proposed Action is not likely to adversely affect critical habitat PBFs in the long term.**

5.4 Southern Resident DPS Killer Whale

This section presents the effects analysis approach and findings. A detailed account of the species, including regulatory status, critical habitat, life history, geographic distribution, threats, and status in the Action Area is provided in Appendix G.

5.4.1 Effects Analysis Approach

Southern Resident killer whales are an endangered population that occurs primarily along the outer coast and inland waters of Washington and British Columbia. The Southern Resident killer whale population currently consists of 74 individual whales (Center for Whale Research 2019) and is comprised of three largely matrilineal groups, referred to as pods J, K and L (Ford et al. 2000). Pods visit coastal sites off Washington and Vancouver Island (Ford et al. 2000), but travel as far south as central California in winter and therefore may be off Oregon and California during the winter and early spring. SRKW survival and fecundity are correlated with Chinook salmon abundance (Ward et al. 2009; Ford et al. 2009). As such, the effects analysis for Southern Resident killer whales is focused on the potential effects of the Proposed Action on the abundance of Chinook salmon, their primary food source (Hanson et al. 2021).

The food resource analysis includes an evaluation of anticipated short-term and long-term effects to Chinook salmon, the primary food resource for Southern Resident killer whales (Ford and Ellis 2006; Ohlberger et al.

2019; Hanson et al. 2020). The short-term effects analysis approach follows the coho salmon analysis presented in Section 5.1.1, and includes a review of suspended sediment, dissolved oxygen, and bedload deposition effects that are anticipated to occur during reservoir drawdown and dam removal. Like coho salmon, Chinook salmon may also be impacted by pre-drawdown activities, high sediment and low dissolved oxygen levels during drawdown and dam removal, and bedload deposition during and following dam removal. Long-term effects to Chinook salmon include reduced hatchery production of sub-yearling and yearling Chinook salmon associated with the proposed Fall Creek Hatchery and the removal of Iron Gate Hatchery. The Proposed Action is anticipated to result in long-term benefits for Chinook salmon as the Klamath River's temperature regime, hydrology, and sediment characteristics are restored and Chinook salmon regain access to historical habitat upstream of Iron Gate Dam. The Klamath River also contributes a small number of Chinook salmon to the Southern Resident killer whale prey base (2.2% ±2.3%) between mid-winter and early spring when killer whales inhabit outer coastal areas (Hanson et al. 2021).

5.4.1.1 Suspended Sediment Effects Analysis Approach

The suspended sediment effects analysis approach for Chinook salmon follows the approach presented for coho salmon outlined in Section 5.1.1.1 and Appendix H - Suspended Sediment Effects Analysis. Additional detail on the approach specific to Chinook salmon is included in Appendix J – Klamath River Chinook Salmon Analysis.

Chinook salmon period of use in the mainstem Klamath River is presented in Table 5-12. Fall-run Chinook salmon in the Klamath Basin exhibit three juvenile life-history types: Type I (ocean entry at age-0 in early spring within a few months of emergence); Type II (ocean entry at age-0 in fall or early winter); and Type III (ocean entry at age-1 in spring) (Sullivan 1989). Based on outmigrant trapping at Big Bar on the Klamath River from 1997 to 2000, 63 percent of natural Chinook salmon outmigrants are Type I, 37 percent are Type II, and less than 1 percent are Type III (Scheiff et al. 2001). Although trapping efforts are not equal among seasons, the results are consistent with scale analysis of adult return (Sullivan 1989).

Wild spring-run Chinook salmon from the Salmon River appear to primarily express a Type II life history, based on scale analyses of adults returning from 1990 to 1994 in the Salmon River (Olson 1996), as well as otolith analyses of Salmon River fry and adults (Sartori 2006). A small number of fish employ the Type III life history, although it does not appear to be nearly as prevalent as Type II.

Because the Type I life history is the dominant Chinook salmon juvenile life history strategy, the suspended sediment effects analysis focuses on this life history. The Renewal Corporation anticipates Type II and Type III fish will also be affected by suspended sediment concentrations if the fish are rearing in the mainstem Klamath River during reservoir drawdown.

The Renewal Corporation used a 20-day outmigration period, or 9.6 miles/day outmigration rate, for the juvenile Chinook salmon SSC exposure analysis. This migration rate was based on work by Foott et al. (2009) and Wallace (2004). Foott et al. (2009) reported median outmigration travel times for radio-tagged juvenile Chinook salmon released from Iron Gate Hatchery (RM 192.5) to Klamath Glen (RM 8.0) of 10.2 days. Median travel rates through the upper reaches of the Klamath River (Ager bridge and Shasta River reaches) were greater than 2.7 miles/hour, nearly twice as fast as migration rates through downstream reaches. Travel rate differences were in part explained by release timing, because fish released at night moved immediately following release, whereas fish released during the day delayed outmigration (Foott et al. 2009). Water temperature and fish size also influenced outmigration rates. Wallace (2004) reported annual median travel times for coded-wire tagged juvenile Chinook salmon from Iron Gate Hatchery to the estuary of 26 days to 52 days, with a range from 13 days to 109 days from a study completed between 1998 and 2002. The travel times equate to median values of 3.7 miles/day to 7.4 miles/day, with a range from 1.8 miles/day to 14.8 miles/day).

Table 5-12: Chinook Salmon Period of Use by Life Stage, Date, and Duration in the Mainstem Klamath River

Period of Use[1]	Life Stage Analyzed	Date Window[1]	Duration
Upstream Migration	Adults	7/15 – 11/30	14 days
Spawning and Incubation	Adults, Eggs	10/1 – 2/15	60 days
Spring Outmigration (Type I)	Age-0 juveniles	2/15 – 7/31	20 days
Fall Outmigration (Type II)	Age-0 juveniles	10/1 – 1/15 (fall to mid-winter)	20 days
Spring Outmigration (Type III)	Age-1 juveniles	2/15 – 5/31 (spring)	20 days

[1] Period of Use and Date Window information is based on life history strategies presented in Sullivan (1989). Date windows for Type II and Type III are approximate based on the seasonal period.

SSCs derived from the SRH-1D flow and sediment transport model (USBR 2011b; Appendix I) were used to assess Proposed Action effects on adult and juvenile Klamath River Chinook salmon in the Klamath River. The sediment transport model predicts daily SSC as a continuous time series from October 1 of the year before drawdown to September 30 of Year 2 (year following drawdown and dam removal). The time series includes background conditions and SSCs associated with pre-drawdown activities, drawdown and dam removal, and post-drawdown. Modeled flows and SSC values are reported for each of three water quality stations that are represented by existing USGS stream gage stations. Figures J-1 through J-3 in Appendix J – Klamath River Chinook Salmon Analysis, illustrate flow and SSCs, and Figure J-4 includes USGS stream gage station locations.

To determine SSC exposure, the Renewal Corporation used USBR's daily SSC modeling results to calculate the median SSC value for each duration period during the windows of use for each life stage for each of the 48 years within the modeled hydroperiod. For instance, for each 14-day period during the adult upstream migration period (July 15 to November 30), the median SSC was calculated to represent the sustained exposure concentration for that 14-day period. The range of SSCs over the period of use window represents all of the concentrations to which adult Chinook salmon could be exposed under different river entry timing. Using the median SSC for the 14-day exposure period likely represents a moderate condition, because the median SSC value represents the midpoint SSC for that exposure period. Using the median SSC value may overestimate the anticipated SSC effects on salmonids; because, except for extremely high concentrations of suspended sediment, the length of exposure duration appears to influence the severity of the effects more so than the concentration.

To more accurately evaluate the potential effects of SSC exposure on the different populations of Chinook salmon residing in the Klamath Basin, the Renewal Corporation used the modeled SSC values from three of the four SSC model result stations at Iron Gate, Seiad Valley, and Orleans. Table 5-13 contains the location of SSC model results used to determine the exposure concentration for each population of Chinook salmon, and the corresponding exposure duration in days for each life stage.

Table 5-13: Chinook Salmon Natal Areas with Corresponding SSC Stations and Exposure Times (days) by Life Stage

Chinook Salmon Natal Areas	Modeled SSC Station	Life Stage /History	# of Exposure Days
Upper Klamath River, Shasta River	Iron Gate Dam	Adult Migration	14
		Juvenile Outmigration	20
Scott River, Middle Klamath River	Seiad Valley	Adult Migration	14
		Juvenile Outmigration	20
Salmon River, Lower Klamath River, Lower Trinity River, Upper Trinity River, South Fork Trinity River	Orleans	Adult Migration	14
		Juvenile Outmigration	20

Based on a literature review, the most commonly observed effects of suspended sediment on fish include: (1) avoidance of turbid waters in homing adult anadromous salmonids; (2) avoidance or alarm reactions by juvenile salmonids; (3) displacement of juvenile salmonids; (4) reduced feeding and growth; (5) physiological stress and respiratory impairment; (6) damage to gills; (7) reduced tolerance to disease and toxicants; (8) reduced survival; and (9) direct mortality (Newcombe and Jensen 1996). Information on both concentration and exposure duration is necessary to understand the potential severity of suspended sediment effects on salmonids (Newcombe and MacDonald 1991). For Chinook salmon, the Renewal Corporation used the equations derived for adult and juvenile salmonids to predict the SEV (severity) indices (0 to 14) for each combination of median SSC value and exposure duration. Newcombe and Jensen's severity of ill effects was used to rate the severity of exposure to suspended sediment.

Section 5.1.1.1 provides a review of Newcombe and Jensen's (1996) severity of ill effects methodology and how the Renewal Corporation applied the methodology to coho salmon and Chinook salmon life stages. To evaluate the level of impacts that may occur in a given water year under the Proposed Action, each severity of ill effects, or severity value (SEV), score of 9.5 or greater that occurred within the defined life stage period for Chinook salmon was summed to produce a total SEV score for each year within the modeled hydroperiod. The summed SEV scores were then ranked in order from smallest to largest with the highest single total SEV score representing the most severe impact year within the 48-year hydroperiod. Because there are an even number of records in the hydroperiod, there are two median values. To account for this, the Renewal Corporation chose the year with the highest SEV score of the middle 2 years to represent the median impact year. For Chinook salmon, the median impact year is represented by the 1991 water year, and the most severe impact year is represented by the 1973 water year.

5.4.1.2 Dissolved Oxygen Effects Analysis Approach

The Renewal Corporation analyzed short-term effects of the Proposed Action on dissolved oxygen levels and applied the previous long-term effects analysis presented in the 2012 Biological Assessment (USBR 2012b). The Renewal Corporation updated an existing numerical model (Greimann 2010; Stillwater Sciences 2011) to predict short-term dissolved oxygen levels in the Klamath River downstream of Iron Gate Dam. Section 5.1.1.2 provides a review of the dissolved oxygen effects analysis approach for coho salmon, the same process was used for assessing dissolved oxygen effects to Chinook salmon.

Oxygen depletion rates are scaled to the level of SSCs expected under median impact year and severe impact year scenarios developed for juvenile Chinook salmon (1991 and 1973, respectively) based on the USBR hydrology and sediment transport model (Appendix I). Model output was synthesized for the peak daily SSC value for each month from October prior to the drawdown year, through September of the drawdown year. Summary output includes anticipated minimum dissolved oxygen levels, and the location, extent, and duration of depleted oxygen conditions.

5.4.1.3 Bedload Sediment Deposition Effects Analysis Approach

The Renewal Corporation analyzed SRH-1D bed sediment and bedload modeling output, provided by USBR, to assess bedload sediment transport and deposition associated with the Proposed Action. Updated modeling output reflects the Proposed Action's drawdown approach and schedule that results in a slower average drawdown rate and later reservoir sediment evacuation in the Hydroelectric Reach reservoirs then previously modeled by USBR (2012a). Additional detail on the sediment deposition effects analysis approach is presented in Section 5.1.1.3.

5.4.1.4 Hatchery Production Effects Analysis Approach

NOAA-Fisheries (NMFS 2021) completed an analysis to evaluate potential changes in Chinook salmon ocean abundance in the context of Chinook salmon prey availability for Southern Resident killer whales, and ocean harvest following changes in Chinook salmon hatchery production associated with the closure of Iron Gate Hatchery (IGH) and the transition to lower production levels at the proposed Fall Creek Hatchery. Fall Creek Hatchery production levels will be 41 percent lower for sub-yearling Chinook salmon (IGH production goal of 5.1 million sub-yearlings versus Fall Creek Hatchery goal of 3.0 million sub-yearlings), and a 72 percent reduction in yearling Chinook salmon production (IGH production goal of 900,000 yearlings versus Fall Creek Hatchery goal of 250,000 yearlings). The analysis only accounted for changes in hatchery production and did not incorporate other short-term or long-term effects of the dam removal project.

NMFS (2021) used cohort reconstruction models developed for the Klamath River Fall Chinook (KRFC) fisheries (Mohr 2006), to extract estimated ocean abundance and the total ocean harvest of ages 3, 4, and 5 Chinook salmon for IGH sub-yearling and yearling releases between 1996 and 2014. NMFS compared the ocean abundances and ocean harvest associated with the existing IGH and proposed Fall Creek Hatchery production levels. Reduced production effects were averaged for the three age classes over the three brood years.

5.4.1.5 Anticipated Long-term Benefits of the Proposed Action

In the long term, the Renewal Corporation expects the Proposed Action to benefit Chinook salmon production based on Chinook salmon access to expanded spawning and rearing habitats, flow and water quality improvements, and reduced incidence of juvenile salmonid disease-related mortality. The qualitative evaluation of the expected long-term benefits applies recent literature regarding anticipated changes in river flows, water temperature, and aquatic diseases following the Proposed Action; and potential natural production of Chinook salmon in the Upper Klamath Basin over the long term. USFWS and USGS will use the qualitative descriptions of anticipated changes to hydrology, water temperature, hatchery Chinook salmon production, disease prevalence, and Upper Klamath Basin Chinook salmon production to inform the stream salmonid simulator (S3) Klamath River fall-run Chinook production model. NMFS will use the S3 model results to evaluate the expected short- and long-term changes in the numbers of juvenile Chinook salmon outmigrating to the Pacific Ocean, and then quantitatively assess the potential effects of the Proposed Action to Klamath Basin Chinook salmon populations as a food resource for Southern Resident killer whales.

5.4.2 Short-Term Effects

The following section provides an overview of anticipated effects on Chinook salmon, and therefore, effects to Southern Resident killer whales by way of food resources. Many of the short-term effects are similar to the short-term effects presented for juvenile coho salmon presented in Section 5.1.2.

5.4.2.1 In-Water Construction Activities

Pre-drawdown and post-dam removal construction activities at Iron Gate Dam will have similar effects to juvenile Chinook salmon as described for juvenile coho salmon in Section 5.1.2.1.

5.4.2.2 Suspended Sediment Concentrations and Dissolved Oxygen Effects Associated with Reservoir Drawdown

Suspended Sediment Concentrations

Section 5.1.2.2 provides an SSC effects analysis for coho salmon that is applicable to Chinook salmon. Appendix J also includes a detailed analysis of the anticipated short-term effects of SSCs on fall-run Chinook salmon. Table 5-14 includes an overview of background and anticipated Proposed Action impact year scenario effects on Chinook salmon life history stages in Year 1 and Year 2. The Proposed Action is anticipated to result in lethal effects during egg incubation, and up to 20 percent mortality during portions of the Year 1 outmigration period for age-0+ and age-1+ Chinook salmon. Outmigrating juvenile Chinook salmon are anticipated to experience sublethal SSC levels in Year 2.

Table 5-14: Background and Proposed Action Median Impact Year and Severe Impact Year on Chinook Salmon Life History Stages under Year 1 and Year 2

Adult migration (Jul 15 – Oct 31)	Spawning Through Fry Emergence (Oct 15 – Apr 11)	Age-0+ (Type I) Outmigration (Feb 1 – Aug 18)	Age-0+ (Type II) Outmigration (Nov 1 -Dec 9)	Age-1+ (Type III) Outmigration (Feb 1 –Apr 20)
Background Conditions				
MIY: SEV 0 to 5 Sublethal –No effect to Minor physiological stress **SIY**: SEV 1 to 6: Sublethal – Alarm reaction to Moderate physiological stress	Low survival of redds constructed in mainstem Klamath River	**MIY**: SEV 1 to 8 Sublethal - Alarm reaction to Indications of major physiological stress **SIY**: SEV 1 to 8 Sublethal - Alarm reaction to Indications of major physiological stress	**MIY**: SEV 1 to 6 Sublethal - Alarm reaction to Moderate physiological stress **SIY**: SEV 2 to 9 Sublethal – Abandonment of cover to Reduced growth rate	**MIY**: SEV 4 to 7 Sublethal – Short-term reduction in feeding rates to Impaired homing **SIY**: SEV 4 to 9 Sublethal – Short-term reduction in feeding rates to Reduced growth rate
Year 1				
MIY: SEV 7 to 9 Sublethal effects for all populations **SIY**: SEV 7 to 9: Sublethal effects for all populations	Up to 100% mortality of progeny of mainstem spawners	**MIY**: SEV 7 to 10 Impaired homing to Up to 20% mortality during up to 20% of outmigration period **SIY**: SEV 8 to 10 Indications of major physiological stress to Up to 20% mortality during up to 80% of outmigration period	**MIY**: SEV 7 to 9 Sublethal – Impaired homing to Reduced growth rate **SIY**: SEV 7 to 9 Sublethal – Impaired homing to Reduced growth rate	**MIY**: SEV 8 to 10 Indications of major physiological stress to Up to 20% mortality during up to 25% of outmigration period **SIY**: SEV 8 to 10 Indications of major physiological stress to Up to 20% mortality during up to 75% of outmigration period
Year 2				
MIY: SEV 5 to 6 Sublethal effects for all populations **SIY**: SEV 5 Sublethal effects for all populations	Up to 100% mortality of progeny of mainstem spawners	**MIY**: SEV 1 to 8 Sublethal - Alarm reaction to Indications of major physiological stress **SIY**: SEV 1 to 8 Alarm reaction to Indications of major physiological stress	**MIY**: SEV 5 to 7 Sublethal - Minor physiological stress to Impaired homing **SIY**: SEV 5 to 6 Sublethal - Minor physiological stress to Moderate physiological stress	**MIY**: SEV 7 to 8 Sublethal – Impaired homing to Indications of major physiological stress **SIY**: SEV 7 to 8 Sublethal – Impaired homing to Indications of major physiological stress

[1] Analysis includes representative Chinook populations from Bogus Creek to Blue Creek, SSC data for Iron Gate, Seiad Valley, and Orleans stations, 20-day juvenile exposure and 14-day adult exposure, and Median Impact Year (1991) and Severe Impact Year (1973) conditions.

Dissolved Oxygen Effects

The Renewal Corporation updated an existing dissolved oxygen model to evaluate potential effects to age-0+ Chinook salmon during the drawdown year (see Appendix J for model description and detailed results). The model incorporated observed and predicted values for input variables including flow, SSC, immediate and biological oxygen demand, average temperature, and initial dissolved oxygen concentration based on 80 percent and 0 percent saturation. Conditions associated with the peak SSC each month from October of the pre-drawdown year through September of the drawdown year were used for the model boundary conditions. This approach therefore followed a conservative process for assessing potential drawdown effects on dissolved oxygen and age-0+ Chinook salmon.

Under the High Dissolved Oxygen Saturation Scenario, depleted dissolved oxygen conditions during the January SSC event will affect the Klamath River from Iron Gate Dam downstream to RM 148.5 (5 mg/L threshold) near the Scott River confluence (RM 145.1). This event will occur before juvenile Chinook salmon migrate from tributaries to the mainstem, although a small number of yearling Chinook salmon may be rearing in the mainstem and may be affected. The mid-June depleted dissolved oxygen event under the median and severe impact years could affect late downstream migrants before dissolved oxygen levels recover to 5 mg/L at RM 177.8 and RM 166.0, respectively. Table 5-15 includes the percentage of age-0+ Chinook salmon outmigrants sampled at radial screw trap locations on the mainstem Klamath River (Bogus Creek, I-5, and Kinsman) and on the Shasta River in mid-June.

Age-0+ Chinook salmon originating in the Upper Klamath River largely pass the rotary screw traps between late February and early June and will be downstream of the low dissolved oxygen reach prior to the depleted dissolved oxygen event in mid-June. However, approximately 11 percent of the outmigrants from the Upper Klamath River and the Middle Klamath River pass through the reach upstream of the Shasta River after May 31 (the start of the 20-day analysis period that includes the mid-June depleted dissolved oxygen event). Age-0+ Chinook salmon originating in the Shasta River typically outmigrate by mid-June and only 1.6 percent of the outmigrants will be exposed when they enter the Klamath River by mid-June. In summary, under the High Dissolved Oxygen Saturation scenario, in both the median and severe impact years, depleted dissolved oxygen does not recover to the 7 mg/L and 5 mg/L thresholds until downstream of the Shasta River. Hypoxic (<5.0 mg/L) conditions coupled with high SSCs may have sub-lethal and lethal effects on late outmigrating age-0+ Chinook salmon.

Table 5-15: Percentages of Age-0+ Chinook Salmon Populations Outmigrating from the Klamath River Based on Rotary Screw Trap Locations between Bogus Creek and the Shasta River. Affected Percentages are Based on Mid-June Outmigrants. Dissolved Oxygen Levels are Anticipated to Return to 7 mg/L in the Median Impact year by RM 177.8 and RM 166.0 in the Severe Impact Year

Chinook Salmon Natal Reaches	Estimated % Outmigrants in Mid-June Low Dissolved Oxygen Period	Rotary Screw Trap Location
Upper Klamath River	0.2%	Bogus Creek (RM 192.6)
Upper Klamath River	11.2%	I-5 (RM 182.1)
Shasta River	1.6%	Shasta River (RM 179.5)
Middle Klamath River	13.0%	Kinsman (RM 147.6)

Under the Low Dissolved Oxygen Saturation Scenario in a median impact year, depleted dissolved oxygen conditions will affect the Klamath River from Iron Gate Dam downstream to between the Humbug Creek (RM 173.9, 7 mg/L recovery) and Beaver Creek (RM 163.3, 5 mg/L recovery), on average, from February to June.

In the approximate 25 river miles between Iron Gate Dam and the downstream dissolved oxygen recovery zone, outmigrating age-0+ Chinook salmon will experience depleted dissolved oxygen and high SSCs. Low dissolved oxygen levels may amplify high SSC effects resulting in additional sublethal and lethal effects to age-0+ Chinook salmon. The furthest downstream recovery of dissolved oxygen to the 7 mg/L threshold is RM 88.3 (between Seiad Valley and the Salmon River) in mid-January in the median impact year. However, few age-0+ Chinook salmon are anticipated to be in the mainstem Klamath River during this time.

Under the Low Dissolved Oxygen Saturation Scenario in a severe impact year, depleted dissolved oxygen conditions will affect the Klamath River from Iron Gate Dam downstream to between O'Neil Creek (RM 139.1, 7 mg/L recovery) and Horse Creek (RM 149.5, 5 mg/L recovery), during the primary juvenile outmigration between February and mid-June. In the approximate 45 river miles between Iron Gate Dam and the downstream dissolved oxygen recovery zone (to 5 mg/L), outmigrating age-0+ Chinook salmon will experience depleted dissolved oxygen and high SSCs between February and mid-June. The furthest downstream recovery of dissolved oxygen to the 7 mg/L and 5 mg/L thresholds in mid-January are RM 107.0 (Indian Creek) and RM 136.8, respectively.

The High and Low Dissolved Oxygen Saturation Scenarios bracket the anticipated dissolved oxygen effects to rearing and outmigrating age-0+ Chinook salmon during the drawdown year. Dissolved oxygen concentrations are influenced by initial dissolved oxygen saturation, flow, water temperature, and immediate oxygen demand and biological oxygen demand. Under all scenarios, minimum dissolved oxygen concentrations are expected to occur within 2 miles of Iron Gate Dam, and diminished dissolved oxygen conditions improve with downstream distance due to reaeration and additional discharge from tributary streams. Therefore, juvenile Chinook salmon entering the mainstem Klamath River from tributaries closest to Iron Gate Dam such as Bogus Creek during times of low dissolved oxygen conditions are most likely to suffer direct mortality, whereas fish entering from tributaries further downstream in the effected reach such as the Scott River will likely be exposed to dissolved oxygen levels closer to the 7 mg/L threshold and may only experience sublethal effects.

Although 5 and 7 mg/L were used as thresholds to demonstrate the duration of time and length of affected reaches, salmonids persist in depleted dissolved oxygen conditions. For instance, the USEPA (1986) reported that salmonid mortality begins to occur when dissolved oxygen concentrations are below 3 mg/L for periods longer than 3.5 days. A summary of various field studies by WDOE (2002) reported that significant mortality occurs in natural waters when dissolved oxygen concentrations fluctuate the range of 2.5 - 3 mg/L, and that long-term (20 - 30 days) constant exposure to mean dissolved oxygen concentrations below 3 - 3.3 mg/L is likely to result in 50 percent mortality of juvenile salmonids (WDOE 2002). Other studies indicate that water temperatures also play an important factor in the response of salmonids to dissolved oxygen conditions, as coho salmon have recently been found consistently using off-channel habitat with dissolved oxygen concentrations as low as 1 mg/l in the lower Klamath River basin, but water temperatures were generally 15 °C or less (Beesley and Fiori, 2014). However, depleted dissolved oxygen levels and hypoxia will be an additive stressor to the high SSCs age-0+ Chinook salmon will encounter during outmigration, potentially increasing age-0+ Chinook salmon mortality during the drawdown year.

Implementation of AR-2 Actions 2 and 3 will be implemented to reduce the impacts to fish rearing in the mainstem Klamath River or emigrating from tributaries to the mainstem Klamath between January 1 and May 31.

Aquatic Resource Measure 2 - Outmigrating Juveniles

Short-term suspended sediment effects of the Proposed Action will result in mostly sublethal, and in some cases lethal, effects to a portion of the juvenile Chinook salmon that are rearing in, or outmigrating from the mainstem Klamath River during the drawdown year. Deleterious short-term effects on outmigrating juvenile Chinook salmon could be reduced by monitoring mainstem-tributary connectivity to ensure juvenile salmonid access to clear water tributaries during reservoir drawdown (address bedload deposition blockages); and monitoring and salvaging juvenile Chinook salmon from tributary confluences during reservoir drawdown (address SSC and dissolved oxygen effects) (see Section 5.1.2.2 for methods).

Under Aquatic Resource Measure 2, the Renewal Corporation will capture and transport fish only if conditions in the mainstem are as poor as predicted, and tributary water temperatures exceed threshold levels for juvenile coho salmon survival. Due to the uncertainties with suspended sediment modeling, water quality and fish behavior will be monitored by the Renewal Corporation during spring and summer of the drawdown year. Water quality conditions and detection of adverse fish behavior will trigger the initiation and cessation of the capture program and inform suitable release locations.

5.4.2.3 Bedload Sediment Deposition Effects

Over the 2-year simulation period and for some number of years past the simulation period (because the simulation period did not extend to sediment equilibrium), two sediment wedges may affect Chinook salmon downstream of the Iron Gate Dam site through pool filling and redd burial. The bedload deposition model output indicates bedload deposition will occur from Iron Gate Dam downstream to the Willow Creek confluence, although deposition will be most pronounced from Iron Gate Dam to Bogus Creek. From 2001 – 2019, the median number of Chinook salmon carcasses from immediately below Iron Gate Dam to Willow Creek was approximately 100 carcasses per kilometer in the 6.5-kilometer reach, or approximately 650 adult carcasses (Gough et al. 2020). This compares to the long-term (2001-2019) median escapement value for fall-run Chinook salmon in the Klamath River of 4,880 fish (4,469 – 5,309 median 95 percent confidence limit values). Therefore, sediment deposition in the Iron Gate Dam to Willow Creek reach could affect approximately 13 percent of Chinook salmon spawning escapement in the Klamath River upstream from Wingate Bar (Gough et al. 2020).

Additionally, bedload deposition has the potential to affect a minimum of 2 years of Chinook spawning downstream of Iron Gate Dam. A minor amount of sediment will mobilize during reservoir drawdown and deposit downstream of the Iron Gate Dam site. Depending on the channel bed material, hyporheic (intergravel) flow, and cover habitat, adult Chinook salmon could spawn in the recently deposited material during the drawdown year. Subsequent stored sediment mobilization during winter will bury redds. Based on the model simulations, a similar process could be repeated in the post-drawdown year. Further, because the sediment wedges are in an aggrading state at the end of the 2-year model simulations, redd burial could occur in subsequent years until the sediment wedges erode and the Klamath River channel bed downstream of the Iron Gate Dam site stabilizes. Channel bed material fining downstream of the Iron Gate Dam site is caused by an increase in the bed's sand composition, which increases from 16 percent before drawdown to 27 to 43 percent at the end of the 2-year simulation. Although fines and sands in spawning gravels could be evacuated by adult Chinook salmon during redd building, continued delivery of fines from the upstream sediment wedges could affect egg incubation success and alevin survival. Due to the aggraded unstable channel conditions in the near-term, adult Chinook salmon may select other upstream or downstream habitats for spawning, reducing the number of redds that would be impacted by the unstable channel bed conditions.

The results of the model have been used to identify locations where sediment aggradation may be of concern for fish passage and therefore corrective fish passage actions are anticipated to occur. Implementation of fish passage monitoring and corrective actions as described in the Reservoir Area Management Plan (Appendix C), the Tributary–Mainstem Connectivity Monitoring Plan (within Appendix D), and part of Aquatic Resource Measure – Outmigrating Juveniles Action 2 will identify and remediate fish passage issues that may occur within the former reservoir and dam footprints for 6 years following the start of reservoir drawdown. Additional monitoring within the 8-mile reach of the mainstem Klamath River between Iron Gate Dam and Cottonwood Creek for a period of 3 years following the initiation of reservoir drawdown will also be completed.

Over time (5 years to 50 years), the sediment wedges will disperse, and bed elevations will adjust to a new sediment equilibrium, which will include a restored sediment supply from upstream tributaries that was formerly trapped by the Hydroelectric Reach dams. The deposition of the sediment wedge downstream of Iron Gate Dam will occur over a bed that has been degraded over the past 60 years due to the elimination of bedload replenishment. As a result, bed elevations may remain elevated relative to current conditions as sediment processes return to pre-dam conditions. Although Chinook salmon may continue to spawn in the reach below the Iron Gate Dam site following dam removal, restored fish passage may result in adult Chinook salmon moving to upstream reaches to spawn.

5.4.2.4 Reservoir Restoration and Fish Passage Actions

Based on the restoration actions described in Section 2.4 and Appendix C, establishment of herbaceous vegetation in drained reservoir areas will be undertaken to stabilize the surface of the sediment and minimize erosion from exposed terrace surfaces following reservoir drawdown (O'Meara et al. 2010). Section 5.1.2.4 includes potential short-term effects to coho salmon during reservoir restoration actions. The same effects are expected for Chinook salmon.

Following drawdown and dam removal, several actions will be implemented to ensure fish passage for coho salmon and Chinook salmon to habitat in the former Hydroelectric Reach. As described in Appendix D, these actions include fish passage monitoring on the mainstem Klamath River and project-associated fish-bearing tributaries upstream of the former Iron Gate Dam to evaluate blockages and headcuts in residual dam sediment, and the steps to take if they are deemed to be fish passage barriers.

The Proposed Action will affect multiple life stages of Chinook salmon during the pre-drawdown, drawdown and dam removal, and post-drawdown periods due to construction activities, suspended sediment and bedload sediment releases, and dissolved oxygen effects. Aquatic resources measures will be implemented to reduce Proposed Action effects on Chinook salmon. Additionally, because Southern Resident killer whales select larger Chinook salmon as prey items, and the Proposed Action will primarily affect juvenile production in Year 1 and Year 2, the Proposed Action may affect, but is not likely to adversely affect Southern Resident killer whales in the short term.

5.4.3 Long-Term Effects

The following sections provide an overview of anticipated effects on Chinook salmon, and therefore, effects to Southern Resident killer whales by way of food resources. Many of the long-term effects of the Proposed Action for the Southern Resident killer whale will be experienced through the response of Chinook salmon to the Proposed Action; therefore, the sections below describe these effects to the Southern Resident killer whales prey base originating from the Action Area.

5.4.3.1 Chinook Salmon Life-History Diversity

Chinook salmon express diverse life-history strategies that buffer environmental effects to a single year class, and life-history strategies also result in varied ages at both ocean entry and return to freshwater. Because adult Chinook salmon reside in the Pacific Ocean for 1 to 4 years before returning to freshwater to spawn, there are multiple Chinook salmon brood years and age classes in the ocean at any time. Although the Proposed Action is anticipated to cause high mortality of Chinook salmon adult spawning downstream of Iron Gate Dam, and of spawning redds built on the mainstem Klamath River between Iron Gate Dam and the Willow Creek confluence, there will be a repository of juvenile Chinook salmon in tributaries and adult Chinook salmon in the ocean that will be unaffected by the Proposed Action.

From 2001 through 2018, the average ocean abundance of Klamath River Chinook salmon was approximately 352,000 age-3 and age-4 Chinook salmon, and minimum and maximum values of 57,500 and 873,300, respectively. Over the same period, the average number of in-river age-2 through age-5 Chinook salmon averaged nearly 133,000 fish, and the minimum and maximum estimated number of age-2 through age-5 fish were approximately 27,400 and 316,700, respectively. On average, age-2 fish comprised 14 percent of the in-river run, age-3 fish comprised 48 percent, age-4 fish 35 percent, and age-5 fish 2 percent (PFMC 2019).

The brood year associated with the reservoir drawdown and dam removal period will sustain sublethal and lethal effects, mainly due to exposure to high SSCs and depleted dissolved oxygen during reservoir drawdown. Since age-3 Chinook salmon are the most common age class to return to freshwater to spawn, the in-river return 3 years after drawdown will be diminished due to Proposed Action impacts to outmigrating juvenile Chinook salmon during the drawdown year.

5.4.3.2 Reduced Hatchery Production

NMFS (2021) predicted the proposed reduced hatchery production will result in a mean annual reduction of 36,545 ocean adults (ages 3-5), equating to a 1.5 percent reduction in the long-term adult fish abundance in the South of Cape Falcon EEZ, and a 0.15 percent annual reduction in adult Chinook salmon contributing to the SRKW salmon abundance threshold target in the North of Cape Falcon EEZ. Reduced hatchery production will also lead to a mean annual reduction of 2,620 fish available for ocean harvest (ages 3-5, commercial and recreational harvest) equating to a 0.6 percent decrease in ocean harvest. As these are average values, individual years may experience higher or lower effects to ocean abundance and ocean harvest. Reduced hatchery production effects will be greater in years when juvenile survival is high, and lower in years when juvenile survival and recruitment into the adult population is low (NMFS 2021).

5.4.3.3 Anticipated Long-term Benefits

The following sections include the Proposed Action’s anticipated long-term benefits to Chinook salmon.

Hatchery Production

Although hatchery production is responsible for providing salmon for commercial, tribal, and recreational fisheries, there are also negative hatchery effects on wild salmon that are difficult to quantify. Example hatchery-origin salmon effects on wild salmon include juvenile competition for food resources and habitat, predation, genetic risks, disease transfer, and increased fishing pressure on wild stocks. Straying of hatchery-origin Chinook salmon into important wild Chinook salmon spawning tributaries may increase introgression (i.e., interbreeding) of hatchery-origin spawners with wild Chinook salmon. Straying and introgression of hatchery-origin fish with wild fish has been found to lower the genetic diversity and reproductive potential of wild populations. Gough et al. (2018) presented data from 2007 through 2017, showing the proportion of hatchery-origin Chinook salmon carcasses compose the greatest proportion of Chinook salmon carcasses in the Klamath River in the first quarter mile from Iron Gate Dam downstream to Bogus Creek. The mean proportion of hatchery-origin carcasses decreased in a downstream direction with distance from Iron Gate Dam. Hatchery genetics in natural fall-run Chinook salmon also decreased with distance from Iron Gate Hatchery (Kinzinger et al. 2013). Iron Gate Dam is also a physical barrier that blocks all upstream migrating Chinook salmon, concentrating adult spawners and post-spawn carcasses. The accumulation of salmon carcasses infected with the spores that cause *C. shasta*, increases disease potential for outmigrating juvenile Chinook salmon (Robinson et al. 2020).

Iron Gate Hatchery will cease operations during the Proposed Action. Fall Creek Hatchery, will have annual production goals of 3,000,000 sub-yearling and 250,000 yearling Chinook salmon, and 75,000 yearling coho salmon. Production targets include 41 percent fewer sub-yearling and 72 percent fewer yearling Chinook salmon compared to Iron Gate Hatchery production. Hatchery production uncertainty is likely to be greatest in the first 4 years of Fall Creek Hatchery operation as returning adults will have reared at Iron Gate Hatchery, and these fish will not have environmental cues attracting them to Fall Creek Hatchery. In response to this uncertainty, CDFW has developed a plan to capture adult Chinook salmon and coho salmon to meet broodstock needs in the first years of Fall Creek Hatchery operation (see Appendix E – Hatcheries Management and Operations Plan).

Decreased hatchery production and the lack of a physical barrier blocking upstream Chinook salmon migration are likely to have a variable effect on Klamath River Chinook salmon production. Reduced hatchery production will reduce the number of hatchery-origin juvenile Chinook salmon that compete with wild juvenile Chinook salmon and could possibly lower the prevalence of *C. shasta* infection experienced by hatchery and wild juvenile Chinook salmon (Gough et al. 2020). Without a physical barrier blocking the upstream Chinook salmon migration, the percentage of hatchery-origin adult Chinook salmon spawning with wild Chinook salmon may increase. However, over time, as the number of hatchery Chinook salmon in the Klamath River decreases in response to reduced production, natural origin adults will distribute more widely in the basin, potentially leading to recolonization of historical habitat.

Hydrologic Changes

Baseline hydrology for the Action Area is described in USBR (2018) and reviewed by USFWS (2019a) and NMFS (2019a). The Proposed Action will affect the hydrology of the Klamath River downstream of Keno Dam by removing the four Klamath River dams. Dam removals will restore natural river flows downstream of Keno Dam, and the extended residence time created by the existing dams will be replaced by a free-flowing river. Under existing conditions, residence time for J.C. Boyle Reservoir is approximately 2 days during average summer flow conditions (FERC 2007), 32 days in Copco Lake, and 42 days in Iron Gate Reservoir (PacifiCorp 2012).

The modified hydrology will have the greatest effect on Klamath River Chinook salmon populations that spawn and rear proximate to Iron Gate Dam. With increasing downstream distance from Iron Gate Dam, modified hydrology will be less influential to Klamath River Chinook salmon as unregulated tributaries contribute flow to the Klamath River.

Groundwater discharge influences stream flow and thermal regimes throughout the Upper Klamath Basin. Table 5-16 includes a summary of primary spring complexes in the Upper Klamath Basin. Springs produce upwards of 1,900 cfs of groundwater flow in the basin, including approximately 400 cfs in the Hydroelectric Reach. Under existing conditions, Hydroelectric Reach groundwater input benefits are affected by the Hydroelectric Reach reservoirs. Under the Proposed Action, cool water inputs will provide refuge for adult Chinook salmon during the spawning migration. Outmigrating juvenile Chinook salmon may also use cool-water refuges during the outmigration, potentially lowering their susceptibility to *C. shasta* disease progression (Ray et al. 2012; Chiaramonte et al. 2016).

Table 5-16: Estimated Volume of Groundwater Discharge (Springs) into Upper Klamath River Systems

River System	Section	Groundwater Flow (cfs)
Lower Williamson River and Tributaries	Mouth of Williamson River up to Kirks Reef	350
Wood River and Tributaries	Crooked Creek Confluence to Headwaters	490
Sevenmile Creek and Tributaries	Crane Creek Confluence to Headwaters	90
Sprague River	South Fork Sprague River to Sprague River	202
Upper Klamath Lake	Spring in Upper Klamath Lake Including Malone, Crystal, Sucker, and Barclay	350
Klamath River	Keno Dam to J.C. Boyle Powerhouse	285

River System	Section	Groundwater Flow (cfs)
Klamath River and Fall Creek	J.C. Boyle Powerhouse to Iron Gate Dam	128
Total		1,895

Source: NMFS 2013

Water Quality Changes

Hydroelectric projects alter a river's water surface area, depth, and velocity by impounding flowing water. The conversion of a river from free-flowing conditions to a series of impoundments alters the thermal regime, sediment and debris transport, nutrient cycling, and food web. These alterations affect aquatic habitat conditions in the impounded reach and the free-flowing river downstream of the impoundments. The Proposed Action will restore free-flowing conditions through the impounded Hydroelectric Reach, and also result in water quality changes downstream of the Iron Gate Dam site.

Water Temperature

The Proposed Action will decrease water residence time in the reservoirs from several weeks (on average) to less than a day, resulting in improved water quality and a more natural temperature regime. Reservoir removal will also increase the benefits of tributaries and springs such as Fall, Shovel, and Spencer creeks and Big Springs, that will flow directly into the mainstem Klamath River, creating patches of cooler water that could be used as temperature refugia by fish during summer and fall, as well as providing slightly warmer winter water temperatures conducive to the growth of salmonids (Hamilton et al. 2011). The Proposed Action is anticipated to result in a 2 to 10°C decrease in water temperatures during the fall months, and a 1 to 2.5°C increase in water temperatures during spring months (PacifiCorp 2004a; Dunsmoor and Huntington 2006; NCRWQCB 2010b).

Elimination of the thermal lag currently caused by the existing reservoirs will result in water temperatures more in sync with historical fish migration and spawning periods for the Klamath River, warming earlier in the spring, and cooling earlier in the fall compared to existing conditions (Hamilton et al. 2011). Warmer springtime temperatures will result in fry emerging earlier (Sykes et al. 2009), encountering favorable temperatures for growth sooner than under existing conditions, which could support higher growth rates and encourage earlier emigration downstream, thereby reducing stress and disease (Bartholow et al. 2005; FERC 2007). In addition, fall Chinook salmon spawning in the mainstem during fall will no longer be delayed (reducing pre-spawn mortality), and adult migration will occur in more favorable water temperatures than under existing conditions. For example, groundwater inputs in the J.C. Boyle Bypass Reach are anticipated to account for 30 to 40 percent of the total summer flow following dam removal.

Groundwater inputs will have a positive effect on water temperature, benefiting both anadromous and resident fish and other aquatic organisms in the Klamath River.

Water temperature changes will be most apparent closer to the former Iron Gate Dam and decrease in magnitude with distance from Iron Gate Dam as tributary inputs and atmospheric conditions increasingly influence water temperature. Proposed Action water temperature differences will decrease by the Scott River confluence and will no longer be evident downstream of the Salmon River.

Dissolved Oxygen

Replacing the Hydroelectric Reach reservoirs with free-flowing river reaches will restore the riverine processes that influence dissolve oxygen, and substantially change the dissolved oxygen levels in the Hydroelectric Reach. Under current conditions, Copco Lake and Iron Gate Reservoir stratify in the summer, creating supersaturated surface waters and depleted oxygen conditions near the reservoir bottoms. The free-flowing river reaches will not exhibit these dissolved oxygen extremes; rather, oxygen levels will be more representative of free-flowing rivers during summer. During the winter and spring, Copco Lake and Iron Gate Reservoir are unstratified, and dissolved oxygen levels are similar throughout the water column.

Reservoir dissolved oxygen levels in winter and spring will be similar to free-flowing river levels. Long-term dissolved oxygen differences associated with the Proposed Action will be greatest near Iron Gate Dam, will decrease with distance from Iron Gate Dam. Differences will be diminished by Seiad Valley, and there will be no difference by the Trinity River confluence.

Long-term changes in summer-time dissolved oxygen in the vicinity of Iron Gate Dam will benefit juvenile Chinook salmon inhabiting the Klamath River during the summer and fall (i.e., Type II and Type III life-history juveniles), and adult Chinook salmon during the summer and fall migration to spawning grounds.

In addition to restoring a more natural thermal regime, the project will result in overall increases in dissolved oxygen, increased diel variability in dissolved oxygen, and lower microbial oxygen demand due to decreased organic load. The conversion of an additional 22.4 miles of reservoir habitat to riverine and riparian habitat will also improve water quality by restoring the nutrient cycling and aeration processes provided by a natural channel.

Restored Access to Historical Habitat

Klamath River Chinook salmon historically used tributaries throughout the Klamath Basin, including streams and rivers upstream of Upper Klamath Lake. Spring-run and fall-run Chinook salmon migrated throughout the Klamath Basin prior to the construction of the Klamathon Dam (near Iron Gate Dam) and Copco No. 1 Dam. The Klamathon Dam was a log crib structure built in 1889 for a timber mill. The dam was retrofitted with a fish ladder in the 1890s, and the ladder worked intermittently until the dam's destruction during the 1902 Klamathon Fire (Hamilton et al. 2016). Copco No. 1 Dam construction in 1912 created adverse water velocities through a construction bypass channel, and the constructed dam was a complete barrier to anadromous species.

The Proposed Action will restore access to approximately 81 miles of suitable riverine, side channel, and tributary habitat in the hydroelectric reach, and in 49 tributaries accounting for over 420 miles of historical aquatic habitat throughout the basin upstream of Iron Gate Dam. More specifically, the Proposed Action will restore access to historical habitat (Table 5-17) totaling approximately 76 miles for coho salmon, 300 miles for Chinook salmon (Huntington 2004), and 420 miles for steelhead (Huntington 2004, 2006). In addition to increasing the quantity of available habitat, the Proposed Action will restore access to unique habitats, including groundwater springs that are resistant to water temperature increases caused by changes in climate (Hamilton et al. 2011), potentially buffering climate change effects to cold water salmonids.

Table 5-17: Potential Historical Habitat Availability by Species with Removal of the Klamath River Hydroelectric Reach Dams

Species	Potential Historical Habitat Availability (miles)
Chinook salmon	300
Coho salmon	76
Steelhead	420
Pacific lamprey	>420

Historical anadromous fish population estimates suggest the potential productivity of the Klamath Basin upstream from Iron Gate Dam. Hendrix (2011) provided estimates for historical fall-run Chinook salmon populations in the Upper Klamath Basin, and Hendrix also reviewed production models and estimates from others. Hendrix estimated equilibrium population sizes of 23,000 fall-run Chinook salmon in the Keno to Iron Gate reach of the Klamath River, and 35,000 fall-run and spring-run Chinook salmon in tributaries to Upper Klamath Lake. Lindley and Davis (2011) estimated an equilibrium spring-run Chinook salmon population size of 41,000 for the Upper Klamath Basin. Dunsmoor and Huntington (2006) estimated the Upper Klamath Basin above Iron Gate Dam could support approximately 14,864 fall-run Chinook salmon and 32,706 spring-run Chinook salmon under existing habitat conditions. Huntington (2006) also used five different methods to estimate the number of adult Chinook salmon in the Upper Klamath Basin upstream of Iron Gate Dam and estimated between 9,180 and 32,040 adult Chinook salmon. In summary, adult Chinook salmon estimates for the Upper Klamath Basin are in the tens of thousands of adult fall-run and spring-run Chinook salmon, which is within the range of historical anecdotal reports presented in Hamilton et al. (2016) (Table 5-18).

Table 5-18: Historical and Potential Production Estimates for Fall Chinook Salmon, Coho Salmon, and Steelhead in the Klamath River Basin.

Reach	Species	Median Estimate	Estimate Range	Note
Lower Klamath Basin to Copco No. 1 Dam	Fall Chinook Salmon		168,000[4] to 175,000[5]	Estimates based on historical spawning escapement and spawning surveys.
	Coho	15,400[4]	20,000[5] to 70,000[5]	
	Steelhead	300,000[5]	221,000[4] to 750,000[5]	
Iron Gate Dam to Copco No. 1 Dam	Fall Chinook Salmon	2,301[3]	1,113[6] to 18,925[5]	Based on historical spawning data and spawning habitat potential.
	Steelhead	1,144[3]		
Copco No. 1 Dam to Upper Klamath Lake	Fall Chinook Salmon	10,000[1]	2,2920[2] to 19,207[3]	Based on historical spawning data and spawning habitat potential.
	Steelhead	9,550[3]		

[1] FERC 2007
[2] Fortune et al. 1966

[3] Chapman 1981
[4] CDFG 1965
[5] Coots 1977
[6] FERC 1963

Prevalence of Disease

Fish diseases are widespread in the mainstem Klamath River during certain time periods, and in certain years, disease prevalence has been shown to adversely affect survival and productivity of Chinook and coho salmon. High infection rates by the myxozoan parasite *C. shasta* have been documented in emigrating juvenile salmon populations during spring and early summer in the Klamath River (True et al. 2016), which have been linked to population declines in fall Chinook salmon (Fujiwara et al. 2011; True et al. 2013). Fish infected by *C. shasta* are also prone to mortality caused by other pathogens such as *Parvicapsula minibicornis*, to predation, and compromised osmoregulatory systems that are essential for successful ocean entry.

C. shasta infection rates of juvenile Chinook salmon are influenced by *C. shasta* spore densities, water temperature, and juvenile salmonid residence time in areas of high spore densities. See Table 4-4 for a summary of juvenile Chinook salmon prevalence of infection from 2005 to 2019 at the Kinsman RST location 45 river miles downstream of Iron Gate Dam. The Kinsman trap is located in the infectious zone which typically occurs between the confluences of the Shasta River and the Scott River, but may extend as far downriver as the confluence of Seiad Creek (Hallett and Bartholomew 2006). Between 2005 and 2019, outmigrating Chinook salmon experienced an average infection rate of 19.6 percent (minimum of 3 percent to maximum of 58 percent). High spore densities may lead to clinical signs of enteronecrosis and mortality in juvenile Chinook salmon.

The Proposed Action is expected to reduce fish disease impacts to adult and juvenile salmon, especially downstream of Iron Gate Dam. Among the salmon life stages, juvenile salmon tend to be most susceptible to *P. minibicornis* and *C. shasta* (Beeman et al. 2008). The main factors contributing to risk of infection by *C. shasta* and *P. minibicornis* include availability of habitat (pools, eddies, and sediment) and microhabitat characteristics (static flow and low velocities) for the annelid worm intermediate host; annelid colony proximity to spawning areas; increased planktonic food sources from hydroelectric reach reservoirs; water temperatures greater than 15°C (Bartholomew and Foott 2010); and juvenile salmonid residence time in the infectious zone (USFWS 2016). A recent study has also linked the prevalence of infection of juvenile Chinook salmon released from Iron Gate Hatchery in the spring, and peak spore densities measured in the fall and the spring following hatchery release (Robinson et al. 2020). USFWS has also observed a downward trend over the 2001 to 2019 period in the number of Chinook salmon spawners in the Iron Gate Dam to Shasta River confluence reach, perhaps due to decreased survival of juvenile Chinook salmon related to *C. shasta* exposure (Gough et al. 2020).

The Proposed Action will restore natural channel processes including channel bed scour and sediment transport. Annual channel bed scour will disturb the habitat of the annelid worm that hosts *C. shasta* (FERC 2007). Reducing annelid habitat may improve outmigrant survival, potentially leading to an increase in abundance of Chinook salmon smolts reaching the Klamath River estuary.

In summary, the Proposed Action will affect Southern Resident killer whales in the long term by first reducing and later increasing Chinook salmon production as reduced hatchery production is replaced by natural production. Reduced hatchery production will have minimal effect on Southern Resident killer whales as Klamath River fall-run Chinook salmon are a minor contributor to killer whale food resources. SSC and dissolved oxygen effects may impact up to 17 percent of fall-run Chinook salmon juvenile production during Year 1, and bedload may impact 13 percent of adult escapement in Year 2. These effects will be revealed 3 to 4 years after reservoir drawdown as 3-year-old and 4-year-old age class fish will be less abundant in the ocean. Over time as fall-run Chinook salmon access historical habitat and natural production increases, an additional 41,000 naturally-produced adult Chinook salmon will be present in the ocean (Lindley and Davis 2011).

Since Klamath River Chinook salmon contribute a small portion of Southern Resident killer whale prey base and Klamath River Chinook salmon production is anticipated to increase over time, the Proposed Action may affect, but is not likely to adversely affect SRKW in the long term.

5.4.4 Critical Habitat Effects

Based on the natural history of the Southern Resident killer whales and their habitat needs, the following physical or biological features were identified as essential to conservation: (1) water quality to support growth and development; (2) prey species of sufficient quantity, quality, and availability to support individual growth, reproduction, and development, as well as overall population growth; and (3) passage conditions to allow for migration, resting, and foraging. From observed sightings and other data, three “specific areas” were identified in the geographical area occupied by the species, containing important physical or biological features. The designated areas are: (1) the Summer Core Area in Haro Strait and waters around the San Juan Islands; (2) Puget Sound; and (3) the Strait of Juan de Fuca, which comprise approximately 2,560 square miles of marine habitat in the area occupied by Southern Resident DPS killer whales in Washington. Although designated critical habitat for the Southern Resident DPS killer whales is currently several hundred miles to the north of the Action Area, the Proposed Action has the potential to affect the Klamath River-origin Chinook salmon that range into the Puget Sound, and therefore affect PBFs relating to prey species. Furthermore, NMFS has proposed to expand critical habitat to include ocean waters from Cape Flattery, Washington south to Point Sur, California, between the 6.1-meter and 200-meter depth contours, which will be in the Action Area.

The reservoir drawdown will result in the release of sediment and periods of low dissolved oxygen downstream of Iron Gate Dam. These conditions will adversely affect Chinook salmon redds in the mainstem Klamath River, and on outmigrating juvenile Chinook salmon from tributary populations in Year 1. Bedload deposition in Year 2 will affect Chinook salmon spawning through redd burial and scour between Iron Gate Dam and Bogus Creek. Chinook salmon have also been found to make up a small proportion of the Southern Resident killer whale diet (Hanson et al. 2021) and few Klamath River fall-run Chinook salmon migrate north of Cape Falcon, thereby minimizing Klamath River Chinook salmon contribution to the North of Falcon adult Chinook salmon abundance threshold of 966,000 adult Chinook salmon (NMFS 2021). **Therefore, the Proposed Action may affect, but is not likely to adversely affect food resources in the Southern Resident killer whale designated critical habitat.**

5.5 Lost River and Shortnose Suckers

This section presents the effects analysis approach and findings. A detailed account of the species, including regulatory status, critical habitat, life history, geographic distribution, threats, and status of populations and critical habitat in the Action Area is provided in Appendix G.

5.5.1 Effects Analysis Approach

The Lost River sucker and shortnose sucker are native to Upper Klamath Lake and its tributaries. Historically, these species were not known to, and likely did not occupy riverine habitat below Keno Dam (Hamilton et al. 2011). The shortnose sucker is the only lake sucker that occurs in abundance in the Klamath Basin below Keno Dam, and adults have been collected in all three Hydroelectric Reach reservoirs (Beak Consultants 1987, Desjardins and Markle 2000, KRRC 2019). Mean population estimates for the listed suckers in the three reservoirs range from 2,201 to 5,540 suckers with a maximum estimate of 11,531 suckers. The short-term effects analysis focuses on the effects of a pre-drawdown sucker salvage effort and construction work in the reservoirs. The long-term effects analysis consists of the conversion of reservoir habitat to free-flowing riverine habitat in the Hydroelectric Reach.

Critical habitat for Lost River and shortnose suckers is designated in the Upper Klamath Basin upstream from Keno Dam. Therefore, the effects analysis for the listed suckers' critical habitat focuses on changes in the availability of food resources. The effects on food resources were determined by assuming that anadromous salmonids will return to Upper Klamath Lake tributaries and contribute nutrients to the suckers' forage base.

5.5.2 Short-Term Effects

The Proposed Action includes instituting a sucker salvage effort prior to the onset of reservoir drawdown, in addition to pre-drawdown activities that will be implemented to prepare for reservoir drawdown and dam removal. Activities to be completed in Copco No. 1 Reservoir in advance of reservoir drawdown include dredging sediment from the upstream side of Copco No. 1 Dam and disposing of dredged material in open water in the reservoir. Iron Gate Reservoir activities include improvements to road crossings on tributaries to Iron Gate Reservoir, Fall Creek Hatchery construction, and construction of a work pad on the upstream side of Iron Gate Dam. **Therefore, reservoir drawdown and dam removal are likely to adversely affect Lost River and shortnose suckers in the short term.**

The following sections describe short-term effects of the Proposed Action on Lost River and shortnose sucker.

5.5.2.1 Sucker Salvage Effort

The Renewal Corporation will conduct a sucker salvage effort following the guidelines in the Aquatic Resource Measure – Sucker Adaptive Management Plan prepared for suckers inhabiting J.C. Boyle Reservoir in Oregon (Oregon Plan) and Copco No. 1 Reservoir and Iron Gate Reservoir in California (California Plan).

The Adaptive Management Plans are included as part of the Aquatic Resources Management Plans in Appendix D. The management plans outline the salvage and translocation efforts that will be conducted in advance of reservoir drawdown and dam removal (see Section 2.5). This project minimization measure is intended to salvage and translocate listed suckers from the reservoirs in advance of the project, to preserve adult listed suckers. Translocated adult listed suckers will preserve breeding stock, provide broodstock for the Klamath National Fish Hatchery sucker recovery program, or be used to establish other redundant listed sucker populations in the Upper Klamath Basin. Juveniles will not be targeted due to the difficulty of identifying Lost River and shortnose suckers from non-listed sucker species.

The Renewal Corporation has established a level of effort and target number of listed suckers for salvage and translocation based on coordination with USFWS, ODFW, and CDFW. The Renewal Corporation calculated mean population estimates for the listed suckers in the three reservoirs between 2,201 and 5,540 suckers, with a maximum estimate of 11,531 suckers. The Renewal Corporation intends to salvage and translocate 300 listed suckers from J.C. Boyle Reservoir, and a total of 300 listed suckers from Copco No. 1 Reservoir and Iron Gate Reservoir. These targets equate to 17 percent and 12 percent of the average sucker population estimates for J.C. Boyle Reservoir, and Copco No. 1/Iron Gate Reservoir, respectively, and 15 percent of the average sucker population estimate across the three reservoirs.

Salvage and translocation methods will follow techniques outlined in the Adaptive Management Plan for Suckers prepared for Oregon and California. Suckers will be translocated to the Klamath National Fish Hatchery, the Klamath Tribes rearing facility, Tule Lake Sump 1A, or other translocation sites that may be identified based on further planning and agreement between USFWS, ODFW, CDFW, and the Renewal Corporation.

Translocated fish will first be taken to the Klamath National Fish Hatchery to support the Sucker Assisted Rearing Program. The hatchery currently has capacity for 100 adult suckers based on existing facilities. A total of 60 to 70 shortnose suckers, including 30 to 35 from J.C. Boyle Reservoir and 30 to 35 from Copco No. 1 Reservoir, and 30 to 40 Lost River suckers from J.C. Boyle Reservoir, will be delivered to the Klamath National Fish Hatchery. USFWS will hold delivered suckers in isolation and suckers will receive an external parasite treatment before they are integrated into hatchery groups. Translocated sucker genetics will be analyzed and fish will be added to broodstock.

The Renewal Corporation will translocate additional listed suckers exceeding the Klamath National Fish Hatchery's capacity, from J.C. Boyle Reservoir to the Klamath Tribes' sucker rearing facility east of Chiloquin, Oregon. The Klamath Tribes' rearing facility currently includes two ponds and several more ponds are planned for development in 2021. The Klamath Tribes anticipate creating the capacity for up to 2,000 adult suckers. Suckers delivered to the Klamath Tribes' ponds will be placed in separate ponds including one pond for Lost River suckers, one pond for shortnose suckers, and one pond for suckers that are not easily identifiable. Translocated suckers will be genetically tested and fish health investigations will be conducted by the Klamath Tribes, ODFW, or USFWS before fish are released in the future. Rearing pond effluent will be discharged to a dry basin so that no pond effluent will discharge to the Sprague River. Delivered suckers will also receive an external parasite treatment before release into the rearing ponds. The Klamath Tribes anticipate holding translocated suckers for up to 3 to 5 years before suckers are released either into Upper Klamath Lake or another location to be determined in the future.

Translocated listed suckers from Copco No. 1 Reservoir and Iron Gate Reservoir that exceed the capacity of the Klamath National Fish Hatchery, will be translocated to Tule Lake Sump 1A. Historically, Tule Lake was the terminal lake for the Lost River. Agricultural development in the basin has altered the Lost River, and Lost River and shortnose suckers in Tule Lake Sump 1A are now isolated to the Tule Lake sump complex and a 5-mile reach of the Lost River between Tule Lake Sump 1A and Anderson-Rose Dam. Tule Lake Sump 1A functions as an agricultural sump that is maintained by agricultural return flow. Until 2018, USFWS used Tule Lake Sump 1A as a release site for Lost River suckers and shortnose suckers salvaged from canals in the basin. However, since 2018, USFWS has transferred salvaged suckers from other areas of the basin to the Klamath National Fish Hatchery rather than to Tule Lake Sump 1A. Adult Lost River and shortnose suckers are known to occupy Tule Lake Sump 1A and listed suckers have been relocated from the sump to Upper Klamath Lake in the past (Courter et al. 2010). Tule Lake Sump 1A is known to currently have the capacity for an additional 3,000 relocated suckers (J. Rasmussen, USFWS, personal communication, 2017). Management of Tule Lake Sump 1A is complicated by multiple user groups and the periodic need to draw down the reservoir for sediment maintenance. USFWS will continue to manage Tule Lake Sump 1A for multiple uses.

Return flows to Tule Lake Sump 1A are influenced by agricultural production and basin water availability. During drought periods, flows to Tule Lake Sump 1A diminish and sucker habitat availability decreases. Tule Lake Sump 1A water quality is also impacted by agricultural inputs, algal blooms, and the effects of these conditions on dissolved oxygen levels. Drought conditions likely exacerbate water quality concerns as agricultural constituents are concentrated in lower return flows. Non-native predatory fish species in Tule Lake Sump 1A may prey on juvenile suckers, adult suckers are large enough they will not be preyed upon by non-native fish species. Fish-eating birds including American white pelicans (*Pelecanus erythrorhynchos*) and double-crested cormorants (*Phalacrocorax auratus*) are known to prey on suckers in Upper Klamath Lake and in Clear Lake east of Tule Lake Sump 1A. PIT tags from suckers consumed by American white pelicans and double-crested cormorants located at mixed-species colonies, were associated with suckers that ranged in size (fork length) from 72 to 694 mm (Evans et al. 2016). The authors determined that 50 depredated Lost River suckers in Upper Klamath Lake had a median fork length of 616 mm and the largest sucker consumed was a 730 mm female Lost River sucker (measured 2-1/2 years before the tag was located) from Upper Klamath Lake (Evans et al. 2016). Depredated shortnose suckers (n = 162) from Clear Lake had a median fork length of 360 mm. For comparison, the maximum size Lost River sucker and shortnose sucker captured by the Renewal Corporation was 765 mm (J.C. Boyle Reservoir) and 555 mm (Copco No. 1 Reservoir), respectively (Renewal Corporation 2020). Based on sampled sucker sizes from the Lower Klamath Project reservoirs, suckers translocated to Tule Lake Sump 1A could be susceptible to bird predation.

Lost River and shortnose suckers in the Hydroelectric Reach reservoirs have not been formally evaluated for parasites and disease. The Renewal Corporation recorded sucker body surface afflictions during sucker sampling. Between 11 percent and 33 percent of the sampled suckers had notable body surface afflictions over the four sampling periods (Renewal Corporation 2020). Translocating listed suckers from the reservoirs to Tule Lake Sump 1A has the potential to introduce parasites and diseases to Tule Lake Sump 1A. However, past studies have determined high rates of parasites and deformities on juvenile suckers in Tule Lake Sump 1A (Sutton et al. 2014). Fish health investigations completed by USFWS prior to the relocation of listed suckers from Tule Lake Sump 1A to Upper Klamath Lake in 2010 (Courter et al. 2010), found similar diseases and parasites in Tule Lake Sump 1A listed suckers as in Upper Klamath Lake listed suckers (Scott Foott, USFWS, personal communication).

Potential effects of pesticides on listed suckers have also been assessed. USBR evaluated the use of pesticides and herbicides on lands around Tule Lake in previous Section 7 consultations, and incidental take coverage was provided in the USFWS Biological Opinions 1-7-95-F-26 and 1-10-07-F-0056, dated February 9, 1995 and May 31, 2007, respectively. In both Biological Opinions, the USFWS determined that the maintenance action of pesticide application will not jeopardize the continued existence of Lost River and shortnose suckers. The findings of investigations and monitoring of pesticides in Tule Lake indicate pesticides are not present in concentrations that will adversely affect suckers (USFWS 2019a). In addition, an ecological risk assessment specific to soil fumigants (e.g., Vapam) used on federal lease lands within the Tule Lake National Wildlife Refuge analyzed the toxicity, environmental fate, transport, and exposure pathways, finding that there is “sufficient information that ecological risks to terrestrial, aquatic, and invertebrate species are negligible” for the majority of exposure scenarios (USFWS 2019a). Based on an evaluation of all life stages of Lost River and shortnose suckers in Tule Lake Sump 1A, USFWS 2019a concluded that conditions in Tule Lake Sump 1A including predation risk, water quality, and entrainment are not likely to impact sucker populations in Tule Lake Sump 1A.

Using Tule Lake Sump 1A as a translocation recipient waterbody will provide USFWS with management flexibility concerning Lost River and shortnose suckers. Tule Lake Sump 1A’s shallow depths and known sucker habitats, will make recapturing translocated suckers easier than capturing suckers in Upper Klamath Lake. For that reason, USFWS may use Tule Lake Sump 1A suckers to meet future broodstock needs for the Sucker Assisted Rearing Program, to augment recovery populations in Upper Klamath Lake, or to initiate redundant sucker populations in the Upper Klamath Basin. Despite the challenging environmental conditions in Tule Lake Sump 1A, the listed suckers have persisted in the sump for decades.

USFWS recently completed genetic libraries for the four sucker species native to the Upper Klamath Basin (Smith et al. 2020). USFWS is currently developing genetic assays that will be used to test sucker genetics. Genetic test outcomes will be used to determine the genetic composition of Hydroelectric Reach suckers and inform future sucker management decisions including using salvaged suckers for broodstock and releasing salvaged suckers to natural waterbodies.

Even though there may be injury or mortality to individual suckers associated with implementation of the AR-6 Adaptive Management Plan for Suckers (see Courter et al. 2010), and Tule Lake Sump 1A poses some risk due to impaired water quality and quantity, potential predator effects, and agricultural drainage to the sump, the measure will remove listed suckers from the Hydroelectric Reach reservoirs prior to reservoir drawdown, dam removal, and conversion of reservoir habitat to flowing riverine conditions. Salvaged and translocated suckers are expected to have a better chance of survival than suckers remaining in the Hydroelectric Reach reservoirs.

5.5.2.2 J.C. Boyle Reservoir Actions

In-Water Blasting

The sucker salvage effort is anticipated to be completed prior to in-water blasting at J.C. Boyle Reservoir. The final stages of drawdown will be initiated by removing one of the diversion-culvert concrete stoplogs, followed by the second stoplog. The Renewal Corporation anticipates that the stoplogs will be removed by controlled blasting. The drawdown process for J.C. Boyle Reservoir is considered complete when both diversion culverts are fully open and operating. Reservoir water levels will continue to subside through the spring and summer months as Klamath River flow rates decrease. The blasting to open the diversion culvert has the potential to affect suckers in the reservoir as the blasting of the concrete stoplogs will occur after the sucker salvage effort has been completed. The reservoir pool depth will be approximately 17 feet deep (bottom of power intake pipe to the bottom of diversion culverts) at the time of blasting. The reservoir pool will be narrowed to within approximately 500 feet of the dam (based on power intake pipe invert elevation and channel bed elevations). Additional sucker salvage prior to the blasting will not be allowed due to safety concerns and access. Water quality conditions are also anticipated to be extremely poor in the vicinity of the J.C. Boyle Dam due to the rapid drawdown rate, and floating and submerged debris. This is also likely to be a high concentration of non-native and native fish in the pool, making removal of listed suckers more challenging. For these reasons, any listed suckers remaining in the reservoirs may be impacted during the blasting.

5.5.2.3 Copco No. 1 Reservoir Actions

Sediment Dredging

Two locations immediately upstream from Copco No. 1 Dam will be dredged between August and September in the pre-drawdown year. Although the sucker salvage effort is being planned for the spring of the pre-drawdown year, a fall salvage could take place instead of the spring salvage if the project, permitting, or stakeholders require a later additional sucker salvage effort. Given the proposed dredging schedule, the sucker salvage effort could be completed following the sediment dredging. Approximately 4,800 cy of material will be dredged from an area of approximately 0.5 acre from the upstream side of the dam outlet tunnel. The dredged material is expected to include cobble, boulders, and fine sediment.

Dredged material will be transferred to a dredge barge for open water disposal at an approximately 2.25-acre deep-water (greater than 50 feet) site in the reservoir. Because the dredge and disposal areas will not be isolated during dredging or disposal, fish present in the affected areas will be free to leave the affected areas and move to cleaner water areas. Past sucker sampling (Desjardins and Markle 2000; Renewal Corporation 2019) and tracking of radio-tagged shortnose suckers (Beak Consultants 1987) found suckers use shallower areas of Copco No. 1 Reservoir. Locating the dredge spoil site in deeper water is likely to reduce potential effects on listed suckers in the reservoir because suckers prefer shallower habitats and disposed sediments will distribute over a broad area as the material sinks through the water column. Listed suckers could be affected by open water sediment disposal if suckers are in the vicinity of the dredge barge at the time of sediment disposal. Additional effort to remove listed suckers from the dredging or disposal areas prior to the work will be complicated by safety concerns and difficult boat access to the reservoir.

In-Water Blasting

One low-level reservoir outlet tunnel will be constructed through the approximate center of Copco No. 1 Dam. The tunnel will be constructed by drilling and blasting from the downstream side of the dam. A concrete plug will remain to separate the tunnel from the reservoir until reservoir drawdown begins on January 1 of the drawdown year. The concrete plug will be blasted to facilitate reservoir drawdown and sediment evacuation. The final blasting to open the outlet tunnel has the potential to affect suckers in the reservoir. However, the blasting of the concrete plug will occur after the sucker salvage effort has been completed. Additional effort to remove listed suckers from the dredging or disposal areas prior to the work will be complicated by safety concerns and difficult boat access to the reservoir. Any listed suckers remaining in the reservoirs may be impacted during the blasting.

5.5.2.4 Iron Gate Reservoir Actions

The sucker salvage effort is expected to be completed before the Iron Gate Reservoir actions are implemented, although if the sucker salvage effort is conducted in the fall, some in-water work described below may precede the sucker salvage effort.

Tributary Road Crossing Improvements

Road crossing improvements will be completed on two tributaries to Iron Gate Reservoir, and on the Klamath River upstream from Iron Gate Reservoir, in advance of reservoir drawdown.

The Scotch Creek and Camp Creek culverts are upstream of the reservoir and shortnose suckers are unlikely to inhabit the stream reaches between the culverts and the reservoir. Streamflow will be bypassed at each site using a pipeline and/or open channel. Electric or gas-powered pumps will be used to further dewater the construction site as necessary for project construction.

A temporary bridge will be constructed immediately upstream of the Daggett Road bridge crossing on the Klamath River near the upstream end of Iron Gate Reservoir. The temporary bridge will include placing rock abutments on either side of the Klamath River, and spanning the river with a 140-foot-long by 18-foot-wide bridge. Abutments will extend approximately 100 feet and 40 feet into the channel from the river-left and river-right banks, respectively. Abutment construction will require site excavation of vegetation, soil, and loose channel bed materials, placement of rock fill and riprap, and construction of cast-in-place or pre-cast concrete structures in the wetted channel. Construction during low flows, or by reducing inflows to Iron Gate Reservoir, will improve construction efficiency and reduce turbid water discharge. Due to the anticipated volume of river flow, it will not be feasible to pump turbid water from the construction site unless a more intensive effort is required to isolate the work area.

Iron Gate Reservoir Work Pad Construction

Beginning in July of the year before drawdown, the installation of the new control gate on the Iron Gate Dam outlet tower will require a crane work platform to be constructed on the upstream side of Iron Gate Dam in the reservoir footprint in the space between the embankment crest and the overflow spillway, at the right abutment and near the gate house. Construction of the work platform is expected to take approximately 10 days, and the work is planned to occur after the reservoir is lowered to elevation 2340.5 feet so that rock and general fill can be placed in dry conditions. However, because of the unpredictability of river flows that vary based on weather and snowmelt, the work platform base could be in water. If a spring sucker salvage effort is completed, this work will be completed following the salvage. However, if a later salvage is desired, the work pad construction could precede the salvage. Based on shortnose sucker preferred habitat metrics, shortnose suckers are unlikely to be immediately adjacent to the spillway and dam. Suckers that are in the area will be able to volitionally leave the area during work pad construction. Additional effort to remove listed suckers from the work pad construction area prior to the work will be complicated by safety concerns and difficult boat access to the reservoir.

5.5.2.5 Reservoir Drawdown and Dam Removal

The Proposed Action will eliminate existing habitat for Lost River and shortnose suckers in the Lower Klamath Project reservoirs. Drawdown of the reservoirs and conversion of the reservoirs to a free-flowing river is expected to result in the loss of sucker populations in the reservoirs. The Renewal Corporation will implement AR-6 Adaptive Management Plan for Suckers to salvage and relocate suckers from the reservoirs prior to the reservoir drawdown (see Section 2.5). However, given existing information, the USFWS does not consider reservoir populations and habitat below Keno Dam as contributing significantly to sucker recovery (Hamilton et al. 2011; USFWS 2013c) although understanding of reservoir sucker populations has evolved over the last 3 years with USFWS' development of the Klamath suckers' genetic library (Smith et al. 2020), and the completion of the Renewal Corporation's sucker sampling effort (Renewal Corporation 2020). Additionally, whereas reservoir sucker populations in the past were likely a fraction of the size of the Lost River and shortnose sucker recovery populations, recent sucker die-offs and declining sucker abundance in Upper Klamath Lake since the early 2000s, have increased the potential ecological value of reservoir sucker populations for species' recovery. Translocating listed suckers to the Klamath National Fish Hatchery and Tule Lake Sump 1A will provide USFWS with the flexibility to recapture translocated suckers in the future to meet management goals. Those Lost River and shortnose suckers not relocated by the Renewal Corporation prior to reservoir drawdown will likely be lost; but with little or no successful reproduction (Buettner et al. 2006), and no connection to upstream populations, the individuals downstream of Keno Dam minimally contribute to sucker recovery (Hamilton et al. 2011, USFWS 2012, USFWS 2013c).

5.5.3 Long-Term Effects

The Proposed Action will eliminate all Lost River and shortnose sucker habitat downstream of Keno Dam. This altered hydrology will result in a long-term reduction in usable habitat for the two species, and those Lost River and shortnose suckers not relocated to the Klamath National Fish Hatchery or Tule Lake Sump 1A prior to reservoir drawdown are not expected to persist in the reservoirs. Even though suckers in the Hydroelectric Reach reservoirs experience little or no successful reproduction (Buettner et al. 2006), have no connection to upstream populations, and the individuals downstream of Keno Dam do not currently contribute to the recovery of the two species (Hamilton et al. 2011), the loss of reservoir habitat will result in the long-term loss of Lost River and shortnose suckers. The loss of the reservoir suckers will result in the overall reduction of living Lost River and shortnose suckers and potentially reduce the long-term viability of the two species. The Lost River sucker population in Upper Klamath Lake has declined precipitously since 2002, declining nearly 70 percent to approximately 45,000 adult fish (USGS, unpublished preliminary data). From 2009 through 2018, the Upper Klamath Lake shortnose sucker population declined from approximately 27,000 adults to 8,000 adults in 2018 (USGS, unpublished preliminary data). Although USFWS did not review the reservoir populations as part of the recent 5-year status reviews (USFWS 2019d; 2019e) or the Species Status Assessment (USFWS 2019f), Lost River and shortnose suckers in the reservoirs provide redundant populations that, absent the implementation of the Proposed Action, could contribute to the persistence of the two species if recovery populations in Upper Klamath Lake continue to decline due to periodic fish die-offs and poor recruitment of juvenile fish into the adult reproductive populations (USFWS 2019f).

The return of anadromous salmonids to the Upper Klamath Basin may also have long-term effects on Lost River and shortnose suckers through predation in the Williamson River and Sprague River systems. Juvenile Chinook salmon and steelhead rearing in Upper Klamath Lake tributaries may prey on sucker eggs during sucker spawning, and on larval suckers drifting from riverine spawning sites in the Williamson and Sprague Rivers to Upper Klamath Lake.

Therefore, the Proposed Action will have an adverse effect on Lost River and shortnose suckers residing in the Lower Klamath Project reservoirs in the long term. The Proposed Action may affect, and is likely to adversely affect Lost River and shortnose suckers spawning and rearing in tributaries to Upper Klamath Lake as restored access to historical habitat for anadromous salmonids is likely to result in predation on listed suckers' eggs, larvae, and juvenile life stages.

5.5.4 Critical Habitat Effects

Designated critical habitat for Lost River and shortnose suckers that is in the Action Area is limited to Upper Klamath Lake and its tributaries. As stated in 77 FR 73740, the PBFs essential for the conservation of the Lost River and shortnose suckers include:

1. Areas with sufficient water quantity and depth in lakes, reservoirs, streams, marshes, springs, groundwater sources, and refugia habitats with minimal physical, biological, or chemical impediments to connectivity. Water must have varied depths to accommodate each life stage: Shallow water (up to 3.28 feet [1.0 meters]) for larval life stage, and deeper water (up to 14.8 feet [4.5 meters]) for older life stages.
2. Spawning and rearing habitat. Streams and shoreline springs with gravel and cobble substrate at depths typically less than 4.3 feet (1.3 meters) with adequate stream velocity to allow spawning to occur. Areas containing emergent vegetation adjacent to open water provides habitat for rearing, and facilitates growth and survival of suckers, as well as protection from predation and protection from currents and turbulence.
3. Food. Areas that contain an abundant forage base, including a broad array of chironomidae, crustacea, and other aquatic macroinvertebrates.

The return of anadromous salmonids to the Upper Klamath Basin may have a beneficial effect on the food PBF for Lost River and shortnose suckers. Although the Upper Klamath Basin is a nutrient-rich system, the addition of anadromous salmonids will introduce marine derived nutrients as adult Chinook salmon and steelhead spawn and perish (steelhead may spawn multiple times during lifetime) in Upper Klamath Lake tributaries. Carcasses, eggs, larvae, and juvenile fish will provide food resources for aquatic macroinvertebrates that could enhance the ecology of streams and increase the forage base for Lost River and shortnose suckers. Increased food resources could have a beneficial effect on the food PBF.

Because habitat downstream of Keno Dam is not designated critical habitat, the Proposed Action effects to critical habitat are limited to upstream of Keno Dam. However, to determine the proportional loss of Lost River and shortnose sucker habitat in the Lower Klamath Project reservoirs relative to designated critical habitat, the reservoir areas and reservoir areas with sucker-preferred habitat were calculated (Table 5-19). The estimated lost habitat area is presented for each reservoir at full pool, and for the area of each reservoir up to 14.8 feet deep, which is the habitat PBF for older sucker life stages identified in the critical habitat designation (USFWS 2012).

Table 5-19: Total Area at Full Pool and Area Less Than 14.8 feet of Depth at Full Pool in the Hydroelectric Reach Reservoirs

Reservoir	Total Area at Full Pool (acres)	Area less than 14.8-feeet deep at Full Pool (acres)
J.C. Boyle Reservoir	377.0	312.5
Copco No. 1 Reservoir	1,012.3	192.5
Iron Gate Reservoir	963.1	172.4
Total	2,352.4	677.4

USFWS (2012) designated 117,848 acres and 123,590 acres of lake and reservoir habitat as critical habitat for Lost River suckers and shortnose suckers, respectively. The displaced total reservoir habitat for the Hydroelectric Reach reservoirs is 1,389 acres (excludes Iron Gate Reservoir) for Lost River suckers, and 2,352 acres for shortnose suckers. Compared to the total designated critical habitat area, the displaced total reservoir habitat area is 1.2 percent of the area for Lost River suckers and 1.9 percent for shortnose suckers. Compared to the total designated critical habitat area, the reservoir habitat area up to 14.8 feet deep that will be lost will only represent approximately 0.4 percent of the designated critical habitat area for Lost River suckers and 0.5 percent for shortnose suckers if the area were to be designated as critical habitat.

The Proposed Action will potentially benefit the food PBF for Lost River and shortnose sucker critical habitat. **Therefore, the Proposed Action may affect, but is not likely to adversely affect the habitat space, spawning and rearing habitat, or food resources PBFs for Lost River and shortnose sucker critical habitat.**

5.6 Bull Trout

This section presents the effects analysis approach and findings. A detailed account of the species, including regulatory status, critical habitat, life history, geographic distribution, population trends, threats, and status in the Action Area is provided in Appendix G.

5.6.1 Effects Analysis Approach

Bull trout inhabit the cold headwaters of Upper Klamath Lake tributaries, and therefore are upstream of the Hydroelectric Reach. Bull trout may be affected by anadromous salmonids that will have the opportunity to access historical habitat in Upper Klamath Lake tributaries once the dams are removed. Therefore, the effects analysis for bull trout focuses on potential long-term effects related to predation and the potential for disease transmission.

Critical habitat for bull trout is designated in the Upper Klamath Basin in tributaries to Upper Klamath Lake. Therefore, the effects analysis for bull trout critical habitat focuses on changes in the availability of food resources. The effects on food resources were determined by assuming that Chinook salmon and steelhead will reoccupy historical habitat upstream of Upper Klamath Lake. The effects analysis also assumes that bull trout, being highly piscivorous, will take advantage of the availability of these increased food resources (anadromous salmonid egg, fry, juveniles, and adult carcasses).

5.6.2 Short-Term Effects

Bull trout do not inhabit mainstem river reaches or tributary streams in the Hydroelectric Reach or downstream of Iron Gate Dam, where short-term effects of reservoir drawdown and dam removal activities are expected to occur. **Therefore, reservoir drawdown or dam removal activities will have no effect on bull trout in the short term.**

5.6.3 Long-Term Effects

The Proposed Action will restore access of anadromous salmonids to habitat bull trout utilize. Even though bull trout eggs and fry could become prey for anadromous salmonids, the increase in available food sources (e.g., eggs, fry, and juvenile salmonids) will benefit bull trout. Bull trout are currently exposed to the same pathogens that occur downstream of Iron Gate Dam, and therefore are not likely to be adversely affected by disease carried by anadromous salmonids. **Due to the potential for predation on bull trout eggs and fry, the Proposed Action is likely to adversely affect bull trout populations in the long term.**

The following sections describe the long-term effects of the Proposed Action on bull trout.

5.6.3.1 Predation Effects

The Proposed Action will result in restored passage for anadromous salmon to tributaries to Upper Klamath Lake, where they could interact with bull trout. Because of this, bull trout could be affected by increased predation from salmonids now able to access these areas. However, because adult Chinook salmon and steelhead do not feed during their spawning migrations, the Renewal Corporation does not expect the adult life stages of these species to affect bull trout. However, steelhead, which may occupy bull trout habitat, are known to prey on a variety of food resources, including eggs and fry of other fish. Juvenile salmonids may also interact with juvenile bull trout, competing for rearing habitat and possibly preying on juvenile bull trout where their rearing habitats overlap.

Age-0 bull trout rear in shallow, low-velocity, stream-margin habitats during the summer. An advantage to rearing in stream margins is avoidance of larger piscivorous bull trout and other aquatic predators.

In general, juvenile and sub-adult fluvial and adfluvial bull trout start to migrate to larger river or lake habitats after age 2 or 3, and begin feeding on larger prey, with fish becoming an increasing part of their diets (Pratt 1992; Ratliff and Howell 1992). Fraley and Shepard (1989) found that bull trout greater than 110 millimeters (mm) in the upper Flathead River consumed small trout and sculpin. Underwood et al. (1995) found bull trout (less than 200 mm) from three southeastern Washington streams feeding on a wide range of food sources, including mayfly nymphs, midge larva, rainbow trout, and frogs.

Ratliff et al. (1996) found that some of the age-2 and older bull trout in the Metolius River system did not continue to disperse downstream of early juvenile rearing habitats, but instead moved into adjacent warmer tributaries not used by bull trout for spawning. Ratliff et al. (1996) suggested that bull trout movement into these warmer tributaries was apparently for feeding opportunities on abundant sculpin. Goetz et al. (2004) considered large adult, migratory bull trout to be “apex predators” that feed opportunistically, based on what food items are most available at any one time or location. This may include cannibalism of other bull trout by larger adults (Beauchamp and Van Tassel 2001; Spangler and Scarnecchia 2001). Bull trout will be expected to benefit from the increase in food resources provided by anadromous salmonid eggs, fry, and juveniles.

However, there is potential that adult and juvenile steelhead as well as juvenile Chinook salmon may overlap with current and future bull trout distribution, as these species are expected to access habitats upstream of Upper Klamath Lake and therefore may result in some increased predation of bull trout eggs or fry. Even though bull trout eggs and fry could become prey for anadromous salmonids, this loss will be offset by an increase in available food sources for bull trout (e.g., eggs, fry, and juvenile salmonids) (Hamilton et al. 2010).

5.6.3.2 Potential for Introduction of Disease

In the Klamath River, *P. minibicornis* and *C. shasta* share the same invertebrate host, an annelid worm, *Manayunkia occidentalis sp. nov.* (Atkinson et al. 2020). The invertebrate host for the parasite is present in a variety of habitat types, including runs, pools, riffles, edge-water, and reservoir inflow zones, as well as sand, gravel, boulders, bedrock, and aquatic vegetation, and is frequently present with the periphyton species *Cladophora* (Bartholomew and Foott 2010). Slow-flowing habitats may have higher densities of annelids; and areas that are more resistant to disturbance, such as eddies and pools with sand and *Cladophora*, may support increased densities of annelid populations, especially if flow disturbance events are reduced or attenuated (Bartholomew and Foott 2010).

Observations below Iron Gate Dam indicate *C. shasta* has the potential to infect large portions of Chinook salmon and coho salmon adults and juveniles and cause significant mortality. If salmon spawning migrations were to occur above Iron Gate Dam, an upriver infectious nidus for *C. shasta* may be created like the one that currently occurs downstream of Iron Gate Dam where salmon spawning congregations occur. The likelihood of this happening is unknown. Although *C. shasta* has been detected above Iron Gate Dam in the lower Williamson River (a tributary of Upper Klamath Lake) and in areas below Iron Gate Dam in nearly equal levels, the effects on fish have differed between these two areas. The pathogen exposure portion of a study by Maule et al. (2009) demonstrates that *C. shasta* is abundant in the Williamson River. Historically, *C. shasta* occurred and continues to be present in the Upper Klamath Basin, and resident fish above the dams evolved with these parasites. Historically, anadromous fish and their associated pathogens migrated to the Upper Klamath Basin, and available information suggests that the likelihood of introducing new pathogens that will affect existing populations is minimal (Bartholomew 1998; Stocking and Bartholomew 2007). Additionally, little is known about bull trout susceptibility to *C. shasta* although bull trout have shown resilience to whirling disease, another myxosporean parasite that infects salmonids.

Columnaris and Ich are ubiquitous in freshwater systems, and both are present throughout the Klamath River system above and below Iron Gate Dam. The Proposed Action will eliminate the Hydroelectric Reach reservoirs and the populations of warmwater fish that are potential hosts to *columnaris* and Ich. Generally, with the exception of *columnaris* and Ich, pathogens associated with anadromous fish do not impact non-salmonids, including federally listed suckers (Administrative Law Judge 2006). Whirling disease, another myxozoan parasite spreading in the western United States in recent decades, is absent from the Klamath River (S. Foott, Service, pers. comm.), and sampling has found no evidence of the disease in Upper Klamath Basin streams.

Infectious haematopoietic necrosis (IHN) is uncommon in the Klamath River, and the type of IHN present in coastal California is not virulent to trout species, only Chinook salmon (direct testimony of J. Scott Foott, Project Leader of the California-Nevada Fish Health Center in [Administrative Law Judge 2006]). FERC concluded there is a slight risk of transmission of disease IHN to the upper watershed (FERC 2007). Because of its low levels, *R. salmoniranrum,* the causative agent of bacterial kidney disease in salmon, does not appear to pose a significant risk of disease in the salmonid population in the Klamath River system; consequently, the bacteria will not pose a significant threat to fish in the upper basin (Administrative Law Judge 2006). Similarly, the parasitic trematode *metacercaria* of *Nanophyetus salminicola*, the host to the Rickettsia bacterium that causes salmon poisoning in canines, is present in many juvenile and adult salmon; however, they do not appear to present a significant health threat to resident fish in the Upper Klamath Basin. Because a majority of the pathogens currently found in the lower basin also exist in the upper basin of the Klamath River system, a logical conclusion is that migration of anadromous fish above Iron Gate Dam will not be a significant factor contributing to disease for resident fish (Administrative Law Judge 2006).

Bull trout could be at risk if pathogens present downstream of Iron Gate Dam were not present in the Upper Klamath Basin. However, based on the presence of the same pathogens upstream and downstream of Iron Gate Dam and the evolution of bull trout in the presence of these pathogens, the restoration of passage for anadromous salmonids upstream of Iron Gate Dam is not anticipated to result in adverse effects to bull trout.

5.6.4 Critical Habitat Effects

Bull trout critical habitat is not designated in the Hydroelectric Reach. However, food resources are a PBF of bull trout critical habitat, which is in Upper Klamath Lake and its tributaries. The restoration of passage for

Chinook salmon and steelhead into bull trout habitat will result in increased food resources for bull trout (Chinook salmon and steelhead eggs, fry, smolts, and adult carcasses). Increased food resources will result in a beneficial effect on bull trout's food resources. **Therefore, the restoration of passage for anadromous salmonids upstream of Iron Gate Dam may result in a beneficial effect on bull trout critical habitat.**

5.7 Northern Spotted Owl

This section presents the effects analysis approach and findings for the northern spotted owl (NSO). A detailed account of the species, including regulatory status, critical habitat, life history, geographic distribution, threats, and status in the Action Area is provided in Appendix G.

5.7.1 Effects Analysis Approach

The Proposed Action includes the removal or modifications to project facilities to benefit anadromous and resident fish and the ecosystem in the long term. However, construction required for the removal or modification of project structures will necessitate the use of blasting, helicopters, and other heavy equipment.

As described in Appendix G, one NSO activity center is in the vicinity of the Copco Lake (approximately 1.3 miles southeast of the eastern end of Copco Lake and 5 miles from Copco No. 1 Dam). The nearest known NSO activity center is more than 4 miles from the J.C. Boyle Dam. There are no known NSO activity centers near the Iron Gate Dam.

The majority of habitat in the Action Area is considered unsuitable for NSO. Adjacent to the J.C. Boyle powerhouse, there are small, isolated stands of trees that may provide roosting and foraging opportunities, as described further below. Southeast of Copco Lake, there is nesting, roosting, and foraging habitat that supports a known activity center (see Appendix G, Figure G-10).

No construction activities will affect the suitable habitat southeast of Copco Lake. The nearest construction activity that could affect suitable NSO habitat southeast of Copco Lake will entail reservoir restoration, at a distance of more than 1 mile from the closest known activity center, BLM Master Site Number (MSNO) 2191/CNDDB SIS0301.

The Renewal Corporation, in coordination with USFWS, determined that disturbance-only surveys should be conducted to evaluate the potential for NSO to occur and be affected by noise from blasting and other construction activities in the J.C. Boyle area. Based on the lack of suitable spotted owl habitat near the facilities associated with Copco No. 1, Copco No. 2, and Iron Gate Dams and reservoirs, no surveys were conducted in those areas.

Disturbance-only protocol surveys for northern spotted owl were conducted during the 2018 breeding season from April to August. Nighttime station calling surveys were conducted at 18 calling stations in the vicinity of the J.C. Boyle Reservoir, Dam, and powerhouse following the 2012 USFWS NSO Survey Protocol.

Calling stations were determined based on habitat suitability information provided as spatial layers (see Appendix G, Figures G-8 and G-9) and verified during a field reconnaissance with USFWS in October 2017.

In subsequent planning for and conducting the protocol surveys, habitat for NSO in the J.C. Boyle area was observed to be marginal at best. The majority of the forested habitat consisted of younger forest stands with open canopies; however, a small number of isolated patches of habitat that may support roosting and/or foraging were observed. These isolated patches consisted of two or three larger diameter trees in close proximity and with features such as leaning or fallen trees, broken limbs, dense tangles, or other structure. No northern spotted owls were detected during the six surveys conducted in the vicinity of the J.C. Boyle Reservoir, Dam, and Powerhouse.

Project activities that may remove individual or small numbers of trees or other vegetation, such as widening existing roads, are not anticipated to rise to the level of NSO habitat modification. Proposed disposal sites at Iron Gate and Copco are not in potential NSO habitat. Based on the Proposed Action (described in Chapter 2), the previously proposed disposal site in a partially forested area at J.C. Boyle will not be used. The current design indicates the earthen material from the dam will be disposed on the left and right banks of the J.C. Boyle Reservoir; demolished concrete, primarily from the intake and power canal in conjunction with earth fill from the forebay area will be used to infill the scour hole; and powerhouse concrete rubble will be filled into the powerhouse cavity and tailrace. These sites do not provide NSO habitat. Therefore, the effects analysis for northern spotted owls focuses on disturbance from noise. The effects analysis for NSO critical habitat considers the limited vegetation removal that is anticipated to occur for the relocation of the J.C. Boyle Powerhouse access road. All effects described for spotted owl are considered short-term effects.

The Renewal Corporation's effects analysis approach for NSO considered effects of anticipated deconstruction actions on NSO activity centers and nesting and roosting habitat for actions resulting in disturbance. Owls can be disturbed by noise, visual, or physical disturbances that can include effects of downdrafting from a large helicopter. Noise disturbance distances were identified for construction activities that may affect an NSO during the breeding period (Table 5-20). These distances were based on the USFWS (2006a) publication "Estimating the Effects of Auditory and Visual Disturbance to Northern Spotted Owls in Northwestern California" and in coordination with USFWS. Each construction action was analyzed using best available information of known activity centers, suitable nesting and roosting habitat, construction activity locations, and construction timing. Compiled information and analysis include the sources listed below.

- Information about NSO activity center locations in the project vicinity was provided by the USFS (D. Freeling, Wildlife Biologist, Goosenest Ranger District. pers comm., June 16, 2017) and USFWS (Klamath Falls USFWS office (E. Willy, Wildlife Biologist, Klamath Falls Office, pers. comm., April 26, 2018).
- A habitat assessment within an 8-kilometer (5-mile) buffer of Iron Gate, Copco No. 1 and Copco No. 2 dams was conducted by Oakley Consulting in June 2011 (Oakley Consulting 2011). The habitat-based assessment used Google Earth aerial photographs, vegetation maps, and knowledge of the area.
- Habitat suitability mapping layers for the Action Area were provided by USFWS (S. Galloway, Biologist USFWS Yreka Office, pers. comm., May 24, 2017). BLM provided habitat suitability mapping for the

Oregon portion of the Action Area (S. Hayner, Biologist, Lakeview District, Klamath Falls Resource Area, pers. comm., August 24, 2017).

- Construction locations (i.e., haul routes, disposal sites, and helicopter staging areas) were identified by the Renewal Corporation.
- Preliminary spotted owl calling stations were mapped by the Renewal Corporation Technical Representative with input from USFWS in preparation for protocol surveys to be conducted in 2018.

Table 5-20: Disturbance Distances for the Northern Spotted Owl During the Breeding Period

Source of Noise	Disturbance Distance[1]
Blasting	1,760 yards (1 mile)
Hauling on open roads	440 yards (0.25 mile)
Heavy equipment	440 yards (0.25 mile)
Rock crushing	440 yards (0.25 mile)
Helicopter—Type I[2]	880 yards (0.5 mile)
Aircraft—Fixed-Wing	440 yards (0.25 mile)

[1] Noise distances were developed in coordination with the Arcata USFWS office using an estimation of auditory and visual disturbance effects (USFWS 2006a) as a basis.
[2] Type I helicopters seat at least 16 people and have a minimum capacity of 2,300 kilograms (5,000 pounds). Both a CH 47 (Chinook) and UH 60 (Blackhawk) are Type I helicopters.

Spatial analysis was conducted to determine if a deconstruction activity has a potential to result in disturbance to a known activity center; or in suitable nesting and roosting habitat that has the potential to support a future activity center. Within the disturbance distance of each deconstruction activity, the presence of any activity centers and suitable habitat were identified. The effect thresholds listed below were made based on the location of the activity center, the presence of suitable nesting and roosting habitat, the timing of the construction activity, and implementation of minimization measures.

- May Affect and Likely to Adversely Affect: If an activity center is within the disturbance distance and the deconstruction activity occurs within the critical-breeding season (California: February 1–July 9; Oregon: March 1–August 10), or suitable habitat is present and no implementation of minimization measures.
- May Affect but Not Likely to Adversely Affect: If an activity center is within the disturbance distance and activity occurs during the late breeding season (California: July 10–September 15; Oregon: August 11–September 30), or suitable habitat is present and implementation of minimization measures.
- No Effect: If an activity center is within the disturbance distance and activity occurs outside of the entire breeding season (California: February 1–September 15; Oregon March 1–September 30), if an activity center is outside of the disturbance distance, or no suitable habitat is present and no implementation of minimization measures. (Protocol-level surveys resulting in no activity center will also result in a No Effect.)

5.7.2 Short-Term Effects

As described above, the Renewal Corporation conducted disturbance-only protocol surveys for NSO were conducted during the 2018 breeding season from April to August in the vicinity of the J.C. Boyle Reservoir, Dam, and powerhouse following the 2012 USFWS NSO Survey Protocol.

No NSO were detected during the six surveys conducted in the vicinity of the J.C. Boyle Reservoir, Dam, and powerhouse. Although it is possible that the species may be present in the vicinity, the best available information from these recent surveys indicates there are no activity centers within the noise disturbance distances discussed below. Although protocol surveys were deemed appropriate in 2018 based on the available information at the time, additional protocol surveys are not proposed because habitat in the J.C. Boyle area was found to be marginal at best. A small number of isolated patches of habitat may support roosting and/or foraging of individual owls; however, these small isolated patches will not be expected to support a future nesting pair given the lack of nesting, roosting, and foraging habitat available in the surrounding vicinity.

The only NSO activity center that is known to be currently active in the Action Area is BLM MSNO 2191 (aka CNDDB SIS0301), approximately 1.3 miles southeast of the eastern end of Copco Lake, and more than 5 miles southeast of the Copco No. 1 Dam and powerhouse (D. Freeling, USFS Goosenest Ranger District. Pers comm., June 16, 2017). The effects of anticipated construction/de-construction actions on this NSO activity center were assessed for actions resulting in disturbance from noise.

The Proposed Action includes, but is not limited to, the removal or modification of project structures, upgrading roads, and restoration. These activities will result in noise that may disturb NSO. Effects of noise can either result in a northern spotted owl being distracted to such an extent that its normal behavior is disrupted, or create the likelihood of significantly disrupting breeding, feeding, or sheltering. The disturbance distance is the distance from the source of noise outward, which could cause a NSO, if present, to be affected. Therefore, the noise effects analysis relied on established disturbance buffers from noise sources to known NSO nest sites during the breeding period (USFWS 2006a) (Table 5-20).

No current NSO activity centers are within the disturbance distance of the anticipated construction activities analyzed. Activity Center BLM MSNO 2191 (CNDDB SIS0301) is in the mixed coniferous forest at higher elevations above Copco Lake. Along Ager-Beswick Road that runs along the south side of the reservoir, the habitat consists of relatively young deciduous oak woodland in the lower elevations. Suitable NSO habitat at the higher elevations is more than 1 mile from the far eastern end of Copco Lake, and is outside the noise disturbance distance for all construction activities, including helicopter use during restoration of the reservoir (e.g., for seeding and movement of equipment and materials).

At J.C. Boyle, protocol surveys conducted in 2018 did not detect NSO, nests, or activity centers, and habitat to support future nesting spotted owl pairs is not present within the disturbance distance (i.e., 1 mile for blasting, 0.25 mile for all other activities) of Proposed Action activities at J.C. Boyle, including blasting at the dam, excavation of dam embankment, demolition of dam components, power canal (flume), forebay structures, penstocks, and powerhouse structures, backfilling of tailrace channel area and canal spillway scour hole, removal of transmission lines, and improvement and use of haul routes (including relocation of the access road near the scour hole, as discussed further in the critical habitat effects section).

As described above, protocol surveys for NSO conducted during the breeding season in 2018 indicate there are no activity centers in the J.C. Boyle vicinity and there is no nesting, roosting, and foraging habitat to support future nesting spotted owl pairs. Therefore, adverse effects on nesting owls are not anticipated and seasonal restrictions on construction are not proposed. However, the following measures will be implemented, based on input from USFWS:

- To prevent disturbance to the known NSO activity center approximately 1.3 miles southeast of the eastern end of Copco Lake (CNDDB Masterowl number SIS0301 and BLM Master Site Number [MSNO] 2191), helicopter flight paths will stay at least 1 mile from the known NSO activity center. No new surveys will be conducted and occupancy by nesting birds will be assumed.
- To address the potential for NSO to move into other areas that support NRF habitat south of Copco Lake, helicopter flight paths will stay at least 1 mile from suitable NRF habitat, as identified in the USFWS Relative Habitat Suitability mapping layer (S. Galloway, Biologist USFWS Yreka Office, pers. comm., May 24, 2017).
- If helicopter flight paths cannot avoid the areas that support NRF habitat south of Copco Lake, then disturbance-only surveys will be conducted.
- No nesting, roosting, or foraging habitat will be affected by the Proposed Action. Modification of critical habitat during relocation and widening of the J.C. Boyle Powerhouse access road at the scour hole will be limited to areas of NSO dispersal habitat. Dispersal habitat will not be downgraded as a result of tree removal.

With the implementation of these minimization measures, disturbance generated by the Proposed Action may affect, but is not likely to adversely affect the northern spotted owl.

5.7.3 Long-Term Effects

No long-term adverse effects on NSO are anticipated from the Proposed Action. In the long term, restoration of the river channel and associated riparian forest will result in an increase in dispersal habitat for NSO.

5.7.4 Critical Habitat Effects

NSO critical habitat is designated within 1 mile of the J.C. Boyle Dam and adjacent to the J.C. Boyle Powerhouse. Critical habitat is also present north of Iron Gate Reservoir and south of the Klamath River east of Copco Lake, as described in Appendix G.

The NSO critical habitat designation (USFWS 2012a, b) includes the following PBFs that are essential to a species' conservation: (i) forest types that support the species across its geographic range; (ii) nesting, roosting, and foraging habitat; and (iii) dispersal habitat. These features are described in further detail in Appendix G.

Relocation of the J.C. Boyle Powerhouse access road at the scour hole will entail removal of approximately 0.4 acre of NSO dispersal habitat. The access road will be shifted to the west, which will require the western slope to be cut and graded, and trees to be removed. This area is dominated by Douglas-fir with average canopy cover of 30 percent, and a slightly denser understory dominated by Douglas-fir saplings and serviceberry with an average cover of 40 percent. Noise and lighting from the nearby forebay and the adjacent access road results in a moderate level of ambient disturbance. Therefore, this area may provide dispersal habitat for NSO, but will not support nesting, roosting, or foraging habitat.

NSO nesting, roosting, or foraging habitat within the Action Area is limited to that in the vicinity of the activity center 1.3 miles southeast of the eastern end of Copco Lake. A portion of this habitat is included in the 1.5-mile buffer surrounding the hydroelectric reach; however, no construction activities will occur in nesting, roosting, or foraging habitat. Therefore, no nesting, roosting, or foraging habitat will be affected by the Proposed Action. Removal of 0.4 acre of dispersal habitat will not change the functional characteristics of the habitat for NSO that may disperse through the area. The amount of habitat affected will be small, is on the edge of currently disturbed areas, and will not influence forest conditions with respect to spotted owl life history (i.e., the function of the habitat at scales important to spotted owls will remain the same). In the long term, restoration of the river channel and associated riparian forest will result in an increase in dispersal habitat. **Therefore, the Proposed Action may affect, but is not likely to adversely affect designated critical habitat for the northern spotted owl.**

5.8 Oregon Spotted Frog

This section presents the effects analysis approach and findings. A detailed account of the species, including regulatory status, critical habitat, life history, geographic distribution, population trends, threats, and status in the Action Area is provided in Appendix G.

5.8.1 Effects Analysis Approach

Within the Action Area, the Oregon spotted frog (OSF) occupies the upper reaches of Spencer Creek (approximately 11 miles upstream of where the stream flows into J.C. Boyle Reservoir) and two watersheds that flow into Upper Klamath Lake: Klamath Lake and Wood River (79 FR 51666–51667). Thus, the species' distribution is limited to areas outside of the Hydroelectric Reach where short-term effects of reservoir drawdown and dam removal activities are expected to occur. However, OSF may be affected by anadromous salmonids that regain access to historical habitat in Spencer Creek and OSF-occupied streams upstream of Upper Klamath Lake. Therefore, the effects analysis for OSF focuses on long-term effects related to potential predation by anadromous salmonids.

Critical habitat for OSF has been designated in the Middle and Upper Klamath Basins and consists of two critical habitat units: Upper Klamath Lake and Upper Klamath. The Proposed Action will not result in any modifications to OSF critical habitat nor will it affect any of the PBFs of critical habitat for the species.

5.8.2 Short-Term Effects

OSFs do not inhabit areas in the Hydroelectric Reach or downstream of Iron Gate Dam, where short-term effects of reservoir drawdown and dam removal activities are expected to occur. **Therefore, reservoir drawdown and dam removal activities will have no effect on OSF in the short term.**

5.8.3 Long-Term Effects

5.8.3.1 Predation Effects

The Proposed Action will provide anadromous salmonids with access to historical habitats in the Middle and Upper Klamath Basins. This includes a number of streams, and associated seasonally wetted areas, that are currently occupied by OSF such as Spencer Creek, Sevenmile Creek, Wood River, Fort Creek, Annie Creek, and Sun Creek (79 FR 51666). As a result, OSF could be subject to predation from anadromous salmonids where the species' distributions overlap. Because adult Chinook salmon and steelhead do not feed during their spawning migrations, the Renewal Corporation does not expect the adult life stages of these species to have any predation effects on OSF. However, Chinook salmon and steelhead rearing habitats may overlap with suitable OSF egg-laying and nursery sites (i.e., shallow pools near flowing water or seasonally connected to larger bodies of water) and juveniles of both species are known to be opportunistic foragers. Therefore, there is some potential that juvenile Chinook salmon and steelhead could prey upon tadpoles or recently metamorphosed young frogs, depending on the size of the fish.

Little information is available regarding salmonid predation on OSF. However, an ongoing study of juvenile redband trout (*Oncorhynchus mykiss spp.*) growth patterns in the Upper Klamath Basin has not documented any predation upon amphibians in the Wood River complex where OSF are known to occur (J. Ortega, pers. comm., February 17, 2021). Although the study has documented redband trout predation upon Pacific treefrogs (*Pseudacris regilla*) in the Sycan River, findings to date suggest that amphibian predation by redband trout is very low overall (J. Ortega, pers. comm., February 17, 2021). It is anticipated that the feeding behaviors demonstrated by juvenile anadromous salmonids will be similar to those exhibited by redband trout because of their similar biology and ecology; thus, it is expected that the potential for OSF predation by juvenile anadromous salmonids will be similarly low.

Additionally, although juvenile anadromous salmonids may inhabit cold shallow water habitats where vulnerable life stages of OSF may be present early in their development, it is expected that as fish grow, they will quickly move to warmer more productive reaches where food resources are more abundant. Therefore, it is expected that the spatial and temporal overlap between juvenile anadromous salmonids and OSF life stages that are more vulnerable to predation will be limited.

Nonnative brook trout are reportedly widespread in areas of the Upper Klamath Basin where OSF are known to occur and are a likely predator of the species. OSF populations persist where they co-occur with brook trout because OSF have evolved to lay eggs in areas where fish do not occur (W. Tinniswood, pers. comm., February 18, 2021). It is possible that Chinook with their much larger body size, potentially earlier spawning, and earlier emergence will outcompete the nonnative, predatory brook trout.

Based on the anticipated limited spatial and temporal overlap between juvenile anadromous salmonids and vulnerable OSF life stages, predation of OSF by juvenile anadromous salmonids is expected to be limited., **Therefore, the Proposed Action may affect, but is not likely to adversely affect the Oregon spotted frog.**

5.8.4 Critical Habitat Effects

Designated critical habitat for OSF habitat occurs in the Middle Klamath Basin in upstream reaches of Spencer Creek and in the Upper Klamath Basin in tributaries to Upper Klamath Lake. **Based on the location of OSF critical habitat relative to the area of effects associated with the Proposed Action, the Proposed Action will have no effect on OSF critical habitat.**

5.9 Consequences of Other Activities Caused by the Proposed Action

5.9.1 Interim Measure 16

Under IM-16, PacifiCorp will remove the screened diversions from Shovel and Negro creeks prior to the time that anadromous fish are likely to be present upstream of Copco Lake.

The work proposed for the IM-16 Project is in the reach between the upstream end of Copco Lake and J.C. Boyle Dam, and therefore will have no effect on bull trout, sDPS green sturgeon, coho salmon, sDPS eulachon, or Southern Resident killer whales. Any suspended sediment–generated removal of the diversions and screens will settle out in the reservoirs downstream. **No effect from the production of turbid water to these species is expected. No effect on critical habitat components of these species is expected. However, the increase in flow in these creeks will have a beneficial effect on salmonids.**

It is likely that the presence of listed suckers in the J.C. Boyle reach is limited to downstream emigration of juveniles and adults from their preferred lake habitat (PacifiCorp 2004c). In addition, they do not maintain self-sustaining populations below Keno Dam; and due to the timing of the project, sensitive/vulnerable life stages (larvae) of suckers will be absent. The potential for shortnose and Lost River suckers to occur in the Action Area is therefore limited. **Therefore, the proposed IM-16 project may affect, but is not likely to adversely affect LRS or SNS or their proposed critical habitat.**

The nearest NSO activity center is at least 2.5 miles west of Shovel Creek. Diversion and screen removal activities will occur outside of the NSO breeding season (February 1– September 15), and will not impact suitable nesting, roosting, or foraging habitat for this species. **The proposed project will have no effect on nesting or roosting spotted owls.** The nearest NSO critical habitat is 1.25 miles west of Shovel Creek. **No critical habitat will be removed or modified by IM-16 activities, and therefore there will be no effect.**

Chapter 6: Cumulative Effects

6. CUMULATIVE EFFECTS

This section describes the cumulative effects of the Proposed Action. A cumulative effects analysis needs to consider the "future state, tribal, local or private actions that are reasonably certain to occur in the Action Area" (USFWS and NMFS 1998). Any federal actions (including hatcheries, National Forest timber harvest, water projects, instream restoration activities) that will require separate consultations are not considered in this cumulative analysis (USFWS 2008a and NMFS 2010a). Federal actions not considered include those actions carried out by non-federal entities that have a federal nexus. These actions include projects using federal funding and requiring approval by a federal entity, such as PacifiCorp's KHP and USBR's Klamath Project (as described in Section 1.2 of this BA), federal highway projects, and projects requiring a federal permit.

Several ongoing programs and projects in the Klamath Basin benefit coho salmon and other species, including implementation of Klamath Basin total maximum daily loads (TMDLs), the Northwest Forest Plan, the Trinity River Restoration Program, the Five Counties Salmonid Conservation Program, and the Klamath Basin Conservation Area Restoration Program. Several anadromous fish reintroduction and conservation plans developed by the Tribes and ODFW aim to conserve coho salmon and their habitat, and support restoration efforts. Other stream and watershed restoration actions, such as those being completed by the Hoopa Valley Tribe and Siskiyou County, also aim to improve habitat for coho salmon. These programs and projects all have a federal nexus and have conducted their own ESA consultations on potential effects on listed species; thus, they are not considered in this section.

6.1 Activities Considered and Effects Analysis

6.1.1 State Actions

No state actions, including road work or timber harvest projects slated in the near term, were identified on state lands in the Action Area (CDFW and ODFW 2020).

CDFW is conducting various restoration, monitoring, and management activities in tributaries downstream of Iron Gate Dam, including Bogus Creek, Shasta River, Scott River, Humbug Creek, Beaver Creek, Horse Creek, and Fort Goff Creek. These activities are expected to have long-term beneficial impacts on aquatic habitats supporting federally listed fish species.

The California Department of Transportation (Caltrans) is pursuing a bridge replacement project at the SR-263 bridge over the Klamath River, inside the Action Area near Yreka, California Construction is projected to be completed by the end of the year before drawdown. Caltrans and Del Norte County are proceeding with replacement of the Hunter Creek bridge at Requa Road in Klamath, California, near the Action Area immediately north of the estuary. Construction from this project is expected to occur in 2022-2023 (County of Del Norte 2013). The Caltrans Horse Creek Bridge Replacement Project is on Highway 96 near Horse

Creek and would replace the iron bridge over the Klamath River. This project is in the planning stages, with possible construction in 2024 (California Highways 2020).

ODOT is planning to retrofit and rehabilitate several bridges and overpasses on The Dalles-California Highway (US-97) along the eastern side of Upper Klamath Lake. In the Action Area, this project is expected to include improvements to the US-97 bridge over the Klamath River, south of Klamath Falls, Oregon, and the US-97 bridge over the Link River north of Lake Euwana. Improvements are also planned for the US 97 bridge over the Williamson River south of Chiloquin, Oregon, which is just outside of the Action Area. This project is anticipated to go to bid in summer 2021 (ODOT n.d.).

Because these state-affiliated transportation projects are proposed in areas adjacent to jurisdictional waters, it is anticipated that they would have a federal nexus and be covered under programmatic agreements for ESA Section 7; therefore, they are dismissed from further consideration.

6.1.2 Tribal Actions

6.1.2.1 In-River Fish Harvest

Harvest of coho salmon has been prohibited in the Klamath River since 1994, with the exception of sanctioned tribal harvest for subsistence, ceremonial, and commercial purposes by the Yurok, Hoopa Valley, and Karuk tribes. Tribal fishing for coho salmon in the Yurok Tribe's reservation on the lower Klamath River has been monitored since 1992. The Yurok Tribal Fisheries Program reported that annual harvest of coho salmon from reservation lands on the lower Klamath River has ranged from 25 to 2,452 fish per year and averaged 612 fish between 1992 and 2009 (Williams 2010). Williams (2010) estimated that the Yurok Tribal harvest captured between 0.9 and 16.9 percent (average 3.7 percent) of the Klamath River coho salmon escapement. Similar data reviewed from 2010 to 2018 (CDFW 2019a) showed Yurok Tribal harvest captured between 20 and 416 coho salmon per year and averaged 193 coho salmon. No data on Yurok Tribal harvest was available for 2017 and 2018. The recent Yurok Tribe Fall Harvest Management Plan (Yurok Tribe 2018) includes weekly fishing closures intended to protect coho salmon from harvest.

A review of harvest data from the Hoopa Valley Tribe from 2010 to 2014 showed an average annual harvest of 462 coho salmon per year, with approximately 80 percent of those fish harvested over 5 years being of hatchery origin (CDFW 2019a). No data for Hoopa Tribal harvest since 2014 were available.

Although the in-river harvest does not target coho salmon for commercial purposes, an average of 11.5 percent (based on data from 2010 through 2015) of the Klamath River's escapement is taken for sanctioned purposes and is therefore likely to have ongoing adverse effects on adult coho salmon.

Green sturgeon and eulachon are also harvested in the Yurok tribal fisheries, but no information on green sturgeon harvest rates was available. Adult eulachon presence was documented in the Klamath River in the spawning seasons of 2011-2014 (Gustafson et al. 2016), and five eulachon were captured and turned into the Yurok Tribal Fisheries Department in 2011. Directed in-river tribal harvest of eulachon is allowed. Given the very small number of fish taken and the infrequent nature of the harvest, the impact of tribal harvest on the sDPS of eulachon is expected to be minor.

Tribal in-river harvest activities will not occur in areas known to support bull trout, Lost River sucker or shortnose sucker; therefore, such activities are not expected to impact these species.

6.1.2.2 Other Tribal Projects and Programs

The Karuk Tribe engages in water quality monitoring and habitat restoration projects throughout the Upper and Middle Klamath River Basin. In coordination with the Mid Klamath Watershed Council (MKWC), the Karuk Tribe is conducting two-large scale habitat enhancement projects throughout various tributaries in the Upper and Middle Klamath River Basins: the Klamath Tributary Fish Passage Improvement Project, and the Mid Klamath Coho Rearing Habitat Enhancement Project. In addition, stream habitat enhancement or restoration projects have been proposed or are currently underway at Humbug Creek, Tom Martin Creek, Bogus Creek, Cottonwood Creek, Beaver Creek, Horse Creek, Middle Creek, Fort Goff Creek, Cougar Creek, Stanshaw Creek, and others. The Karuk Tribe is coordinating with the MKWC and/or federal agencies (e.g., USFS) on many of these projects.

The Karuk Tribe's water quality monitoring program has been in effect since 1998 and involves monitoring of various water quality parameters throughout the mainstem Klamath River and its major tributaries. The Karuk Tribe works collaboratively with PacifiCorp, USBR, USEPA, USGS, Oregon State University, the Yurok Tribe and other groups to conduct these efforts (Karuk Tribe of California 2013). The program is funded by USEPA, USBR, and PacifiCorp as part of IM-15, and data are managed by the Klamath Basin Monitoring Partnership.

The Yurok Tribe also engages in various restoration, monitoring, and management activities related to fish and wildlife along the Lower Klamath River. For example, the Yurok Wildlife Department conducts marbled murrelet and NSO surveys in coordination with Bureau of Indian Affairs and operates a reintroduction program for the California condor. The Yurok Fisheries Department engages in monitoring and migration tracking of salmonids, sturgeon, and lamprey populations; and implements stream habitat restoration projects, including habitat restoration projects at Hunter, Terwer, Waulkell, and lower McGarvey Creeks. The Yurok Tribe Environmental Program Water Division has conducted monitoring of various water quality parameters such as nutrients, water temperature, dissolved oxygen, algae, macroinvertebrates, and pathogens (YTEP 2014). The program is funded by PacifiCorp as part of IM-15, and data are managed by the Klamath Basin Monitoring Partnership.

The Klamath Tribes have conducted water quality monitoring in Upper Klamath Lake since 1990 (Kann 2017); they have also engaged in recent stream restoration and fish passage improvement projects on the Wood River and its tributaries. The Klamath Tribes, in cooperation with the Klamath Basin Rangeland Trust, USFWS, Trout Unlimited, landowners, and other groups are part of an ongoing effort to reconnect Sun Creek to the Wood River.

The Hoopa Valley Tribe monitors nutrients in the Klamath River from mid-May to mid-October at Saints Rest Bar near the confluence of the Klamath River and Trinity Rivers. The Hoopa Valley Tribe also monitors *E. coli* levels and water temperatures in the Trinity River and its tributaries during the summer. The Hoopa Valley water quality monitoring efforts are funded by the USEPA (Hoopa Valley Tribal Environmental Protection Agency 2008). The Quartz Valley Tribe has also engaged in water quality monitoring on their tribal lands along the Scott River in accordance with the CWA (Quartz Valley Tribal Environmental Program 2009). The Resighini Rancheria has also established a water quality ordinance to protect water quality on the rancheria (Resighini Rancheria Environmental Protection Authority 2006).

These tribal programs and activities will have long-term beneficial effects on federally listed species in the Action Area such as localized improvements to aquatic habitats where stream restoration or enhancement activities are conducted. Some of the aforementioned water quality monitoring programs have a federal nexus and would be covered under their own ESA analysis.

6.1.3 Local and Regional Projects and Programs

Several local nonprofit organizations are engaged in water quality monitoring, habitat restoration projects, fire and forest management, invasive plant removal, and river cleanups in the Action Area to benefit coho salmon. See Appendix G, Section G.1.1.13 for more details. Many of these activities involve cooperation with private, tribal, or state and local governments, and are independent of federal agencies.

The Somes Bar Integrated Fire Management Project is a collaborative effort between the Karuk Tribe, federal agencies, local fire safety groups, research groups, and several other environmental, community, and stakeholder groups to implement various fire management methods (including traditional Karuk practices) across 5,570 acres along the Klamath River north of the Salmon River confluence. The project is in the final planning stages and calls for the phase-in of the proposed fire management practices over the next 15 years. The proposed project is intended to mitigate the occurrence of and impacts from high-severity wildfires in this region. Reducing wildfire severity would reduce loss of habitat associated with fire, and reduce post-fire water quality impacts (i.e., erosion) (USDA Forest Service 2018). This project has a federal nexus and would be covered under its own ESA analysis.

The Klamath Falls Spring Street wastewater treatment plant (WWTP) and the South Suburban Sanitary District wastewater treatment facility discharge to Lake Euwana, which feeds into the Upper Klamath River. The implementation of nutrient TMDLs (nitrogen, phosphorus) for the Upper Klamath River in 2010 by ODEQ prompted the City of Klamath Falls and the South Suburban Sanitary District to consider upgrades to these facilities. Successful upgrades to wastewater treatment systems could result in benefits to water quality in the Klamath River and improvements to aquatic habitat.

The City of Klamath Falls is currently in the design phase for upgrades to the 2.4-million-gallon-per-day (mgd) capacity Spring Street WWTP. The City approved contracts for these upgrades in May 2016 and approved additional funding for design work in February 2018 (Bassinger 2018). Planned improvements may include, but are not limited to, upgrading the facility headworks, structural concrete repairs, and nutrient removal system upgrades. As reported by Herald and News in February 2021, City of Klamath officials estimate completion of the Spring Street upgrade project by late 2022 (Dillemuth 2021).

The South Suburban Sanitary District wastewater treatment facility is also considering upgrades and process modifications to comply with the updated TMDL requirements. The 2.1-mgd facility currently consists of 130 acres of facultative wastewater stabilization lagoons and a chlorine disinfection system. Upgrades at this facility are not imminent, and the timeline for implementation is uncertain.

As required by the 2014 Sustainable Groundwater Management Act (SGMA), Siskiyou County is developing Groundwater Sustainability Plans (GSP) for four basins (Shasta Basin, Scott Basin, Butte Valley Basin, Tulelake Subbasin) (CDFW SGMA 2018). Per the SGMA, these GSPs must be developed by January 31, 2022. The Siskiyou County Flood Control and Water Conservation District acts as the agency coordinating the development of the GSP for the Shasta, Scott, and Butte Valley Basins. The Siskiyou County Board of Supervisors is coordinating with the City of Tulelake, Tulelake Irrigation District, and Modoc County to develop the GSP for the Tulelake Subbasin. Siskiyou County is also coordinating with public, private, and Tribal entities to develop each of the GSPs.

These ongoing and planned local and regional activities are expected to have beneficial impacts on federally listed species in the Action Area including improved surface and groundwater management, a reduced risk of wildfire spread and associated habitat loss through the implementation of fire management practices as well as improved aquatic habitat conditions resulting from upgrades to wastewater infrastructure.

6.1.4 Private Activities

The Action Area includes a significant base of timberlands that are subject to commercial harvest for dimension lumber. Based on information provided by CDFW's Biogeographic Information and Observation System viewer in Timberland Conservation Program in April 2020, no timber harvest projects on private lands were identified in the Action Area. However, timber harvest may occur in the Klamath River watershed in the Action Area during the period of dam removal and restoration on both private commercial and individual landowner properties. These timber harvest plans will undergo review by the California Department of Forestry and Fire Protection and the effects of and to sedimentation, water temperature and protected species would be analyzed for their impacts in the plan permitting process. Portions of the watershed surrounding the J.C. Boyle portion of the project are surrounded by private commercial timberlands. The State of Oregon also has a timber harvest review process with similar analysis and effects disclosure criteria.

Chapter 7: Conclusion

7. CONCLUSION

This section summarizes the conclusions of the effects analysis for listed species considered in this BA for which it was determined that the project may have an effect. Table 7-1 provides the effects determinations for each species, followed by a summary discussion. Short-term and long-term effects are defined in Chapter 5.

In addition to the species addressed in this BA, there were 31 other species that were considered but excluded from further analysis in this BA because they do not occur in the Action Area. Appendix B summarizes information on each of the species' distributions and habitat associations.

Table 7-1: Summary of Effects Determinations

Species	Effect Determination
NMFS Species and Critical Habitat	
SONCC coho salmon	Likely to adversely affect
SONCC coho salmon critical habitat	Likely to adversely affect
Southern DPS green sturgeon	Not likely to adversely affect
Southern DPS green sturgeon critical habitat	Not likely to adversely affect
Southern DPS eulachon	Likely to adversely affect
Southern DPS eulachon critical habitat	Likely to adversely affect
Southern Resident killer whale	Likely to adversely affect
Southern Resident killer whale critical habitat	Likely to adversely affect
USFWS Species and Critical Habitat	
Lost River sucker	Likely to adversely affect
Lost River sucker critical habitat	No effect
Shortnose sucker	Likely to adversely affect
Shortnose sucker critical habitat	No effect
Bull trout	Likely to adversely affect
Bull trout critical habitat	Not likely to adversely affect, beneficial
Northern spotted owl	Not likely to adversely affect
Northern spotted owl critical habitat	Not likely to adversely affect
Oregon spotted frog	Not likely to adversely affect
Oregon spotted frog critical habitat	No effect

7.1 NMFS Species

7.1.1 Coho Salmon

The Proposed Action will likely result in high mortality of any coho salmon redds and their fry in the mainstem Klamath River downstream of Iron Gate Dam. Although no single year-class is expected to be completely lost, mortality of a portion of any juveniles rearing in the mainstem during summer and winter and smolts outmigrating from tributaries within the Upper Klamath River, Mid-Klamath River, Shasta River, Scott River, Salmon River, Lower Klamath River, and three Trinity River population units may affect the strength of the associated year classes. These losses will be minimized by the implementation of an adaptive management plan that ensures river-tributary connectivity for adult and juvenile salmonids, augments spawning habitat if post-dam removal habitat is deficient, actively translocates yearling coho, and monitors and potentially relocates juvenile salmonids during reservoir drawdown. During the drawdown year, CDFW will also modify the release timing of coho smolts from Iron Gate Hatchery to reduce smolt exposure to high SSCs in the Klamath River. Although the proposed conservation measures are expected to reduce juvenile coho salmon exposure to high SSCs, measures will not negate impacts. **Therefore, the Proposed Action is likely to adversely affect coho salmon from the Upper Klamath River, Shasta River, Scott River, Salmon River, Lower Klamath River, Upper Trinity River, Lower Trinity River, and South Fork Trinity River population units in the short term.**

The Proposed Action will restore coho salmon access to at least 76 miles of additional habitat (DOI 2007, NMFS 2007b), including approximately 53 miles in the mainstem, and tributaries such as Fall, Jenny, Shovel, and Spencer creeks, and others; and approximately 22.4 miles currently inundated by the Hydroelectric Reach reservoirs (Cunanan 2009). **Therefore, the effect of the Proposed Action will be beneficial for the coho salmon from the Upper Klamath River, Mid-Klamath River, Lower Klamath River, Shasta River, Scott River, and Salmon River population units in the long term. The effect of the Proposed Action on coho salmon from the three Trinity River population units will also likely be beneficial over the long term.**

The initial drawdown and release of sediment is likely to adversely affect the spawning sites, food resources, and water quality PBFs of mainstem Klamath River coho salmon's critical habitat in the short term. **Therefore, in the short term, the Proposed Action will have an adverse effect on Southern Oregon Northern California Coast (SONCC) coho salmon critical habitat.**

The Proposed Action will result in more natural sediment transport and hydrologic processes downstream of Iron Gate Dam, which will help create more natural substrate characteristics, increase the number and quality of spawning sites, enhance food resources, improve water quality, reduce disease prevalence, and expand the amount of riparian vegetation available for coho salmon. **Therefore, in the long term, the Proposed Action will have a beneficial effect on the SONCC coho salmon critical habitat.**

7.1.2 Southern DPS green sturgeon

SDPS green sturgeon will not be exposed to elevated SSCs resulting from the initial winter/spring period drawdown. June through September SSCs during the drawdown year will be higher than background conditions; however, green sturgeon are not sight feeders, and generally feed on benthic organisms detected in fine sediments by their sensitive barbels. This trait will likely reduce the impacts of suspended sedimentation on the species in terms of feeding ability (EPIC et al. 2001). In addition, the Renewal Corporation expects only a small proportion of the total sDPS green sturgeon population to use the Klamath River estuary during the drawdown year, further minimizing the potential for any short-term impacts related to the project. **Therefore, the Proposed Action may affect, but is not likely to adversely affect the sDPS green sturgeon in the short term.**

In the long term, conditions in the estuary are not expected to be significantly different than the current condition. **Therefore, the Proposed Action may affect, but is not likely to adversely affect the sDPS green sturgeon in the long term.**

There is no designated critical habitat in the Klamath River estuary. However, the nearshore area beyond about a 1-mile area north, south, and offshore of the mouth of the river is considered critical habitat. The Proposed Action is anticipated to have minimal to no effect on critical habitat due to the dilutive effects of the marine environment. **Therefore, the Proposed Action may affect, but is not likely to adversely affect sDPS green sturgeon critical habitat.**

7.1.3 Southern DPS Eulachon

Adult eulachon entering the Klamath River in late-winter and spring of the drawdown year may be exposed to high SSCs for a portion of their migration, spawning, and incubation period depending on the water year. For the median impact year scenario, 7-day median SSCs are expected to be within the range of modeled background conditions and would likely result in conditions that eulachon are adapted to experiencing within the Klamath River estuary during winter. For the severe impact year, modeled SSCs are predicted to be substantially higher than would be likely to occur under background conditions and may result in direct mortality of migrating and spawning eulachon as well as impacting eggs, larvae, and quality of spawning substrate. **Therefore, the Proposed Action is likely to adversely affect the sDPS eulachon in the short term.**

The return to a temperature and flow regime that follows the Proposed Action will more closely mimic historical patterns that eulachon evolved with. **Therefore, for the long term, the Proposed Action is likely to have a beneficial effect for the sDPS eulachon.**

The initial drawdown and release of sediment may adversely affect freshwater spawning and incubation sites and adult and larval migration habitat PBFs of sDPS eulachon critical habitat in the short term but is not likely to adversely affect the nearshore and offshore marine foraging habitat PBF. **Therefore, the Proposed Action is likely to adversely affect sDPS eulachon critical habitat in the short term. The Proposed Action is not likely to adversely affect critical habitat PBFs in the long term.**

7.1.4 Southern Resident DPS Killer Whale

Southern Resident killer whales, which typically occupy coastal waters, are primarily salmonid predators that show strong selectivity for Chinook salmon (Ford et al. 2010), and the whales selectively prey on the largest Chinook salmon (Ford et al. 1998; Ohlberger et al. 2019). The Proposed Action is anticipated to result in the loss of approximately 12 percent of total Klamath Basin Chinook production caused by the mortality of mainstem Klamath River Chinook salmon redds during the reservoir drawdowns, and up to 17 percent of natural origin juvenile Chinook salmon entering the Klamath River from tributaries in the spring of Year 1 may perish from high SSCs. Despite the impacts to the pre-drawdown year brood, these fish would not comprise a substantial portion of Southern Resident killer whale food resources since whales focus on larger, more mature fish that would already be residing in the Pacific Ocean prior to the Proposed Action. Age-2, age-3, and age-4 Chinook salmon located off the Oregon and California coast in Year 1 and Year 2 (age classes that would not be affected in the ocean environment by the Proposed Action), are more likely to provide the prey base for Southern Resident killer whales in the short term. **Therefore, because Southern Resident killer whales select larger Chinook salmon as prey items, and the Proposed Action will primarily affect juvenile production in Year 1, the Proposed Action may affect, but is not likely to adversely affect Southern Resident killer whales in the short term.**

Klamath River Chinook salmon populations will be variable over time as populations respond to improving river conditions (e.g., hydrology and water quality), restored access to historical spawning and rearing habitat, decreased hatchery production, and an anticipated reduction in disease prevalence. Previous population modeling efforts predicted upwards of 40,000 adult Chinook salmon could return to the Upper Klamath Basin over time (Dunsmoor and Huntington 2006; Hendrix 2011; Lindley and Davis 2011), nearly 35 percent more natural origin adult Chinook than currently return to the Klamath Basin (CDFW 2018a). Although upper basin production is anticipated to substantially increase over time as historical habitat is recolonized and other river habitat improvements occur, Chinook salmon production in the 3 to 12-year period following drawdown will likely decrease due to hatchery production reductions and impacts to natural production associated with the Proposed Action. Fall Creek Hatchery Chinook salmon production targets will be approximately 46 percent less than Iron Gate Hatchery production. Reduced production is likely to result in fewer juvenile Chinook salmon recruiting to the adult population that is available to Southern Resident killer whales. However, beyond 12 years, Proposed Action potential benefits, including restored hydrology, access to historical habitat, and reduced disease prevalence, could increase the abundance of both hatchery origin and natural origin juvenile Chinook salmon reaching the ocean. **Since Klamath River Chinook salmon contribute a small portion of Southern Resident killer whale prey base and Klamath River Chinook salmon production is anticipated to increase over time, the Proposed Action may affect, but is not likely to adversely affect SRKW in the long term.**

7.2 USFWS Species

7.2.1 Lost River and Shortnose Suckers

Those Lost River and shortnose suckers not relocated to Tule Lake Sump 1A, the Klamath National Fish Hatchery, or the Klamath Tribes sucker rearing facility prior to reservoir drawdown will likely be lost. **Therefore, reservoir drawdown and dam removal are likely to adversely affect Lost River and shortnose suckers in the short term.**

The Proposed Action will eliminate all Lost River and shortnose sucker habitat downstream of Keno Dam. Even though suckers in the Hydroelectric Reach have low reproductive success and are isolated from recovery populations in the Upper Klamath Basin, Lost River and shortnose suckers inhabiting the Hydroelectric Reach reservoirs will be lost in the long term due to conversion of their habitat from lake-type to free-flowing conditions. **Therefore, the Proposed Action is likely to adversely affect Lost River and shortnose suckers in the long term.**

The return of anadromous salmonids to the Upper Klamath Basin is likely to result in juvenile salmonid predation on Lost River and shortnose sucker eggs and larvae in the Williamson River and Sprague River. Due to the large reproductive potential of spawning Lost River and shortnose suckers and the known abundance of drifting sucker larvae in the Williamson River and Sprague River, juvenile Chinook salmon and steelhead are unlikely to substantially impact larval Lost River and shortnose sucker abundance. **Therefore, the Proposed Action may affect, but is not likely to adversely affect LRS and SNS recovery populations located in designated critical habitat in the Upper Klamath Basin.**

Designated critical habitat for the Lost River and shortnose suckers is upstream of Keno Dam. **Because the Proposed Action will only directly affect sucker habitat downstream of Keno Dam, implementation of the Proposed Action will have no effect on Lost River and shortnose suckers designated critical habitat.**

7.2.2 Bull Trout

Bull trout do not currently inhabit mainstem river reaches or tributary streams in or downstream of the Hydroelectric Reach. **Therefore, the Proposed Action will have no effect on bull trout in the short term.**

Even though bull trout eggs and fry could become prey for anadromous salmonids, the increase in available food sources (e.g., eggs, fry, and juvenile salmonids) will benefit bull trout. Bull trout are currently exposed to the same pathogens that occur downstream of Iron Gate Dam, and therefore are not likely to be adversely affected by disease carried by anadromous salmonids. **Due to the potential for predation on bull trout eggs and fry, the Proposed Action is likely to adversely affect bull trout populations in the long term.**

Critical habitat for bull trout is not designated downstream of the Upper Klamath Lake. However, the restoration of passage for anadromous salmonids into designated critical habitat upstream of Upper Klamath Lake will increase the food resources physical and biological feature (PBF) of bull trout critical habitat. **Therefore, the Proposed Action is not likely to adversely affect, and may have a beneficial effect on bull trout critical habitat.**

7.2.3 Northern Spotted Owl

The Proposed Action includes, but is not limited to, the removal or modification of project structures, upgrading roads, and restoration. These activities will result in noise from the use of demolition equipment, blasting, helicopters, haul trucks, and other heavy equipment that may disturb northern spotted owls. Based on the evaluation described in Section 5.7.2, noise disturbance **may affect, but is not likely to adversely affect northern spotted owls**, given that northern spotted owls are not nesting within the disturbance buffers defined for the Proposed Action.

The Proposed Action will have no effect on northern spotted owl in the long term. Restoration of the river channel and associated riparian forest will result in an increase in dispersal habitat for northern spotted owl.

Removal of 0.4 acre of trees and vegetation at the J.C. Boyle access road near the scour hole will occur within designated critical habitat. This area may provide dispersal habitat. However, the functional characteristics of NSO nesting, roosting, or foraging habitat will not be degraded or removed. Removal of 0.4 acre of dispersal habitat will not influence forest conditions with respect to spotted owl life history (i.e., the function of the habitat at scales important to spotted owls will remain the same). In the long term, restoration of the river channel and associated riparian forest will result in an increase in dispersal habitat. **Therefore, the Proposed Action may affect, but is not likely to adversely affect designated critical habitat for the northern spotted owl.**

7.2.4 Oregon Spotted Frog

Oregon spotted frogs do not inhabit areas in the Hydroelectric Reach or downstream of Iron Gate Dam, where short-term effects of reservoir drawdown and dam removal activities are expected to occur. **Therefore, reservoir drawdown and dam removal activities will have no effect on Oregon spotted frogs in the short term.**

There is some potential that juvenile Chinook salmon and steelhead could prey upon Oregon spotted frog tadpoles or recently metamorphosed young frogs, depending on the size of the fish. Little information is available regarding salmonid predation on Oregon spotted frog. The Renewal Corporation expects that amphibian predation by juvenile anadromous salmonids will be similar to that exhibited by redband trout, which is low. Additionally, the Renewal Corporation expects that the spatial and temporal overlap between juvenile anadromous salmonids and Oregon spotted frog life stages that are more vulnerable to predation would be limited. **Therefore, the Proposed Action may affect, but is not likely to adversely affect the Oregon spotted frog.**

Designated critical habitat for Oregon spotted frog habitat occurs in the Middle Klamath Basin in upstream reaches of Spencer Creek and in the Upper Klamath Basin in tributaries to Upper Klamath Lake. **Based on the location of Oregon spotted frog critical habitat relative to the area of effects associated with the Proposed Action, the Proposed Action will have no effect on Oregon spotted frog critical habitat.**

Chapter 8: References

8. REFERENCES

Ackerman, N. K., B. Pyper, I. Courter, and S. Cramer. 2006. Estimation of returns of naturally produced coho to the Klamath River. Review draft. Klamath coho integrated modeling framework technical memorandum series. Technical Memorandum #1 of 8. Prepared by Cramer Fish Sciences, Gresham, Oregon submitted to the Bureau of Reclamation, Klamath Basin Area Office, Klamath Falls, Oregon.

Adams, C. 2013. Survival and movement of juvenile coho salmon (Onchorynchus kisutch) in the Shasta River, California. (Master's thesis). Humboldt State University.

Adams, C. and C. Bean 2016. Shasta River Brood Year 2012 Juvenile Coho Salmon PIT Tagging Study. California Department of Fish and Wildlife Yreka Fisheries. January 13, 2016. 62pp.

Administrative Law Judge. 2006. Decision in the matter of Klamath Hydroelectric Project, FERC Project Number 2082. Docket Number 2006-NOAA Fisheries Service-0001, 27 September 2006.

Allen, M. A., and T. J. Hassler. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest), Chinook salmon. U.S. Fish and Wildlife Service Biological Report 82 (11.49).

Allen, L. G., M. M. Yoklavich, G. M. Cailliet, and M. H. Horn. 2006. Bays and estuaries. Pages 119–148 *in* L. G. Allen, D. J. Pondella, and M. H. Horn, editors. The ecology of marine fishes: California and adjacent waters. University of California Press, Berkeley.

Anderson, J. G. T. 1991. Foraging behavior of the American white pelican (*Pelecanus ethrorhynchos*) in western Nevada. Colonial Waterbirds 14:166-172.

Anderson, J. H., P. L. Faulds, K. D. Burton, M. E. Koehler, W. I. Atlas, and T. P. Quinn. 2014. Dispersal and productivity of Chinook (*Oncorhynchus tshawytscha*) and coho (*Oncorhynchus kisutch*) salmon colonizing newly accessible habitat. Canadian journal of fisheries and aquatic sciences, 72, 454-465. doi: 10.1139/cjfas-2014-0180.

Anthony, R. G., E. D. Forsman, A. B. Franklin, D. R. Anderson, K. P. Burnham, G. C. White, C. J. Schwarz, J. D. Nichols, J. E. Hines, G. S. Olson, S. H. Ackers, L. S. Andrews, B. L. Biswell, P. C. Carlson, L. V. Diller, K. M. Dugger, K. E. Fehring, T. L. Fleming, R. P. Gerhardt, S. A. Gremel, R. J. Gutiérrez, P. J. Happe, D. R. Herter, J. M. Higley, R. B. Horn, L.L. Irwin, P. J. Loschl, J. A. Reid, S. G. Sovern. 2006. Status and trends in demography of northern spotted owls, 1985– 2003. Wildlife Monographs. 163(1): 1–48.

Armstrong, N., and G. Ward. 2008. Coherence of nutrient loads and AFWO Klamath River grab sample water quality database. Technical Report. Prepared for USFWS, Arcata Fish and Wildlife Office, Arcata, California.

Asarian, E., J. Kann, and W. W. Walker. 2009. Multi-year nutrient budget dynamics for Iron Gate and Copco Reservoirs, California. Prepared by Riverbend Sciences and Kier Associates, Eureka, California, Aquatic Ecosystem Sciences, LLC, Ashland, Oregon, and William Walker, Concord, Massachusetts for the Karuk Tribe, Department of Natural Resources, Orleans, California.

Asarian, E., J. Kann, and W. W. Walker. 2010. Klamath River nutrient loading and retention dynamics in free-flowing reaches, 2005–2008. Prepared by Kier Associates, Eureka, California and Aquatic Ecosystem Sciences, LLC, Ashland, Oregon for the Yurok Tribe Environmental Program, Klamath, California.

Asarian, E. and J. Kann. 2013. Synthesis of Continuous Water Quality Data for the Lower and Middle Klamath River, 2001-2011. Prepared by Kier Associates and Aquatic Ecosystem Sciences for the Klamath Basin Tribal Water Quality Work Group. 50p. + appendices.

Asper, E. D., W. G. Young, and M. T. Walsh. 1988. Observations on the birth and development of a captive-born killer whale. International Zoo Yearbook 27: 295–304.

ASR (Aquatic Scientific Resources). 2005. Preliminary research on *Aphanizomenon flos-aquae* at Upper Klamath Lake, Oregon. Investigations to set direction for research of factors with potential for influencing Aphanizomenon growth at Upper Klamath Lake. Prepared by Aquatic Scientific Resources, Portland, Oregon for Klamath Basin Ecosystem Restoration Office, Klamath Falls Fish and Wildlife Office, Klamath Falls, Oregon.

Atkinson, S., and J. Bartholomew. 2010a. Disparate infection patterns of *Ceratomyxa shasta* (Myxozoa) in rainbow trout (*Oncorhynchus mykiss*) and Chinook salmon (*Oncorhynchus tshawytscha*) correlate with internal transcribed spacer-1 sequence variation in the parasite." International Journal for Parasitology 40: 599–604.

Atkinson, S., and J. Bartholomew. 2010b. Spatial, temporal and host factors structure the Ceratomyxa shasta (Myxozoa) population in the Klamath River basin. Infection, Genetics and Evolution 10: 1019–1026.

Atkinson, S. D., J. L. Bartholomew, G. W. Rouse. 2020. The invertegrate host of salmonid fish parasites *Certanova shasta* and *Parvicapsula minibicornis* (Cnidaria: Myxozoa), is a novel fabriciid annelid, Manayunkia occidentalis sp. Nov. (Sabellida: Fabriciidae). Zootaxa 4751(2): 310-320.Baird, R. W. 2000. The killer whale: foraging specializations and group hunting. Pages 127–153 *in* J. Mann, R. C. Connor, P. L. Tyack, and H. Whitehead, editors. Cetacean societies: field studies of dolphins and whales. University of Chicago Press, Chicago, Illinois.

Australian Government. 2010. Public Release Summary on the Evaluation of the New Active Prodiamine in the Product Barricade Turf Herbicide APVMA Product Number 62982. Australian Pesticides and Veterinary Medicines Authority. 45p.

Banet, N., Fish Biologist, USGS Klamath Falls, personal communication with Troy Brandt, The Renewal Corporation, December 13, 2018.

Bain, D.E. 1990. Testing the validity of inferences drawn from photo-identification data, with special reference to the studies of the killer whales (Orcinus orca) in British Columbia. Report of the International Whaling Commission Special Issue 12: 93-100.

Banish, N. P., B. J. Adams, and R. S. Shively. 2007. Distribution and habitat associations of radio-tagged adult Lost River and shortnose suckers in UKL, Oregon: 2005 and 2006 report. U.S. Geological Survey, Western Fisheries Research Center, Klamath Falls Field Station.

Banish, N. P., B. J. Adams, R. S. Shively, M. M. Mazur, D. A. Beauchamp, and T. M. Wood. 2009. Distribution and habitat associations of radio-tagged adult Lost River and shortnose suckers in Upper Klamath Lake, Oregon. Transactions of the American Fisheries Society 138:153-168.

Banish, N. 2018. USBR personal communication bull trout populations in Long Creek in Sycan River watershed.

Barnhart, R.A. 1994. Salmon and steelhead populations of the Klamath-Trinity Basin, California. Pp. 73-97. In: T.J. Hassler (ed.). Klamath Basin Fisheries Symposium. Humboldt State University. Arcata, CA.

Barry, P. M, A. C. Scott, C. D. Luton, and E. C. Janney. 2007a. Monitoring of Lost River, shortnose, and Klamath largescale suckers at the Sprague River Dam Fish Ladder. *In* Investigations of adult Lost River, shortnose, and Klamath largescale suckers in Upper Klamath Lake and its tributaries, Oregon. Annual Report 2005. U.S. Geological Survey, Western Fisheries Research Center, Klamath Falls Field Station.

Barry, P. M., B. S. Hayes, E. C. Janney, R. S. Shively, A. C. Scott, and C. D. Luton. 2007b. Monitoring of Lost River (*Deltistes luxatus*) and shortnose (Chasmistes brevirostris) suckers in Gerber and Clear Lake reservoirs 2005–2006. USGS, Western Fisheries Research Center, Klamath Falls Field Station.

Bartholomew, J. L. 1998. Host resistance to infection by the myxosporean parasite Ceratomyxa shasta: a review. Journal of Aquatic Animal Health 10: 112–120.

Bartholomew, J. L., and J. S. Foott. 2010. Compilation of information relating to myxozoan disease effects to inform the Klamath Basin Restoration Agreement. Oregon State University, Department of Microbiology, Corvallis, and U.S. Fish and Wildlife Service, California-Nevada Fish Health Center.

Bartholomew, J. L., C. E. Smith, J. S. Rohovec, and J. L. Fryer. 1989. Characterization of a host response to the myxosporean parasite, *Ceratomyxa shasta* (Noble), by histology, scanning electron-microscopy and immunological techniques. Journal of Fish Diseases 12:509–522.

Bartholomew, J. L., M. J. Whipple, D. G. Stevens, and J. L. Fryer. 1997. The life cycle of *Ceratomyxa shasta*, a myxosporean parasite of salmonids, requires a freshwater polychaete as an alternate host. Journal of Parasitology 83: 859–868.

Bartholomew, J.L., S. Halett, R. Holt, J. Alexander, S. Atkinson, R. Craig, A. Javaheri, M. Babar-Sebens. 2017. Klamath River Fish Health Studies: Salmon Disease Monitoring and Research. FY2016 Annual Report. 50 pp.

Bartholow, J. M. 2005. Recent water temperature trends in the lower Klamath River, California. North American Journal of Fisheries Management 25: 152–162.

Bash, J. C. Berman, and S. Bolton. 2001. Effects of Turbidity and Suspended Solids on Salmonids. 80 pp.

Bassinger, S. 2018. New tech cuts cost of Spring Street Sewage plant overhaul. February 6, 2018, Herald and News, Klamath Falls, Oregon.

Battin, J., M. W. Wiley, M. H. Ruckelshaus, R. N. Palmer, E. Korb, K. K. Bartz, and H. Imaki. 2007. Projected impacts of climate change on salmon habitat restoration. Proceedings of the National Academy of Sciences of the United States of America 104: 6,720–6,725.

Batzer, D.P., and S.A. Wissinger. 1996. Ecology of insect communities in nontidal wetlands. Annual Reviews: Entomology 41:75-100.

Beak Consultants, Inc. 1987. Shortnose and Lost River sucker studies: Copco Reservoir and the Klamath River. Prepared for City of Klamath Falls, Oregon.

Beamesderfer, R. C. P., and M. A. H. Webb. 2002. Green sturgeon status review information. S. P. Cramer and Associates, Gresham, Oregon. 44 pp.

Beauchamp, D. A., and J. J. Van Tassell. 2001. Modeling seasonal trophic interactions of adfluvial bull trout in Lake Billy Chinook, Oregon. Transactions of the American Fisheries Society 130: 204–216.

Beckstrand, J., D. M. Mauser, D. Thomson, and L. A. Hicks. 2001. Ecology of shortnose and Lost River suckers in Tule Lake National Wildlife Refuge, California, Progress Report #2, February – December 2000.

Beeman, J., S. Juhnke, G. Stutzer and K. Wright. 2012. Effects of Iron Gate Dam discharge and other factors on the survival and migration of juvenile coho salmon in the lower Klamath River, northern California, 2006-09: U.S. Geological Survey Open-File Report 2012-1067, 96 pp.

Beesley, S., and R. A. Fiori. 2008. Cooperative Restoration of Tribal Trust Fish and Wildlife Habitat in Lower Klamath River Tributaries. Yurok Tribal Fisheries Program, Klamath, California.

Beesly, S. and R. Fiori. 2014. Enhancement of Rearing Habit for Natal and Non-Natal Salmonids in McGarvey Creek-Lower Klamath River. Prepared in partnership with the U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, and National Fish and Wildlife Foundation.

Belchik, M., D. Hillemeier, R.M. Pierce. 2004. The Klamath River Fish Kill of 2002; Analysis of Contributing Factors. Yurok Tribal Fisheries Program. 42 pp.

Bell, E., and W. Duffy. 2007. Previously undocumented two-year freshwater residency of juvenile coho salmon in Prairie Creek, California. Transactions of the American Fisheries Society 136: 966–970.

Bellinger, M. R., M. A. Banks, S. J. Bates, E. D. Crandall, J. C. Garza, G. Sylvia, and P. W. Lawson. 2015. Geo-referenced, abundance calibrated ocean distribution of Chinook Salmon (*Oncorhynchus tshawytscha*) stocks across the West Coast of North America. PloS ONE. 10(7): e0131276.

Bennetts, D., C. Korson, and R. Piaskowski. 2004. A-canal fish screen monitoring and evaluation activities in 2003. Unpublished report prepared by United States Bureau of Reclamation, Klamath Falls, Oregon.

Benson, S. 2014. *Ceratomyxa Shasta*: Timing of myxospore release from juvenile Chinook salmon. Humboldt State University

Benson, R. L., S. Turo, B. W. McCovey, Jr. 2007a. Migration and movement patterns of green sturgeon (*Aciperser medirostris*) in the Klamath and Trinity rivers, California, USA. Environ Biol Fishes 79:269-279.

Benson, S. R., Karin Forney, James Harvey, James Carretta, and P. H. Dutton. 2007b. Abundance, distribution, and habitat of leatherback turtles (*Dermochelys coriacea*) off California, 1990-2003. Fishery Bulletin. 105. 337-347.

Berg, L., and T.G. Northcote. 1985. Changes in territorial, gill-flaring, and feeding behaviour in juvenile coho salmon (Oncorhynchus kisutch) following short-term pulses of suspended sediment. Canadian Journal of Fisheries and Aquatic Sciences 42: 1410–1417.

Berman, C. H., and T. P. Quinn. 1991. Behavioural thermoregulation and homing by spring chinook salmon, *Oncorhynchus tshawytscha* (Walbaum), in the Yakima River. Journal of Fish Biology 39: 301–312.

Berry, W., N. I. Rubinstein, B. Melzian, and B. Hill. 2003. The biological effects of suspended and bedded sediment in aquatic systems: a review. Report to EPA, Office of Research and Development, National Health and Environmental Effects Laboratory, Narragansett, Rhode Island.

Bettaso, J. 2017 - 2018. United States Forest Service. Personal communications with Renewal Corporation Representatives. November 15, 2017 and January 24, 2018.

Bigg, M. A., P. F. Olesiuk, G. M. Ellis, J. K. B. Ford, and K. C. Balcomb III. 1990. Social organization and genealogy of resident killer whales (*Orcinus orca*) in the coastal waters of British Columbia and Washington State. Report of the International Whaling Commission, Special Issue 12: 383–405.

Bladon, K. D., M.B. Emelko, U. Silins, and M. Stone. 2014. Wildfire and the future of water supply. Environmental Science and Technology 48: 8936-8943.

Bjork, S. J., J. L. Bartholomew. 2009. Effects of Ceratomyxa shasta dose on a susceptible strain of rainbow trout and comparatively resistant Chinook and coho salmon. Diseases of Aquatic Organisms 86, 29-37.

Bjork, S. J., and J. L. Bartholomew. 2010. Invasion of Ceratomyxa shasta (Myxozoa) and comparison of migration to the intestine between susceptible and resistant fish hosts. International Journal for Parasitology 40: 1,087–1,095.

Bjornn, T. C., and D. W. Reiser. 1991. Habitat requirements of salmonids in streams. American Fisheries Society Special Publication 19: 83–138.

BLM (Bureau of Land Management). 2000. Klamath-Iron Gate Watershed Analysis, Version 1.1. January 2000. Medford District Office-Ashland Resource Area. Medford, Oregon. 237 pp including maps.

BLM. 2010. Vegetation Treatments Using Herbicides on BLM Lands in Oregon. Final Environmental Impact Statement (EIS) and Record of Decision (ROD). U.S. Bureau of Land Management, Pacific Northwest Region, Portland, Oregon.

Bondi, C.A., S.M. Yarnell, and A.J. Lind. 2013. Transferability of habitat suitability criteria for a stream breeding frog (*Rana boylii*) in the Sierra Nevada, California. Herpetological Conservation and Biology 8(1): 88-103.

Borisenko, A., and M.P. Hayes. 1999. Status of the foothill yellow-legged frog (*Rana boylii*) in Oregon. Final report prepared for The Nature Conservancy under contract to the United States Fish and Wildlife Service. 38 pp.

Bortleson, G. C., and M. O. Fretwell. 1993. A review of possible causes of nutrient enrichment and decline of endangered sucker populations in Upper Klamath Lake, Oregon. Water Resources Investigation Report 93-4087. United States Geological Survey, Portland, Oregon.

Bottcher, J. L. and S. M. Burdick. 2010. Temporal and spatial distribution of endangered juvenile Lost River and shortnose suckers in relation to environmental variables in Upper Klamath Lake, Oregon: 2009 annual data summary, Open File Report 2010-1261. U.S. Geological Survey, Reston, Virginia.

Bourque, R. 2008. Spatial ecology of an inland population of the foothill yellow-legged frog (*Rana boylii*) in Tehama County, California. M.S. Thesis, Humboldt State University, Arcata, CA.

Bowen, B. W., F. A. Abreu-Grobois, G. H. Balazs, N. Kamezaki, C. J. Limpus, and R. J. Ferl. 1995. Trans-Pacific migrations of the loggerhead turtle (*Caretta caretta*) demonstrated with mitochondrial DNA markers. Proceedings of the National Academy of Sciences of the United States of America 92: 3,731–3,734.

Boyd M., S. Kirk, M. Wiltsey., and B. Kasper. 2002. Upper Klamath Lake drainage total maximum daily load (TMDL) and water quality management plan (WQMP). Oregon Department of Environmental Quality, Portland, Oregon, 188 pp. Bozek, M. A., and M. K. Young. 1994. Fish mortality resulting from delayed effects of fire in the Greater Yellowstone ecosystem. The Great Basin Naturalist 54: 91-95.

Bradbury J. P., S. M. Coleman, and R. L. Reynolds. 2004. The history of recent limnological changes and human impact on Upper Klamath Lake, Oregon. Journal of Paleolimnology 31: 151–161.

Brandt, J. USFWS California Condor Coordinator. Personal communication with Ken Sanchez, February 17 and 21, 2021.

Brett, J. R. 1971. Energetic responses of salmon to temperature. A study of some thermal relations in the physiology and freshwater ecology of sockeye salmon (*Oncorhynchus nerka*). American Zoologist 11: 99–113.

Brewitt, K. S., and E. M. Danner. 2014. Spatio-temporal temperature variation influences juvenile steelhead (*Oncorhynchus mykiss*) use of thermal refuges. Ecosphere. 5(7): 1-26.

Bricker, S., B. Longstaff, W. Dennison, A. Jones, K. Boicourt, C. Wicks, and J. Woerner. 2007. Effects of Nutrient Enrichment in the Nation's Estuaries: A Decade of Change. NOAA Coastal Ocean Program Decision Analysis Series No. 26. National Centers for Coastal Ocean Science, Silver Spring, Maryland. 328 pp.

Brodeur, R. D., E. A. Daly, R. A. Schabetsberger and K. L. Mier. 2007. Interannual and interdecadal variability in juvenile coho salmon (*Oncorhynchus kisutch*) diets in relation to environmental changes in the northern California Current. Fisheries Oceanography 16: 395–408.

Brown, K. 2007. Evidence of spawning by green sturgeon, Acipenser medirostris, in the upper Sacramento River, California. Environmental Biology of Fishes 79:297-303.

Buchanan, D. V., M. E. Hanson, and R. M. Hooton. 1997. Status of Oregon's bull trout: distribution, life history, limiting factors, management considerations, and status. Oregon Department of Fish and Wildlife, Portland.

Buchanan, D., M. Buettner, T. Dunne, and G. Ruggerone. 2011. Scientific assessment of two dam removal alternatives on resident fish. Draft report. Klamath River Expert Panel with the assistance of Atkins (formerly PBS&J).

Buchanan, J. B. 1991. Spotted owl nest site characteristics in mixed conifer forests of the eastern Cascades, Washington. Master's thesis. University of Washington, Seattle.

Buettner, M. 2000. Analysis of Tule Lake water quality and sucker telemetry, 1992-1995. Unpublished report. U.S. Bureau of Reclamation, Klamath Basin Area Office, Klamath Falls, Oregon.

Buettner, M., and G. Scoppettone. 1990. Life history and status of Catostomids in Upper Klamath Lake, Oregon. Completion Report. USFWS, National Fisheries Research Center, Reno Field Station, Nevada.

Buettner, M. and G. Scoppettone. 1991. Distribution and information on the taxonomic status of shortnose sucker, *Chasmistes brevirostris*, and Lost River sucker, *Deltistes luxatus*, in the Klamath River Basin, California. Reno Substation, Seattle National Fisheries Research Center, U.S. Fish and Wildlife Service, U.S. Department of Interior, Reno, Nevada.

Buktenica, M. W., D. K. Hering, N. Scott, C. Lambert, J. McKee, E. Maletis, J. Pellissier, W. Tinniswood, and N. Banish. 2018. A Long-Term Watershed-Scale Partnership to Restore Bull Trout Across Federal, State, Private, and Historic Tribal Land Near Crater Lake National Park, Oregon. Fisheries, 43: 183-193. Doi:10.1002/fsh.10047.

Burdick, S. M, 2012. Distribution and condition of larval and juvenile Lost River and shortnose suckers in the Williamson River Delta restoration project and Upper Klamath Lake, Oregon—2010 annual data summary: U.S. Geological Survey Open-File Report 2012-1027, 39 pp. Available online at: http://pubs.usgs.gov/of/2012/1027/.

Burdick, S. M., and D. T. Brown. 2010. Distribution and condition of larval and juvenile Lost River and shortnose suckers in the Williamson River Delta Restoration Project and Upper Klamath Lake, Oregon: 2009 Annual Data Summary: Open-file Report 2010-1216. Page (U. S. G. Survey, Ed.). Reston, Virginia.

Burdick, S. M., and D. A. Hewitt. 2012, Distribution and condition of young-of-year Lost River and shortnose suckers in the Williamson River Delta restoration project and Upper Klamath Lake, Oregon, 2008–10—Final Report: U.S. Geological Survey Open-file Report 2012-1098, 52 pp.

Burdick, S.M., and Martin, B.A., 2017, Inter-annual variability in apparent relative production, survival, and growth of juvenile Lost River and SNS in Upper Klamath Lake, Oregon,2001–15: U.S. Geological Survey Open- File Report 2017–1069, 55p. Available online at: https://doi.org/10.3133/ofr20171069.

Burdick, S. M., S. P. VanderKooi, and G. O. Anderson. 2009a. Spring and summer habitat use by endangered juvenile Lost River and shortnose suckers in Upper Klamath Lake, Oregon: 2007 Annual Report: USGS Open-File Report 2009-1043. 56 pp.

Burdick, S. M., C. Ottinger, D. T. Brown, S. P. VanderKooi, L. Robertson, and D. Iwanowicz. 2009b. Distribution, health, and development of larval and juvenile Lost River and shortnose suckers in the Williamson River Delta Restoration Project and Upper Klamath Lake, Oregon: 2008 annual data summary. USGS Open-File Report 2009-1287. 76 pp.

Burdick, S. M., D. G. Elliott, C. O. Ostberg, C. M. Conway, A. Dolan-Caret, M. S. Hoy, K. P. Feltz, and K. R. Echols. 2015. Health and condition of endangered juvenile Lost River and shortnose suckers relative to water quality and fish assemblages in Upper Klamath Lake, Oregon, and Clear Lake Reservoir, California. U.S. Geological Survey Open-File Report 2015-1217.

Burdick, S. M., and B. A. Martin. 2017. Inter-annual variability in apparent relative production, survival, and growth of juvenile Lost River and shortnose suckers in Upper Klamath Lake, Oregon, 2001-2015. Open-File Report 2017-1069. U.S. Geological Survey, Reston, VA.

Burdick, S. M., C. O. Ostberg, and M. S. Hoy. 2018. Juvenile Lost River and shortnose sucker year class strength, survival, and growth in Upper Klamath Lake, Oregon, and Clear Lake Reservoir, California: 2016 monitoring report. Open-file report 2018-1066. Reston, Virginia.

Butler, V. L., J. A. Miller, D. Y. Yang, and N. Misarti. 2010. The use of archaeological fish remains to establish predevelopment salmonid biogeography in the Upper Klamath Basin. Final Report. Portland State University Department of Anthropology, Portland, Oregon.

California Herps. 2011. A guide to the amphibians and reptiles of California. Available online at: www.californiaherps.com.

California Herps. 2019. Foothill Yellow-legged Frog- Rana boylii. Available at: http://www.californiaherps.com/frogs/pages/r.boylii.html#description.

California Highways. 2020. State Route 96. Available at: https://www.cahighways.org/ROUTE096.html. Accessed on March 8, 2021.

Callahan, Heather A., R. Wayne Litaker and Edward J. Noga. 2002. Molecular Taxonomy of the Suborder Bodonina (Order Kinetoplastida), Including the Important Fish Parasite, Ichthyobodo necator. J. Eukaryot. Microbiol., 49(2), 2002 pp. 119–128. 2002 by the Society of Protozoologists.

Caltopo. 2021. Mapping Tool. Available online at: https://sartopo.com/about. Accessed on February 15, 2021.

Cameron, J. M. 2008. Pesticide monitoring results for Tule Lake, California. 2007.

Carretta, J.V., M.M. Muto, J. Greenman, K. Wilkinson, J. Viezbicke, and J. Jannot. 2017. Sources of human-related injury and mortality for U.S. Pacific west coast marine mammal stock assessments, 2011-2015. Draft document PSRG-2017-07 reviewed by the Pacific Scientific Review Group, Feb. 2017, Honolulu, HI. 125 p

Carter, K. 2005. The Effects of Dissolved Oxygen on Steelhead Trout, Coho Salmon, and Chinook Salmon Biology and Function by Life Stage. California Regional Water Quality Control Board, North Coast Region. 10.

Catenazzi, A., and S.J. Kupferberg. 2013. The importance of thermal conditions to recruitment success in stream-breeding frog populations distributed across a productivity gradient. Biological Conservation 168 (2013): 40-48.

Cayan, D. R., P. D. Bromirski, K. Hayhoe, M. Tyree, M. D. Dettinger and R. E. Flick. 2008. Climate change projections of sea level extremes along the California coast. Climatic Change 87, Supplement 1: S57–S73.

CBD (Center for Biological Diversity), Center for Food Safety, Xerces Society, & Dr. Lincoln Brower. 2014. Petition to Protect the Monarch Butterfly (*Danaus plexippus plexippus*) Under the Endangered Species Act. 159 pp.

CBD, Oregon Wild, EPIC (Environmental Protection Information Center), and The Larch Company. 2011. Petition to list Upper Klamath Chinook salmon (*Oncorhynchus tshawytscha*) as a threatened or endangered species.

CDFG (California Department of Fish and Game, now CDFW). 1965. California Fish and Wildlife Plan, Volume III, Supporting Data, Part B. Inventory (Salmon-Steelhead and Marine Resources): 429 pp.

CDFG. 2001. Proposal: 2001 Fall Chinook Salmon Tagging and Release Strategy at Iron Gate Fish Hatchery. California Department of Fish and Game Klamath River Project 303 South Street Yreka, California 96097.

CDFG. 2002a. California Department of Fish and Game comments to NMFS regarding green sturgeon listing.

CDFG. 2002b. Status review of California coho salmon north of San Francisco. Candidate Species Status Review Report 2002-3. Prepared by CDFG, Sacramento, California to the California Fish and Game Commission.

CDFG. 2003. September 2002 Klamath River fish kill: preliminary analysis of contributing factors, CDFG, Northern California-North Coast Region.

CDFG. 2004. Unpublished data on coded wire tagged Chinook salmon from Iron Gate Hatchery.

CDFG. 2005. Species accounts – fish. Pages 63–97 *in* The status of rare, threatened, and endangered plants and animals of California 2000–2004.

CDFG and NMFS (National Marine Fisheries Service). 2001. Joint Hatchery Review Committee, Final report on anadromous salmonid fish hatcheries in California. CDFG–NMFS, Joint Hatchery Review Committee Sacramento.

CDFW (California Department of Fish and Wildlife). 2015a. State Wildlife Action Plan Update: A Conservation Legacy for Californians, Chapter 5.1 North Coast and Klamath Province. September.

CDFW. 2015b. Klamath River Basin spring Chinook salmon spawner escapement, river harvest and run-size estimates, 1980-2014. Available online at: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=100231&inline.

CDFW. 2016. Scott River Brood Year 2013 Juvenile Coho Salmon PIT Tagging Study. Prepared by Yreka Fisheries. 1625 S. Main Street, Yreka, California 96097. August 5, 2016.

CDFW. 2018a. Klamath River Basin Fall Chinook Salmon Spawner Escapement, In-river Harvest and Run-size Estimates, 1978-2018 (KRFC Megatable). Unpublished data. 17 pp.

CDFW 2018b. Considerations for Conserving the Foothill Yellow-Legged Frog. May.

CDFW. 2019a. Coho Megatable October 2019. Unpublished data.

CDFW. 2019b. Spotted Owl Observations Database Management Framework. California Department of Fish and Wildlife. Sacramento, CA. Available online at: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=166159&inline.

CDFW. 2020. Biogeographic Information and Observation System. Timberland Viewer. Available online at: https://wildlife.ca.gov/Data/BIOS.

CDFW. 2021. California Natural Diversity Database. Available online at: https://wildlife.ca.gov/data/cnddb.

CDFW SGMA (Sustainable Groundwater Management Program). 2018. Bulletin 118 Groundwater Basins – 2018. Available online at: https://water.ca.gov/Programs/Groundwater-Management/Bulletin-118.

CDFW and ODFW (Oregon Department of Fish and Wildlife). 2020. Personal communications between Amy Henderson, CDFW, and Jennifer Jones, The Renewal Corporation, on January 9, 2020; and between Ted Wise, ODFW, and Jennifer Jones, The Renewal Corporation, on January 24, 2020.

CDFW and PacifiCorp. 2014. Hatchery and genetic management plan for Iron Gate Hatchery coho salmon. Prepared for National Oceanic and Atmospheric Administration – National Marine Fisheries Service. 163 pp.

California HSRG (California Hatchery Scientific Review Group). 2012. California Hatchery Review Report. Prepared for the U.S. Fish and Wildlife Service and Pacific States Marine Fisheries Commission. June 2012. Appendix VIII.

CDM. 2011. Screening-level evaluation of contaminants in sediments from three reservoirs and the estuary of the Klamath River, 2009–2011. Prepared for the U.S. Department of the Interior, Klamath River Secretarial Determination, Water Quality Sub Team, Sacramento, California.

CDM Smith. 2018. Memorandum: Evaluation of potential construction worker exposure to arsenic levels in J.C. Boyle sediment samples. March 2018.

CDWR (California Department of Water Resources). 2013. Comments submitted in response to NMFS' invitation to review the green sturgeon Southern DPS draft status review.

CDWR. 2018. SGMA Groundwater Management. California Department of Water Resources website. Available online at: https://water.ca.gov/Programs/Groundwater-Management/SGMA-Groundwater-Management.

Center for Whale Research. Southern Resident Killer Whale ID Guide. Friday Harbor, WA: Center for Whale Research, 2019.

Chapman, D.W. 1981. Pristine production of anadromous salmonids – Klamath River. Final consultant report to the Bureau of Indian Affairs. Bureau of Indian Affairs, U.S. Department of the Interior, Portland, Oregon. July 1981.

Chatters, J. C., V. L. Butler, M. J. Scott, D. M. Anderson and D. S. Neitzel. 1992. A paleoscience approach to estimating the effects of climatic warming on salmonid fisheries of the Columbia River basin. Prepared for U.S. Department of Energy under Contract DE-AC06-76RLO 1830. Pacific Northwest Laboratory. Richland, Washington.

Cherr, G.N., and W.H. Clark. 2005. Jelly release in eggs of the white sturgeon (*Acipenser transmontanus*): an enzymatically mediated event. Journal of Experimental Zoology, 230:145-149.

Chesney, D. and M. Knechtle. 2015. Shasta River Chinook and coho salmon observations in 2014 Siskiyou County, CA. California Department of Fish and Wildlife, Yreka, California.

Chesney, W. R., B. J. Cook, W. B. Crombie, H. D. Langendorf, and J. M. Reader. 2007. Annual report – Shasta and Scott River juvenile salmonid outmigrant study, 2006. Anadromous fisheries Resource Assessment and Monitoring Program.

Chesney, W. R., C. C. Adams, W. B. Crombie, H. D. Langendorf, S. A. Stenhouse, and K. M. Kirkby. 2009. Shasta River Juvenile Coho Habitat & Migration Study. Report prepared for U.S. Bureau of Reclamation, Klamath Area Office. Funded by U.S. Bureau of Reclamation, National Oceanic and Atmospheric Administration and California Department of Fish and Game. California Department of Fish and Game, Yreka, California.

Childress, E. 2018. USBR personal communication regarding Upper Klamath Lake water surface elevation and water quality.

Chiaramonte L.V., R.A. Ray, R.A. Corum, T. Soto, S.L. Hallett and J.L. Bartholomew. 2016. Klamath River thermal refuge provides juvenile salmon reduced exposure to the parasite *Ceratonova shasta*. Transactions of the American Fisheries Society 145: 810-820, DOI: 10.1080/00028487.2016. 1159612.

Clark, S. T., D. K. Odell, and C. T. Lacinak. 2000. Aspects of growth in captive killer whales (*Orcinus orca*). Marine Mammal Science 16: 110–123.

Clay, C.H. 1995. Design of Fishways and Other Fish Passage Facilities, Second Edition, CRC Press, Boca Raton, Florida.

CNPS (California Native Plant Society). 2018. Rare Plant Program. Inventory of Rare and Endangered Plants of California (online edition, v8-03 0.39). Available online at: http://www.rareplants.cnps.org.

Coleman, M. E., and A. M. McGie. 1988. Annual Progress Report 1987, Fish Research Project, No. E-2. Oregon Department of Fish and Wildlife, Portland, Oregon.

Colway, C., and D. E. Stevenson. 2007. Confirmed records of two green sturgeon from the Bering Sea and Gulf of Alaska. Northwestern Naturalist 88:188-192.

Committee on the Status of Endangered Wildlife in Canada. 2011. COSEWIC assessment and status report on the Oregon spotted frog *Rana pretiosa* in Canada. COSEWIC. Ottawa. xi + 47 pp. Available online at: www. sararegistry.gc.ca/status/status_e.cfm.

Connelly, M., and L. Lyons. 2007. Upper Sprague watershed assessment. Prepared by Klamath Basin Ecosytem Foundation, Klamath Falls, Oregon and Oregon State University Klamath Basin Research and Extensions Center with technical assistance from E&S Environmental Chemistry, Inc., Corvallis, Oregon.

Cook, F.R. 1984. Introduction to Canadian amphibians and reptiles. National Museum of Natural Science, National Museum of Canada.

Cooperman, M., and D. F. Markle. 2000. Ecology of Upper Klamath Lake shortnose and Lost River suckers, larval ecology of shortnose and Lost River suckers in the Lower Williamson River and Upper Klamath Lake. Oregon State University, Department of Fisheries and Wildlife, Corvallis, Oregon.

Cooperman, M. S., and D. F. Markle. 2003. Rapid outmigration of Lost River and shortnose sucker larvae from in-river spawning beds to in-lake rearing grounds. Transactions of the American Fisheries Society 132: 1,138–1,153.

Coots, M. 1962. Shasta River, Siskiyou County, 1958 king salmon count, with yearly totals from 1930-1961. California Department of Fish and Game, Inland Fisheries Branch, Sacramento,California.

Coots, M. 1965. Occurrences of the Lost River Sucker, Deltistes luxatus (Cope), and Shortnose Sucker, Chasmistes brevirostris (Cope), in Northern California. California Fish and Game 51:68-73.

Coots, M. 1977. Klamath River Anadromous Fisheries. Draft comments prepared in reference to the People vs. Ederhardt case in Del Norte County Superior Court., California Department of Fish and Game: 63 pp.

Cordone, A. J., and D. W. Kelley. 1961. The influences of inorganic sediment on the aquatic life of streams. California Fish and Game 47: 189–228.

County of Del Norte, California. 2013. Projects. Available at: http://www.co.del-norte.ca.us/departments/community-development-department/engineering-division/projects. Accessed on: March 8, 2021.

Courter, I., S. P. Cramer, R. Ericksen, C. Justice, and B. Pyper. 2008. Klamath coho life-cycle model, Version 1.3. Prepared by Cramer Fish Sciences for USDI Bureau of Reclamation, Klamath Basin Area Office.

Courter, I., J. Vaughn, and S. Duery. 2010. 2010 Tule Lake sucker relocation project summary report. Prepared for the Bureau of Reclamation Klamath Basin Area Office. Cramer Fish Sciences, Gresham, Oregon.

Cramer Fish Sciences. 2010. Scott River Spawning Gravel Evaluation and Enhancement Plan. Submitted to the Pacific States Marine Fisheries Commission and the California Department of Fish and Game. 116.

Crozier, L. G., A. P. Hendry, P. W. Lawson, T. P. Quinn, N. J. Mantua, J. Battin, R. G. Shaw, and R. B. Huey. 2008. Potential responses to climate change in organisms with complex life histories: evolution and plasticity in Pacific salmon. Evolutionary Applications 1:252−270.

Cunanan, M. 2009. Historic anadromous fish habitat estimates for Klamath River mainstem and tributaries under Klamath Hydropower reservoirs. U.S. Fish and Wildlife Service, Arcata, California.

Curran, K. J., P. S. Hill, and T. G. Milligan. 2002. Fine-grained suspended sediment dynamics in the Eel River flood plume. Continental Shelf Research 22: 2,537–2,550.

Cushman, K.A. and C.A. Pearl. 2007. A conservation assessment for the Oregon spotted frog (Rana pretiosa). U.S. Department of Agriculture Forest Service Region 6, U.S. Department of Interior Bureau of Land Management Oregon and Washington. 46 pp.

Dalton, M. M., P. W. Mote, and A. K. Snover [Eds.]. 2013. Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities. Island Press, Washington, DC.

Dark, S. J., R. J. Gutiérrez, and G. I. Gould, Jr. 1998. The barred owl (*Strix varia*) invasion in California. The Auk 115: 50–56.

DaSilva, A. R. 2016. Study 306. Surface water monitoring for pesticides in agricultural areas of northern California. Prepared for the California Department of Pesticide Regulation. September.

David, A.T., S.A. Gough, and W.D. Pinnix. 2016. Summary of Abundance and Biological Data Collected During Juvenile Salmonid Monitoring on the Mainstem Klamath River Below Iron Gate Dam, California,

2014. U.S. Fish and Wildlife Service. Arcata Fish and Wildlife Office, Arcata Fisheries Data Series Report Number DS 2016-47, Arcata, California.

David, A. T., S. A. Gough, and W. D. Pinnix. 2017. Summary of abundance and biological data collected during juvenile salmonid monitoring on the mainstem Klamath River below Iron Gate Dam, California, 2015. U.S. Fish and Wildlife Service. Arcata Fish and Wildlife Office, Arcata Fisheries Data Series Report Number DS 2017-48.

Davidson, C. 2004. Declining downwind: Amphibian population declines in California and historical pesticide use. Ecological Applications 14(6): 1892-1902.

Davis, J.C. 1975. Minimal dissolved oxygen requirements of aquatic life with emphasis on Canadian species: a review. Journal of Fisheries Research Board Canada. 32(12), 2295-2332.

Davis, R. J., R. Horn, P. Caldwell, S. Cross, R. Crutchley, K. Fukuda, C. Larson, J. Lowden, M. O'Hara, J. Stegmeier, and H. Wise. 2010. Demographic characteristics of northern spotted owls (*Strix occidentalis caurina*) in the Klamath Mountain Province of Oregon, 1985–2009. Northern spotted owl monitoring annual report, FY 2009.

Davis, R. J., B. Hollen, J. Hobson, J. E. Gower, D. Keenum. 2016. Northwest Forest Plan—the First 20 Years (1994–2013): Status and Trends of Northern Spotted Owl Habitats. Gen. Tech. Rep. PNW-GTR-929. Portland, Oregon: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 54 pp.

Dean, M. 1994. Life history, distribution, run size, and harvest of spring Chinook salmon in the south fork Trinity River Basin. Chapter VII – job VII in Trinity River Basin monitoring project 1991– 1992.

Dean, M. 1995. Life history, distribution, run size, and harvest of spring Chinook salmon in the south fork Trinity River Basin. Chapter VII – job VII in Trinity River Basin monitoring project 1992–1993.

De Roode, J. C. 2018. PART II Monarchs as Herbivores, Prey, and Hosts. Pages 43-94 In Oberhauser, K. S., K. R. Nail, and S. Altizer, editors. Monarchs in a Changing World, Cornell University Press, Ithaca, NY.

D'Elia, J., S. M. Haig, M. Johnson, B. G. Marcot, and R. Young. 2015. Activity-specific Ecological Niche Models for Planning Reintroductions of California Condors (Gymnogyps californianus). Biological Conservation. Vol. 184, April 2015, 10 pp.Desjardins, M., and D.F. Markle. 2000. Distribution and biology of suckers in Lower Klamath Reservoirs. 1999 Final report submitted to PacifiCorp, Portland, Oregon. Di Lorenzo, E., N. Schneider, K. M. Cobb, P. J. S. Franks, K. Chhak, A. J. Miller, J. C. McWilliams, S. J. Bograd, H. Arango, E. Curchitser, T. M. Powell, and P. Riviere. 2008. North Pacific gyre oscillation links ocean climate and ecosystem change. Geophysical Research Letters 35.

Diez, J, C.M. D'Antonio, J.S. Dukes, E.D. Grosholz, J.D. Olden, C. J B. Sorte, D.M. Blumenthal, B.A. Bradley, R. Early, I. Ibáñez, S.J. Jones, J.J. Lawler, and L. P. Miller. 2012. Will Extreme Climatic Events Facilitate Biological Invasions? Front Ecol Environ 2012; 10(5): 249–257, doi:10.1890/110137.

Dileanis, P. D., S. E. Schwarzbach, and J. Bennett. 1996. Detailed study of water quality, bottom sediment, and biota associated with irrigation drainage in the Klamath Basin, California and Oregon, 1990-92. Water-Resources Investigations Report 95-4232. U.S. Geological Survey and U.S. Fish and Wildlife Service.

Dillemuth, H. 2021. $54 million in sewage plant upgrades underway in Klamath Falls. February 12, 2021. Herald and News, Klamath Falls, Oregon. Available online at: https://www.heraldandnews.com/news/local_news/54-million-in-sewage-plant-upgrades-underway-in-klamath-falls/article_c618b264-2e9b-56ea-9ea5-6dd1acf7574c.html.

Dodd, C. K., Jr. 1988. Synopsis of the biological data on the loggerhead sea turtle (*Caretta caretta*) (Linnaeus 1758). U.S. Fish and Wildlife Service, Biological Report 88(14), 110 pp.

DOI (United States. Department of the Interior). 2007. Modified terms and conditions, and prescriptions for fishways filed pursuant to sections 4I and 18 of the Federal Power Act with the Federal Energy Regulatory Commission for the Klamath River Hydroelectric Project No. 2082. Bureau of Land Management, Bureau of Reclamation, Fish and Wildlife Service, and National Marine Fisheries Service. Sacramento, California.

DOI. 2011. Reservoir Area management plan for the Secretary's Determination on Klamath River dam removal and basin restoration, Klamath River, Oregon and California. Prepared by S. O'Meara, B. Greimann, and J. Godaire (Reclamation), Brian Cluer (National Oceanic and Atmospheric Administrati–n - National Marine Fisheries Service), and R. Synder (Reclamation).

DOI and NMFS (National Marine Fisheries Service). 2013. Department of the Interior and Department of Commerce, National Marine Fisheries Service. Klamath Dam Removal Overview Report for the Secretary of the Interior – An Assessment of Science and Technical Information (a.k.a. the Secretarial Determination of Record [SDOR]). Version 1.1. March 2013.

Duffield, D. A., D. K. Odell, J. F. McBain, and B. Andrews. 1995. Killer whale (*Orcinus orca*) reproduction at Sea World. Zoo Biology 14: 417–430.

Dugger, K. M., E. D. Forsman, A. B. Franklin, R. J. Davis, G. C. White, C. J. Schwarz, K. P. Burnham, J. D. Nichols, J. E. Hines, C. B. Yackulic, P. F. Doherty Jr., L. L. Bailey, D. A. Clark, S. H. Ackers, L. S. Andrews, B. Augustine, B. L. Biswell, J. A. Blakesley, P. C. Carlson, M. J. Clement, L. V. Diller, E. M. Glenn, A. Green, S. A. Gremel, D. R. Herter, J. M. Higley, J. Hobson, R. B. Horn, K. P. Huyvaert, C. McCafferty, T. L. McDonald, K. McDonnell, G. S. Olson, J. A. Reid, J. Rockweit, V. Ruiz, J. Saenz, S. G. Sovern. 2016. The effects of habitat, climate and barred owls on the long-term population demographics of northern spotted owls. Condor 118: 57–116.

Dunne, T., G. Ruggerone, D. Goodman, K. Rose, W. Kimmerer, and J. Ebersole. 2011. Scientific assessment of two dam removal alternatives on coho salmon and steelhead. Klamath River Expert Panel Final Report with appendices. With the assistance of Atkins (formerly PBS&J).

Dunsmoor, L. K., and C. W. Huntington. 2006. Suitability of environmental conditions within Upper Klamath Lake and the migratory corridor downstream for use by anadromous salmonids. Technical Memorandum. Klamath Tribes, Chiloquin, Oregon.

DWR (California Department of Water Resources). 2004. Matrix of Life History and Habitat Requirements For Feather River Fish Species Sp-F3.2 Task 2 - Coho Salmon State of California, The Resources Agency, Department of Water Resources.

Eagles-Smith, C. A., and B. L. Johnson. 2012. Contaminants in the Klamath Basin: Historical patterns, current distribution, and data gap identification. U.S. Geological Survey Administrative Report, 88 pp.

East, A.E., G.R., Pess, J.A. Bountry, C.S. Magirl, A.C. Ritchie, J.B. Logan, T.J. Randle, M.C. Mastin, J.T. Minear, J.J. Duda, and M.C. Liermann. 2015. Large-scale dam removal on the Elwha River, Washington, USA: River channel and floodplain geomorphic change. Geomorphology, 228, pp.765-786.

East, A.E., J.B. Logan, M.C. Mastin, A.C. Ritchie, J.A. Bountry, C.S. Magirl, and J.B. Sankey. 2018. Geomorphic evolution of a gravel-bed river under sediment-starved versus sediment-rich conditions: River response to the world's largest dam removal. Journal of Geophysical Research: Earth Surface, 123(12), pp.3338-3369.

Eaton, J. G., and R. M. Scheller. 1996. Effects of climate warming on the fish thermal habitat in streams of the United States. Limnol. Oceanogr. 41: 1,109–1,115.

Ebert, D. Principal Environmental Scientist, PacifiCorp, Portland, Oregon. Personal communication with Benjamin Swann, The Renewal Corporation, January 22, 2018.

Edwards, A. G. 1991. Global warming from an energy perspective, Chapter 8: global climate change and California *in* J. B. Knox and A. F. Scheuring, editors. Potential impacts and responses.

Eilers, J. M., J. Kann, J. Cornett, K. Moser, and A. St. Amand. 2004. Paleolimnological evidence of change in a shallow, hypereutrophic lake: Upper Klamath Lake, Oregon, USA. Hydrobiologia 520: 7–18.

Elder, D., B. Olson, A. Olson, J. Villeponteaux, and P. Brucker. 2002. Salmon River subbasin restoration strategy: steps to recovery and conservation of aquatic resources. Prepared by Klamath National Forest, Yreka California and Salmon River Restoration Council, Sawyers Bar, California for the Klamath Basin Restoration Task Force.

Ellsworth, C. M., and B. A. Martin. 2012, Patterns of larval sucker emigration from the Sprague and lower Williamson Rivers of the Upper Klamath Basin, Oregon, after the removal of Chiloquin Dam – 2009–10 Annual Report: U.S. Geological Survey Open-File Report 2012– 1037, 34 pp.

Ellsworth, C. M., T. J. Tyler, S. P. VanderKooi, and D. F. Markle. 2008. Patterns of Larval Catostomid Emigration from the Sprague and Lower Williamson Rivers of the Upper Klamath Basin, Oregon, Prior to the Removal of Chiloquin Dam. 47 pp.

Ellsworth, C. M., D. T. Banks, and S. P. VanderKooi. 2011. Patterns of Larval Sucker Emigration from the Sprague and Lower Williamson Rivers of the Upper Klamath Basin, Oregon, Prior to the Removal of Chiloquin Dam - 2007/2008 Annual Report. U.S. Geological Survey Open-File Report 2011-1108. 40 pp.

Emmett, R. L., S. L. Stone, S. A. Hinton, and M. E. Monaco. 1991. Distribution and abundance of fishes and invertebrates in west coast estuaries. Volume 2: Species life history summaries. ELMR Report No. 8. NOS/NOAA Strategic Environmental Assessment Division, Rockville, Maryland.

Engler, J., and D.C. Friesz. 1998. Draft 1998 Oregon spotted frog breeding surveys, Conboy Lake National Wildlife Refuge, Klickitat County, Washington. Unpublished Report. 5 pp.

Entek (Entek Consulting Group, Inc). 2020a. Hazardous Materials Survey Final Report for the Copco No. 1 Development. November 2020. 295pp.

Entek. 2020b. Hazardous Materials Survey Final Report for the Copco No. 2 Development. November 2020. 528 pp.

Entek. 2020c. Hazardous Materials Survey Final Report for the Iron Gate Development. November 2020. 282 pp.

Entek. 2020d. Hazardous Materials Survey Final Report for the J.C. Boyle Development. November 2020. 466 pp.

EPIC, CBD, and WaterKeepers (Environmental Protection Information Center, Center for Biological Diversity, and WaterKeepers Northern California). 2001. Petition to list the North American green sturgeon (*Acipenser medirostris*) as an endangered or threatened species under the Endangered Species Act. EPIC, Garberville, California; CBD, Berkeley, California; and WaterKeepers, San Francisco, California.

Esparza, Erik. 2020. Design Manager, Kiewit, The Renewal Corporation Design Build Contractor. Personal communication to K. Stenberg, The Renewal Corporation Technical Representative. February 12, 2020.

Eulachon Research Council. 2000. Notes summarizing meetings in Terrace, B.C. (May 4), New Westminster, and Bella Coola, B.C. (May 9). Informal joint report prepared jointly by B.C. Forests, Department of Fisheries and Oceans-Canada. 24 pp.

Evans, A. G., D.A. Hewitt, Q. Payton B.M. Cramer, K. Collis, and D.D. Roby. 2016, Colonial water bird predation on Lost River and shortnose suckers in the Upper Klamath Basin: North American Journal of Fisheries Management: v. 36, pp. 1,254–1,268.

Farnsworth, K. L., and J. A. Warrick. 2007. Sources, dispersal, and fate of fine sediment supplied to coastal California. U.S. Geological Survey Scientific Investigations Report 2007-5254.

Felleman, F. L., J. R. Heimlich-Boran, and R. W. Osborne. 1991. The feeding ecology of killer whales (*Orcinus orca*) in the Pacific Northwest. Pages 113–147 *in* K. Pryor and K. S. Norris, editors. Dolphin societies: discoveries and puzzles. University of California Press, Berkeley, California.

FERC (Federal Energy Regulatory Commission). 1963. Opinion and order for petition to require licensee to construct, operate, and maintain a fish hatchery, amending license, and directing revised filings, Opinion No. 381, Issued March 14, 1963. Washington D.C., Formerly Federal Power Commission: 1-13.

FERC. 2006. Draft Environmental Impact Statement for Hydropower License, Klamath Hydroelectric Project, FERC Project No. 2082-027, Oregon and California. Office of Energy Projects, Division of Hydropower Licensing, Washington, D.C.

FERC. 2007. Final Environmental Impact Statement for hydropower license. Klamath Hydroelectric Project (FERC Project No. 2082-027). Available online at: http://www.ferc.gov/industries/hydropower/enviro/eis/2007/11-16-07.asp.

Field, C. B., G. C. Daily, S. Gaines, P. A. Matson, J. Melack and N. L. Miller. 1999. Confronting climate change in California–a - ecological impacts on the Golden State. The Union of Concerned Scientists and the Ecological Society of America: 1–62.

Fingerle, A. 2018. Methodist Creek juvenile coho investigation. Unpublished data.

FISHPRO. 2000. Fish Passage Conditions on the Upper Klamath River. July 2000. Port Orchard, WA.

Foley, M.M., J. E. Evans, S. L. Greene, F. J. Magilligan, C. S. Magirl, J. J. Major, G. R. Pess, T. J. Randle, P. B. Shafroth, C. E. Torgersen, D. Tullos, and A. C. Wilcox. 2017, Dam removal: Listening in, Water Resource. Res., 53, 5229–5246, doi:10.1002/2017WR020457.

Foott, J. S. 1997. Diagnostic Laboratory Results-Klamath Lake Suckers. Letter Dated September 18, 1997. 8 pp.

Foott, J. S. 2004. Health Monitoring of Adult Lost River Sucker (*Deltistes luxatus*) and Shortnose Sucker (*Chasmistes brevirostris*) in Upper Klamath Lake, Oregon, April – September 2003. Joint U.S. Fish and Wildlife Service and U.S. Geological Survey Project. 37 pp.

Foott, J. S., R. Stone, E. Wiseman, K. True, and K. Nichols. 2006. Longevity of *Ceratomyxa shasta* and *Parvicapsula minibicornis* actinospore infectivity in the Klamath River: April-June 2005. FY 2005 Investigational Report U.S. Fish and Wildlife Service, Anderson, California and California-Nevada Fish Health Center, Anderson, California.

Foott, J. S., R. Stone, R. Fogerty, and K. True. 2009. FY2008 Technical Report: *Ceratomyxa shasta myxospore* survey of Fall-run Chinook salmon carcasses and sentinel trout exposures in Bogus Creek: Component of joint OSU-Yurok Fisheries-CDFG pilot project testing the effect of carcass removal on C. shasta levels in Bogus Creek, 2008. U.S. Fish and Wildlife Service California – Nevada Fish Health Center, Anderson, California.

Foott, J.S., R. J.L. Barthomew, R. W. Perry, and C. E. Walker. 2011. Conceptual Model for Disease Effects in the Klamath River. Whitepaper prepared for the Klamath Basin Restoration Agreement Secretarial Overview Report Process. 12 pp.

Foott, S. 2018. USBR personal communication regarding Upper Klamath Lake Canal A Pump Station sucker parasites and disease.

Ford, J. K. B. 2002. Killer *whale Orcinus orca*. Pages 669-676 in W. F. Perrin, B. Würsig, and J. G. M. Thewissen, editors. Encyclopedia of marine mammals. Academic Press, San Diego, California.

Ford, J. K. B., and G. M. Ellis. 2006. Selective foraging by fish-eating killer whales *Orcinus orca* in British Columbia. Marine Ecology Progress Series 316: 185–199.

Ford J. K. B., B.M. Wright, G.M. Ellis, J.R. Candy. 2010. Chinook salmon predation by resident killer whales: seasonal and regional selectivity, stock identity of prey, and consumption rates. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/101. iv + 43 p. 2010.

Ford, J. K. B., G. M. Ellis, and K. C. Balcomb. 2000. Killer whales: the natural history and genealogy of *Orcinus orca* in British Columbia and Washington State. 2nd edition. UBC Press, Vancouver, British Columbia.

Ford, J. K. B., G. M. Ellis, L. G. Barrett-Lennard, A. B. Morton, R. S. Palm, and K. C. Balcomb III. 1998. Dietary specialization in two sympatric populations of killer whales (*Orcinus orca*) in coastal British Columbia and adjacent waters. Canadian Journal of Zoology 76: 1,456–1,471.

Ford J. K. B., G. M. Ellis, P. F. Olesiuk, and K. C. Balcomb. 2009. Linking killer whale survival and prey abundance: food limitation in the oceans' apex predator? Biol. Lett. 6: 139–142.

Ford, M. J., J. Hempelmann, B. Hanson, K. L. Ayres, R. W. Baird, C. K. Emmons, J. I. Lundin, G. S. Schorr, S. K. Wasser, and L. K. Park. 2016. Estimation of a killer whale (Orcinus orca) population's diet using sequencing analysis of DNA from feces. PLoS ONE. 11(1): e0144956.

Fortune, J. D., A. R. Gerlach and C. J. Hanel. 1966. A study to determine the feasibility of establishing salmon and steelhead in the Upper Klamath Basin. Oregon State Game Commission and Pacific Power and Light Company, Portland, Oregon.

Foster, K., and D. Bennetts. 2006. Link River Dam surface spill: 2005 pilot testing report. Bureau of Reclamation.

Fraley, J. J., and B. B. Shepard. 1989. Life history, ecology and population status of migratory bull trout (*Salvelinus confluentus*) in the Flathead Lake and River system, Montana. Northwest Science 63: 133–143.

Freeling, Debra. 2017. Wildlife Biologist, U.S. Forest Service, Goosenest Ranger District. Personal communication with Jennifer Jones, The Renewal Corporation, June 16, 2017.

Fry, D. H., Jr. 1979. Anadromous fishes of California. CDFG, Sacramento, California.

Fujiwara, M., M. S. Mohr, A. Greenberg, J. S. Foott, and J. L. Bartholomew. 2011. Effects of ceratomyxosis on population dynamics of Klamath fall Chinook salmon. Transactions of the American Fisheries Society 140: 1380–1391.

Fuller, T.E., K.L. Pope, D.T. Ashton, and H.H. Welsh. 2011. Linking the distribution of an invasive amphibian (*Rana catesbeiana*) to habitat conditions in a managed river system in northern California. Restoration Ecology, 19(201), pp.204-213.

Gale, D. B. 2009a. Instream and riparian enhancement of mainstem McGarvey Creek (Phase I). Yurok Tribal Fisheries Program, Klamath, California.

Gale, D. B. 2009b. Lower Terwer Creek Riparian Restoration Project (Phase IV). Yurok Tribal Fisheries Program, Klamath, California.

Gale, D. B., and D. B. Randolph. 2000. Lower Klamath River Sub-Basin Watershed Restoration Plan. Yurok Tribal Fisheries Program and Watershed Restoration Program. Klamath, California.

Galloway, Shaughn. 2017. Wildlife Biologist, U.S. Fish and Wildlife Service, Yreka. Personal communication with Kate Stenberg, The Renewal Corporation, May 24, 2017.

Gannett, M. W. 2010. E mail reply to John Hamilton, Yreka, California. As cited in Hamilton et al. 2011.

Gannett, M. W., K. E. J. Lite, J. L. La Marche, B. J. Fisher and D. J. Polette. 2007. Groundwater hydrology of the upper Klamath Basin, Oregon and California. Scientific Investigations Report 2007-5050. U.S. Geological Survey.

Garakouei, M. Y., Z. Pajand, M. Tatina, and H. Khara. 2009. Median lethal concentrations (LC_{50}) in two sturgeon species, *Acipenser persicus* and *Acipenser stellatus* fingerlings. Journal of Fisheries and Aquatic Sciences 4(6):285-295.

Garcia-Reyes, M., and J. Largier. 2010. Observations of increased wind-driven coastal upwelling off central California. Journal of Geophysical Research 115.

Garfin, G., G. Franco, H. Blanco, A. Comrie, P. Gonzalez, T. Piechota, R. Smyth, and R. Waskom. 2014: Ch. 20: Southwest. Climate Change Impacts in the United States: The Third National Climate

Assessment, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 462-486. doi:10.7930/J08G8HMN.

Garwood, J. 2012. Historic and recent occurrence of coho salmon (*Oncorhynchus kisutch*) in California streams within the Southern Oregon/Northern California Evolutionarily Significant Unit. California Department of Fish and Game, Fisheries Branch Administrative Report.

Gearheart, R. A. 1995. Watershed strategies for improving water quality in Upper Klamath Lake, Oregon. Volumes I–III. Humboldt State University, Arcata, California.

GEC (Gathard Engineering Consulting). 2006. Klamath River dam and sediment investigation. Prepared by GEC, Seattle, Washington.

Gessner, J. and R. Bartel. 2000. Sturgeon spawning grounds in the Odra River tributaries: a first assessment. Boletin Instituto Espanol de Oceanografia 16:127- 137.

Gilliom, R. J., J. E. Barbash, C. G. Crawford, P. A. Hamilton, J. D. Martin, N. Nakagaki, N. H. Nowell, J. C. Scott, P. E. Stackelberg, G. P. Thelin, and D. M. Wolock. 2006. The Quality of Our Nation's Waters - Pesticides in the Nation's Streams and Ground Water, 1992-2001: U.S.

Giudice, D. and M. Knechtle. 2019a. Recovery of Fall-run Chinook and Coho Salmon at Iron Gate Hatchery. October 8, 2018 to December 18, 2018. Siskiyou County, California. May 20, 2019. 22 pp.

Giudice, D. and M. Knechtle. 2019b. Shasta River Salmonid Monitoring 2018 Siskiyou County, California. Draft Report. April 8, 2019. 28 pp.

GMA (GMA Hydrology, INC). 2018. 2018 Klamath Dam Removal Project Topo bathymetric Lidar & Sonar Technical Data Report. Project Number 60537920. December 2018.

Goetz, F. A., E. Jeanes, and E. Beamer. 2004. Bull trout in the nearshore. Preliminary draft report. U.S. Army Corps of Engineers, Seattle District, Seattle, Washington.

Gorman, M. P. 2016. Juvenile Survival And Adult Return As A Function Of Freshwater Rearing Life History For Coho Salmon In The Klamath River Basin. Humboldt State University.

Gough, S. A., A. T. David, and W. D. Pinnix. 2015. Summary of Abundance and Biological Data Collected During Juvenile Salmonid Monitoring in the Mainstem Klamath River Below Iron Gate Dam, California, 2000-2013. U.S. Fish and Wildlife Service. Arcata Fish and Wildlife Office, Arcata Fisheries Data Series Report Number DS 2015-43, Arcata, California.

Gough, S. A., C. Z. Romberger, and N. A. Som. 2018. Fall Chinook Salmon Run Characteristics and Escapement in the Mainstem Klamath River below Iron Gate Dam, 2017. U.S. Fish and Wildlife Service. Arcata Fish and Wildlife Office, Arcata Fisheries Data Series Report Number DS 2018–58, Arcata, California.

Gough, S.A., K.I. Wilcox, T.T. Daley, and N.A. Som. 2020. Fall-run Chinook Salmon run characteristics and escapement in the mainstem Klamath River below Iron Gate Dam, 2019. U.S. Fish and Wildlife Service. Arcata Fish and Wildlife Office, Arcata Fisheries Data Series Report Number DS 2020–64, Arcata, California.

Green Diamond Resource Company. 2017. California Timberlands Forest Management Plan. Green Diamond Resource Company, California Timberlands Division, Korbel, California.

B. Greimann, pers. comm., December 23, 2010

Greimann, B. P., D. Varyu, J. Godaire, K. Russell, G. Lai, and R. Talbot. 2011. Hydrology, hydraulics and sediment transport studies for the Secretery's Determination on Klamath River dam removal and basin restoration, Klamath River, Oregon and California, Mid-Pacific Region. Draft Technical Report No. SRH-2011-02. Prepared for USDI Bureau of Reclamation, Mid-Pacific Region, Technical Service Center, Denver, Colorado.

Guillen, G. 2003. Klamath River Fish Die-off, September 2002: Causative Factors of Mortality. U.S. Fish and Wildlife Service. Report Number AFWOF-02-03. 128 pp.

Gustafson, R., J. Drake, R. Emmett, K. Fresh, M. Rowse, D. Teel, M. Wilson, P. Adams, E. Spangler, and R. Spangler. 2008. Summary of scientific conclusions of the review of the status of eulachon (*Thaleichthys pacificus*) in Washington, Oregon, and California. NMFS, Northwest Fisheries Science Center, Seattle, Washington.

Gustafson, R. G., M. J. Ford, D. Teel, and J. S. Drake. 2010. Status review of eulachon (*Thaleichthys pacificus*) in Washington, Oregon, and California. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-105.

Gustafson, R., Y.-W. Lee, E. Ward, K. Somers, V. Tuttle, and J. Jannot. 2016. Status review update of eulachon (*Thaleichthys pacificus*) listed under the Endangered Species Act: southern distinct population segment. 25 March 2016 Report to National Marine Fisheries Service – West Coast Region from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112.

Gutermuth, B., C. Watson, and R. Weider. 1999. Link River hydroelectric project—Eastside and westside powerhouses annual entrainment study report (March 1997–July 1998). New Earth Corp., Klamath Falls, Oregon.

Gutermuth, B., E. Pinkston, and D. Vogel. 2000a. A Canal Fish Entrainment during 1997 and 1998 with Emphasis on Endangered Suckers. Klamath Falls, Oregon.

Gutermuth, B., C. Watson, and J. Kelly. 2000b. Link River Hydroelectric Project (east and Westside powerhouses) Final Entrainment Study Report. Unpublished Work.

Gutiérrez, R. J., A. B. Franklin, and W. L. Lahaye. 1995. Spotted owl (*Strix occidentalis*). Pages No. 179 *in* Poole and F. Gill, editors. The birds of North America. The Academy of NaturalSciences, Philadelphia, Pennsylvania and The American Ornithologists' Union, Washington, D.C.

Haenel, N. J. 1986. General notes on the behavioral ontogeny of Puget Sound killer whales and the occurrence of allomaternal behavior. Pages 285–300 *in* B. C. Kirkevold and J. S. Lockard, editors. Behavioral biology of killer whales. Alan R. Liss, New York, New York.

Halofsky, J. E., D. L. Peterson, J. J. Ho, N. J. Little, L. A. Joyce, eds. 2018. Climate change vulnerability and adaptation in the Intermountain Region [Part 1]. Gen. Tech. Rep. RMRS-GTR-375. Fort Collins, Colorado: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. p. 1-197.

Halterman, M. D., M. J. Johnson, J. A. Holmes and S. A. Laymon. 2015. A Natural History Summary and Survey Protocol for the Western Distinct Population Segment of the Yellow-billed Cuckoo: U.S. Fish and Wildlife Techniques and Methods, 45 p.

Hamer, T. E. 1988. Home range size of the northern barred owl and the northern spotted owl in western Washington. Master's thesis. Western Washington University, Bellingham.

Hamer, T. E., E. D. Forsman, A. D. Fuchs, and M. L. Walters. 1994. Hybridization between barred and spotted owls. The Auk 111: 487–492.

Hamilton, J. B., D. W. Rondorf, W. T. Tinniswood, R. J. Leary, T. Mayer, C. Gavette, and L. A. Casal. 2016. The persistence and characteristics of Chinook salmon migrations to the upper Klamath River prior to exclusion by dams. OHQ 117: 326–377.

Hamilton, J. B., G. L. Curtis, S. M. Snedaker, and D. K. White. 2005. Distribution of anadromous fishes in the upper Klamath River Watershed prior to hydropower da– -- a synthesis of the historical evidence. Fisheries 30: 10–20.

Hamilton, J., R. Quinones, D. Rondorf, K. Schultz, J. Simondet, and S. Stresser. 2010. Biological synthesis for the secretarial determination on potential removal of the lower four dams on the Klamath River. Draft report. Prepared by the Biological Subgroup for the Secretarial Determination Regarding Potential Removal of the Lower Four Dams on the Klamath River.

Hamilton, J., D. Rondorf, M. Hampton, R. Quiñones, J. Simondet, and T. Smith. 2011. Synthesis of the effects to fish species of two management scenarios for the secretarial determination on removal of the lower four dams on the Klamath River. Prepared by the Biological Subgroup for the Secretarial Determination Regarding Potential Removal of the Lower Four Dams on the Klamath River. Accessed on December 21, 2011.

Hammond, P. E., 1983. Volcanic formations along the Klamath River near Copco Lake. California Geology. V.36, no. 5, p. 99-109.

Hampton, M. 2010. Bogus Creek Coho Restoration Project Summer Reconnaissance Survey, 2009. N. R. California Department of Fish and Game, Yreka, California.

Hansen, J.F. and D.B. Hayes. 2012. Long-term implications of dam removal for macroinvertebrate communities in Michigan and Wisconsin rivers, United States. River Research and Applications 28: 1540-1550. doi: 10.1002/rra.1540.

Hanson, A. J. Orr, H. Huber, M. S. Lowry, J. Barlow, J. E. Moore, D. Lynch, L. Carswell, and Robert L. Brownell Jr. 2017. U.S. Pacific Marine Mammal Stock Assessments: 2016. June 2017. U.S. Department of Commerce. NOAA-TM-NMFS-SWFSC-577. 414p.

Hanson, M. B., R. W. Baird, J. K. B. Ford, J. Hempelmann-Halos, D.M. Van Doornik, J. R. Candy, C.K. Emmons, G.S. Schorr, B. Gisborne, K. L. Ayres, S. K. Wasser, K. C. Balcomb, K. Balcomb-Bartok, J. G. Sneva, and M.J. Ford. 2010. Species and stock identification of prey consumed by endangered southern resident killer whales in their summer range. Endangered Species Research 11:69-82.

Hanson, M. B., C. K. Emmons, and E. J. Ward. 2013. Assessing the coastal occurrence of endangered killer whales using autonomous passive acoustic recorders. The Journal of the Acoustical Society of America. 134(5): 3486–3495.

Hanson, M. B., E. J. Ward, C. K. Emmons, M. M. Holt and D. M. Holzer. 2017. Assessing the movements and occurrence of Southern Resident Killer Whales relative to the U.S. Navy's Northwest Training Range Complex in the Pacific Northwest. Prepared for: U.S. Navy, U.S. Pacific Fleet, Pearl Harbor, Hawaii. Prepared by: National Oceanic and Atmospheric Administration, Northwest Fisheries Science Center under MIPR N00070-15-MP-4C363. 30 June 2017. 23 pp.

Hanson, M.B., C.K. Emmons, M.J. Ford, M. Everett, K. Parsons, L.K. Park, et al. 2021. Endangered predators and endangered prey: Seasonal diet of Southern Resident killer whales. PLoS ONE 16(3): e0247031. https://doi.org/10.1371/journal.pone.0247031

Hardy, T., R. Addley, and E. Saraeva. 2006. Evaluation of Flow Needs in the Klamath River Phase II. Final Report. Institute for Natural Systems Engineering, Utah Water Research Laboratory, Utah State University, Logan, Utah. 84322-4110.

Hart, J. L. 1973. Pacific fishes of Canada. Fisheries Research Board of Canada Bulletin. No. 180. 739 pp.

Hartill, T., and S. E. Jacobs. 2007. Distribution and abundance of bull trout in the upper Sprague River (Upper Klamath Basin), 2006. Interim Report. Oregon Department of Fish and Wildlife, Corvallis, Oregon.

Hatch, J.J., and D.V. Weseloh. 1999. Doublecrested cormorant (Phalacrocorax auritus) in A. Poole and F. Gill, editors. The birds of North America. The Academy of Natural Sciences, Philadelphia, Pennsylvania, USA, and The American Ornithologists Union, Washington, D.C., USA.

Hay, D. E., and McCarter, P. B. 2000. Status of the eulachon *Thaleichthys pacificus* in Canada. Department of Fisheries and Oceans Canada, Canadian Stock Assessment Secretariat, Research Document 2000-145. Ottawa, Ontario.

Hayes, pers. comm., October 19, 2018

Hayes, B. S., E. C. Janney, and R. S. Shively. 2004. Monitoring of Lost River and shortnose suckers at Upper Klamath Lake shoreline spawning areas. Monitoring of adult Lost River suckers and shortnose suckers in Upper Klamath Lake and its tributaries, Oregon: Annual Report 2003. U.S. Geological Survey, Western Fisheries Research Center, Klamath Falls Field Station.

Hayes, B. S., and R. Shively. 2001. Monitoring of Lost River and shortnose suckers at shoreline spawning areas in Upper Klamath Lake, Oregon. Annual Report 2000. USGS Biological Resources Discipline (BRD).

Hayes, B. S., R. S. Shively, E. C. Janney, and G. N. Blackwood. 2002. Monitoring of Lost River and shortnose suckers at Upper Klamath Lake shoreline spawning areas in Upper Klamath Lake, Oregon. Monitoring of Lost River and shortnose suckers in the Upper Klamath Basin, Oregon: Annual Report 2001. U.S. Geological Survey, Western Fisheries Research Center, Klamath Falls Field Station.

Hayes, M.P. 1997. Status of the Oregon spotted frog (*Rana pretiosa sensu stricto*) in the Deschutes basin and selected other systems in Oregon and northeastern California with a rangewide synopsis of the species' status. Final report prepared for The Nature Conservancy under contract to the U.S. Fish and Wildlife Service, Portland, Oregon. Unpublished Report. 57 pp.

Hayes M.P., C.A. Wheeler, A.J. Lind, G.A. Green, and D.C. Macfarlane. 2016. Foothill yellow-legged frog conservation assessment in California. Gen. Tech. Rep. PSW-GTR-248. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 193 p.

Hayhoe, K., D. Cayan, C. B. Field, P. C. Frumhoff, E. P. Maurere, N. L. Miller, S. C. Moser, S. H. Schneider, K. N. Cahill, E. E. Cleland, L. Dale, R. Drapek, R. M. Hanemann, L. S. Kalkstein, J. Lenihan, K. Lunch, R. P. Neilson, S. C. Sheridan, and J. H. Verville. 2004. Emissions pathways, climate change, and impacts on California. PNAS 101: 12,422–12,427.

Hayner, Steve. 2017. Wildlife Biologist, Bureau of Land Management, Lakeview District, Klamath Falls Resource Area. Personal communication with Jennifer Jones, The Renewal Corporation, August 24, 2017.

HDR Alaska, Inc. 2008. A survey of eulachon spawning activity near the Twentymile River Bridge, Alaska. Prepared for the Alaska Department of Transportation and Public Facilities. Seward Highway MP 75-90 road and bridge rehabilitation project.

Healey, M. C. 1991. The life history of Chinook salmon (*Oncorhynchus tshawytscha*). Pages 312–393 *in* Groot and Margolis, editors. Pacific salmon life histories. University of British Columbia Press, Vancouver, B.C.

HEC. 2019. HEC-RAS, Version 5.0.7 [Computer Program]

Helm, B. P., and W. Fields. 1998. Aquatic macro-invertebrate assemblages occurring in selected vernal pools on the Agate Desert and nearby sites in Jackson County, Oregon. Oregon Natural Heritage Program, Portland, Oregon.

Heimlich-Boran, J. R. 1988. Behavioral ecology of killer whales (*Orcinus orca*) in the Pacific Northwest. Canadian Journal of Zoology 66: 565–578.

Hendrix, N. 2011. Forecasting the response of Klamath Basin Chinook populations to dam removal and restoration of anadromy versus no action. Review Draft Report. R2 Resource Consultants, Redmond, Washington.

Hendrixson, H. A., S. M. Burdick, B. L. Herring, and S. P. VanderKooi. 2007a. Differential habitat use by juvenile suckers in Upper Klamath Lake, Oregon. *In* Nearshore and offshore habitat use by endangered, juvenile Lost River and shortnose suckers in Upper Klamath Lake, Oregon. Annual Report 2004. USGS, Western Fisheries Research Center, Klamath Falls Field Station.

Hendrixson, H. A., S. M. Burdick, B. L. Herring, and S. P. VanderKooi. 2007b. Ecology of juvenile suckers in open waters of Upper Klamath Lake, Oregon. *In* Nearshore and offshore habitat use by endangered, juvenile Lost River and shortnose suckers in Upper Klamath Lake, Oregon. Annual Report 2004. U.S. Geological Survey, Western Fisheries Research Center, Klamath Falls Field Station.

Hereford, D. M., S. M. Burdick, D. G. Elliott, A. Dolan-Caret, C. M. Conway, and A. C. Harris. 2016. Survival, movement, and health of hatchery-raised juvenile Lost River suckers within a mesocosm in Upper Klamath Lake, Oregon. U.S. Geological Survey Open-File Report 2016-1012.

Hereford, D.M., Conway, C.M., Burdick, S.M., Elliott, D.G., Perry, T., Dolan-Caret, A., and Harris, A.C. 2018. Assessing causes of mortality for Juvenile Lost River suckers in Mesocosms in Upper Klamath Lake, Oregon: U.S. Geological Survey report.

Hetrick, N. J., T. A. Shaw, P. Zedonis, J. C. Polos, and C. D. Chamberlain. 2009. Compilation of information to inform USFWS principals on the potential effects of the proposed Klamath Basin Restoration Agreement (Draft 11) on fish and fish habitat conditions in the Klamath Basin, with Emphasis on Fall Chinook Salmon. U. S. Fish and Wildlife Service, Arcata Fish and Wildlife Office, Arcata, CA.

Heublein, J. C., J. T. Kelly, C. E. Crocker, A. P. Klimley, and S. T. Lindley. 2009. Migration of green sturgeon, Acipenser medirostris, in the Sacramento River. Env. Biol. Fish. 84:245-258.

Heublein, J., R. Bellmer, R. D. Chase, P. Doukakis, M. Gingras, D. Hampton, J. A. Israel, Z. J. Jackson, R. C. Johnson, O. P. Langness, S. Luis, E. Mora, M. L. Moser, L. Rohrbach, A. M. Seesholtz, T. Sommer, and J. S. Stuart. 2017. Life History and Current Monitoring Inventory of San Francisco Estuary Sturgeon. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-589.

Hewitt, USGS, personal communication August 16, 2018.

Hewitt, D. A., and B. S. Hayes. 2013. Monitoring of adult Lost River and shornose suckers in Clear Lake Reservoir, California, 2008-2010. U.S. Geological Survey Open-File Report 2013-1301. U.S. Geological Survey, Reston, VA.

Hewitt, D. A., B. S. Hayes, E. C. Janney, A. C. Harris, J. P. Koller, and M. A. Johnson. 2011. Demographics and run timing of adult Lost River (*Deltistes luxatus*) and shortnose (*Chasmistes brevirostris*) suckers in Upper Klamath Lake, Oregon, 2009: Open-file Report 2011-1088. U.S. Geological Survey, Reston.

Hewitt, D. A., E. C. Janney, B. S. Hayes, and A. C. Harris. 2012. Demographics and run timing of adult Lost River (*Deltistes luxatus*) and shortnose (*Chasmistes brevirostris*) suckers in Upper Klamath Lake, Oregon, 2011: U.S. Geological Survey Open-File Report 2012-1193, 42 pp.

Hewitt, D. A., E.C. Janney, B.S. Hayes, and A.C. Harris. 2014. Demographics and run timing of adult Lost River (*Deltistes luxatus*) and shortnose (*Chasmistes brevirostris*) suckers in Upper Klamath Lake, Oregon, 2012: U.S. Geological Survey Open-File Report 2014-1186, 44 pp. Available online at: http://dx.doi.org/10.3133/ofr20141186.

Hewitt, D. A., E. C. Janney, B. S. Hayes, and A. C. Harris. 2015. Status and trends of adult Lost River (*Deltistes luxatus*) and Shortnose (Chasmistes brevirostris) sucker populations in Upper Klamath Lake, Oregon, 2014. U.S. Geological Survey Open-File Report Pages 2015– 1189.

Hewitt, D. A., E. C. Janney, B. S. Hayes, and A. C. Harris. 2017, Status and trends of adult Lost River (Deltistes luxatus) and shortnose (Chasmistes brevirostris) sucker populations in Upper Klamath Lake, Oregon, 2015: U.S. Geological Survey Open-File Report 2017–1059, 38 p., Available online at: https://doi.org/10.3133/ofr20171059.

Hewitt, D. A., E C. Janney, B. S. Hayes, and A. C. Harris. 2018. Status and trends of adult Lost River (*Deltistes luxatus*) and shortnose (*Chasmistes brevirostris*) sucker populations in upper Klamath Lake, Oregon, 2017: U.S. Geological Survey Open-File Report 2018-1064, 31. pp. Available online at: https://doi.org/10.3133/ofr20181064.

Hicks, L.A., D.M. Mauser, J. Beckstrand, and D. Thomson. 2000. Ecology of Shortnose and Lost River Suckers in Tule Lake National Wildlife Refuge, California, Progress Report, April - November 1999. Klamath Basin National Wildlife Refuges, Tule Lake, California. 39 p.

Hilborn, R., S. P. Cox, F. M. D. Gulland, D. G. Hankin, N. T. Hobbs, D. E. Schindler, and A. W. Trites. 2012. The Effects of Salmon Fisheries on Southern Resident Killer Whales: Final Report of the Independent

Science Panel. Prepared with the assistance of D. R. Marmorek and A. W. Hall, ESSA Technologies Ltd., Vancouver, B.C. for National Marine Fisheries Service (Seattle, WA) and Fisheries and Oceans Canada (Vancouver, BC). Xv + 61 pp. + Appendices.

Hillemeier, D. 1999. An Assessment of pinniped predation upon fall-run chinook salmon in the Lower Klamath River, California, 1997. Yurok Tribal Fisheries Program Report.

Hillemeier, D., T. Soto, S. Silloway, A. Corum, M. Kleeman, and L. Lestelle. 2009. The Role of the Klamath River Mainstem Corridor in the Life-History and Performance of Juvenile Coho Salmon (Oncorhynchus kisutch). Period Covered: May 2007–May 2008. Report submitted to the United States Bureau of Reclamation. Klamath Falls, Oregon, 97603.

Hillemeier, D., M. Belchik, T. Soto, S. C. Tucker, and S. Iedwin. 2017. Measures to Reduce *Ceratonova shasta* Infection of Klamath River Salmonids. A Guidance Document. Disease Technical Advisory Team:113 pp.

Hiner, M. 2006. Seasonal water quality in the Klamath River estuary and surrounding sloughs, 2001–2003.

Hodge, J., and M. Buettner. 2007. Sucker Population Monitoring in Tule Lake and Lower Lost River, 2006. 21 pp.

Hodge, J., and M. Buettner. 2008. Sucker Population Monitoring in Tule Lake and Lower Lost River, 2007. 25 pp.

Hodge, J., and M. Buettner. 2009. Sucker Population Monitoring in Tule Lake and Lower Lost River, 2008. 35 pp.

Hoffman, D.F. and E.J. Gabet. 2007. Effects of sediment pulses on channel morphology in a gravel-bed river. GSA Bulletin, 119(1-2), pp.116-125.

Holland, R. F. 1998. Great Valley vernal pool distribution, photorevised 1996. Pages 71-75 *in*: C. W. Witham, T. Bauder, D. Belk, W. R. Ferren Jr., and R. Ornduff, editors. Ecology, conservation, and management of vernal pool ecosystems—Proceedings from a 1996 Conference. California Native Plant Society, Sacramento, California.

Holt, R. 1997. Upper Klamath Lake fish disease exam report. Oregon Department of Fish and Wildlife, State of Oregon, Corvallis, Oregon.

Hoopa Valley Tribal Environmental Protection Agency. 2008. Hoopa Valley Indian Reservation Water Quality Control Plan. Hoopa Valley Tribal Environmental Protection Agency, Hoopa, California.

Horn M. J, and D. Lieberman. 2005. A risk assessment for low dissolved oxygen in Klamath Lake, Oregon. U.S. Bureau of Reclamation Technical Memorandum 8220-06-02.

Horne, A., and C. Goldman. 1994. Limnology. McGraw-Hill, New York.

Hotaling, T., and P. Brucker. 2010. Salmon River Community Weak Stocks Assessment Program – 2008. DRAFT Final Report, Agreement # P0710302 00, August 27, 2008 through March 31, 2010. Prepared for: California Department of Fish and Game.

Huang, J. V., and B. Greimann. 2010. User's manual for SRH-1D V2.6. Sedimentation and river hydraulics-one dimension. USDI Bureau of Reclamation, Technical Service Center, Sedimentation and River Hydraulics Group, Denver, Colorado.

Hubbs, C. L. 1925. A revision of the osmerid fishes of the North Pacific. Proceedings of the Biological Society of Washington 38: 49–56.

Huff, D. D., S. T. Lindley, B. K. Wells and F. Chai. 2012. Green sturgeon distribution in the Pacific Ocean estimated from modeled oceanographic features and migration behavior. PLoSONE 7(9): e45852. Doi:10.1371/journal.pone.0045852.

Huntington, C. W. 2004. Klamath River flows within the J.C. Boyle Bypass and below the J.C. Boyle Powerhouse. Clearwater BioStudies, Canby, Oregon.

Huntington, C. W. 2006. Estimates of anadromous fish runs above the site of Iron Gate Dam. Technical memorandum to the Klamath Tribes, Chiloquin, Oregon. Clearwater BioStudies, Inc., Canby, Oregon. January 15, 2006.

Hurst, C. N., R. A. Hold, and J. L. Bartholomew. 2011. Dam removal and implications for fish health: *Ceratomyxa shasta* in the Williamson River, Oregon, USA. North American Journal of Fisheries Management 32: 14–23.

Huyer, A., P. A. Wheeler, P. T. Strub, R. L. Smith, R. Letelier, and P. M. Kosro. 2007. The Newport line off Oregon-studies in the north east Pacific. Progress in Oceanography 75: 126–160.

ISAB (Independent Scientific Advisory Board). 2007. Climate change impacts on Columbia River basin fish and wildlife. ISAB Climate Change Report 2007-2. Prepared by ISAB, Portland, Oregon for Northwest Power and Conservation Council, Columbia River Basin Indian Tribes, and National Marine Fisheries Service, Portland, Oregon.

ISRP (Independent Scientific Review Panel). 2005. The Current Risk of Extinction of the Lost River and Shortnose Suckers. Cascade Quality Solutions, Natural Resource Mediation and Facilitation, Klamath Falls, Oregon. 230p.

Isbell, C. 2018. Fire Ecologist, United States Forest Service, Klamath National Forest, Yreka, California. Personal communication with Jennifer Jones, The Renewal Corporation, March 19, 2018.

Janik, A. J., D. F. Markle, J. R. Heidel, and M. L. Kent. 2018. Histopathology and external examination of heavily parasitized Lost River sucker Deltistes luxatus (Cope 1879) and shortnose sucker Chasmistes brevirostris (Cope 1879) from Upper Klamath Lake, Oregon. Journal of Fish Diseases 2018:1–13.

Janney, E., USGS, pers. comm., May 11, 2018

Janney, E. and D. Hewitt, USGS, pers. comm., 16 August 2018

Janney, E. C., B. S. Hayes, D. A. Hewitt, P. M. Barry, A. Scott, J. Koller, M. Johnson, and G. Blackwood. 2009. Demographics and 2008 run timing of adult Lost River (*Deltistes luxatus*) and shortnose (*Chasmistes brevirostris*) suckers in Upper Klamath Lake, Oregon, 2008. U.S. Geological Survey, Reston, Virginia.

Janney, E. C., R. S. Shively, B. S. Hayes, P. M. Barry, and D. Perkins. 2008. Demographic Analysis of Lost River Sucker and Shortnose Sucker Populations in Upper Klamath Lake, Oregon. Transactions of the American Fisheries Society 137:1812-1825.

Jassby, A., and J. Kann. 2010. Upper Klamath Lake monitoring program: preliminary analysis of status and trends for 1990-2009. Technical Memorandum prepared by Aquatic Ecosystem Sciences LLC for The Klamath Tribes Natural Resources Department, Chiloquin Oregon. 55 pp.

Jefferson, A., E. G. Gordon, and S. L. Lewis. 2007. A river runs underneath it: geological control of spring and channel systems and management implications, Cascade Range, Oregon. Advancing the fundamental sciences. Proceedings of the Forest Service National Earth Sciences Conference, San Diego, California.

Jetter, C.N. and W.R Chesney. 2016. Shasta and Scott River Outmigration Study, 2016 Report. California Department of Fish and Wildlife Anadromous Fisheries Resource Assessment and Monitoring Program. August 2016

Johnson, D. M., R. R. Petersen, D. R. Lycan, J. W. Sweet, M. E. Neuhaus, and A. L. Schaedel, 1985. Atlas of Oregon Lakes. Oregon State University Press, Corvallis, Oregon. 317 pp.

Johnson, S. L., M. F. Solazzi, and T. E. Nickelson. 1990. Effects on survival and homing of trucking hatchery yearling coho salmon to release sites. North American Journal Fish Management 10: 427–433.

Jong, H.W. 1997. Evaluation of Chinook spawning habitat quality in the Shasta and South Fork Trinity River, 1994. Inland Fisheries Administrative Reports. 97.

Kann, J. 1993. Chapter 3: limnological trends in Agency Lake, Oregon-1992. Pages 91–98 *in* S. G. Campbell, editor. Environmental research in the Klamath Basin, Oregon, 1992 Annual Report R-93-16. Applied Sciences Branch, Research and Laboratory Services Division, U.S. Department of Interior, Bureau of Reclamation, Denver, Colorado.

Kann, J. 2006. *Microcystis aeruginosa* occurrence in the Klamath River system of southern Oregon and northern California. Technical Memorandum.

Kann, J. 2008. Microcystin bioaccumulation in Klamath River fish and freshwater mussel tissue: preliminary 2007 results. Technical Memorandum. Prepared by Aquatic Ecosystem Sciences, LLC, Ashland, Oregon for the Karuk Tribe of California, Orleans, California.

Kann, J. 2010. Compilation of Klamath Tribes upper Klamath Lake water quality data, 1990–2009. Prepared by Aquatic Ecosystem Sciences, LLC, Ashland, Oregon for the Klamath Tribes Natural Resources Department, Chiloquin, Oregon.

Kann, J. 2017. Upper Klamath Lake 2016 data summary report. Prepared by Aquatic Ecosystem Sciences, LLC, Ashland, Oregon for the Klamath Tribes Natural Resources Department, Chiloquin, Oregon.

Kann, J., and S. Corum. 2009. Toxigenic *Microcystis aeruginosa* bloom dynamics and cell density/ chlorophyll-a relationships with microcystin toxin in the Klamath River, 2005–2008. Technical Memorandum. Prepared by Aquatic Ecosystem Sciences, LLC, Ashland, Oregon and the Karuk Tribe Department of Natural Resources for the Karuk Tribe Department of Natural Resources, Orleans, California.

Kann, J., and W. W. Walker. 1999. Nutrient and hydrologic loading to Upper Klamath Lake, Oregon, 1991–1998. Draft report. Prepared by Aquatic Ecosystem Sciences, LLC, Ashland, Oregon for the Klamath Tribes Natural Resources Department, U.S. Bureau of Reclamation Cooperative Studies.

Kann, J., L. Bowater, G. Johnson, and C. Bowman. 2011. Preliminary 2010 microcystin bioaccumulation results for Klamath River salmonids. Technical Memorandum. Prepared by Aquatic Ecosystem Sciences LLC for the Karuk Tribe Department of Natural Resources, Orleans California.

Karuk Tribe of California. 2001. Karuk aboriginal territories Indian Creek and Elk Creek water quality monitoring report for the fall 2000 monitoring period. Prepared by the Karuk Tribe of California, Department of Natural Resources, Orleans, California.

Karuk Tribe of California. 2002. Water quality monitoring report, Water Year 2000 and 2001. Karuk Tribe of California, Water Resources, Department of Natural Resources, Orleans, California.

Karuk Tribe of California. 2003. Water quality monitoring report, Water Year 2002. Karuk Tribe of California, Water Resources, Department of Natural Resources, Orleans, California.

Karuk Tribe of California. 2007. 2007 Water quality assessment report for Klamath River, Salmon River, Scott River, Shasta River, Ti-Bar Creek, and Irving Creek. Prepared by Karuk Tribe of California, Water Resources, Department of Natural Resources, Orleans, California.

Karuk Tribe of California. 2009. 2008 Water quality assessment report for Klamath River, Salmon River, Scott River, Shasta River, and Bluff Creek. Prepared by Karuk Tribe of California, Water Quality, Department of Natural Resources, Orleans, California.

Karuk Tribe of California. 2010. Water quality report for the mid-Klamath, Salmon, Scott, and Shasta rivers: May-December 2009. Prepared by Karuk Tribe of California, Water Quality Program, Department of Natural Resources, Orleans, California.

Karuk Tribe of California. 2013. Water quality assessment report: Klamath River, Salmon River, Scott River, Shasta River, and Camp Creek. Prepared by Karuk Tribe of California, Water Quality, Department of Natural Resources, Orleans, California.

Kastelein, R. A., J. Kershaw, E. Berghout, and P. R. Wiepkema. 2003. Food consumption and suckling in killer whales Orcinus orca at Marineland Antibes. International Zoo Yearbook 38: 204–218.

Kier, M. C., J. Hileman, and K. Lindke. 2019. Annual Report – Trinity River Basin Salmon and Steelhead Monitoring Project: Chinook and Coho Salmon and Fall-run Steelhead Run-size Estimates Using Mark-Recapture Methods: 2018-19 Season. California Department of Fish and Wildlife, Northern Region, Klamath-Trinity Program.

Kiewit. 2020. Klamath River Renewal Project 100% Design Report and Plans.

Kinziger, A. P., M. Hellmair, and D. G. Hankin. 2008. Genetic structure of Chinook salmon (*Oncorhynchus tshawytscha*) in the Klamath-Trinity Basin: implications for within-basin genetic stock identification. Hoopa Valley Tribal Fisheries Department and Humboldt State University, Department of Fisheries Biology, Arcata, California.

Kirk, S., D. Turner, and J. Crown. 2010. Upper Klamath and Lost River subbasins total maximum daily load (TMDL) and water quality management plan (WQMP). Oregon Department of Environmental Quality, Bend, Oregon.

Kjelland, M.E., C.M. Woodley, T.M. Swannack, and D.L. Smith. 2015. A review of the potential effects of suspended sediment on fishes: potential dredging-related physiological, behavioral, and transgenerational implications. Environ Syst Decis 35:334-350.

Klamath Tribes. 1996. A synopsis of the early life history and ecology 451ditors451idsids, with a focus on the Williamson River Delta. Unpublished manuscript. Natural Resources Department, Chiloquin, Oregon.

Kluber, Matt. 2017. Green Diamond Resource Company. Personal communications with Renewal Corporation Representatives. October 10, 2017.

Knechtle, M., and D. Giudice. 2018. 2017 Bogus Creek Salmon Studies – Final Report. Prepared for California Department of Fish and Wildlife. August 28, 2018. 22 pp.

Knechtle, M., and D. Giudice. 2019. 2018 Scott River Salmon Studies – Final Report. Prepared for California Department of Fish and Wildlife. April 30, 2019. 26 pp.

Koch, D. L., and G. P. Contreras. 1973. Preliminary survey of the fishes of the Lost River system including Lower Klamath Lake and Klamath Strait drain with special reference to the shortnose (*Chasmistes brevirostris*) and Lost River suckers (*Catostomus luxatus*). Center for Water Resources Research, Desert Research Institute, University of Nevada, Reno, Nevada.

Koford, C.B. 1953. The California condor. National Audubon Society, New York, NY. 154 pp. Kope, R. 2005. Performance of ocean salmon fisheries management relative to National Marine Fisheries Service Endangered Species Act consultation standards. National Marine Fisheries Service, Northwest Fisheries Science Center.

Korson, C. 2010. Miller Hill Pumping Plant Entrainment Monitoring, 2008. U.S. Bureau of Reclamation, Klamath Basin Area Office, Klamath Falls, Oregon. 19 pp.

Korson, C., and C. Kyger. 2012. Klamath Project: A Canal Endangered Sucker Monitoring, 2011. U.S. Bureau of Reclamation, Klamath Basin Area Office. June 2012. 21 pp.

Korson, C., A. Wilkens, and D. Taylor. 2011. Klamath Project: A Canal Endangered Sucker Monitoring, 2010. U.S. Bureau of Reclamation, Klamath Basin Area Office, Klamath Falls, Oregon. 19 pp.

Kostow, K. E., A. R. Marshall, and S. R. Phelps. 2003. Naturally spawning hatchery steelhead contribute to smolt production but experience low reproductive success. Transactions of the American Fisheries Society 132: 780–790.

Kostow, K. E., and S. Zhou. 2006. The effect of an introduced summer steelhead hatchery stock on the productivity of a wild winter steelhead population. Transactions of the American Fisheries Society 135: 825–841.

KP (Knight Piésold Ltd.) and RES. 2019. Klamath River Renewal Project 60% Design Report. February 2019.

KP. 2020. Memorandum VA20-01512, Drawdown Model – KBRA Inflows for USBR.

Krahn, M. M., P. R. Wade, S. T. Kalinowski, M. E. Dahlheim, B. L. Taylor, M. B. Hanson, G. M. Ylitalo, R. P. Angliss, J. E. Stein, and R. S. Waples. 2002. Status review of Southern Resident killer whales (*Orcinus orca*) under the Endangered Species Act. NOAA Technical Memorandum NMFS-NWFSC- 54, U.S. Department of Commerce, Seattle, Washington.

Krahn, M. M., M. B. Hanson, G.S. Schorr, C.K. Emmons, D.G. Burrows, J.L. Bolton, R.W. Baird, and G.M. Ylitalo. 2009. Effects of age, sex and reproductive status on persistent organic pollution concentrations in “Southern Resident” killer whales. Marine Pollution Bulletin 58: 1522–1529. doi: 10.1016/j.marpolbul.2009.05.014.

KRTT (Klamath River Technical Team). 2019. Ocean Abundance Projections and Prospective Harvest Levels for Klamath River Fall Chinook, 2019 Season. 31 pp.

Kupferberg, S.J. 1996. Hydrologic and geomorphic factors affecting conservation of a river-breeding frog (*Rana Boylii*). Ecological Applications 6(4): 1332-1344.

Kupferberg, S.J., A.J. Lind, V. Thill, and S.M. Yarnell. 2011. Water velocity tolerance in tadpoles of the foothill yellow-legged frog (*Rana boylii*): Swimming performance, growth, and survival. Copeia 1: 141-152.

Kupferberg, S.J., W.J. Palen, A.J. Lind, S. Bobzien, A. Catenazzi, J. Drennan, and M.E. Power. 2012. Effects of flow regimes altered by dams on survival, population declines, and range-wide losses of California river-breeding frogs. Copeia 26(3): 513-524.

Kyger, C., and A. Wilkens. 2011. Endangered Lost River and shortnose sucker distribution and relative abundance in Lake Ewauna, and use of the Link River Dam fish ladder, Oregon. Annual report 2010. USDI Bureau of Reclamation, Mid-Pacific Region, Klamath Basin Area Office, Klamath Falls, Oregon.

Kyger, C., and A. Wilkens. 2012. Demographic Analysis of Adult Lost River and Shortnose Suckers in Lake Ewauna, and Use of the Link River Dam Fish ladder, Oregon 2008 to 2011.

Lacy, R. C., R. Williams, E. Ashe, Kenneth C. Balcomb III, L. J. N. Brent, C. W. Clark, D. P. Croft, D. A. Giles, M. MacDuffee, and P. C. Paquet. 2017. Evaluating anthropogenic threats to endangered killer whales to inform effective recovery plans. Scientific Reports. 7(1): 1-12.

Lafferty, K. D., C. C. Swift, and R. F. Ambrose. 1999. Postflood persistence and recolonization of endangered tidewater goby populations. North American Journal of Fisheries Management 19: 618–622.

LaHaye, W. S. 1988. Nest site selection and nesting habitat of the northern spotted owl (*Strix occidentalis caurina*) in northwestern California. Master's thesis. Humboldt State University, Arcata, California.

Larson, R., and B. J. Brush. 2010. Upper Klamath Basin wetlands: an assessment. Poster. Klamath Basin Science Conference, Klamath Basin Aquatic Ecosystems, 1 February–5 February 2010. U.S. Fish and Wildlife Service, Klamath Falls, Oregon.

Larson, Z. S., and M. R. Belchik. 1998. A preliminary status review of eulachon and Pacific lamprey in the Klamath River Basin. Yurok Tribal Fisheries Program, Klamath, CA.

Lawler J. J., and M. Mathias. 2007. Climate Change and the Future of Biodiversity in Washington. Report prepared for the Washington Biodiversity Council.

Leeseberg, C. A., P. M. Barry, G. Whisler, and E. Janney. 2007. Monitoring of Lost River (*Deltisies luxatus*) and shortnose (*Chasmistes brevirostris*) suckers in Gerber and Clear Lake reservoirs. Annual Report, 2004. U.S. Geological Survey, Western Fisheries Research Center, Klamath Falls Field Station.

Leonard, W. P., H.A. Brown, L.L.C. Jones, K.R. McAllister, and R.M. Storm. 1993. Amphibians of Washington and Oregon. Seattle Audubon Society, Seattle, Washington. 168 pp.

Lerum, L. 2012. Site Management Plan for Oregon spotted frog (*Rana pretiosa*) Buck Lake Complex, Klamath County, Oregon. Prepared for USDA-Fremont-Winema National Forest, Klamath Ranger District, Klamath Falls, Oregon. 24 pp.

Leskiw, T., and R. J. Gutiérrez. 1998. Possible predation of a spotted owl by a barred owl. Western Birds 29: 225–226.

Licht, L.E. 1971. Breeding habits and embryonic thermal requirements of the frogs *Rana aurora aurora* and *Rana pretiosa pretiosa* in the Pacific Northwest. Ecology 52:116– 124.

Licht, L.E. 1974. Survival of embryos, tadpoles, and adults of the frogs *Rana aurora aurora* and *Rana pretiosa pretiosa* sympatric in southwestern British Columbia. Canadian Journal of Zoology 52:613–627.Liermann, Martin, George Pess, Mike McHenry, John McMillan, Mel Elofson, Todd Bennett, and Raymond Moses. 2017. Relocation and Recolonization of Coho Salmon in Two Tributaries to the Elwha River: Implications for Management and Monitoring, Transactions of the American Fisheries Society, 146:5, 955-966, DOI: 10.1080/00028487.2017.1317664

Lind, A.J., H.H. Welsh, and R. Wilson. 1996. The effects of a dam on breeding habitat and egg survival of the foothill yellow-legged frog (*Rana boylii*) in Northwestern California. Herpetological Review 27(2): 62-67.

Lind, A.J., H.H. Welsh, and C.A. Wheeler. 2016. Foothill yellow-legged frog (*Rana boylii*) oviposition site choice at multiple spatial scales. Journal of Herpetology 50(2): 263-270.

Lindley, S. T., and H. Davis. 2011, draft. Using model selection and model averaging to predict the response of Chinook salmon to dam removal. Review Draft Report. National Marine Fisheries Service, Fisheries Ecology Division, NOAA Fisheries Service Southwest Fisheries Science Center, Santa Cruz, California.

Lindley, S. T., C. B. Grimes, M. S. Mohr, W. Peterson, J. Stein, J. T. Anderson, L. W. Botsford, D. L. Bottom, C. A. Busack, T. K. Collier, J. Ferguson, J. C. Garza, A. M. Grover, D. G. Hankin, R. G. Kope, P. W. Lawson, A. Low, R. B. MacFarlane, K. Moore, M. Palmer-Zwahlen, F. B. Schwing, J. Smith, C. Tracy, R. Webb, B. K. Well, and T. H. Williams. 2009. What caused the Sacramento River fall Chinook stock collapse? Pre-publication report to the Pacific Fishery Management Council, submitted on March 18, 2009.

Lindley, S. T., R. S. Schick, E. Mora, P. B. Adams, J. J. Anderson, S. Greene, C. Hanson, B. May, D. McEwan, R. B. MacFarlane, C. Swanson, and J. G. Williams. 2007. Framework for assessing viability of threatened and endangered Chinook salmon and steelhead in the Sacramento-San Joaquin Basin. San Francisco Estuary and Watershed Science 5(1): article 4.

Lindley, S. T., M. L. Moser, D. L. Erickson, M. Belchik, D. W. Welch, E. Rechisky, J. T. Kelly, J. Heublein, and A. P. Klimley. 2008. Marine migration of North American green sturgeon. Trans. Am. Fish. Soc. 137:182-194.

Lindley, S. T., D. L. Erickson, M. L. Moser, G. Williams, O. P. Langness, B. W. McCovey, M. Belchik, D. Vogel, W. Pinnix, J. T. Kelly, J. C. Heublein, and A. P. Klimley. 2011. Electronic tagging of green sturgeon reveals population structure and movement among estuaries. Trans. Am. Fish. Soc. 140:108-122.

Loftus, M. E. 2001. Assessment of potential water quality stress to fish: supplement to Effects of water quality and lake levle on the biology and habitat of selected fish species in Upper Klamath Lake. Portland, Oregon.

Lom, J. and Dyková, I. 1992. Protozoan parasites of fishes. Developments in aquaculture and fisheries science, Elsevier, Amsterdam.

Lowe, J. P., R. D. Cooper-Caroselli, L. S. Brophy, and R. N. Fuller. 2018. Coastal Resource Planning within the Klamath River Estuary, Task 3 (Spit Assessment): Summary Report. Prepared for the Yurok Tribe, Klamath, California, USA. Estuary Technical Group, Institute for Applied Ecology, Corvallis, Oregon, USA.

Magneson, M., and S. A. Gough. 2006. Mainstem Klamath River coho salmon redd surveys 2001 to 2005. Arcata fisheries data series report DS 2006-7. Prepared by U.S. Fish and Wildlife Service, Arcata Fish and Wildlife Office, Arcata, California.

Major, J.J., J.E. O'Connor, C.J. Podolak, M.K. Keith, G.E. Grant, K.R. Spicer, S. Pittman, H.M. Bragg, J.R. Wallick, D.Q., Tanner, and A. Rhode. 2012. Geomorphic response of the Sandy River, Oregon, to removal of Marmot Dam (p. 64). Reston, VA: US Geological Survey.

Manhard, C. V., N. A. Som, R. W. Perry, J. R. Faukner, and T. Soto. 2018. Estimating freshwater productivity, overwinter survival, and migration patterns of Klamath River Coho Salmon. U.S. Fish and Wildlife Service. Arcata Fish and Wildlife Office, Arcata Fisheries Technical Report Number TR 2018-33, Arcata, California.

McHenry, M., G. Pess, J. Anderson, and H. Hugunin. 2017. Spatial distribution of Chinook Salmon (Oncorhynchus tshawytscha) spawning in the Elwha River, Washington State during dam removal and early stages of recolonization (2012-2016).

Meneks, M. 2018. 2017 Fall Chinook Salmon Spawning Ground Survey. Salmon-Scott Rivers Range District Klamath National Forest. 52 p.

Magneson, M. and K. Wright. 2010. Mainstem Klamath River Fall Chinook Salmon Redd Survey 2009. U. S. Fish and Wildlife Service, Arcata Fish and Wildlife Office, Arcata Fisheries Data Series Report Number DS 2010-19, Arcata, California.

Manga, M. 1999. On the timescales characterizing groundwater discharge at springs. Journal of Hydrology 219: 56–69.

Mantua, N. J., and S. R. Hare. 2002. The Pacific decadal oscillation. Journal of Oceanography 58: 35–44.

Markle, D. F., and K. Clausen. 2006. Ontogenetic and Habitat-Related Changes in Diet of Late Larval and Juvenile Suckers (*Catostomidae*) in Upper Klamath Lake, Oregon. Western North American Naturalist 66: 492-501.

Markle, D. F., S.A. Reithel, J. Crandall, T. Wood, T.J. Tyler, M. Terwilliger, and D.C. Simon. 2009. Larval Fish Transport and Retention and the Importance of Location for Juvenile Fish Recruitment in Upper Klamath Lake, Oregon. Transactions of the American Fisheries Society 138:328–347.

Martin, B., K. Echols, K. Feltz, D. G. Elliot, C. M. Conway. 2015. Effects of microcystins on juvenile Lost River suckers. Conference paper, American Fisheries Society 145th Annual Meeting, August 2015, Portland Oregon. Available online at: https://afs.confex.com/afs/2015/webprogram/Paper 19806.html.

Matkin, C. O., D. R. Matkin, G. M. Ellis, E. Saulitis, and D. McSweeney. 1997. Movements of resident killer whales in southeastern Alaska and Prince William Sound, Alaska. Marine Mammal Science 13: 469–475.

Maule, A.G., S.P. VanderKooi, J. Hamilton, R.W. Stocking, and J.L. Bartholomew. 2009. Physiological development and vulnerability to Ceratomyxa shasta in the upper Klamath River Watershed. North American Journal of Fisheries Management 29, 1743-1756.

May C., C. Luce, J. Casola, M. Chang, J. Cuhaciyan, M. Dalton, S. Lowe, G. Morishima, P. Mote, A. Petersen, G. Roesch-McNally, and E. York. 2018. Northwest. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 1036–1100. doi: 10.7930/NCA4.2018.CH24

Mayer, T. 2008. Analysis of trends and changes in Upper Klamath Lake hydroclimatology. United States Fish and Wildlife Service, Water Resources Branch, Portland, Oregon.

Mayer, T. D., and S. W. Naman. 2011. Streamflow response to climate in the Klamath Basin as influenced by geology and topography. Journal of American Water Resources: 1-15

McAllister, K.R., and W.P. Leonard. 1997. Washington State status report for the Oregon spotted frog. Washington Department of Fish and Wildlife, Olympia. 38 pp.

McAllister, K.R., and W.P. Leonard, and R.M Storm 1993. Spotted frog (*Rana pretiosa*) surveys in the Puget Trough of Washington, 1989-1991. Northwestern Naturalist 74:10-15.

McCovey, B. 2011. Eulachon project capture information. Yurok Tribal Fisheries Program.

McCovey, B., Jr. 2012. Yurok Tribe Studies of Eulachon Smelt in the Klamath River Basin, California. Progress Report, November 1, 2011, to April 30, 2012, NOAA Grant # NA10NMF4720374. 5 pp.

McCovey, B., Jr., and L. Walker. 2013. Yurok Tribe Studies of Eulachon Smelt in the Klamath River Basin, California. Progress Report, November 1, 2012, to April 30, 2013, NOAA Grant # NA10NMF4720374. 8 pp.

McCullough, D. A. 1999. A review and synthesis of effects of alterations to the water temperature regime of freshwater life stages of salmonids, with special reference to Chinook salmon. Columbia River Inter-Tribal Fish Commission.

McElhany, P., M. H. Ruckelshaus, M. J. Ford, T. C. Wainwright, and E. P. Bjorkstedt. 2000. Viable salmonid populations and the recovery of evolutionarily significant units. NOAA Technical Memorandum NMFS-NWFSC-42. National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle, Washington.

McMichael, G. A., C. S. Sharpe, and T. N. Pearsons. 1997. Effects of residual hatchery-reared steelhead on growth of wild rainbow trout and spring chinook salmon. Transactions of the American Fisheries Society. 126(2): 230-239.

McMillen-Jacobs Associates. 2020. Email from Mort McMillen dated March 6, 2020 to The Renewal Corporation and The Renewal Corporation Technical Representatives.

McPhail, J. D., and J. S. Baxter. 1996. A review of bull trout (*Salvelinus confluentus*) life-history and habitat use in relation to compensation and improvement opportunities. Fisheries Management Report No. 104. University of British Columbia, Department of Zoology, Vancouver.

Meretsky, V.J., and N.F.R. Snyder. 1992. Range use and movements of California condors. Condor 94:313–335.

Meyer, J. S., and J. A. Hansen. 2002. Subchronic toxicity of low dissolved oxygen concentrations, elevated pH, and elevated ammonia concentrations to Lost River suckers. Transactions of the American Fisheries Society 131:656–666.

Miller, M. A., R. M. Kudela, A. Mekebri, D. Crane, S. C. Oates, et al. 2010. Evidence for a novel marine harmful algal bloom: cyanotoxin (microcystin) transfer from land to sea otters. PLoS ONE 5: e12576. doi:10.1371/journal.pone.0012576.

Miller, R. R., and G. R. Smith. 1981. Distribution and Evolution of Chasmistes (Pisces: Catostomidae) in Western North America. Occasional Papers of the Museum of Zoology, University of Michigan, Ann Arbor. 696:1-46.

Mohr, M.S. 2006. The cohort reconstruction model for Klamath River Fall Chinook salmon. National Marine Fisheries Service, Santa Cruz, CA, USA.

Montgomery, D. R., and J. M. Buffington. 1997. Channel-reach morphology in mountain drainage basins. Geological Society of America Bulletin 109: 596–611.

Moody, J. A., and D. A. Martin. 2009. Synthesis of sediment yields after wildland fire in different rainfall regimes in the United States. International Journal of Wildland Fire 18: 96-115.

Moore, T. 2006. Distribution and abundance of bull trout and redband trout in Leonard and Deming Creeks, July and August, 2005. Interim Report. Oregon Department of Fish and Wildlife, Corvallis, Oregon.

Moore, K. A., R. L. Wetzel, and R. J. Orth 1997. Seasonal pulses of turbidity and their relations to eelgrass (*Zostera marina* L.) survival in an estuary. Journal of Experimental Marine Biology and Ecology 215: 115–134.

Mora, E. A. 2016. A Confluence of Sturgeon Migration: Adult Abundance and Juvenile Survival. PhD Dissertation, Univ. Calif., Davis.

Morace, J. L. 2007. Relation between selected water-quality variables, climatic factors, and lake levels in Upper Klamath and Agency Lakes, Oregon, 1990–2006. U.S. Geological Survey Scientific Investigations Report 2007-5117. Available online at: http://pubs.water.usgs.gov/sir20075117.

Morris, J.M., E. Snyder-Conn, J.S. Foott, R.A. Holt, M.J. Suedkamp, H.M. Lease, S.J. Carpenter, and J.S. Meyer. 2006. Survival of Lost River Sucker (Deltistes luxatus) Challenged with Flavobacterium columnare During Exposure to Sublethal Ammonia Concentrations at pH 9.5. Archives of Environmental Contamination and Toxicology 50:256-263.

Moser, M., and S. Lindley. 2007. Use of Washington estuaries by subadult and adult green sturgeon. Environmental Biology of Fishes DOI 10 1007/sl0641-006-9028-1.

Mote, P. W., E. A. Parson, A. F. Hamlet, W. S. Keeton, D. Lettenmaier, N. Mantua, E. L. Miles, D. W. Peterson, D. L. Peterson, R. Slaughter, and A. K. Snover. 2003. Preparing for climatic change: the water, salmon, and forests of the Pacific Northwest. Climatic Change 61: 45–88.

Mote, P. W., A. F. Hamlet, M. P. Clark, and D. P. Lettenmaier. 2005. Declining snowpack in western North America. Bulletin of the American Meteorological Society 2005: 39–49.

Mote, P. W., A. K. Snover, S. Capalbo, S. D. Eigenbrode, P. Glick, J. Littell, R. Raymondi, and S. Reeder, 2014: Ch. 21: Northwest. Climate Change Impacts in the United States: The Third National Climate Assessment, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 487-513. doi:10.7930/J04Q7RWX.

Mote, P. W., J. Abatzoglou, K. D. Dello, K. Hegewisch, and D. E. Rupp. 2019. Fourth Oregon Climate Assessment Report. Oregon Climate Change Research Institute. occri.net/ocar4.

Moyle, P. B. 2002. Inland fishes of California. Revised edition. University of California Press, Berkeley.

Moyle, P. B., P. J. Foley, and R. M. Yoshiyama. 1992. Status of green sturgeon, Acipenser medirostris, in California. Final report. Prepared by University of California, Davis for National Marine Fisheries Service.

Moyle, P. B., R. M. Yoshiyama, J. E. Williams, and E. D. Wikramanayake. 1995. Eulachon. Pages 123–127 *in* Fish species of special concern in California. Prepared by Department of Wildlife and Fisheries Biology, University of California, Davis for California Department of Fish and Game, Inland Fisheries Division, Rancho Cordova.

Moyle, P. B., J. A. Isreal, and S. E. Purdy. 2008. Salmon, steelhead, and trout in California: status of an emblematic fauna. Prepared for California Trout by University of California Davis, Center for Watershed Sciences.

Moyle P. B., J. D. Kiernan, P. K. Crain, R. M. Quiñones. 2013. Climate Change Vulnerability of Native and Alien Freshwater Fishes of California: A Systematic Assessment Approach. PLoS ONE 8(5): e63883. Available online at: https://doi.org/10.1371/journal.pone.0063883.

Myers, J. M., R. G. Kope, T. D. Bryant, L. J. Lierheimer, T. C. Wainwright, W. S Grant, F.W. Waknitz, K. Neely, S. T. Lindley, and R. S. Waples. 1998. Status review of chinook salmon from Washington, Idaho, Oregon, and California. NMFS-NWFSC-35. National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle, Washington.

NCRWQCB (North Coast Regional Water Quality Control Board). 2010a. Klamath River total maximum daily loads (TMDLs) addressing temperature, dissolved oxygen, nutrient, and microcystin impairments in California, the proposed site-specific dissolved oxygen objectives for the Klamath River in California, and the Klamath River and Lost River implementation plans. Final Staff Report. North Coast Regional Water Quality Control Board, Santa Rosa, California.

NCRWQCB. 2010b. Action plan for the Klamath River total maximum daily loads addressing.

Neary, D. G., K.C. Ryan, and L.F. DeBano, editors. 2005. Wildland fire in ecosystems: effects on soils and water. Gen. Tech. Rep. RMRS-GTR-42-vol 4. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, Utah.

Newcombe, C. P., and D. D. MacDonald. 1991. Effects of suspended sediments on aquatic ecosystems. North American Journal of Fisheries Management 11: 72–82.

Newcombe, C. P., and J. O. T. Jensen. 1996. Channel suspended sediment and fisheries: a synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management 16: 693-727.

Nielsen J.M., J. Kann, M.T. Brett. 2017. Phase II report- combined analyses of water quality and plankton dynamics of Upper Klamath Lake. Prepared for The Klamath Tribes Natural Resources Department, Chiloquin, OR.

Nishiwaki, M. 1972. General biology. Pages 3–204 *in* S. H. Ridgway, editor. Mammals of the sea: biology and medicine. Thomas, Springfield, Illinois.

Nishiwaki, M., and C. Handa. 1958. Killer whales caught in the coastal waters off Japan for recent 10 years. Scientific Reports of the Whales Research Institute 13: 85–96.

NMFS (National Marine Fisheries Service). 1997. Endangered and threatened species: threatened status for southern Oregon/northern California coast evolutionarily significant unit (ESU) of coho salmon. Federal Register 62: 24588-24609.

NMFS. 1999a. Designated critical habitat; central California Coast and Southern Oregon/Northern California Coast coho salmon. Federal Register 64: 24049-24062.

NMFS. 1999b. Status review update for deferred ESUs of west coast Chinook salmon (*Oncorhynchus tshawytscha*) from Washington, Oregon, California, and Idaho. Report of West Coast Biological Review Team to NOAA Fisheries Service, Seattle, Washington. Available online at: http://www.nwr.noaa.gov/Publications/Biological-Status-Reviews/loader.cfm?csModule=security/getfile&pageid=21676.

NMFS. 2000. Guidelines for Electrofishing Waters Containing Salmonids Listed Under the Endangered Species Act. June. 5 pp.

NMFS. 2001. Status review update for coho salmon (*Oncorhynchus kisutch*) from the Central California Coast and the California portion of the Southern Oregon/Northern California Coasts evolutionarily significant units. 12 April revised version. NMFS, Southwest Fisheries Science Center, Santa Cruz, California.

NMFS. 2002. Biological opinion for the Klamath Project operations. Consultation conducted by National Marine Fisheries Service, Southwest Region, Arcata, California.

NMFS. 2003. Biological opinion for the continued maintenance of weir ponds and proposed fish passage improvement at monitoring facilities located on North Fork Caspar Creek and South Fork Caspar Creek, NMFS. 2006. Endangered and Threatened Species: Endangered and Threatened Wildlife and Plants: Threatened Status for Southern Distinct Population Segment of North American Green Sturgeon. April 7, 2006. Federal Register 71 FR 17757.

NMFS. 2007a. Recovery plan. Magnuson-Stevens Reauthorization Act Klamath River coho salmon recovery plan, Southwest Fisheries Science Center, Santa Cruz, California

NMFS. 2007b. National Marine Fisheries Service modified prescriptions for fishways and alternatives analysis for the Klamath Hydroelectric Project (FERC Project No. 2082).

NMFS. 2008a. Species of concern: green sturgeon (*Acipenser medirostris*), Northern DPS. NMFS, Office of Protected Resources, Species of Concern Program, Silver Spring, Maryland.

NMFS. 2008c. Recovery plan for Southern resident killer whales (*Orcinus orca*). Prepared by NMFS, Northwest Regional Office, Seattle, Washington.

NMFS. 2009. Klamath River Basin: 2009 Report to Congress. Prepared by NMFS, Arcata, California.

NMFS. 2010a. Biological opinion for operation of the Klamath Project between 2010 and 2018. Consultation conducted by National Marine Fisheries Service, Southwest Region, Arcata, California. File number: 151422SWR2008AR00148.

NMFS. 2010b. Ocean ecosystem indicators 2009. National Oceanic and Atmospheric Administration Available online at: http://www.nwfsc.noaa.gov/research/divisions/fed/oeip/b-latestupdates.cfm.

NMFS. 2010c. Five-year review of Pacific coast salmon essential fish habitat. Draft report. Prepared by NMFS, Northwest Regional Office, and the Pacific Fishery Management Council.

NMFS. 2010d. Status review update for eulachon in Washington, Oregon, and California. NMFS Northwest Fisheries Science Center. Seattle, Washington.

NMFS. 2010e. Endangered and threatened wildlife and plants: Threatened status for southern distinct population segment of eulachon. Federal Register 75(52), 13012–13024. Available online at: http://www.gpo.gov/fdsys/pkg/FR-2010-03-18/pdf/2010-5996.pdf.

NMFS. 2011. Office of Protected Resources species information. Website. NOAA Fisheries, Office of Protected Resources, Silver Spring, Maryland. Available online at: http://www.nmfs.noaa.gov/pr/species/.

NMFS. 2012. Biological Opinion on the Proposed Issuance of an Incidental Take Permit to PacifiCorp Energy for Implementation of the PacifiCorp Klamath Hydroelectric Project Interim Operations Habitat Conservation Plan for Coho Salmon. Conducted By: National Marine Fisheries Service Southwest Region, February 22, 2012.

NMFS. 2013. Biennial Report to Congress on the Recovery Program for Threatened and Endangered Species. October 1, 2010 – September 30, 2012. National Marine Fisheries Service. Silver Spring, Maryland. 28 pp.

NMFS. 2014. Final Recovery Plan for the Southern Oregon/Northern California Coast Evolutionarily Significant Unit of Coho Salmon (*Oncorhynchus kisutch*). National Marine Fisheries Service. Arcata, CA.

NMFS. 2015a. 12-Month Finding on a Petition To Revise the Critical Habitat Designation for the Southern Resident Killer Whale Distinct Population Segment. Federal Register 80 FR 9682. February 24, 2015.

NMFS. 2015b. Southern Distinct Population Segment of the North American Green Sturgeon (Acipenser medirostris) 5-Year Review: Summary and Evaluation. West Coast Region, Long Beach, California.

NMFS. 2016a. Recovery Plan for Oregon Coast Coho Salmon Evolutionarily Significant Unit. National Marine Fisheries Service, West Coast Region, Portland, Oregon.

NMFS. 2016b. Southern Resident Killer Whales (*Orcinus orca*) 5-Year Review: Summary and Evaluation. National Marine Fisheries Service, West Coast Region, Seattle, WA, 98115.

NMFS. 2017. Recovery Plan for the Southern Distinct Population Segment of Eulachon (*Thaleichthys pacificus*). National Marine Fisheries Service, West Coast Region, Protected Resources Division, Portland, Oregon, 97232.

NMFS. 2018a. Species Directory. Killer Whale Overview. Available online at: https://www.fisheries.noaa.gov/species/killer-whale. Accessed August 14, 2018.

NMFS. 2018b. Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response Consultation on effects of the 2018-2027 *U.S. v. Oregon* Management Agreement. NMFS Consultation Number: WCR-2017-7164.

NMFS. 2018c. Endangered and threatened wildlife; 90-Day Finding on a Petition to List Chinook Salmon in the Upper Klamath-Trinity Rivers Basin as Threatened or Endangered Under the Endangered Species Act. Proposed Rule. February 27, 2018. Federal Register 83: 8410-8414.

NMFS. 2018d. Personal email communication, Joseph Dillon, Water Quality Specialist, NMFS to The Renewal Corporation Technical Representatives. June 14, 2018.

NMFS. 2019a. Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion, and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response, Klamath Project Operations from April 1, 2019 through March 31, 2024. NMFS Consultation Number: WCR-2019-11512, WCRO-2019-00113.

NMFS. 2019b. Proposed Revision of the Critical Habitat Designation for Southern Resident Killer Whales. Draft Biological Report (to accompany the Proposed Rule). September.

NMFS. 2021. Projected Implications of Reduced Klamath River Fall Chinook Salmon Hatchery Production for Ocean Abundance, Southern Resident Killer Whale Prey Availability, and Ocean Harvest. Will Satterthwaite, Southwest Fisheries Science Center. Unpublished report. 3 p.

NMFS and CDFW. 2018. Technical Staff Recommendation for Klamath River Hatchery Operations in California Post-Dam Removal, May 31, 2018, as updated in 2019.NMFS and USFWS (United States Fish and Wildlife Service). 2012. Joint preliminary biological opinion on the proposed removal of four dams on the Klamath River. NMFS Southwest Region and USFWS Region 8.

NMFS and USFWS 2013. Biological Opinions on the Effects of Proposed Klamath Project Operations from May 31, 2013, through March 31, 2023, on Five Federally Listed Threatened and Endangered Species. NMFS file number: SWR-20129372; FWS file number: 08EKLA00-2013-F-0014. May 2013.

NMFS and WDFW (Washington Department of Fish and Wildlife). 2018. Southern Resident Killer Whale Priority Chinook Stocks Report. NOAA Fisheries West Coast Region and Washington Department of Fish and Wildlife. June 22, 2018.

Nelson, P. A., D. Behrens, J. Castle, G. Crawford, R. N. Gaddam, S. C. Hackett, J. Largier, D. P. Lohse, K. L. Mills, P. T. Raimondi, M. Robart, W. J. Sydeman, S. A. Thompson, S. Woo. 2008. Developing wave energy in coastal California: potential socio-economic and environmental effects. California Energy Commission, PIER Energy-Related Environmental Research Program & California Ocean Protection Council CEC-500-2008-083.

Nickelson, T. 2003. The influence of hatchery coho salmon (*Oncorhynchus kisutch*) on the productivity of wild coho salmon populations in Oregon coastal basins. Can. J. Fish Aquat. Sci. 60:1050–1056.

Ninth Circuit. 2013. Conservation Congress v. U.S. Forest Service, No. 12-16452. Ninth Circuit Clarifies ESA's "Cumulative Effects" Requirement. Available online at: https://www.californialanduse developmentlaw.com/2013/07/19/ninth-circuit-clarifies-esas-cumulative-effects-requirement/.

Noren, D. P. 2011. Estimated field metabolic rates and pretty requirements of resident killer whales. Marine Mammal Science 27: 60-77.

NHC (Northwest Hydraulic Consultants, Inc). 2019. Hydraulic Model Update for the Klamath River Dam Removal, 60% Design Report. Prepared for Knight Piesold on behalf of The Renewal Corporation. December 2019.

NRC (National Research Council). 2002. Scientific Evaluation of Biological Opinions on Endangered and Threatened Fishes in the Klamath River Basin: Interim Report. 26 pp.

NRC (National Research Council). 2004. Endangered and threatened fishes in the Klamath Basin: causes of decline and strategies for recovery. The National Academies Press, Washington, D.C. Available online at: http://www.nap.edu/openbook.php?isbn=0309090970.

NRCS (Natural Resources Conservation Service). 1983. Soil survey of Siskiyou County, California, Central Part. 116 pp.

Nussbaum, R.A., E.D. Brodie, Jr., and R.M. Storm. 1983. Amphibians and reptiles of the Pacific Northwest. University of Idaho Press, Moscow.

Oakley Consulting. 2011. Northern spotted owl habitat within the Iron Gate, Copco, and Copco 2 dam removal project area. Letter to L. Finley, USFWS, Yreka, California from C. Oakley, Oakley Consulting, Jacksonville, Oregon.

Odemar, M. W. 1964. Southern range extension of the eulachon, *Thaleichthys pacificus*. Calif. Fish Game 50: 305–307.

ODEQ (Oregon Department of Environmental Quality). 1998. Oregon's final 1998 water quality listed streams- 303(d) list. Available online at: http://www.deq.state.or.us/wq/assessment/docs/rpt98.pdf.

ODEQ. 2002. Upper Klamath Lake drainage total maximum daily load (TMDL) and water quality management plan (WQMP). Portland, Oregon.

ODEQ. 2017. Upper Klamath and Lost River Subbasins TMDL and water quality management plan. 154 p.

ODEQ. 2018. Clean Water Act Section 401 Certification for the Klamath River Renewal Corporation License Surrender and Removal of the Lower Klamath Project (FERC No. 14803) Klamath County, Oregon. September.

ODFW (Oregon Department of Fish and Wildlife). 2005. 2005 Oregon native fish status report. Volume I, species management unit summaries. Prepared by ODFW, Fish Division, Salem, Oregon.

ODFW. 2016. Klamath Watershed District Stock Status Review of Native Fish. January 2016 ODFW, Klamath Falls, Oregon. 109 pp.

ODFW. 2020. Shapefile of potential anadromous streams created by: Mark E. Hereford, Oregon Department of Fish and Wildlife.

ODOT. No date (n.d.). US97:OR58 – California Border Open House. Available online at: https://odotopenhouse.org/us97-or58-california-border. Accessed March 8, 2021.

Ohlberger, J., D.E. Schindler, E.J. Ward, T.E. Walsworth, T.E. Essington. 2019. Resurgence of an apex marine predator and the decline in prey body size. Proceedings of the National Academy of Sciences of the

United States of America. 2019; 116(52):26682–9. https://doi.org/10.1073/pnas.1910930116 PubMed PMID: WOS:000504656900076. PMID: 31843884

Olesiuk, P. F., M. A. Bigg, and G. M. Ellis. 1990. Life history and population dynamics of resident killer whales (*Orcinus orca*) in the coastal waters of British Columbia and Washington State. Report of the International Whaling Commission, Special Issue 12: 209–243.

Olson, A. 1996. Freshwater rearing strategies of spring Chinook salmon (*Oncorhynchus tshawytscha*) in Salmon River tributaries, Klamath Basin, California. Master's thesis. Humboldt State University, Arcata, California.

Olson, J. M. 1998. Temporal and spatial distribution patterns of sightings of southern community and transient orcas in the inland waters of Washington and British Columbia. Master’s thesis. Western Washington University, Bellingham, Washington’

Olson, D.H., and R.J. Davis. 2007. Conservation assessment for the foothill yellow-legged frog in Oregon. Unpubl. Report, United States Dept. of Agriculture Forest Service. Pacific Northwest Research Station.

O'Meara, S., B. Greimann, J. Godaire, B. Cluer, and R. Snyder. 2010. Reservoir area management plan for the secret’ry's determination on Klamath River Dam removal and basin restoration, Klamath River, Oregon and California. Draft Report. Prepared by Bureau of Reclamation, NOAA-National Marine Fisheries Service, and Bureau of Land Management’

Osborne, R. W. 1999. A historical ecology of Salish Sea “resident” killer whales (*Orcinus orca*): with implications for management. Ph.D. thesis, University of Victoria, Victoria, British Columbia.

PacifiCorp. 2004a. 2004 Terrestrial resources technical report, botanical and wildlife resources. Klamath Hydroelectric Project, FERC Project No. 2082, PacifiCorp, Portland, Oregon.

PacifiCorp. 2004b. Water resources for the Klamath Hydroelectric Project (FERC Project No. 2082). Final Technical Report. Prepared by PacifiCorp, Portland, Oregon.

PacifiCorp. 2004c. Analysis of potential Klamath Hydroelectric Project effects on water quality aesthetics for the Klamath Hydroelectric Project (FERC Project No. 2082). Final Technical Report. Prepared by PacifiCorp, Portland, Oregon.

PacifiCorp. 2004d. Environmental Report. Final License Application, Volume 2, Exhibit E. Klamath Hydroelectric Project, FERC No. 2082. Portland, Oregon.

PacifiCorp. 2006. Causes and effects of nutrient conditions in the upper Klamath River for the Klamath Hydroelectric Project (FERC Project No. 2082). PacifiCorp, Portland, Oregon.

PacifiCorp. 2008. Water quality monitoring during turbine venting tests at the Iron Gate Powerhouse, Klamath Hydroelectric Project (FERC Project No. 2082). Final Technical Report. Prepared by PacifiCorp, Portland, Oregon.

PacifiCorp. 2009. Final datasonde data from below Iron Gate Dam. Water quality preliminary raw data collected with a YSI 6600 Datasonde on the Klamath River downstream of Iron Gate Dam (RM 189.7) from January 16, 2009 through December 31, 2009. Collected by PacifiCorp, Portland, Oregon. Available online at: http://www.pacificorp.com/es/hydro/hl/kr.html. Accessed December 12, 2010.

PacifiCorp. 2010. Results of 2010 turbine venting tests to improve dissolved oxygen below Iron Gate Dam. Klamath Hydroelectric Project (FERC Project No. 2082). PacifiCorp, Portland, Oregon.

PacifiCorp. 2011. Results of 2010 Turbine Venting Tests to Improve Dissolved Oxygen below Iron Gate Dam. PacifiCorp Energy Portland, Oregon September 2011.

PacifiCorp. 2012. PacifiCorp Klamath Hydroelectric Project Interim Operations Habitat Conservation Plan for Coho Salmon. Prepared by PacifiCorp Energy, Inc, Portland, Oregon for National Marine Fisheries Service, Arcata Area Office, Arcata, California. February 16, 2012.

PacifiCorp. 2013a. Klamath Hydroelectric Project FERC Project No. 2082, Interim Operations Habitat Conservation Plan for Coho Salmon, Iron Gate Gravel Augmentation Plan, version 1.0. Prepared by PacifiCorp Energy, Inc., Portland, Oregon. February 19, 2013.

PacifiCorp. 2013b. PacifiCorp Klamath Hydroelectric Project Interim Operations Habitat Conservation Plan for Lost River and Shortnose Suckers. Prepared by PacifiCorp Energy, Inc., Portland, OR. Submitted to the U.S. Fish and Wildlife Service, Klamath Falls Fish and Wildlife Office, Klamath Falls, OR. November 20, 2013.

PacifiCorp. 2015. Klamath Hydroelectric Project Interim Operations Habitat Conservation Plan (HCP). Annual Report on HCP Activities During 2014. Prepared by PacifiCorp Energy, Inc., Portland, Oregon. Submitted to the National Marine Fisheries Service, Arcata Area Office, Arcata, California. April 24, 2015.

PacifiCorp. 2016a. Interim Measure 11, Activity 6 – Study of Algal Conditions Management within a Reservoir Cove Using Physical Measures. July. 22pp.

PacifiCorp. 2016b. Iron Gate Reservoir 2016 Intake Barrier Study Plan. July. 9 pp.

PacifiCorp. 2018a. Klamath Hydroelectric Settlement Agreement: Implementation Report. August. 66 pp.

PacifiCorp. 2018b. DO Sonde Data. Available at: https://www.pacificorp.com/content/dam/pcorp/documents/en/pacificorp/energy/hydro/klamath-river/water-quality-reports-and-data/data/2018_KRBI_SondeData_7-30-2019.xlsx

PacifiCorp. 2019. Klamath Hydroelectric Project Interim Operations Habitat Conservation Plan (HCP). Annual Report on HCP Activities During 2018. Prepared by PacifiCorp, Portland, Oregon. Submitted to the National Marine Fisheries Service, Arcata Area Office, Arcata, California. April 29, 2019.

PacifiCorp 2020a. Final Study Plan. Klamath Hydroelectric Project Interim Measure 11 Study Activities for 2020. April 2020. 11pp.

PacifiCorp. 2020b. Klamath Hydroelectric Settlement Agreement: Implementation Report. FERC Project 2082. April. 54 pp. Available publicly at https://www.pacificorp.com/energy/hydro/klamath-river/khsa-implementation.html.

PacifiCorp. 2020c. Klamath Hydroelectric Project Interim Operations Habitat Conservation Plan (HCP) for Coho Salmon Annual Report on HCP Activities During 2019. April 28. Patterson, W. D. 2009. Klamath River Estuary Wetlands Restoration Prioritization Plan. Yurok Tribe Environmental Program-Water Division, Klamath California.

Pearl, C.A., M.J. Adams, and N. Leuthold. 2009. Breeding habitat and local population size of the Oregon spotted frog (Rana pretiosa) in Oregon, USA. Northwestern Naturalist 90:136-147.

Peregrine Fund. 2019. Condor Recovery Program Confirms 1000th Chick Zion National Park biologists spot chick north of Angels Landing. July 9, 2019. Downloaded on February 15, 2021. https://peregrinefund.org/news-release/condor-recovery-program-confirms-1000th-chick-zion-national-park-biologists-spot-chick.

Perkins, D. L., and G. G. Scoppettone. 1996. Spawning and migration of Lost River suckers (*Deltistes luxatus*) and Shortnose suckers (*Chasmistes brevirostris*) in the Clear Lake drainage, Modoc County, California. National Biological Service, California Science Center, Reno Field Station, Reno, Nevada.

Perkins, D. L., G. G. Scoppettone, and M. Buettner. 2000a. Reproductive biology and demographics of endangered Lost River and shortnose suckers in Upper Klamath Lake, Oregon. Report to the Bureau of Reclamation. October 2000.

Perkins, D. L., J. Kann, and G. G. Scoppettone. 2000b. The role of poor water quality and fish kills in the decline of endangered Lost River and Shortnose suckers in Upper Klamath Lake. Final report. U.S. Geological Survey, Biological Resources Division, Western Fisheries Research Center, Reno Field Station, Reno, Nevada.

Peterson, N. P. 1982. Population characteristics of juvenile coho salmon (*Oncorhynchus kisutch*) overwintering in riverine ponds. Canadian Journal of Fisheries and Aquatic Sciences 39: 1,303–1,307.

PFMC (Pacific Fishery Management Council). 2018a. Salmon Rebuilding Plan for Klamath River Fall Chinook. (Document prepared for the Council and its advisory entities.) Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384.

PFMC. 2018b. Review of 2017 Ocean Salmon Fisheries, Stock Assessment and Fishery Evaluation Document for the Pacific Coast Salmon Fishery Management Plan. Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384.

PFMC. 2019. Salmon Rebuilding Plan for Klamath River Fall Chinook draft 12. Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384.

PFMC. 2020a. Collation of Preliminary Salmon Management Alternatives for 2020 Ocean Fisheries. Available from: https://www.pcouncil.org/documents/2020/03/e-6-a-supplemental-stt-report-1-collation-of-preliminary-salmon-management-alternatives-for-2020-ocean-fisheries-march-6-2020.pdf/

PFMC. 2020b. Pacific Fishery Management Council Salmon Fishery Management Plan Impacts to Southern Resident Killer Whales Final Draft Risk Assessment. Available from: https://www.pcouncil.org/documents/2020/02/e-3-a-srkw-workgroup-report-1-electronic-only.pdf/

PFMC. 2020c. Review of 2019 Ocean Salmon Fisheries: Stock Assessment and Fishery Evaluation Document for the Pacific Coast Salmon Fishery Management Plan. (Document prepared for the Council and its advisory entities.) Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384. Available from: https://www.pcouncil.org/documents/2020/02/review-of-2019-ocean-salmon-fisheries.pdf/

Phillips, B., J. Ross, and A. Wilkens. 2011. Klamath Project: Endangered Sucker Distribution and Relative Abundance in Reconnected Wetlands and open Water Areas adjacent to the Klamath River, Oregon; 2010 Report. Klamath Basin Area Office, U.S. Bureau of Reclamation, Klamath Falls, Oregon. 22 pp.

Piaskowski, R. 2003. Movements and habitat use of adult Lost River and shortnose suckers in Link River and Keno Impoundment, Klamath River Basin, Oregon. Klamath Falls, Oregon.

Pinnix, W.D., N.J. Harris, and S. Quinn. 2011. Juvenile Salmonid Monitoring on the Mainstem Trinity River at Willow Creek, California, 2008. U. S. Fish and Wildlife Service, Arcata Fish and Wildlife Office, Arcata Fisheries Data Series Report Number DS 2011-20, Arcata, California.

Pogue, C. 2018. Western Lily Species Lead, Division of Ecological Services, USFWS, Arcata Fish and Wildlife Office, Arcata, California. Personal communication with Kate Stenberg, The Renewal Corporation, March 9, 2018.

Pogue, C. 2021. USFWS. Personal communication with Ken Sanchez, February 21, 2021.

Poytress, W. R., J. J. Gruber, D. A. Trachtenbarg and J. P. Van Eenennaam. 2009. 2008 Upper Sacramento River green sturgeon spawning habitat and larval migration surveys. Annual Report of U.S. Fish and Wildlife Service to US Bureau of Reclamation, Red Bluff, CA.

Poytress, W. R., J. J. Gruber and J. P. Van Eenennaam. 2010. 2009 Upper Sacramento River green sturgeon spawning habitat and larval migration surveys. Annual Report of U.S. Fish and Wildlife Service to U.S. Bureau of Reclamation, Red Bluff, CA.

Poytress, W. R., J. J. Gruber, and J. P. Van Eenennaam. 2011. 2010 upper Sacramento River green sturgeon spawning habitat and larval migration surveys. Annual Report of U.S. Fish and Wildlife Service to U.S. Bureau of Reclamation, Red Bluff, CA.

Poytress, W. R., J. J. Gruber, and J. P. Van Eenennaam. 2012. 2011 upper Sacramento River green sturgeon spawning habitat and larval migration surveys. Annual Report of U.S. Fish and Wildlife Service to U.S. Bureau of Reclamation, Red Bluff, CA.

Pratt, K. L. 1992. A review of bull trout life history. Pages 5–9 *in* P. J. Howell and D. V. Buchanan, editors. Proceedings of the Gearhart Mountain bull trout workshop. American Fisheries Society, Oregon Chapter, Corvallis.

Prince, D. J., S. M' O'Rourke, T. Q. Thompson, O. A. Ali, H. S. Lyman, I. K. Saglam, T. J. Hotaling, A. P. Spidle, and M. R. Miller. 2017. The evolutionary basis of premature migration in Pacific salmon highlights the utility of genomics for informing conservation. Science Advances 3: e1603198.

Quartz Valley Tribal Environmental Program. 2009. Quartz Valley Indian Reservation Water Quality Monitoring and Assessment Report 2008. Quartz Valley Tribal Environmental Program, Fort Jones, California.

Quinn, T. 1997. Homing, straying, and colonization. W. S. Grant, editor. Proceedings of the workshop: genetic effects of straying on non-native hatchery fish into natural populations. NOAA Technical Memoradum, NMFS NWF–C - 30.

Rabe, A., and C. Calonje. 2009. Lower Sprague-lower Williamson watershed assessment. Prepared by Rabe Consulting, with maps and figures by E&S Environmental Chemistry, Inc., Corvallis, Oregon.

Radtke, L.D. 1966. Distribution of smelt, juvenile sturgeon, and starry flounder in the Sacramento-san Joaquin Delta with observations on food of sturgeon. Fish Bulletin 136:115–129.

Railsback S.F., B.C. Harvey, S.J. Kupferberg, M.M. Lang, S. McBain, and H.H. Welsh. 2015. Modeling potential river management conflicts between frogs and salmonids. Canadian Journal of Fisheries and Aquatic Sciences 73: 773-784.

Raphael, M.G., G.A. Falxa, and A.E. Burger. 2018. Chapter 5: Marbled Murrelet. In: T.A. Spies, P.A. Stine, R. Gravenmier, J.W. Long, & M.J. Reilly (editors). Synthesis of science to inform land management within the Northwest Forest Plan area, Vol. 1. pp. 301–350. Gen. Tech. Rep. PNW-GTR-966. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. Portland, Oregon.

Rasmussen, J. E., and E. S. Childress. 2018. Population Viability of Endangered Lost River Sucker and Shortnose Sucker and the Effects of Assisted Rearing. Journal of Fish and Wildlife Management 9:582–592.

Ratliff, D. E., and P. J. Howell. 1992. The status of bull trout populations in Oregon. Pages 10–17 *in* P. J. Howell and D. V. Buchanan, editors. Proceedings of the Gearhart Mountain bull trout workshop. American Fisheries Society, Oregon Chapter, Corvallis.

Ratliff, D. E., S. L. Thiesfeld, W. G. Weber, A. M. Stuart, M. D. Riehle, and D. V. Buchanan. 1996. Distribution, life history, abundance, harvest, habitat, and limiting factors of bull trout in the Metolius River and Lake Billy Chinook, Oregon, 1983–94. Information Report No. 96-7. Oregon Department of Fish and Wildlife, Fish Division, Portland.

Ray, R. A., R. A. Holt, and J. L. Bartholomew. 2012. Relationship between temperature and Ceratomyxa shasta-induced mortality In Klamath River salmonids. Journal of Parasitology 98:520–526.

Ray, R. A., R. W. Perry, N. A. Som, and J. L. Bartholomew. 2014. Using Cure Models for Analyzing the Influence of Pathogens on Salmon Survival. Transactions of the American Fisheries Society, 143(2), 387-398. doi:10.1080/00028487.2013.862183.

Raymond, R. 2008. Water quality conditions during 2007 in the vicinity of the Klamath Hydroelectric Project. Prepared by E&S Environmental Chemistry, Inc., Corvallis, Oregon for PacifiCorp Energy, Portland, Oregon.

Raymond, R. 2009. Water quality conditions during 2008 in the vicinity of the Klamath Hydroelectric Project. Prepared by E&S Environmental Chemistry, Inc., Corvallis, Oregon for Ch2MHill, Portland, Oregon and PacifiCorp Energy, Portland, Oregon.

Raymond, R. 2010. Water quality conditions during 2009 in the vicinity of the Klamath Hydroelectric Project. Prepared by E&S Environmental Chemistry, Inc., Corvallis, Oregon for PacifiCorp Energy, Portland, Oregon.

Redding, J.M., C.B. Schreck, and F.H. Everest. 1987. Physiological effects on coho salmon and steelhead of exposure to suspended solids. Trans Am Fish Soc 116:737–744

Reiser, D. W., M. Loftus, D. Chapman, E. Jeanes, and K. Oliver. 2001. Effects of Water Quality and Lake Level on the Biology and Habitat of Selected Fish Species in Upper Klamath Lake. Prepared for the Bureau of Indian Affairs. 147 pp.

Reithel, S. A. 2006. Patterns of retention and vagrancy in larval Lost River and shortnose suckers from Upper Klamath Lake, Oregon. Master's Thesis. Oregon State University, Corvallis, Oregon.

Resighini Rancheria Environmental Protection Authority. 2006. The Resighini Rancheria Tribal Water Quality Ordinance Number 01-2002. Resighini Rancheria, Klamath, CA.

Richter, A., and S. A. Kolmes. 2005. Maximum temperature limits for Chinook, coho, and chum salmon, and steelhead trout in the Pacific Northwest. Reviews in Fisheries Science 13: 23–49.

Ricker, S. 1997. Evaluation of Salmon and Steelhead Spawing Habitat Quality in the Shasta River Basin, 1997. Inland Fisheries Administrative Report No. 97. State of California, The Resources Agency, Department of Fish and Game.

Ridenhour, R.L., and Hofstra, T.D., 1994, Fishery Resources of the Redwood Creek Basin, unpublished report, 46 p.

Rieman, B. E., and J. D. McIntyre. 1993. Demographic and habitat requirements for conservation of bull trout. General Technical Report INT-302. USDA Forest Service, Intermountain Research Station, Ogden, Utah.

Rieman, B. E., and J. D. McIntyre. 1996. Spatial and temporal variability in bull trout redd counts. North American Journal of Fisheries Management 16:132–141.

Rieman, B. E., S. Adams, D. Horan, D. Nagel, and C. Luce. 2007. Anticipated climate warming effects on bull trout habitats and populations across the Interior Columbia River Basin. Transactions of the American Fisheries Society 136: 1,552–1,565.

Riera, A. 2012. Patterns of seasonal occurrence of sympatric killer whale lineages in waters off Southern Vancouver Island and Washington State, as determined by passive acoustic monitoring. University of Victoria.

Risley, J. C., S. J. Brewer, and R. W. Perry. 2012. Simulated effects of dam removal on water temperatures along the Klamath River, Oregon and California, using 2010 Biological Opinion flow requirements. 2331-1258.

Robinson, A. T., P. P. Hines, J. A. Sorensen, and S. D. Bryan. 1998. Parasites and fish health in a desert stream, and management implications for two endangered fishes. North American Journal of Fisheries Management 18:599–608.

Roby, D.D. (ed.). 2011. Impacts of avian predation on salmonid smolts from the Columbia and Snake rivers: A synthesis report to the U.S. Army Corps of Engineers - Walla Walla District. Bird Research Northwest. Available on-line at www.birdresearchnw.org.

Robinson, H. E., J. D. Alexander, S. L. Hallett, and N. A. Som. 2020. Prevalence of infection in hatchery-origin Chinook salmon (*Oncorhynchus tshawytscha*) correlates with abundance of *Ceratonova shasta* spores: implications for management and disease risk. Accepted manuscript. North American Journal of Fisheries Management.

Rodriguez-Gil, J. L., R. Prosser, D. Poirier, I. Lissemore, D. Thompson, and M. Hanson. 2017. Aquatic hazard assessment of MON 0818, a commercial mixture of alkylamine ethoxylates commonly used in glyphosate-containing herbicide formulations. Part 1: Species sensitivity distribution from laboratory acute exposures. Environ. Toxicol. Chem. 36, 501–511.

Rogers, I.H., I.K. Birtwell, and G.M. Kruzynski. 1990. The Pacific eulachon (Thaleichthys pacificus) as a pollution indicator organism in the Fraser River estuary, Vancouver, British Columbia. Science of the Total Environment 97-98:713-27.

Romberger, C.Z. and S. Gwozdz. 2018. Performance of water temperature management on the Klamath and Trinity Rivers, 2017. U.S. Fish and Wildlife Service. Arcata Fish and Wildlife Office, Arcata Fisheries Data Series Number DS 2018-59, Arcata, California.

Rombough, C.J., and M.P. Hayes. 2005. Novel aspects of oviposition site preparation by foothill yellow-legged frogs (*Rana boylii*) Northwestern Naturalist 86: 157-160.

Rosales-Casian, J. R., and C. Almeda-Juaregui. 2009. Unusual occurrence of a green sturgeon (Acipenser medirostris) at El Socorro Bay, Baja California, Mexico. California Cooperative Fisheries Investigations, CalCoFI Reports 50:169-171.

Rubin, S.P., I.M. Miller, M.M. Foley, H.D. Berry, J.J. Duda, B. Hudson, N.E. Elder, M.M. Beirne, J.A. Warrick, M.L. McHenry, A.W. Stevens, E.F. Eidam, A.S. Ogston, G. Gelfenbaum, R. Pedersen. 2017. Increased sediment load during a large-scale dam removal changes nearshore subtidal communities. PLoS ONE 12(12): 1-46.

Saiki, M. K., D. P. Monda, and B. L. Bellerud. 1999. Lethal levels of selected water quality variables to larval and juvenile Lost River and shortnose suckers. Environmental Pollution 105:37–44.

Sandercock, F. K. 1991. Life history of coho salmon (*Oncorhynchus kisutch*). Pages 397–445 *in* C. Groot and L. Margolis, editors. Pacific salmon life histories. University of British Columbia Press, Vancouver, B.C.

Sanville, W.D., C.F. Powers, and A.R. Gahler. 1974. Sediments and sediment-water interchange in Upper Klamath Lake, Oregon. EPA-660/3-74-015. U.S. Environmental Protection Agency, Corvallis, OR.

Sartori, J. C. 2006. Comparative otolith microstructural analysis of adult, juvenile, and fry life stages of Salmon River spring Chinook salmon of northwestern California. Technical report. U.S. Fish and Wildlife Service, Arcata Fish and Wildlife Office, Arcata, California.

Scavia, D., J. C. Field, D. F. Boesch, R. W. Buddemeier, V. Burkett, D. R. Cayan, M. Fogarty, M. A. Harwell, R. W. Howarth, C. Mason, D. J. Reed, T. C. Royer, A. H. Sallenger, and J. G. Titus. 2002. Climate change impacts on U.S. coastal and marine ecosystems. Estuaries 25: 149–164.

Scheiff, T., and P. Zedonis. 2011. The influence of Lewiston Dam releases on water temperatures of the Trinity and Klamath rivers, California. April to October, 2010. Arcata Fisheries Data Series Report

Number DS 2011-22. U.S. Fish and Wildlife Service, Arcata Fish and Wildlife Office, Arcata, California.

Scheiff, A. J., J. S. Lang, and W. D. Pinnix. 2001. Juvenile salmonid monitoring on the mainstem Klamath River at Big Bar and mainstem Trinity River at Willow Creek 1997-2000. Annual report of the Klamath River Fisheries Assessment Program. U.S. Fish and Wildlife Service, Arcata Fish and Wildlife Office, Arcata, California. Juvenile salmonid monitoring annual report 2001.

Scheuerell, M. D., R. W. Zabel, and B. P. Sandford. 2009. Relating juvenile migration timing and survival to adulthood in two species of threatened Pacific salmon (*Oncorhynchus* spp.). Journal of Applied Ecology 46: 983–990.

Schreier, A., O. P. Langness, J. A. Israel and E. Van Dyke. 2016. Further investigation of green sturgeon (Acipenser medirostris) distinct population segment composition in non-natal estuaries and preliminary evidence of Columbia River spawning. Env. Biol. Fish. DOI 10.1007/s10641-016-0538-1

Schultz, L. P., and A. C. DeLacy. 1935. Fishes of the American Northwest. Journal of the PanPacific Research Institute 10: 365–380.

Scoppettone, G. G. 1988. Growth and longevity of the cui-ui and longevity of other catostomids and cyprinids in western North America. Trans Am Fish Soc 117:301–307.

Scoppettone, G., and C. L. Vinyard. 1991. Life history and management of four lacustrine suckers. Pages 359-377 *in* W. L. Minckley and J. E. Deacon, editors. Battle against extincti–n - native fish management in the American west. University of Arizona Press, Tucson, Arizona.

Sedell J. R., G. H. Reeves, F. R. Hauer, J. A. Stanford, C. P. Hawkins. 1990. Role of refugia in recovery from disturbances: Modern fragmented and disconnected river systems. Environmental Management 14: 711-724.

Seesholtz A. M., M. J. Manuel, and J. P. Van Eenennaam. 2015. First documented spawning and associated habitat conditions for green sturgeon in the Feather River, California. Environ. Biol. Fishes 98(3): 905-912.

Servizi, J. A., and D. W. Martens. 1992. Sublethal responses of coho salmon (*Oncorhynchus kisutch*) to suspended sediments. Canadian Journal of Fisheries and Aquatic Sciences. 49(7): 1389-1395.

Shaw, T. A., C. Jackson, D. Nehler, and M. Marshall. 1997. Klamath River (Iron Gate Dam to Seiad Creek) life stage periodicities for Chinook, coho, and steelhead. Prepared by U.S. Fish and Wildlife Service, Coastal California Fish and Wildlife Office, Arcata, California.

Shelton, A. O., W. H. Satterthwaite, E. J. Ward, B. E. Feist, and B. Burke. 2019. Using hierarchical models to estimate stock-specific and seasonal variation in ocean distribution, survivorship, and aggregate abundance of fall run Chinook salmon. Canadian Journal of Fisheries and Aquatic Sciences 76:95-108.

Shively, R. S., M. F. Bautista, and A. E. Kohler. 2000. Monitoring of Lost River and shortnose suckers at shoreline spawning areas in Upper Klamath Lake, 1999. Completion report. U.S. Geological Survey, Biological Resources Division, Klamath Falls Duty Station, Klamath Falls, Oregon.

Sigler, J. W., T. C. Bjornn and F.H. Everest. 1984. Effects of chronic turbidity on density and growth of steelheads and coho salmon. Transactions of the American Fisheries Society 113: 142–150.

Simon, D. C., and D. F. Markle. 2001. Annual survey of abundance and distribution of age 0 shortnose and Lost River suckers in Upper Klamath Lake. Annual Report. Oregon State University. Department of Fisheries and Wildlife, Corvallis, Oregon.

Simon, D. C., G. R. Hoff, and D. F. Markle. 1995. Larval and Juvenile Ecology of Upper Klamath Lake Suckers. Annual Report. Oregon State University, Department of Fisheries and Wildlife, Corvallis, Oregon. 49 pp.

Simon, D. C., G. R. Hoff, D. J. Logan, and D. F. Markle. 1996. Larval and Juvenile Ecology of Upper Klamath Lake Suckers. Annual Report: 1995. Oregon State University, Department of Fisheries and Wildlife, Corvallis, Oregon. 60 pp.

Simon, D. C., M. R. Terwilliger, P. Murtaugh, and D. F. Markle. 2000. Larval and juvenile ecology of Upper Klamath Lake suckers: 1995–1998. Final Report. Oregon State University. Department of Fisheries and Wildlife. Corvallis, Oregon.

Simon, D. C., M. R. Terwilliger, and D. F. Markle. 2009. Larval and Juvenile Ecology of Upper Klamath Lake Suckers: 2004-2008. Final Report for contract 1434-03HQRU1584. Oregon State University, Department of Fisheries and Wildlife, Corvallis, Oregon. 179 pp.

Simon, D. C., M. R. Terwilliger, and D. F. Markle. 2012. Larval and Juvenile Ecology of Upper Klamath Lake Suckers: 2011. Annual Report for Great Basin Cooperative Ecosystems Studies Unit Agency Program Reclamation#2-FG-81-0813 Oregon State University, Department of Fisheries and Wildlife, Corvallis, Oregon. 101 pp.

Sinnott, S. 2010. 2009 Klamath River datasonde report. Final Report. Prepared by Yurok Tribe Environmental Program, Klamath, California.

Sinnott S. 2011. 2010 Klamath River nutrient summary report. Final Report. Prepared by Yurok Tribe Environmental Program, Water Division, Klamath, California.

Smith, W. E., and R. W. Saalfeld. 1955. Studies on Columbia River smelt *Thaleichthys pacificus* (Richardson). Washington Department of Fisheries, Fisheries Research Paper 1: 3–26.

Smith, R., and W. Tinniswood. 2007. Klamath Watershed District Monthly Report, May 2007. Oregon Department of Fish and Wildlife. 7 pp

Smith, M., J. Von Bargen, C. Smith, M. Miller, J. Rasmussen, and D.A. Hewitt. 2020. Characterization of the genetic structure of four sucker species in the Klamath River. Final Report. U.S. Fish and Wildlife Service. 34 p.

Snyder, D. T., and J. L. Morace. 1997. Nitrogen and phosphorus loading from drained wetlands adjacent to Upper Klamath and Agency Lakes, Oregon. Water-Resources Investigations Report 97-4059. U.S. Department of the Interior, U.S. Geological Survey, Denver, Colorado in cooperation with the Bureau of Reclamation.

Snyder, J. O. 1931. Salmon of the Klamath River, California. Fish Bulletin No. 34: 5-22. Division of Fish and Game of California, Sacramento.

Snyder-Conn, E., and T. Hawkes. 2004. Pesticide Impact Assessment in Tule Lake and Lower Klamath National Wildlife Refuges, 1998 - 2000 Growing Season. WO Project ID: 199810004.3. Department of The Interior, U.S. Fish And Wildlife Service, Region 1.

Som, N. A., N. J. Hetrick, J. S Foott, and K. True. 2016a. Response to Som, N. A., and N. J. Hetrick. 2016a. Response to Request for Technical Assistance – Prevalence of *C. shasta* Infections in juvenile and adult salmonids. Unpublished memo to D. Hillemeier, Yurok Tribal Fisheries, and Craig Tucker, Karuk Department of Natural Resources. 17 pp.

Som, N. A., and N. J. Hetrick. 2016. Response to Request for Technical Assistance – *Ceratonova shasta* waterborne spore stages. Unpublished memo to D. Hillemeier, Yurok Tribal Fisheries, and Craig Tucker, Karuk Department of Natural Resources. 12 pp.

Som, N. A., and N. J. Hetrick. 2017. Technical Memorandum: Response to Request for Technical Assistance - Predictive Model for Estimating 80% Outmigration Threshold of Natural Juvenile Chinook Salmon Past the Kinsman Trap Site, Klamath River. Department of The Interior, U.S. Fish and Wildlife Service, Region 1.

Som, N. A., N. J. Hetrick, R. W. Perry, and J. D. Alexander. 2019. Estimating annual Ceratonova shasta mortality rates in juvenile Scott and Shasta River Coho Salmon that enter the Klamath River mainstem. U.S. Fish and Wildlife Service. Arcata Fish and Wildlife Office, Arcata Fisheries Technical Report Number TR 2019-38, Arcata, California.

Sorenson, S. K., and S. E. Schwarzbach. 1991. Reconnaissance Investigation of the Water Quality, Bottom Sediment, and Biota Associated with Irrigation Drainage in the Klamath Basin, California and Oregon, 1988-1989. U.S. Geological Survey, Water Resources Investigation Report 90-4203. 64 pp.

Soto, T., A. Corum, H. Voight, D. Hillemeier, and L. Lestelle. 2008. The role of the Klamath River mainstem corridor in the life-history and performance of juvenile coho salmon (Oncorhynchus kisutch). Phase I

Report 2006-07 Winter. Submitted to U.S. Bureau of Reclamation, Klamath Falls, Oregon. December 2008.

Soto, T., D. Hillemeier, S. Silloway, A. Corum, A. Antonetti, M. Kleeman, and L. Lestelle. 2016. The Role of the Klamath River Mainstem Corridor in the Life History and Performance of Juvenile Coho Salmon (*Oncorhynchus kisutch*). Period Covered: May 2007-August 2011. August 2013. (Updated April 2016). Submitted to: U.S. Bureau of Reclamation Mid-Pacific Region, Klamath Area Office.

Southern Resident Orca Task Force. 2019. Final Report and Recommendations. November.

Spangler, E. A. K. 2002. The ecology of eulachon (*Thaleichthys pacificus*) in Twentymile River, Alaska. Master's thesis. University of Alaska, Fairbanks.

Spangler, R. E., and D. L. Scarnecchia. 2001. Summer and fall microhabitat utilization of juvenile bull trout and cutthroat trout in a wilderness stream, Idaho. Hydrobiologia 452: 145–154.

Stanley E.H., M.A. Luebke, M.W. Doyle, D.W. Marshall. 2002. Short-term changes in channel form and macroinvertebrate communities following low-head dam removal. Journal of the North American Benthological Society 21: 172–187.

Stenhouse, S. A, C. E. Bean, W. R. Chesney, and M. S. Pisano. 2012. Water temperature thresholds for coho salmon in a spring-fed river, Siskyou County, California. California Department of Fish and Game, Anadromous Fisheries Resource Assessment and Monitoring Program 98(1):19-37.

Stewart, I. T., D. R. Cayan, and M. D. Dettinger. 2004. Changes in snowmelt runoff timing in western North America under'a 'Business as Us'al' climate change scenario. Climatic Change 62: 217–232.

Stillwater Sciences. 2008. Klamath River dam removal study: sediment transport DREAM-1 simulation. Technical report. Prepared by Stillwater Sciences, Arcata, California for California Coastal Conservancy, Oakland, California.

Stillwater Sciences. 2009a. Effects of sediment release following dam removal on the aquatic biota of the Klamath River. Technical Report. Prepared by Stillwater Sciences, Arcata, California for State Coastal Conservancy, Oakland, California. Available online at: http://www.Reclamation.gov/mp/kbao/kbra/docs/other/Klamath%20Dam%20Removal%20Biological%20Analysis_FINAL.pdf.

Stillwater Sciences 2009b. Dam removal and Klamath River water quality: a synthesis of the current conceptual understanding and an assessment of data gaps. Technical memorandum. Prepared by Stillwater Sciences, Berkeley, California for California Coastal Conservancy, Oakland, California.

Stillwater Sciences. 2010. Anticipated sediment release from Klamath River dam removal within the context of basin sediment delivery. Final Report. Prepared by Stillwater Sciences, Berkeley, California for State Coastal Conservancy, Oakland, California.

Stillwater Sciences. 2011. Model Development and Estimation of Short-Term Impacts of Dam Removal on Dissolved Oxygen in the Klamath River. Prepared by Stillwater Sciences, Berkeley, California, for the Water Quality Sub Team, Klamath River Secretarial Determination. 39 pp.

Strange, J. 2008. Adult Chinook salmon migration in the Klamath Basin, 2007 Biotelemetry monitoring study final report. Yurok Tribal Fisheries Program, Klamath, California and University of Washington, School of Aquatic and Fishery Science, Seattle, Washington, in collaboration with Hoopa Valley Tribal Fisheries, Hoopa, California.

Strange, J. 2009. Adult Chinook salmon migration in the Klamath Basin, 2008 Biotelemetry monitoring study final report. Yurok Tribal Fisheries Program, Klamath, California and University of Washington, School of Aquatic and Fishery Science, Seattle, Washington, in collaboration with Hoopa Valley Tribal Fisheries, Hoopa, California.

Stocking, R. W., and J. L. Bartholomew. 2007. Distribution and habitat characteristics of *Manayunkia speciosa* and infection prevalence with the parasite, *Ceratomyxa shasta*, in the Klamath River, OR-CA, USA. Journal of Parasitology 93:78-88.

Stone, R. and J. Jacobs. 2015. Lost River Sucker Culture Manual. U.S. Fish and Wildlife Service, California-Nevada Fish Health Center, Anderson, California. 25p.

Streeter, H. W., and E. B. Phelps. 1925. Study of the pollution and natural purification of the Ohio River. Public Health Bulletin No. 146 (reprinted 1958). U.S. Public Health Service, Washington, DC.

Sturdevant, D. 2011. Water quality standards review and recommendations: Arsenic. Report. Prepared by Oregon DEQ, Water Quality Standards Program, Portland, Oregon.

Stutzer, G. M., J. Ogawa, N. J. Hetrick, and T. Shaw. 2006. An initial assessment of radio telemetry for estimating juvenile coho salmon survival, migration behavior, and habitat use in response to Iron Gate Dam discharge on the Klamath River, California. Arcata Fisheries Technical Report Number TR2006-05. U.S. Fish and Wildlife Service, Arcata Fish and Wildlife Office, California.

Sullivan, C. M. 1989. Juvenile life history and age composition of mature fall Chinook salmon returning to the Klamath River, 1984–1986. Master's thesis. Humboldt State University, Arcata, California.

Sullivan, A. B., D. M. Snyder, and S. A. Rounds. 2010. Controls on biochemical oxygen demand in the upper Klamath River, Oregon. Chemical Geology 269: 12–21.

Sullivan, A. B., M. L. Deas, J. Asbill, J. D. Kirshtein, K. Butler, and J. Vaughn. 2009. Klamath River water quality data from Link River Dam to Keno Dam, Oregon, 2008. U.S. Geological Survey Open File Report 2009-1105. Prepared by the U.S. Department of the Interior, U.S. Geological Survey, Reston, Virginia.

Sullivan, A. B., M. L. Deas, J. Asbill, J. D. Kirshtein, K. Butler, M. A. Stewart, R. E. Wellman, and J. Vaughn. 2008. Klamath River water quality and acoustic doppler current profiler data from Link River Dam to Keno Dam, 2007. Open-File Report 2008-1185. Prepared by U.S. Department of Interior, U.S. Geological Survey, Reston, Virginia in cooperation with the Bureau of Reclamation.

Sullivan, A. B., S. A. Rounds, M. L. Deas, J. R. Asbill, R. E. Wellman, M. A. Stewart, M. W. Johnston, and I. E. Sogutlugil. 2011. Modeling hydrodynamics, water temperature, and water quality in the Klamath River upstream of Keno Dam, Oregon, 2006–2009. Scientific Investigations Report 2011-5105. Prepared by Oregon Water Science Center, U.S. Geological Survey, Portland, Oregon in cooperation with the Bureau of Reclamation.

Suryan, R. M., G. R. Balogh, and K. N. Fischer. 2007. Marine habitat use of North Pacific albatross during the non-breeding season and their spatial and temporal interactions with commercial fisheries in Alaska. North Pacific Research Board Project Final Report.

Swift, C. C., J. L. Nelson, C. Maslow, and T. Stein. 1989. Biology and distribution of the tidewater goby, Eucyclobius newberryi (Pisces: Gobiidae) of California. Los Angeles County Museum of Natural History Contributions in Science 404: 1–19.

SWRCB (California State Water Resources Control Board). 2006. Transmittal of the 2006 Clean Water Act Section 303(d) List of Water Quality Limited Segments. Letter with Enclosures from Tom Howard, November 24, 2006.

SWRCB. 2010. 2010 California 303(d) list of water quality limited segments, Category 5. Final 2010 Integrated Report (CWA Section 303(d) List/305(b) Report). State Water Resources Control Board, Sacramento, California. Available online at: http://www.waterboards.ca.gov/water_issues/programs/tmdl/2010state_ir_reports/category5_report.shtml.

SWRCB. 2020a. Final Environmental Impact Report for the Lower Klamath Project License Surrender. State Clearinghouse No. 2016122047. Prepared by Stillwater Sciences, Berkeley, California for the State Water Resources Control Board, Sacramento, California. April.

SWRCB. 2020b. Water Quality Certification for Federal Permit or License. Klamath River Renewal Corporation Lower Klamath Project License Surrender. Federal Energy Regulatory Commission Project No. 14803. April.

Sykes, G. E., C. J. Johnson, and J. M. Shrimpton. 2009. Temperature and flow effects on migration timing of Chinook salmon smolts. Transactions of the American Fisheries Society 138: 1,252–1,265.

Syngenta Crop Production Inc. 2008. Barricade 65WG Herbicide Material Safety Data Sheet. 8p.

Tague C, M. Farrell, G. Grant, S. Lewis, and S. Rey. 2007. Hydrogeologic controls on summer stream temperatures in the McKenzie River basin, Oregon. Hydrological Processes 21(24): 3288-3300.

Tague, C., G. Gordon, M. Farrell, J. Choate and A. Jefferson. 2008. Deep groundwater mediates streamflow response to climate warming in the Oregon Cascades. Climatic Change 86: 189–210.

Terwilliger, M. 2006. Physical Habitat Requirements for Lost River and Shortnose Suckers in the Klamath Basin of Oregon and California: Literature Review. 40 pp.

Terwilliger, M. R., D. C. Simon, and D. F. Markle. 2004. Larval and juvenile ecology of Upper Klamath Lake suckers: 1998–2003. Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon. Final report to Bureau of Reclamation, Klamath Falls, Oregon, under contract HQ-97-RU-01584-09.

Terwilliger, M. R., T. Reece, and D. F. Markle. 2010. Historic and Recent Age Structure and Growth of Endangered Lost River and Shortnose Suckers in Upper Klamath Lake, Oregon. Environmental Biology of Fishes 89:239-252.

The Renewal Corporation. 2017. Klamath River Renewal Project California Environmental Quality Action (CEQA) and California and Oregon 401 Water Quality Certifications Technical Support Document. Submitted to California State Water Resource Control Board and Oregon Department of Environmental Quality. September.

The Renewal Corporation. 2018. Definite Plan for the Lower Klamath Project. June 2018.

The Renewal Corporation. 2019. Klamath River Renewal Project: 2019 Annual Aquatic Resources Survey Report. December. 54 pp.

The Renewal Corporation. 2020a. Lower Klamath Project FERC No. 14803 Definite Decommissioning Plan. July 2020. Prepared by: Kleinschmidt Associates.

The Renewal Corporation. 2020b. 2020 Annual Aquatic Resources Survey Report. 39 p.

Thomas, J. W., M. G. Raphael, and R. G. Anthony. 1993. Viability assessments and management considerations for species associated with late-successional and old-growth forests of the Pacific Northwest. USDA Forest Service.

Thomas, J. W. 1990. A conservation strategy for the spotted owl. Forest Watch 11: 9–12.

Thomas, M. J., A. E. Steel, and A. P. Klimley. (unpublished) Removal of diversion dam enhances spawning migration of green sturgeon. Draft manuscript shared with Phaedra Doukakis May 26, 2015, as cited in NMFS 2015b.

Thompson, J. 2007. Running dry: where will the west get its water? Science Findings, Pacific Northwest Research Station, U.S. Forest Service.

Thomson, R.C., A.N. Wright, and H.B. Shaffer. 2016. California Amphibian and Reptile Species of Special Concern. California Department of Fish and Wildlife, University of California Press. 390 pp.

Tickell, W. L. N. 2000. Albatross. Yale University Press, New Haven, Connecticut.

Trihey and Associates. 1996. Instream flow requirements for tribal trust species in the Klamath River. Prepared by Trihey and Associates, Concord, California.

Tonkin, J.D., S. Stoll, A. Sundermann, and P. Haase. 2014. Dispersal distance and the pool of taxa, but not barriers, determine the colonisation rate of restored river reaches by benthic invertebrates. Freshwater Biology 59: 1843-1855.

Trebitz, A.S., and D.L Taylor. 2007. Exotic and Invasive Aquatic Plants in Great Lakes Coastal Wetlands: Distribution and Relation to Watershed Land Use and Plant Richness and Cover. Journal of Great Lakes Research, 3(4), pp.705-721. https://doi.org/10.3394/0380-1330(2007)33[705:EAIAPI]2.0.CO;2

True, K. 2013. FY2013 Technical Report: Pilot Study of the Effects of Saltwater Rearing on *Ceratomyxa shasta* Infections in Klamath River Juvenile Chinook Salmon, June-August 2013. Fish & Wildlife Service California – Nevada Fish Health Center, Anderson, CA.

True, K., A. Bolick, and J. S. Foott. 2013. Myxosporean parasite (*Ceratomyxa shasta* and *Parvicapsula minibicornis*) prevalence of infection in Klamath River Basin juvenile Chinook salmon, April–August 2012. FY 2012 Investigational Report. California–Nevada Fish Health Center, U.S. Fish and Wildlife Service, Anderson, California. Available online at: https://www.fws.gov/canvfhc/CANVReports.html.

True, K., A. Bolick, and S. Foott. 2015. Myxosporean Parasite (*Ceratanova shasta* and *Parvicapsula minibicornis*) Prevalence of Infection in Klamath River Basin Juvenile Chinook Salmon, April-August 2014.

True, K., A. Voss, and J. S. Foott. 2016. Myxosporean parasite Prevalence of infection in Klamath River Basin juvenile Chinook salmon, April–July 2015. California–Nevada Fish Health Center, U.S. Fish and Wildlife Service, Anderson, California. Available online at: https://www.fws.gov/canvfhc/CANVReports.html).

Tschaplinski, P. J. 1988. The use of estuaries as rearing habitats by juvenile coho salmon. Pages 123–142 *in* T. W. Chamberlin, editor. Proceedings of the workshop: applying 15 years of Carnation Creek results. Department of Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, British Columbia.

Tullos, D.D., D.S. Finn, C. Walter. 2014. Geomorphic and ecological disturbance and recovery from two small dams and their removal. PLOS One 9(9): 1-18.

Tullos, D.D., M.J. Collins, J.R. Bellmore, J.A. Bountry, P.J. Connolly, P.B. Shafroth, and A.C. Wilcox. 2016. Synthesis of common management concerns associated with dam removal. JAWRA Journal of the American Water Resources Association, 52(5), pp.1179-1206.

Tyler, T. J. 2007. Link River 2006 screw trap assessment. Bureau of Reclamation, Klamath Falls, Oregon.

Tyler, T. J., and C. Kyger. 2012. Feasibility of Trapping Juvenile Suckers within Lake Ewauna During the Fall of 2011 to Inform a Potential Relocation Effort. U.S. Bureau of Reclamation, Klamath Basin Area Office, Klamath Falls, Oregon. 14 pp.

Tyler, T. J. 2012a. Estimate of Take for Lost River Suckers Deltistes luxatus and Shortnose Suckers Chasmistes brevirostris through Entrainment Associated with the Operations of Klamath Project at the Southern End of Upper Klamath Lake During 2008, 2009, and 2010. U.S. Bureau of Reclamation, Klamath Basin Area Office, Klamath Falls, Oregon. 26 pp.

Tyler, T. J. 2012b. Estimate of take for Lost River Suckers Deltistes luxatus and Shortnose Suckers Chasmistes brevirostris through Entrainment Associated with the Operations of Klamath Project at the South End of Upper Klamath Lake During 2011. U.S. Bureau of Reclamation, Klamath Basin Area Office, Klamath Falls, Oregon. 22 pp.

Ulev, Elena. 2007. Lynx canadensis. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. Available online at: https://www.fs.fed.us/database/feis/animals/mammal/lyca/all.html.

Underwood, K. D., S. W. Martin, M. L. Schuck, and A. T. Scholz. 1995. Investigations of bull trout (*Salvelinus confluentus*), steelhead trout (*Oncorhychus mykiss*), and spring chinook salmon (*O. tshawytscha*) interactions in southeast Washington streams. 1992 Final Report, BPA Report No. DOE/BP-17758-2. Prepared by Eastern Washington University, Department of Biology and Washington Department of Wildlife for Bonneville Power Administration, Division of Fish and Wildlife, Portland, Oregon.

US Army Corps of Engineers Engineering Center (USACE). 2016. HEC-RAS River Analysis System Hydraulic Reference Manual Version 5.

USACE. 2019. HEC-RAS River Analysis System Release Notes.

USBR (U.S. Bureau of Reclamation). 1992. Biological assessment on long term project operations. February 28, 1992. Klamath Falls, Oregon. 103 pp.

USBR. 1998. Lost River and Shortnose Sucker Spawning in Lower Lost River, Oregon. Completion Report. U.S. Bureau of Reclamation, Klamath Basin Area Office, Klamath Falls, Oregon.

USBR. 2000. Klamath irrigation project sucker salvage and Langell Valley fish survey report - 1999. Klamath Basin Area Office, Bureau of Reclamation, U.S. Department of Interior, Klamath Falls, Oregon.

USBR. 2001. Biological assessment of the Klamath Project's continuing operations on the endangered Lost River sucker and shortnose sucker. Klamath Basin Area Office, Bureau of Reclamation, U.S. Department of Interior, Klamath Falls, Oregon.

USBR. 2002. Biological assessment, the effects of proposed actions related to Klamath Project Operation (April 1, 2002–March 31, 2012) on federally-listed threatened and endangered species. Mid-Pacific Region, Kamath Basin Area Office, Klamath Falls, Oregon.

USBR. 2007. Biological Assessment; The Effects of the Proposed Action to Operate the Klamath Project from April 1, 2008, to March 31, 2018 on Federally-Listed Threatened and Endangered Species. Klamath Basin Area Office, Bureau of Reclamation, U.S. Department of Interior, Klamath Falls, Oregon.

USBR. 2008. Fish handling guidelines for salvaged and transported Klamath Basin suckers. Bureau of Reclamation, Klamath Basin Area Office, Klamath Falls, Oregon.

USBR. 2010. Klamath River Sediment Sampling Program Phase 1- geologic investigations, Mid-Pacific Region, MP-230, Sacramento, California.

USBR. 2011a. Hydrology, hydraulics and sediment transport studies for the secretary's determination on Klamath River Dam removal and basin restoration. Technical Report No. SRH-2011-02, Prepared for Mid-Pacific Region, US Bureau of Reclamation, Technical Service Center, Denver, Colorado.

USBR. 2011b. Sedimentation and river hydraulics – one-dimension (SRH-1D) model. Reclamation Sedimentation and River Hydraulics Group, Technical Service Center, Denver, Colorado. Available online at: http://www.Reclamation.gov/pmts/sediment/model/srh1d/index.html.

USBR. 2011c. Sediment chemistry investigation: sampling, analysis, and quality assurance findings for Klamath River reservoirs and estuary, October 2009–January 2010. U.S. Department of the Interior, Bureau of Reclamation, Mid-Pacific Region, Ecological Research and Investigations Group (86-68220), Technical Service Center, Sacramento, California.

USBR. 2011d. Reservoir Area Management Plan for the Secretary's Determination on Klamath River Dam Removal and Basin Restoration Klamath River, Oregon and California. Technical Report No. SRH2011-19. Mid-Pacific Region. June 2011.

USBR. 2012a. Detailed Plan for Dam Removal – Klamath River Dams – Klamath Hydroelectric Project – FERC License No. 2082 – Oregon-California. July 2012.

USBR. 2012b. Final Biological Assessment on the effects of the proposed action to operate the Klamath Project from April 1, 2013, through March 31, 2023 on Federally-listed threatened and endangered species. Mid-Pacific Region, Sacramento California.

USBR. 2016. Klamath River Basin Study. Prepared for Mid-Pacific Region, U.S. Bureau of Reclamation, Technical Service Center, Denver, Colorado, in partnership with the California Department of Water Resources and Oregon Water Resources Department.

USBR. 2018. Final Biological Assessment – The Effects of the Proposed Action to Operate the Klamath Project from April 1, 2019 through March 31, 2029 on Federally-Listed Threatened and Endangered Species. 447 pp.

USBR. 2019. Biological Assessment on the Effects of Proposed Klamath Project Operations from April 1, 2019, through March 31, 2029 on Federally Listed Threatened and Endangered Species.

USBR and CDFW. 2012. Klamath Facilities Removal. Final Environmental Impact Statement/Environmental Impact Report (EIS/EIR). U.S. Bureau of Reclamation and California Department of Fish and Wildlife, December.

USDA (United States Department of Agriculture) Forest Service. 2005. Wildland Fire in Ecosystems. Effects of Fire on Soil and Water. Available online at: https://www.fs.fed.us/rm/pubs/rmrs_gtr042_4.pdf.

USDA Forest Service. 2010. Biological assessment for the potential effects of invasive plant treatments on terrestrial wildlife species on the Fremont-Winema National Forests. Prepared by A. Markus, Wildlife Biologist, USDA Forest Service, Fremont-Winema National Forests, Lakeview, Oregon.

USDA Forest Service. 2018. Somes Bar Integrated Fire Management Project Final Environmental Assessment. Prepared by USDA Forest Service for the Western Klamath Restoration Partnership. USDA Forest Service, Eureka, California.

USDOI (U.S. Department of Interior). 1967. List of Species Threatened with Extinction. 32FR4001. 1 pp.

USDOI (National Park Service, Redwood National Park and U.S. Fish and Wildlife Service) and the Yurok Tribe. 2019. Northern California Condor Restoration Program Environmental Assessment. Docket No. FWS-R1-ES-2018-0033-0002. 235 pp.

EPA (U.S. Environmental Protection Agency). 1986. Quality Criteria for Water. EPA 440/5-86-001.

EPA. 2001. Trinity River Total Maximum Daily Load for sediment. San Francisco, CA:U.S. Environmental Protection Agency, Region IX.

EPA. 2003. Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards. EPA 910-B-03-002. Region 10 Office of Water, Seattle, WA. 57 pp.

U.S. Fish and Wildlife Service (USFWS). 1967. List of Species Threatened with Extinction. 32FR4001. 1 pp.

USFWS. 1977. Final Rule: Correction and augmentation of published rulemaking on Critical Habitats. 42FR47840. 6 pp.

USFWS. 1988. Endangered and threatened wildlife and plants; determination of endangered status for the shortnose sucker and Lost River sucker. Federal Register 53: 27,130–27,134.

USFWS. 1989. Endangered and Threatened Wildlife and Plants; Animal Candidate Review for Listing as Endangered or Threatened Species: Candidate Species Notice of Review. 54FR554.

USFWS. 1990. Endangered and threatened wildlife and plants; determination of threatened status for the northern spotted owl; final rule. Federal Register 55: 26,114–26,194.

USFWS. 1991. Endangered and Threatened Wildlife and Plants; Animal Candidate Review for Listing as Endangered or Threatened Species: Candidate Species Notice of Review. 56FR58804.

USFWS. 1992. Endangered and threatened wildlife and plants; determination of critical habitat for the northern spotted owl; final rule. Federal Register 57: 1,796–1,838.

USFWS. 1993. Lost River (*Deltistes luxatus*) and shortnose (*Chasmistes brevirostris*) sucker recovery plan. Prepared by K. Stubbs and R. White for USFWS, Region 1, Portland, Oregon.

U.S. Fish and Wildlife Service (USFWS). 1994. Endangered and Threatened Wildlife and Plants; Animal Candidate Review for Listing as Endangered or Threatened Species: Candidate Species Notice of Review. 59FR58982.

USFWS. 1995. Endangered and threatened wildlife and plants; proposed special rule for the conservation of the northern spotted owl on non-Federal lands. Federal Register 60: 9,483–9,527.

USFWS. 1996. California Condor Recovery Plan. Third Revision. Portland, Oregon. 62 pp.

USFWS. 2001. Juvenile salmonid monitoring on the mainstem Klamath River at Big Bar and mainstem Trinity River at Willow Creek, 1997–2000. Annual report of the Klamath River Fisheries Assessment Program. Arcata Fish and Wildlife Office, Arcata, California.

USFWS. 2002a. A Review of the First Five Years of the California Condor Reintroduction Program in Northern Arizona. California Condor Recovery Team and the U.S. Fish and Wildlife Service, California/Nevada Operations Office, Sacramento, California. 70 pp.

USFWS. 2002b. Bull trout (*Salvelinus confluentus*) draft recovery plan. U.S. Fish and Wildlife Service, Portland, Oregon. Available online at: http://pacific.fws.gov/bulltrout/.

USFWS. 2002c. Biological/conference opinion regarding the effects of the U.S. Bureau of Reclamation's proposed 10-year operation plan for the Klamath Project and its effect on the endangered Lost River sucker (Deltistes luxatus), endangered shortnose sucker (Chasmistes brevirostris. Klamath Falls, Oregon.

USFWS. 2003. Recovery Plan for Fritillaria gentneri (Gentner's fritillary). USFWS, Region 1, Portland, Oregon.

USFWS. 2005a. Recovery plan for the tidewater goby (*Eucyclogobius newberryi*). USFWS, Pacific Region, Portland, Oregon.

USFWS. 2005b. Recovery plan for vernal pool ecosystems of California and Southern Oregon. USFWS, Pacific Region, Portland, OR.

USFWS. 2006a. Estimating the effects of auditory and visual disturbance to northern spotted owls and marbled murrelets in northwestern California. USFWS, Arcata Fish and Wildife Office, Arcata, California.

USFWS. 2006b. Recovery Plan for Phlox hirsuta (*Yreka phlox*). USFWS, California/Nevada Operations Office, Sacramento, California.

USFWS. 2007a. Recovery plan for the Pacific Coast population of the western snowy plover (*Charadrius alexandrinus nivosus*), Volume 1-2. USFWS, Sacramento, California.

USFWS. 2007b. Lost River sucker (*Deltistes luxatus*) 5-year review summary and evaluation. Klamath Falls Fish and Wildlife Office, Klamath Falls, Oregon. July 2007. 38 pp.

USFWS. 2007c. Shortnose sucker (*Chasmistes brevirostris*) 5-year review summary and evaluation. Klamath Falls Fish and Wildlife Office, Klamath Falls, Oregon. July 2007.

USFWS. 2007d. 2006 sucker spawning in the lower Lost River, Oregon. U.S. Fish and Wildlife Service, Klamath Falls Fish and Wildlife Office. March 23, 2007.

USFWS. 2008a. Biological/conference opinion regarding the effects of the U.S. Bureau of Reclamation's proposed 10-year operation plan (April 1, 2008 – March 31, 2018) for the Klamath Project and its effects on the endangered Lost River and shortnose suckers. Prepared by the U.S. Fish and Wildlife Service, Klamath Falls Fish and Wildlife Office, Klamath Falls, Oregon and Yreka Fish and Wildlife Office, Yreka, California.

USFWS. 2008b. Endangered and threatened wildlife and plants; revised designation of critical habitat for the tidewater goby (*Eucyclogobius newberryi*); Final rule. Federal Register 73: 5,920-6,006.

USFWS. 2008c. Short-tailed albatross (*Phoebastria albatrus*) recovery plan. Prepared by the Short-Tailed Albatross Recovery Team for USFWS, Region 7, Anchorage, Alaska.

USFWS. 2008d. Bull trout recovery: monitoring and evaluation guidance. Version 1 Report prepared for the U.S. Fish and Wildlife Service, Columbia River Fisheries Program Office, Vancouver, Washington by the Bull Trout Recovery and Monitoring Technical Group (RMEG), Portland, Oregon.

USFWS. 2009a. *Chamaesyce hooveri* (Hoover's Spurge) 5-Year Review: Summary and Evaluation. Available online at: https://ecos.fws.gov/docs/five_year_review/doc2387.pdf.

USFWS. 2009b. Western Lily (*Lilium occidentale*) 5-Year Review: Summary and Evaluation. Available online at: https://ecos.fws.gov/docs/five_year_review/doc2408.pdf.

USFWS. 2009c. Slender Orcutt Grass (*Orcuttia tenuis*) 5-Year Review: Summary and Evaluation. Available online at: https://ecos.fws.gov/docs/five_year_review/doc3226.pdf.

USFWS. 2010. Draft revised recovery plan for the northern spotted owl (*Strix occidentalis caurina*). Prepared by USFWS, Region 1, Portland, Oregon.

USFWS. 2011a. Revised recovery plan for the northern spotted owl (*Strix occidentalis caurina*). Prepared by USFWS, Region 1, Portland, Oregon.

USFWS. 2011b. Climate Change in the Pacific Region. USFWS, Pacific Region Website. Available online at: https://www.fws.gov/pacific/climatechange/changepnw.html.

USFWS. 2012a. Endangered and threatened wildlife and plants; designation of revised critical habitat for the northern spotted owl; final rule. Federal Register 77: 233, 71876-72067.

USFWS. 2012b. Protocol for Surveying Proposed Management Activities That May Impact Northern Spotted Owls. Endorsed by the U.S. Fish and Wildlife Service. February 2, 2011, Revised January 9, 2012.

USFWS. 2012c. Endangered and Threatened Wildlife and Plants: Designation of Critical Habitat for Lost River Sucker and Shortnose Sucker. Final Rule. Federal Register 77 (238): 73740-73768.

USFWS. 2013a. California Condor (*Gymnogyps californianus*) 5-Year Review: Summary and Evaluation. Pacific Southwest Region. Sacramento, California. 64 pp.

USFWS. 2013b. Programmatic Biological Opinion for Aquatic Restoration Activities in the States of Oregon, Washington and portions of California, Idaho and Nevada (ARBO II). Prepared by the Oregon Fish and Wildlife Office Portland, Oregon.

USFWS. 2013c. Revised recovery plan for the Lost River sucker (*Deltistes luxatus*) and shortnose sucker (*Chasmistes brevirostris*). U.S. Fish and Wildlife Service, Pacific Southwest Region, Sacramento, California. xviii + 122 pp.

USFWS. 2014. Endangered and Threatened Wildlife and Plants; 90-Day Findings on Two Petitions. 79FR78775. 4 pp.

USFWS. 2015a. Klamath Recovery Unit Implementation Plan for Bull Trout Recovery Plan. Klamath Falls, Oregon. September 2015. 39 pp.

USFWS. 2015b. Recovery Plan for the Coterminous United States Population of Bull Trout (*Salvelinus confluentus*). Pacific Region U.S. Fish and Wildlife Service Portland, Oregon. 195 pp.

USFWS. 2016. Response to Request for Technical Assistance – Prevalence of C. shasta Infections in Juvenile and Adult Salmonids. Unpublished memo to D. Hillemeier, Yurok Tribal Fisheries, and Craig Tucker, Karuk Department of Natural Resources. 17 pp.

USFWS. 2017. Lower Klamath, Clear Lake, Tule Lake, Upper Klamath and Bear Valley National Wildlife Refuges, Final Comprehensive Conservation Plan and Environmental Assessment. Tule Lake and Sacramento, California: U.S. Fish and Wildlife Service, Pacific Southwest Region.

USFWS. 2018a. Endangered and Threatened Wildlife and Plants: Threatened Species Status for Coastal Distinct Population Segment of the Pacific Marten. Federal Register: 83:50574– 50582. October 9, 2018.

USFWS. 2018b. Monarch on a Mission. USFWS-Klamath Basin National Wildlife Refuge Complex press release. Downloaded on February 8, 2021. (https://www.fws.gov/cno/newsroom/Highlights/2018/monarch_on_a_mission/)

USFWS. 2018c. Plant and animal species information. Website. USFWS, Arcata Fish and Wildlife Office, Endangered Species Program, Pacific Southwest Region, Arcata, California. Available online at: http://www.fws.gov/arcata/.

USFWS. 2018d. Species Status Assessment for Franklin's Bumble Bee (*Bombus franklini*). Oregon Fish and Wildlife Office. Portland, Oregon. 61 pp.

USFWS. 2018e. Status of the Species and Critical Habitat - Northern Spotted Owl. Last updated August 14, 2018.USFWS. 2018f. Yellow-billed Cuckoo (Western Population). Oregon Fish and Wildlife Office. Available online at: https://www.fws.gov/oregonfwo/articles.cfm?id=149489511.

USFWS. 2019a. Biological Opinion on the Effects of Proposed Klamath Project Operations from April 1, 2019, through March 31, 2024, on the Lost River Sucker and the Shortnose Sucker. USFWS, Klamath Falls Fish and Wildlife Office. (TAILS # 08EKLA00-2019-F-0068). 222 pp.

USFWS. 2019b. Endangered and Threatened Wildlife and Plants; Establishment of a Nonessential Experimental Population of the California Condor in the Pacific Northwest. Proposed Rule. Availability of supplemental information. April 5, 2019. 84FR13587. 17 pp.

USFWS. 2019c. Proposed Rule. Endangered and Threatened Wildlife and Plants; Endangered Species Status for Franklin's Bumble Bee (*Bombus franklini*). 84FR40006. 14 pp.

USFWS. 2019d. Lost River Sucker (Deltistes luxatus) 5 Year Review: Summary and Evaluation. Klamath Falls Fish and Wildlife Office. 10 pp.

USFWS. 2019e. Shortnose Sucker (Chasmistes brevirostris) 5 Year Review: Summary and Evaluation. Klamath Falls Fish and Wildlife Office. 10 pp.

USFWS. 2019f. Special Status Assessment for the Endangered Lost River Sucker and Shortnose Sucker. Klamath Falls Fish and Wildlife Office – Pacific Southwest Region. Final Report, version 1. 90 pp.

USFWS. 2020a. Monarch (*Danaus plexippus*) Species Status Assessment Report, V2.1. September 2020. 96 pp + appendices.

USFWS. 2020b. Endangered and Threatened Wildlife and Plants; 12-Month Finding for the Monarch Butterfly. 85FR81813. 10 pp.

USFWS. 2021. Response to Request for Technical Assistance – Estimated prevalence of mortality (POM) for Shasta River-origin Coho Salmon, 2020. Unpublished letter to U.S. Bureau of Reclamation. 1 p.

USFWS and BLM. 2017. Klamath River habitat suitability mapping layers.

USFWS and NMFS. 1998. Endangered species consultation handbook: procedures for conducting consultation and conference activities under Section 7 of the Endangered Species Act. Final report. Washington, DC.

USFWS, USDI BLM, and USDA Forest Service. 2008. Methodology for estimating the number of northern spotted owls affected by proposed federal actions. Version 2.0 (replaces the September 14, 2007 document). Oregon Fish and Wildlife Office, Fish and Wildlife Service, Portland, Oregon.

USGCRP (U.S. Global Change Research Program). 2018. Fourth National Climate Assessment (NC4) 2017/2018 - The National Climate Assessment – Impacts, Risks, and Adaptation in the United States. 1500 pp.

USGS. 2009. Understanding the Habitat Needs of the Declining Western Yellow-Billed Cuckoo. Available online at: https://pubs.usgs.gov/fs/2009/3091/fs2009-3091.pdf.

USGS. 2021. 2020 S3 Modeling Results for *C. shasta* Prevalence of Mortality of Naturally Produced Chinook Salmon Downstream from Iron Gate Dam. Unpublished letter to U.S. Bureau of Reclamation. 2 pp.

Van Kirk, R. W., and S. W. Naman. 2008. Relative effects of climate and water use on base-flow trends in the lower Klamath basin. Journal of the American Water Resources 44: 1,035–1,052.

VanderKooi, S.P., S.M. Burdick, K.R. Echols, C.A. Ottinger, B.H. Rosen, and T.M. Wood. 2010. Algal toxins in upper Klamath Lake, Oregon—Linking water quality to juvenile sucker health: U.S. Geological Survey Fact Sheet 2009-3111, 2 p.

Velez-Espino, L. A., J. K. B. Ford, H. A. Araujo, G. Ellis, C. K. Parken, and R. Sharma. 2014. Relative importance of Chinook salmon abundance on resident killer whale population growth and viability. Aquatic Conservation: Marine and Freshwater Ecosystems. 25(6): 756-780.

Voight, H. N., and D. Gale. 1998. Distribution of fish species in tributaries of the lower Klamath River: an interim report, FY 1996. Yurok Tribal Fisheries Program. Klamath, California.

Wainwright, T. C., and L. A. Weitkamp. 2013. Effects of climate change on Oregon coast Coho salmon: Habitat and life-cycle interactions. Northwest Science 87:219−242.

Walker, L. A., L. Cornell, K. D. Dahl, N. M. Czekala, C. M. Dargen, B. Joseph, A. J. W. Hsueh, and B. L. Lasley. 1988. Urinary concentrations of ovarian steroid hormone metabolites and bioactive follicle-stimulating hormone in killer whales (Orcinus orca) during ovarian cycles and pregnancy. Biology of Reproduction 39: 1,013–1,020.

Walker, W. W. 2001. Development of phosphorus TMDL for Upper Klamath Lake, Oregon. Prepared for Oregon Department of Environmental Quality, Bend, Oregon.

Walker W. W. 2010. Corrected affidavit and direct testimony of Dr. William W. Walker. KBA Case 286, exhibit 286-US-500.

Walker, W. W., J. D. Walker, and J. Kann. 2012, Evaluation of water and nutrient balances for the Upper Klamath Lake Basin in water years 1992–2010. Technical Report Prepared by Aquatic Ecosystem Sciences for the Klamath Tribes Natural Resources Department, 50 pp. plus appendixes.

Walker, J. D., J. Kann, and W. W. Walker. 2015. Spatial and temporal nutrient loading dynamics in the Sprague River Basin, Oregon. Prepared by Aquatic Ecosystem Sciences, J. D. Walker, and W. W. Walker for the Klamath Tribes Natural Resources Department. 73 pp. + appendices.

Wallace, M. 1998. Seasonal water quality monitoring in the Klamath River estuary, 1991–1994. Administrative Report No. 98-9. California Department of Fish and Game, Inland Fisheries, Arcata, California.

Wallace M. 2004. Natural vs. hatchery proportions of juvenile salmonids migrating through the Klamath River Estuary and monitor natural and hatchery juvenile salmonid emigration from the Klamath River Basin. July 1, 1998 through June 30, 2003. Final performance report. Federal Aid in Sport Fish Restoration Act. Project no. F-51-R-6. Arcata, California.

Walters, D. M., M. C. Freeman, D. S. Leigh, B. J. Freeman, M. J. Paul, and C. M. Pringle. 2001. Bed texture and turbidity as indicators of fish biotic integrity in the Etowah River system. Pages 233–236 *in* K. J. Hatcher, editor. Proceedings of the 2001 Georgia Water Resources Conference. 26–27 March 2001.

Wang, L., A.J. Cuthbertson, S.H. Zhang, G. Pender, A.P Shu, and Y.Q. Wang. 2021. Graded bed load transport in sediment supply limited channels under unsteady flow hydrographs. Journal of Hydrology, 595, p.126015.

Ward, E. J., E. E. Holmes, and K. C. Balcomb. 2009. Quantifying the effects of prey abundance on killer whale reproduction. Journal of Applied Ecology 46: 632–640.

Ward, E. J., M. J. Ford, R. G. Kope, J. K. B. Ford, L. A. Velez-Espino, C. K. Parken, L. W. LaVoy, M. B. Hanson, and K. C. Balcomb. 2013. Estimating the Impacts of Chinook Salmon Abundance and Prey Removal by Ocean Fishing on Southern Resident Killer Whale Population Dynamics. July 2013. U.S. Dept. Commer., NOAA Tech. Memo., NMFS-NWFSC-123. 85 pp.

WDOE (Washington State Department of Ecology). 2002. Evaluating Criteria for the Protection of Freshwater Aquatic Life in Washington's Surface Water Quality Standards: Dissolved Oxygen. Draft Discussion Paper and Literature Summary. Publication Number 00-10- 071. 90pp.

Wasser, S. K., J. I. Lundin, K. Ayres, E. Seely, D. Giles, K. Balcomb, J. Hempelmann, K. Parsons, and R. Booth. 2017. Population growth is limited by nutritional impacts on pregnancy success in endangered Southern Resident killer whales (Orcinus orca). PLoS ONE. 12(6): 1-22.

Watercourse Engineering, Inc. 2011. Klamath River baseline water quality sampling, 2009 Annual Report. Prepared for the KHSA Water Quality Monitoring Group.

Watercourse Engineering, Inc. 2015. Klamath River baseline water quality sampling, 2014 Annual Report. Prepared for the KHSA Water Quality Monitoring Group.

Watercourse Engineering, Inc. 2016. Klamath River baseline water quality sampling, 2015 Annual Report. Prepared for the KHSA Water Quality Monitoring Group.

Watercourse Engineering, Inc. 2017. Klamath River baseline water quality sampling, 2016 Annual Report. Prepared for the KHSA Water Quality Monitoring Group.

WDFW and ODFW. 2001. Washington and Oregon eulachon management plan. Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife.

Wells, B. K., C. B. Grimes, J. G. Sneva, S. McPherson, and J. B. Waldvogel. 2008. Relationships between oceanic conditions and growth of Chinook salmon (*Oncorhynchus tshawytscha*) from California, Washington, and Alaska, USA. Fisheries Oceanography 17: 101–125.

West, J. R., O. J. Dix, A. D. Olson, M. V. Anderson, S. A. Fox, and J. H. Power. 1990. Evaluation of fish habitat conditions and utilization in Salmon, Scott, Shasta, and Mid-Klamath sub-basin tributaries. Annual report for interagency agreement 14-16-0001-89508. Prepared by USDA Forest Service, Klamath National Forest, Yreka, California and Shasta Trinity National Forest, Weaverville, California.

Western Association of Fish and Wildlife Agencies. 2019. Western monarch butterfly conservation plan, 2019–2069. Version 1.0.

Wheatcroft, R. A., D. E. Drake, J. C. Borgeld, and C. A. Nittrouer. 1997. Rapid and widespread dispersal of flood sediment on the northern California continental margin. Geology 25: 163–166.

Wheeler, C.A., H.H. Welsh, and L.L. Heise. 2003. *Rana boylii* (foothill yellow-legged frog) oviposition behavior. Herpetological Review 34(3): 234.

Wheeler, C.A. and H.H. Welsh. 2008. Mating strategy and breeding patterns of the foothill yellow-legged frog (*Rana boylii*). Herpetological Conservation and Biology 3(2): 128-142.

Wheeler, C.A., J.B. Bettaso, D.T. Ashton, and H. H. Welsh. 2015. Effects of water temperature on breeding phenology, growth, and metamorphosis of foothill yellow-legged frogs (*Rana boylii*): A case study of the regulated mainstem and unregulated tributaries of California's Trinity River. River Research and Applications 31(10):1276-1286.

Wherry, S. A., and T. M. Wood. 2018. A metabolism-based whole lake eutrophication model to estimate the magnitude and time scales of the effects of restoration in Upper Klamath Lake, south-central Oregon: U.S. Geological Survey Scientific Investigations Report 2018-5042, 43 pp.

Wherry, S.A., Wood, T.M., and Anderson, C.W., 2015, Revision and proposed modification of a total maximum daily load model for Upper Klamath Lake, Oregon: U.S. Geological Survey Scientific Iinvestigations Report 2015–5041, 55 p.

WHO (World Health Organization). 1999. Toxic cyanobacteria in water: a guide to their public health consequences, monitoring and management. E & FN Spon, London, England.

Wiles, G. J. 2004. Washington State Status Report for the Killer Whale. March 2004. WDFW, Olympia, Washington. 120 pp.

Williams, D. 2010. Yurok Tribal fisheries – harvest of species listed under the Endangered Species Act. Yurok Tribal Fisheries Program, Klamath, California.

Williams, T. H., B. C. Spence, W. Duffy, D. Hillemeier, G. Kautsky, T. E. Lisle, M. McCain, T. E. Nickelson, E. Mora, and T. Pearson. 2008. Framework for assessing viability of threatened coho salmon in the southern Oregon/northern California coast evolutionarily significant unit. NOAA Technical Memorandum. NOAA-TM-NMFS-SWFSC-432. Prepared by National Marine Fisheries Service, Southwest Fisheries Science Center, Santa Cruz, California.

Williams, T. H., E. P. Bjorkstedt, W. G. Duffy, D. Hillemeier, G. Kautsky, T. E. Lisle, M. McCain, M. Rode, G. Szerlong, R. S. Schick, M. N. Goslin, and A. Agrawal. 2006. Historical population structure of coho salmon in the southern Oregon/northern California coasts evolutionarily significant unit. NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-390. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center.

Williams, T. H., S. T. Lindley, B. C. Spence, D. A. Boughton. 2011a. Status review update for Pacific salmon and steelhead under the Endangered Species Act: Southwest. 20 May 2011 – Update to 5 January 2011 report. National Marine Fisheries Service, Southwest Fisheries Science Center. Santa Cruz, California.

Williams, T. H., J. C. Garza, N. Hetrick, S. T. Lindley, M. S. Mohr, J. M. Myers, M. R. O'Farrell, R. M. Quinones, and D. J. Teel. 2011b. Upper Klamath and Trinity River Chinook salmon Biological Review Team report. National Marine Fisheries Service, Southwest Fisheries Science Center, La Jolla, California.

Williams, T. H., B. C. Spence, D. A. Boughton, R. C. Johnson, L. G. Crozier, N. J. Mantua, M. R. O 'Farrell, and T. Lindley. 2016. Viability assessment for Pacific salmon and steelhead listed under the Endangered Species Act: Southwest U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-564:170pp.

Willson, M. F., R. H. Armstrong, M. C. Hermans, and K. Koski. 2006. Eulachon: a review of biology and an annotated bibliography. Alaska Fisheries Science Center Processed Report 2006-12. Auke Bay Laboratory, Alaska Fisheries Science Center, NOAA, National Marine Fisheries Service, Juneau, Alaska. Available online at: http://www.afsc.noaa.gov/publications/ProcRpt/PR%202006-12.pdf.

Willy, Elizabeth. 2018. Senior Wildlife Biologist, U.S. Fish and Wildlife Service, Klamath Falls Office. Personal communication with Jennifer Jones, The Renewal Corporation, March 26, 2018.

Witmore, S. 2014. Seasonal Growth, Retention, and Movement of Juvenile Coho Salmon in Natural and Constructed Habitats of the Mid-Klamath River [MS thesis]. Humboldt State University, Arcata, California. 83 pages. Available at http://humboldt-dspace.calstate.edu/handle/10211.3/124018.

Wondzell, S. M and J. G. King. 2003. Postfire erosional processes in the Pacific Northwest and Rocky Mountain regions. Forest Ecology and Management 189: 75-87.

Wood, T. M., G. J. Fuhrer, and J. L. Morace. 1996. Relation between selected water-quality variables and lake level in Upper Klamath and Agency Lakes, Oregon. U.S. Geological Survey Water-Resources Investigations Report 96-4079. Portland, Oregon.

Wood, T. M., S. A. Wherry, D. C. Simon, and D. F. Markle. 2014. Particle-tracking investigation of the retention of sucker larvae emerging from spawning grounds in Upper Klamath Lake, Oregon: U.S. Geological Survey Open-File Report 2014-1061.

Wyman, M. T., M. J. Thomas, R. McDonald, A. R. Hearn, P. Kinzel, J. T. Minear, E. A. Mora, and A. P. Klimley. (unpublished). Fine-scale spawning habitat suitability of green sturgeon (Acipenser medirostris) in the upper Sacramento River. Draft manuscript shared with Phaedra Doukakis May 26, 2015, as cited in NMFS 2015b.

Xerces Society and Thorp. 2010. Petition to List Franklin's Bumble Bee *Bombus franklini* (Frison), 1921, As An Endangered Species Under the U.S. Endangered Species Act. Submitted by The Xerces Society for Invertebrate Conservation and Dr. Robbin W. Thorp, June 23, 2010. 40 pp.

Yokel, E., S. K. Witmore, B. Stapleton, C. Gilmore, and M. M. Pollock. 2018. Scott River Beaver Dam Analogue Coho Salmon Habitat Restoration Program 2017 Monitoring Report. 57 pp. Scott River Watershed Council. Etna, California.

Yount, J.D. and G.J. Niemi. 1990. Recovery of lotic communities and ecosystems from disturbance: a narrative review of case studies. Environmental Management 14:547– 570.

YTEP (Yurok Tribe Environmental Program). 2005. Water year 2004 (WY04) report, 1 October 2003-30 September 2004. Final Report. Prepared by Yurok Tribe Environmental Program, Klamath, California.

YTEP. 2009. 2009 Klamath River Nutrient Summary Report. Prepared by Yurok Tribe Environmental Program, Klamath, California.

YTEP. 2011. 2011 Klamath River Continuous Water Quality Monitoring Summary Report. Prepared by Yurok Tribe Environmental Program, Klamath, California.

YTEP. 2012. 2012 Klamath River Nutrient Summary Report. Prepared by Yurok Tribe Environmental Program, Klamath, California.

YTEP. 2014. 2014 Klamath River Nutrient Summary Report. Prepared by Yurok Tribe Environmental Program, Klamath, California.

YTEP. 2015. Wetlands Species and Water Temperature Analysis October 1, 2013, through September 30, 2015. Prepared by Yurok Tribe Environmental Program, Klamath, California.

Yuan, C. L., Z. Z. Xu, M. X. Fan, H. Y. Liu, Y. H. Xie, T. Zhu. 2014. Study on characteristics and harm of surfactants. J. Chem. Pharm. Res. 6:2233-2237.

Yurok Tribe. 2018. 2018 Fall Harvest Management Plan. Available online at: http://www.yuroktribe.org/departments/fisheries/documents/Fall_HMP_2018.pdf.

Zamon, J. E., T. J. Guy, K. Balcomb, and D. Ellifrit. 2007. Winter observations of Southern Resident Killer Whales (Orcinus orca) near the Columbia River plume during the 2005 spring Chinook salmon (Oncorhynchus tshawytscha) spawning migration. Northwestern Naturalist. 88(3): 193-198.

Zanchett, G. and E. Oliveira-Filho. 2013. Cyanobacteria and cyanotoxins: From impacts on aquatic ecosystems and human health to anticarcinogenic effects. Toxins, 5: 2013.

Zielinski, W.J., W.D. Spencer, and R.H. Barrett. 1983. Relationship between food habits and activity patterns of pine martens. American Society of Mammalogists 64(3): 387–396.

Ziller, J. S. 1992. Distribution and relative abundance of bull trout in the Sprague River subbasin, Oregon. Pages 18–29 *in* P. J. Howell and D. V. Buchanan, editors. Proceedings of the Gearhart Mountain bull trout workshop. American Fisheries Society, Oregon Chapter, Corvallis.

Zunka, J.P., D.D. Tullos, and S.T. Lancaster. 2015. Effects of sediment pulses on bed relief in bar-pool channels. Earth Surface Processes and Landforms, 40(8), pp.1017-1028.

Chapter 9: List of Preparers

9. LIST OF PREPARERS

Name	Education	Qualifications
Emma Argiroff	Master of Urban Planning; B.A. Program in the Environment	3 years of experience in National Environmental Policy Act (NEPA), regulatory compliance and permitting
Sam Bankston	B.S. Aquatic Biology	7 years of experience, fisheries and wildlife science, stream assessment, threatened and endangered species surveys, biological/water quality sampling, wetland delineation, data analysis using R statistical software and GIS support
Diane Barr	B.A. Environmental Studies	27 years of permitting and regulatory experience in renewable energy and conservation, obtaining federal, state, and local permits, establishing compliance programs, and facilitating multi-party processes
Troy Brandt	M.S. Environmental Studies – Aquatic Ecology; B.S. Environmental Biology and Management; Certified Fisheries Professional – American Fisheries Society	22 years of experience, ecological restoration and fisheries science, habitat assessment, biological sampling, habitat restoration and fish passage design, regulatory compliance and permitting, construction administration and oversight, post-construction monitoring
Daniel Chase	M.S. Physiology and Behavioral Biology; B.S. Conservation Resource Studies	16 years of experience, fisheries and wildlife science, habitat assessment, threatened and endangered species surveys, habitat restoration, regulatory compliance and permitting, mitigation, construction/post-construction monitoring
Pete Gruendike	B.S. Environmental Sciences	17 years of experience, fisheries, river and stream restoration, regulatory compliance and permitting, field survey and assessment, spatial and statistical analysis
Jennifer Jones	M.S. Environmental Science; B.A. Biology; Certified Ecologist – Ecological Society of America;	20 years of experience, wildlife and fisheries science, regulatory compliance and permitting, NEPA/California Environmental Quality Act (CEQA), ecological restoration, wetland delineation, threatened and endangered species surveys, site assessment and remediation, biological/ water quality/soil and sediment sampling
Adam Khalaf	M.S. Biological Engineering; B.S. Ecological Engineering	2 years of experience, stream and wetland restoration design, NEPA, plant and wildlife surveys
Matt Robart	M.S. Ecology; B.S. Fisheries Science	19 years of experience in aquatic ecology, water quality, and regulatory compliance and permitting
Ken Sanchez	B.S. Wildlife Management	4 years of experience with the U.S. Forest Service in land management, wildlife and fisheries science, and National Environmental Policy Act (NEPA), Endangered Species Act (ESA) regulatory compliance, 26 years of experience with the U.S. Fish and Wildlife Service administering the ESA, and 5 years experience as a private consultant in policy and permitting.
Jonathan Stead	M.S. Ecology; B.S. Biology (Ecology, Behavior, and Evolution)	22 years of experience in application of fish and wildlife biology and ecosystem science to planning and environmental compliance for dam removal, fish passage, stream restoration, and infrastructure projects

Name	Education	Qualifications
Kate Stenberg	Ph.D. Wildlife and Fisheries Science and Regional Planning; Master of Administration in Land Use Planning	35 years of experience, wildlife and fisheries science, regulatory compliance, NEPA/CEQA
Scott Wright	B.S. Civil Engineering M.S. Civil Engineering Professional Engineer (PE) and Project Management Professional (PMP)	27 years of professional experience in civil engineering, water resources, river and stream restoration, regulatory compliance and permitting, and project management
Jack Zunka	PhD Geology M.S. Water Resources Engineering B.A. Earth and Environmental Science	15 years of experience in geology, hydrology, sediment and water quality sampling and evaluation, sediment transport, geomorphic assessment, dam removal, and landscape evolution

www.klamathrenewal.org