RECLAMATION

Managing Water in the West

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


Cover photo: Link River Dam with Upper Klamath Lake in the background.

U.S. Department of the Interior
Bureau of Reclamation

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Mission Statements

The U.S. **Department** of the **Interior** protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated Island Communities.

The **mission** of the **Bureau of Reclamation** is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

EXECUTIVE SUMMARY

This Biological Assessment (BA) has been prepared pursuant to section 7(a)(2) of the Endangered Species Act (ESA) of 1973, as amended, (16 United States Code [U.S.C.] § 1531 *et seq*.), to evaluate the potential effects of the continued operation of the Bureau of Reclamation's (Reclamation) Klamath Project (Project) on species listed as threatened or endangered under the ESA. The Project is located in south-central Oregon and northeastern California and contains approximately 230,000 acres of irrigable land. Reclamation stores, diverts, and conveys waters of the Klamath and Lost Rivers to meet authorized Project purposes and contractual obligations in compliance with state and federal laws and carries out the activities necessary to maintain the Project and ensure its proper long-term functioning and operation.

Federally-listed species that occur within the Action Area and are considered as part of this consultation are the endangered Lost River sucker (*Deltistes luxatus*), endangered shortnose sucker (*Chasmistes brevirostris*), threatened Southern Oregon/Northern California Coast (SONCC) coho salmon *(Oncorhynchus kisutch),* threatened Southern Distinct Population Segment (DPS) of the North American green sturgeon (*Acipenser medirostris),* endangered Southern Resident DPS killer whale (*Orcinus orca*), and threatened DPS of Pacific eulachon (*Thaleichthys pacificus*).

Reclamation currently meets its obligations under the ESA by operating the Project in accordance with 2013 Biological Opinions on the Effects of Proposed Klamath Project Operations from May 31, 2013, through March 31, 2023 provided by the U.S. Fish and Wildlife Service and National Oceanic and Atmospheric Administration's National Marine Fisheries Service. Reclamation has reinitiated consultation with those agencies on its operation of the Project and has prepared this BA to assist with the reinitiated consultation. Reclamation's Proposed Action (PA) for this BA is the operation of the Project from April 1, 2019, through March 31, 2029. Reclamation proposes to continue to store waters of the Klamath and Lost Rivers, operate the Project, for the delivery of water to meet authorized Project purposes and contractual obligations inclusive of deliveries to national wildlife refuges in compliance with applicable state and federal law. Reclamation also proposes to conduct routine maintenance activities on Project facilities that are not only limited in duration, but necessary to maintain Project facilities and ensure the proper long-term viability, functioning, and operation of the Project.

Reclamation has considered the best scientific and commercial information available and determined the potential effects of the Proposed Action on federally-listed species. This analysis shows that the Proposed Action may affect, and is likely to adversely affect Lost River and shortnose suckers and SONCC coho salmon. This analysis also indicates that designated critical habitat for the suckers is likely to be adversely affected and designated critical habitat for the coho salmon is also likely to be adversely affected. The analysis further demonstrates that the Proposed Action may affect, but is not likely to adversely affect the Southern DPS North American green sturgeon, the Southern Resident DPS killer whale, and the Southern DPS of

Pacific eulachon, and may affect, but is not likely to adversely affect designated critical habitat for the Southern DPS of Pacific eulachon.

Based on these conclusions, Reclamation is requesting formal consultation under section 7(a)(2) of the ESA with the USFWS on the Lost River and shortnose suckers and their designated critical habitat, and with NMFS on the coho salmon and their designated critical habitat, the Southern DPS North American green sturgeon, the Southern Resident DPS killer whale, and the Southern DPS Pacific eulachon and its designated critical habitat.

ACRONYMS AND ABBREVIATIONS

AF	acre-feet
ACT	Agency Coordination Team
ACFFOD	Amended and Corrected Findings of Fact and Order of Determination
AFA	*Aphanizomenon flos-aquae*
ASR	Aquatic Scientific Resources
Bio	Biology
BiOp	Biological Opinion
BA	Biological Assessment
BIA	Bureau of Indian Affairs
BOD	biochemical oxygen demand
°C	degrees Celsius
CDFW	California Department of Fish and Wildlife
C.F.R.	Code of Federal Regulations
cfs	cubic feet per second
Copco	California Oregon Power Company
DDT	dichlorodiphenyltrichloroethane
DPS	Distinct Population Segment
DO	dissolved oxygen
EOM	end of month
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
EWA	Environmental Water Account
°F	degrees Fahrenheit
feet/s	feet per second
FASTA	Flow Account Scheduling Technical Advisory
FERC	Federal Energy Regulatory Commission
FR	Federal Register
GCID	Glenn-Colusa Irrigation District
Hydro	Hydrology
HCP	Habitat Conservation Plan
HID	Horsefly Irrigation District
IGD	Iron Gate Dam
IGH	Iron Gate Hatchery
KBAO	Klamath Basin Area Office
KBRA	Klamath Basin Restoration Agreement
KBPM	Kamath Basin Planning Model
KDD	Klamath Drainage District
kg	kilogram(s)
KHSA	Klamath Hydroelectric Settlement Agreement
KID	Klamath Irrigation District
KLS	Klamath largescale sucker

KPFA	Klamath Power and Facilities Agreement
KRRC	Klamath River Renewal Corporation
KSD	Klamath Straits Drain
KWUA	Klamath Water Users Association
LKNWR	Lower Klamath National Wildlife Refuge
LRD	Link River Dam
LRDC	Lost River Diversion Channel
LRS	Lost River Sucker(s)
LVID	Langell Valley Irrigation District
m/s	meters per second
mg/L	milligrams per Liter
mg O_2/L	milligrams of oxygen per Liter
µg/L	micrograms per Liter
mm	millimeter
N	nitrogen
NFWF	National Fish and Wildlife Foundation
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
NRCS	Natural Resources Conservation Service
NWR	National Wildlife Refuge
ODE	Oregon Department of Environmental Quality
O&M	Operation and Maintenance
OM	organic matter
OWRD	Oregon Water Resources Department
pHOS	proportion of hatchery fish on spawning grounds
pNOB	natural origin fish used in hatchery broodstock
P	phosphorus
PA	Proposed Action
PAH	polynuclear aromatic hydrocarbons
PCB	polychlorinated biphenyl
PIT	Passive Integrated Transponder
POI	prevalence of infection
POR	Period of Record
PP	particulate phosphorus
Project	Klamath Project
PVID	Poe Valley Improvement District
QA/QC	quality assurance/quality control
Reclamation	U.S. Bureau of Reclamation
rkm	river kilometer
RBM	River Basin Model-10
RM	river mile
ROC	reinitiation of consultation
RPA	reasonable and prudent alternative
SAR	Smolt-to-adult return
Secretary	Secretary of the Interior

Services	United States Fish and Wildlife Service as well as the National Marine Fisheries Service
SNS	Shortnose Sucker(s)
SONCC	Southern Oregon/Northern California Coast
SRCD	Siskiyou Resource Conservation District
SRKW	Southern Resident Killer Whale
SRP	soluble reactive phosphorus
Stat.	Statute
TAF	thousand acre-feet
TID	Tulelake Irrigation District
TIN	total inorganic nitrogen
TL	total length
TMDL	total maximum daily load
TP	Total phospohrus
UKL	Upper Klamath Lake
U.S.	United States
U.S.C.	United States Code
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WDFS	Washington State Department of Fish and Wildlife
WRIMS	Water Resource Integrated Modeling System
WUA	weighted usable area
WY	water year
YOY	Young-of-the-Year

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1. INTRODUCTION

1.1. Purpose of the Biological Assessment

The United States Bureau of Reclamation (Reclamation) currently meets its obligations under the Endangered Species Act (ESA) by operating the Klamath Project (Project) in accordance with 2013 Biological Opinions (BiOps) on the Effects of Proposed Klamath Project Operations from May 31, 2013, through March 31, 2023 provided by the United States Fish and Wildlife Service (USFWS) and National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS; collectively referred to as the Services). Reclamation reinitiated consultation with the Services (50 Code of Federal Regulations (C.F.R.) section 402.16) at least as early as January 2017 after the estimated amount of incidental take of Southern Oregon Northern California Coast (SONCC) coho salmon – as calculated according to the metric included in NMFS' 2013 incidental take statement – exceeded the amount of take that was anticipated in the take statement in 2014 and 2015. The reinitiated consultation will analyze Reclamation's proposal to modify the water management approach for Project operations as well as the availability of new scientific information related to the effects of Project operations on listed species and/or their designated critical habitat. In particular, Reclamation proposes to continue to store waters of the Klamath and Lost rivers, operate the Project, for the delivery of water to meet authorized Project purposes and contractual obligations inclusive of deliveries to national wildlife refuges (NWRs) in compliance with applicable state and federal law. Reclamation also proposes to conduct routine maintenance activities on Project facilities that are not only limited in duration, but necessary to maintain Project facilities and ensure the proper long-term viability, functioning, and operation of the Project. Reclamation also proposes to carryout various conservation measures to minimize the effects of its action on ESA-listed species and/or their critical habitat.

Reclamation has prepared this Biological Assessment (BA) pursuant to section 7(a)(2) of the ESA of 1973, as amended (16 United States Code [U.S.C.] section1531 *et seq.*) to evaluate the potential effects to federally-listed species that could result from the continued operation and maintenance (O&M) of the Project.

This BA provides information on the anticipated effects of the Proposed Action (PA) that cover the period from April 1, 2019 through March 31, 2029[1], on federally-listed species for use by the Services in preparation of their respective BiOps (collectively referred to as the BiOp). Reclamation has collaborated extensively with each of the Services in the development of the PA

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[1] Reclamation's PA has a term of 10 years (2019 to 2029) or until such time that reinitiation of formal consultation is required as outlined in Section 7(b) 402.16 of the ESA. Reclamation determined that term of the 2019 PA is consistent with previous proposed actions (e.g., 2012), and is appropriate due to uncertainties that may occur within the Klamath River Basin (e.g., dam removal on the Klamath River) and the inability to describe the PA over a period longer than 10 years.

and BA. As a result, Reclamation has prepared a single BA for the purposes of its reinitiated section 7(a)(2) consultation with each agency.

1.2. Klamath Project Description

Authorized in 1905, the purpose of the Project is to provide water for irrigation, domestic, and related purposes (e.g., stock watering) to approximately 230,000 acres of farmland in southern Oregon and northern California. The Project's service area encompasses lands in Klamath County, Oregon and Siskiyou and Modoc counties, California. Communities within the Project include Klamath Falls, Bonanza, Merrill, and Malin in Oregon, and Tulelake and Newell in California.

The Project consists of a complex network of storage and conveyance features including reservoirs, lakes, dams, diversion dams, canals, and drains. Major Project facilities in Oregon include the A, B, C, D, E, F and G canals; Link River Dam (LRD); Gerber Dam; Malone Diversion Dam; Miller Creek Diversion Dam; the Lost River Diversion (Wilson) Dam and Channel; Anderson-Rose Diversion Dam; and the Klamath Straits Drain (KSD). Major Project facilities in California include, the D, J, M, N, R, Q, and P canals; Clear Lake Dam; and the Tule Lake Tunnel (*see* Figure 1-1 and Appendix 1A). Water made available through these facilities is delivered to Project lands through approximately 675 miles of canals and laterals. Irrigation return flows and local runoff is collected from irrigated lands through approximately 545 miles of drains. Approximately 50 separate pumps are used to convey irrigation and drainage water to different portions of the Project.

In addition to Project facilities, in which title is vested in the U.S., locally and privately-owned irrigation works, such as Harpold Dam on the Lost River and the Ady and North canals in the Lower Klamath Lake area, are also are used to divert and convey Project water to its place of use. In certain cases, Reclamation has agreements with the owners of these facilities, concerning their construction and continued operation.

The waters of the Upper Klamath and Lost River watersheds are used for irrigation and related purposes within the Project. The water so used is considered as Project water whether stored in Upper Klamath Lake (UKL), Clear Lake Reservoir, or Gerber Reservoir, or diverted from natural flow in both the Klamath and Lost rivers. Total active storage capacity of the Project's three reservoirs is approximately 1,066,000 acre-feet (AF).

Stored water in Clear Lake and Gerber reservoirs is generally used for irrigation purposes in Langell and Yonna valleys, although it can be and occasionally has been used for irrigation in the portion of the Project between Klamath Falls and Tulelake. Project water stored in UKL is used for irrigation on lands surrounding the lake, between Klamath Falls and Tulelake, the Lower Klamath Lake area, and along the Klamath River between Lake Ewauna and the town of Keno. Natural flow in the Lost River above Harpold Dam is primarily used in Langell and Yonna valleys, although all water in the Lost River below Harpold Dam is generally diverted and used within the Project during the irrigation season. Natural flow in the Klamath River, resulting from natural runoff and other discharges into the river below LRD, is primary used in the Lower

Klamath Lake area. (*See* Part 1.3.3., Reclamation Water Supply Contracts, for further information on the Project's service area.)

Project water is also delivered from various sources to two USFWS NWRs. *See* Part 1.3.6, National Wildlife Refuges, regarding how water is delivered and used within the refuges.

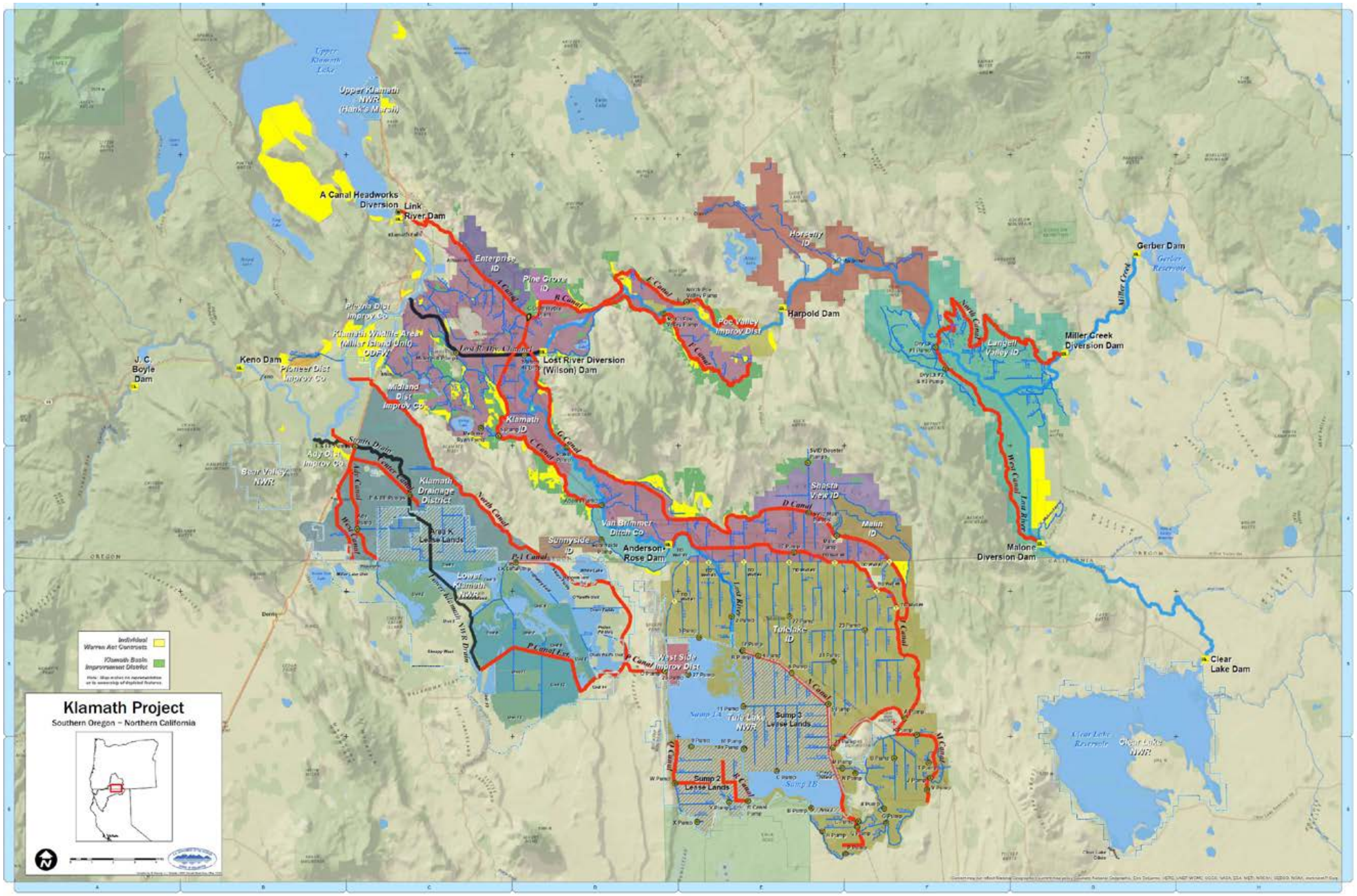

Figure 1-1. Klamath Project Map

1.3 Overview of Klamath Project Operations

Legal and statutory authorities and obligations, water rights, and contractual obligations have informed and shaped Reclamation's PA. This section of the BA elaborates on those authorities, responsibilities, and obligations.

1.3.1. Project Authorization and Purpose

The Project is one of the earliest federal reclamation projects. The Act of February 9, 1905, (Reclamation Act; 33 Stat. 714), authorized the Secretary of the Interior (Secretary) to change the level of several lakes and to dispose of certain lands that were later included in the Project. The Oregon and California legislatures, on January 20 and February 3, 1905, respectively, passed legislation ceding certain lands to the U.S. for use as Project lands[2]. The Project was authorized by the Secretary in May 1905, in accordance with the Reclamation Act of 1902 (Public Law No. 57-161, 32 Stat. 388 (codified as 43 U.S.C. § 371 *et seq.*)), and approved by President William Howard Taft on January 5, 1911, pursuant to the Advances to the Reclamation Fund Act of 1910 (36 Stat. 835).

The Secretary's authorization provided for the construction of Project works with the purpose to drain portions of Lower Klamath and Tule lakes; reclaim and homestead the uncovered lakebeds (including providing protection against flooding); and to appropriate water for irrigation of public and private lands within the Project area.

1.3.2. Project Water Rights

The Project diverts water to storage for irrigation, and related purposes from streams and natural lakes in both Oregon and California. Section 8 of the Reclamation Act of 1902 requires that Reclamation obtain water rights for its projects and administer those water rights in accordance to state law relating to the appropriation of water for beneficial uses, unless the applicable state laws are inconsistent with express or clearly implied congressional directives. 43 U.S.C. §383; Cal. v. U.S., 438 U.S. 645, 678 (1978); appeal on remand, 694 F.2d 117 (1982).

On May 19, 1905, pursuant to Oregon state law, Reclamation filed a notice with the State Engineer of Oregon claiming, on behalf of the Project, "all the waters of the Klamath Basin in Oregon consisting of the entire drainage basins of the Klamath River and Lost River … and their tributaries." Notices of water rights were filed in California, pursuant to California law, for water from the Lost River and its tributaries. Reclamation's initial plans for the Project, on which these notices were based, contemplated providing water for irrigation purposes to generally the same area currently served by the Project.

In addition to Reclamation's 1905 notices and related filings, Reclamation acquired several canals and related companies that existed prior to the Project's authorization. Reclamation used portions of these existing canals, like the Henley-Ankeny Canal and the Adams Canal, in

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[2] *See* 1905 Or. Laws, p. 63; 1905 Cal. Stat., p. 4.

constructing the Project. Associated water rights were generally included in these purchases, and in some cases (e.g., the Henley-Ankeny Canal), Reclamation was obligated to provide water to lands then already being irrigated.

Since 1975, the State of Oregon has been in the process of adjudicating all pre-1909 and federally-reserved water rights to water from the Klamath River and its tributaries in the State of Oregon, including the rights associated with Reclamation's 1905 notices and the various canal systems Reclamation acquired at the time. This process, generally known as the Klamath Basin General Stream Adjudication, will eventually result in a final determination of the nature and relative priority of water rights for the Project to water from the Klamath River and its tributaries, including UKL.

As part of Klamath Basin General Stream Adjudication, in 2013 the State of Oregon issued a Findings of Fact and Order of Determination, which has since been amended and corrected. Under Oregon law, this Amended and Corrected Findings of Fact and Order of Determination (ACFFOD) is enforceable unless judicially stayed. Enforcement of the ACFFOD occurs through the Oregon Water Resources Department (OWRD), based on a "call" by a water user that there is a deficiency in the water available to meet their water rights. In that event, in accordance with the legal doctrine of prior appropriation, OWRD may curtail diversions from the same source under water rights with later ("junior") priority dates, in order to make water available for water rights with earlier ("senior") priority dates.

According to the ACFFOD, the priority date of the water rights for the Project based on Reclamation's 1905 notices is May 19, 1905. Since issuance of the ACFFOD in 2013, Reclamation, along with districts and other water users within the Project, have made a "call" on the Project water rights in 2013, 2014, and 2015, which have resulted in the OWRD temporarily curtailing diversions from UKL and its various tributaries under junior water rights.

As it currently stands, the ACFFOD identifies 203,500 acres that may be irrigated within the Project with water from UKL and the Klamath River, including lands within Lower Klamath and Tule Lake NWRs and the service area for Van Brimmer Ditch Company. The ACFFOD imposes various conditions on the way these water rights may be exercised (e.g., rate of diversion, volume of water used, time of use).

The ACFFOD also recognizes separate, federally-reserved water rights appurtenant to various portions of Tule Lake and Lower Klamath NWRs, for the water necessary to satisfy the primary purposes of the refuges. These federally-reserved water rights for the refuges currently have priority dates later than the water rights for the Project based on Reclamation's 1905 notices.

The ACFFOD is subject to ongoing judicial review before the Klamath County Circuit Court. Parties claiming water rights in the Adjudication, including the U.S., have filed various exceptions to the ACFFOD. The resolution of those exceptions is still ongoing, and the schedule for completing the adjudication is uncertain. The ACFFOD may be modified when this legal process is complete. Parties may also petition the court to judicially stay enforcement on all or portions of the ACFFOD while the exceptions are being resolved.

The Klamath Basin General Stream Adjudication does not encompass water rights to water from the Lost River or its tributaries. Project water rights to water from the Lost River and its tributaries are not subject to the Lost River decree issued in 1918 and have never been adjudicated. Until such a process is completed in a manner that binds the U.S. these water rights are unenforceable in the State of Oregon, in terms of curtailing water users with junior rights.

In general terms, a water right constitutes a legal right to appropriate water (i.e., divert from a natural waterbody and apply it to beneficial use), in accordance with applicable state law. A water right does not guarantee or assure that water will physically be there to satisfy any given water right, regardless of priority, or that other conditions or requirements do not preclude being able to divert the water that is physically available.

With respect to the Project, in certain circumstances, Reclamation may be unable to deliver water due to shortages or other legal or physical reasons. *See* Parts 1.3.7., Endangered Species Act, and 1.3.8., Tribal Water Rights and Trust Resources. *See also*, for example, Klamath Water Users Assoc. v. Patterson, 204 F. 3d 1206 (9th Cir. 2000) and Kandra v. U.S., 145 F. Supp. 2d 1192 (D. Or. 2001).

1.3.3. Reclamation Water Supply Contracts

Between 1908 and 1972, Reclamation, acting through and on behalf of the Secretary, entered into over 150 perpetual contracts with district entities and individual landowners to provide water from the Project for irrigation and related purposes, in exchange for payment of Project costs and other conditions. In total, Reclamation's perpetual contracts for water from the Project (UKL, Klamath and Lost River, Clear Lake and Gerber reservoirs) cover 204,239 irrigable acres, including portions of Lower Klamath and Tule Lake NWRs. Note that there are portions of the Project that are not served under a perpetual water contract (*see* Part 1.3.4. Temporary Water Contracts).

Water supply contracts on the Project fall into one of three categories. In some cases, these contracts encompass lands for which the owners claimed non-federal water rights that predated the Project. Those types of contracts are generally called "settlement contracts." In other situations, Reclamation only agreed to deliver water to a specified point, and the contracting entity or individual was then responsible for constructing and operating the non-federal facilities necessary to convey the water to its intended place of use. Those types of contracts are generally called "Warren Act contracts." Lastly, in some cases Reclamation constructed all the works necessary to deliver the water to its intended place of use, in which case the contracts are called "repayment contracts." All three types of contracts are included in the general term "water supply contracts."

Some of Reclamation's water supply contracts specify a maximum volume of water to be provided on an annual basis (e.g., 2.0 or 2.5 AF per irrigable acre), whereas other contracts only limit the volume to be provided to the requirements of beneficial irrigation use (which in some cases is defined by state law, such as the 3.5 AF per irrigable acre on-field duty established in the ACFFOD).

Some water supply contracts do not specify or otherwise limit the sources of water Reclamation is obligated to provide water from. Most notably, Reclamation has at certain times in the past made water available from Clear Lake and Gerber reservoirs to satisfy irrigation needs within Tulelake Irrigation District (TID) and Klamath Irrigation District (KID).

Some water supply contracts establish different contractual priorities to Project water. In these cases, Project water may be available to one contractor when it is not otherwise available to another. Reclamation generally notifies Project contractors by letter and phone if water is temporarily unavailable due to a shortage in the available supply.

In some cases, in addition to providing for a water supply, Reclamation's contracts provide for district entities to operate and maintain specified Project facilities. Districts with such contracts include KID, TID, and Langell Valley Irrigation District (LVID). In operating Project facilities, these districts are obligated to perform delivery and drainage services to lands outside their respective district service areas. For example, KID operates Project facilities that provide irrigation and drainage service to eight other district entities and hundreds of individual landowners under separate contracts with Reclamation for water from UKL and the Klamath River.

1.3.4. Temporary Water Contracts

On a year to year basis, Reclamation and two districts within the Project (KID and TID) enter into contracts or agreements to temporarily provide water to lands not covered by perpetual repayment contracts. Water is generally only available under such temporary water contracts to the extent there is water in excess of the needs of water users served under perpetual water supply contracts. Project water is delivered to lands covered under temporary contracts through the existing Project facilities.

In recent years, Reclamation has limited the availability of temporary water contracts to private lands capable of receiving water from the P Canal system, which conveys excess water from the Tule Lake Sumps that is pumped from Tule Lake Sump 1A to the Lower Klamath Lake area via Pumping Plant D. There are currently approximately 2,900 acres of privately-owned land that can receive water from the P Canal system. In addition to private lands, turnouts on the P Canal system also deliver water to lands within or administered as part of Lower Klamath NWR. If not delivered through a turnout, water in the P Canal system is discharged into units of Lower Klamath NWR.

The acreage served by KID and TID under temporary water contracts varies but is approximately 2,000 acres combined. Note that in addition to a contract or agreement for water with either Reclamation, KID, or TID, lands using Project water from UKL and the Klamath River must be within the current place of use identified in the ACFFOD, except in the case of a temporary water right transfer approved by the State of Oregon in accordance with Oregon Senate Bill 206 (2015).

1.3.5. Project - Power Contracts

In 1917, the U.S. entered into a contract with California Oregon Power Company (Copco) for the construction and operation of the LRD, at the outlet of UKL. Pursuant to the 1917 contract, the

U.S. holds title (ownership) to the LRD. In 1956, the Federal Energy Regulatory Commission (FERC) licensed Copco's "Project 2082" subject to the condition of extension of the 1917 contract for an additional 50 years, to 2006. Project 2082 consisted of Copco's construction and operation of seven hydroelectric developments on the Klamath River, totaling 169 megawatts: (1) East Side and (2) West Side hydroelectric facilities on the Link River, (3) Keno Dam (non-generating), (4) J.C. Boyle Dam, (5) Copco No. 1 Dam, (6) Copco No. 2 Dam, (7) and Iron Gate Dam (IGD). Under the 1956 contract, Copco operated and maintained LRD and sold power at low fixed rates to designated irrigation loads within and above the Project. Copco also, pursuant to the 1956 contract and subject to the irrigation needs of the Project, set and maintained the level of UKL and Klamath River flows to facilitate power generation at Copco hydroelectric facilities.

From 1921 until 1997, Copco (now PacifiCorp) controlled UKL elevations and Klamath River flows downstream for power generation purposes subject to Project irrigation needs. In 1997, a letter agreement was signed, amending the 1956 contract to allow PacifiCorp to continue to be responsible for the daily operations and maintenance procedures at LRD and to provide power to irrigation lands, but recognizing Reclamation's responsibility for specifying Klamath River flows and UKL elevations through LRD, as it is Reclamation's primary point of control for Klamath River flows.

The 1956 contract expired in 2006. As a result, irrigation and drainage power rates paid by Project irrigators have increased up to twenty-fold to full retail tariffs. Reclamation and PacifiCorp amended the 1956 contract to continue PacifiCorp's O&M of LRD.

Currently, PacifiCorp's February 16, 2012, Interim Operations Habitat Conservation Plan (HCP) and subsequent Incidental Take Statement issued by NMFS requires PacifiCorp to operate Iron Gate Dam (IGD), located 63 miles below LRD, in accordance with any required flow releases identified in a BiOp resulting from Reclamation's current or future section 7 consultations.

In March 2014, PacifiCorp stopped operating East Side and West Side power plants on the Link River for power generation. Water continues to be routed through these power plant facilities to comply with water delivery contracts and to slow the deterioration of the historic wooden flume on the East Side diversion at LRD.

1.3.6. National Wildlife Refuges

The Upper Klamath, Lower Klamath, Tule Lake, and Clear Lake NWRs are adjacent to or within the Project service area and are affected by Project operations. These refuges were established by various executive orders starting in 1908. The USFWS manages the refuges, as part of the Klamath Basin Refuge Complex, under the Migratory Bird Treaty Act (codified as 16 U.S.C. §§ 703-712), NWR System Administration Act of 1966 (16 U.S.C. §§ 668dd-668ee), NWR System Improvement Act (Pub. L. 105-57, 111 Stat. 1252-1260), the 1964 Kuchel Act (Pub. L. 88-567) (Kuchel Act; described below), and other laws pertaining to the NWR System.

These refuges support numerous fish and wildlife species and provide habitat and resources for migratory birds of the Pacific Flyway. Approximately 80 percent of the migrating waterfowl on the Pacific Flyway come through the Klamath Basin on both spring and fall migrations. During the peak of the migration, there are on average one million birds in the Klamath Basin Refuge Complex, primarily in Lower Klamath and Tule Lake NWRs.

Project operations make water available for use on the refuges, and water within the refuges is commonly used for both irrigation and fish and wildlife purposes. *See* Part 1.3.2., Project Water Rights, regarding the various water rights appurtenant to lands in Lower Klamath and Tule Lake NWRs.

Operationally, Lower Klamath NWR can receive Project water from UKL and the Klamath River, as well as water from the Tule Lake Sumps, which is conveyed through Sheepy Ridge via the Tule Lake Tunnel. Tule Lake NWR can receive Project water from irrigation return flows, which are stored in the Tule Lake Sumps; however, when irrigation demand is high, stored water from UKL (diverted at the Lost River Diversion Channel [LRDC] and released through Station 48) may be used to meet associated demands within the refuge. Tule Lake NWR can also utilize water from natural flow in the Lost River. In some instances, stored water from Clear Lake Reservoir has been released to support irrigation operations within TID, including Tule Lake NWR.

Note that all of Tule Lake NWR is served under Reclamation's water supply contract with TID (Contract No. 14-06-200-5954, dated September 10, 1956), which provides for the district to provide delivery and drainage services to these lands through Project facilities for which the O&M is transferred to TID. The portion of Lower Klamath NWR in Oregon, comprising approximately 5,600 acres, is served under the water supply contract between Reclamation and Klamath Drainage District (KDD) (Contract No. Ilr-402c, dated April 28, 1943). In addition, the USFWS has a separate agreement with KDD, dated May 25, 1940, for use of the Ady Canal to deliver water to the portion of Lower Klamath NWR in California.

In connection with Upper Klamath NWR, the USFWS manages two federally-acquired parcels adjacent to the NWR (Agency Lake and Barnes Ranch) with associated water rights. In 2017, USFWS applied to OWRD to temporarily transfer the water rights from the Agency Lake and Barnes Ranch properties to Lower Klamath NWR through the 2021 irrigation season. OWRD approved this application, designated as number T-12642, by order dated August 2, 2017. The USFWS temporary water right transfer from the Agency Lake and Barnes Ranch properties is not part of Reclamation's PA, though it is considered within the environmental baseline and accounted for in anticipated operations as described in the PA.

1.3.6.1. Refuge Agricultural Lands

Portions of Lower Klamath and Tule Lake NWRs are also used for agricultural purposes and are administered through either Reclamation's agricultural leasing program or the USFWS cooperative farming program. In Lower Klamath NWR, approximately 26,000 acres are used for the production of small grains, grass hay, and grazing (though only 10,000 acres can be irrigated in any year under the ACFFOD). In Tule Lake NWR, approximately 17,000 acres are utilized for the production of small grains, alfalfa, potatoes and onions.

When the Project was authorized in 1905, lands uncovered by draining Lower Klamath and Tule lakes were intended to be homesteaded and receive irrigation water from the Project pursuant to

Reclamation laws. From 1910 to the early 1950s, Reclamation planned and constructed Project facilities for this objective. In the 1960s, Congress and interested stakeholders debated whether lands within Lower Klamath and Tule Lake NWRs should be homesteaded or instead set aside for refuge purposes. This controversy ultimately led to passage of the Kuchel Act (Pub. L. 88-567) in 1964.

The Kuchel Act provided that all lands within Tule Lake, Lower Klamath, Upper Klamath, and Clear Lake NWRs "are hereby dedicated to wildlife conservation," and that homesteading of these lands was discontinued, and these lands were to be administered by the Secretary of the Interior "for the major purpose of waterfowl management, but with full consideration to optimum agricultural use that is consistent therewith." Further Congress directed that the Secretary was to "continue the present pattern of leasing" refuge lands, "consistent with proper waterfowl management." In 1977, Congress amended the NWR System Administration Act of 1966 (Pub. L. 94-223) to provide, in part, that "all lands, waters, and interests therein administered by the Secretary [of the Interior] as wildlife refuges … shall be administered by the Secretary through [USFWS]…." Pursuant to these two laws, Reclamation and USFWS entered in a cooperative agreement in 1977 (Coop. Agreement 1977) relating to the administration of Tule Lake, Lower Klamath, and Clear Lake NWRs. This agreement provided for Reclamation to continue administering the leasing program for refuge lands, in consultation and subject to the approval of the USFWS.

In accordance with the 1977 cooperative agreement, Reclamation currently administers 15,000 acres in Tule Lake NWR and 5,600 acres in Lower Klamath NWR under annual lease contracts. Current lease contracts commonly give the lessee the option to renew the lease for up to five years. The terms of these contracts vary based on location and are regularly updated to reflect current conditions and refuge needs. The remainder of the agricultural lands within the Refuges, namely 2,500 acres in Tule Lake and 20,000 acres Lower Klamath NWR, are managed by the USFWS as part of its cooperative farming program.

1.3.7. Endangered Species Act

To paraphrase, the ESA requires every federal agency to ensure that any discretionary action it authorizes, funds, or carries out is not likely to jeopardize the continued existence of any endangered or threatened species or destroy or adversely modify its critical habitat (*see* 16 U.S.C. 1536(a)(2); 50 C.F.R. § 402.03). To ensure compliance with those mandates, the ESA's implementing regulations outline a detailed process that requires federal agencies to consult with USFWS or NMFS, or both, depending on the species involved, on such actions if they "may affect" listed species and/or critical habitat. Among other things, the consultation analyzes the potential impacts of a proposed action on ESA-listed species and their critical habitat. A federal agency prepares a BA to determine whether formal consultation or a conference is necessary. A BA evaluates the potential effects of the action on listed and proposed species and designated and proposed critical habitat and determines whether any such species or habitat are likely to be adversely affected by the action. 50 C.F.R. § 402.12. Reclamation has prepared this BA accordingly.

For the purposes of this BA, impacts to listed species are analyzed with respect to: (1) storage and release or the delivery of water; and (2) the O&M activities necessary to maintain Project facilities to ensure long-term functioning and operation.

1.3.8. Tribal Water Rights and Trust Resources

There are seven federally recognized Indian Tribes in the Klamath Basin including The Klamath Tribes in Oregon (which include the Klamath, Modoc, and Yahooskin Tribes; collectively The Klamath Tribes), and the Yurok Tribe, the Karuk Tribe, the Hoopa Valley Tribe, and the Quartz Valley Tribe, and the Resighini Rancheria in California. Reclamation has a trust responsibility, as a federal agency, to protect tribal trust resources of three of the seven federally recognized tribes: The Yurok, Hoopa Valley, and Klamath Tribes.

Based on the treaty between the U.S. and The Klamath Tribes, dated October 14, 1864, the Klamath Tribes and the U.S. Bureau of Indian Affairs (BIA) have claimed federally-reserved water rights to support hunting, fishing, and gathering by The Klamath Tribes within their former reservation boundaries. In 2013, the State of Oregon issued the ACFFOD, which identifies specific instream flows in tributaries to UKL within the boundaries of the former Klamath Indian Reservation. The ACFFOD also recognizes a water right in UKL, to maintain water surface at various elevations during different times of the year. Under the ACFFOD, these water rights are held by the BIA, on behalf of The Klamath Tribes, and have a priority date of “time immemorial,” making them prior to (“senior”) all other water rights recognized in the ACFFOD.

A stipulated agreement between the U.S., The Klamath Tribes, and Project water users provides that thewater right for minimum water surface levels in UKL will not be exercised against any water rights prior to August 9, 1908. The stipulated agreement is valid until the judicial review of the Klamath Basin General Stream Adjudication within the Klamath County Circuit Court is complete. As discussed further in Part 1.3.2., the ACFFOD is subject to ongoing judicial review, but is still currently enforceable absent a petition to a court to stay enforcement of all or portions of the ACFFOD during this legal process. The Klamath Tribes, through the BIA, have made a call to enforce some or all of the water rights for instream flows in tributaries to UKL, at varying levels, every year since issuance of the ACFFOD in 2013.

The Yurok and Hoopa Valley Tribes have Federal Indian reserved fishing rights to take anadromous fish within their reservations in California. These rights were secured to the Yurok and Hoopa Valley Indians by a series of nineteenth century executive orders. These executive orders also reserved rights to an instream flow of water sufficient to protect the Yurok and Hoopa Valley Tribes rights to take fish within their reservations. These rights were vested at the latest in 1891 and perhaps as early as 1855. (*See* U.S. v. Adair, supra; Arizona v. California, 373 U.S. 546, 600 [1963]; U.S. v. Winans, 198 U.S. 371 [1905].)

1.4. Action Area

The Action Area is generally defined by the PA and those areas directly and indirectly affected by that PA (50 C.F.R. 402.02), relative to any federally-listed species and/or critical habitat or those species proposed for listing. For suckers, the action area includes UKL, the Lost River

Basin from Clear Lake and Gerber reservoirs downstream to Tule Lake, all other areas within the boundaries of the Project, and the Klamath River between Link River and Keno Dam. For coho salmon, the action area includes the area within the boundaries of the Project and the Klamath River from Upper Klamath Lake to the mouth of the river at Klamath, California. Note that a separate action area for Southern Resident Killer Whaler (SRKW) includes a discontiguous section of ocean where there is species overlap between Chinook salmon and SRKW, reflecting the feeding area of this species (*see* Part 4.1 and Part 9.1.2. for more details).

1.5. Species Considered

The federally-listed species that may be affected by the PA and therefore considered in this document were identified in coordination with the Services. The list of species considered was generated based on letters received from the Services in response to Reclamation's species list requests (*see* Appendix 1B).

Table 1-1 lists the endangered and threatened species that are known to, or, are suspected to occur within the Action Area that may be affected by the PA and which are considered in this document. Table 1-2. lists the endangered and threatened species that are known to, or, are suspected to occur within the Action Area for which Reclamation has determined the Project has no effect upon. As such, the species identified in Table 1-2. will not be discussed further in this document.

1.5.1. USFWS Jurisdiction

Reclamation submitted a memorandum to the USFWS requesting concurrence on species that may be present in the Action Area (50 C.F.R. § 402.12(c)) on November 21, 2018. The USFWS provided a species list on November 27, 2018.

1.5.2. NMFS Jurisdiction

Reclamation submitted a letter to NMFS requesting concurrence on species that may be present in the Action Area and which species that may be affected by Reclamation's PA (50 C.F.R. § 402.12(c)) on November 21, 2018. NMFS provided concurrence on November 26, 2018.

Table 1-1. Endangered and threatened species that are known to, or, are suspected to occur within the Action Area that may be affected by the Proposed Action and which are considered in this document.

Phylum	Species Common Name	Species Scientific Name	ESA Status	Critical Habitat Designation
Fish	Lost River sucker	*Deltistes luxatus*	Endangered	Designated
Fish	Shortnose sucker	*Chasmistes brevirostris*	Endangered	Designated
Fish	SONCC coho Salmon	*Oncorhynchus kisutch*	Threatened	Designated
Fish	North American green sturgeon (Southern Distinct Population Segment [DPS])	*Acipenser medirostris*	Threatened	Designated
Fish	Pacific eulachon (Southern DPS)	*Thaleichthys pacificus*	Threatened	Designated
Mammal	Southern Resident killer whale (DPS)	*Orcinus orca*	Endangered	Designated

Table 1-2. Endangered, threatened, and proposed species that are known or are suspected to occur within the Action Area for which Reclamation has determined the Project has no effect upon. The species denoted with an asterisk (*) will be analyzed while the remainder of the species will NOT be analyzed in this document[3].

Phylum	Species Common Name	Species Scientific Name	ESA Status	Critical Habitat Designation
Mammal	Gray wolf	*Canis lupus*	Endangered	None
Mammal	North American Wolverine	*Gulo gulo luscus*	Proposed	n/a
Mammal	Fisher	*Pekiana pennant*	Proposed	n/a
Plant	Applegate's milk-vetch*	*Astragalus applegatei*	Endangered	None
Plant	Greene’s tuctoria	*Tuctoria greenei*	Endangered	Designated
Bird	Northern spotted owl	*Strix occidentalis caurina*	Threatened	Designated
Bird	Yellow-billed cuckoo (Western Distinct Population Segment)	*Coccyzus americanus occidentalis*	Threatened	Proposed
Fish	Bull trout*	*Salvelinus confluentus*	Threatened	Designated
Amphibian	Oregon spotted frog*	*Rana pretiosa*	Threatened	Designated
Plant	Slender Orcutt grass	*Orcuttia tenuis*	Threatened	Designated
Invertebrate	Shasta crayfish	*Pacifastacus fortis*	Endangered	None
Plant	Yreka phlox	*Phlox hirsuta*	Endangered	None
Plant	Gentner’s fritillary	*Fritillaria gentneri*	Endangered	Designated
Amphibian	California red-legged frog	*Rana aurora draytonii*	Threatened	Designated

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[3] Note: Further discussion on Reclamation’s determination to omit these species from further consideration in this BA is provided in Part 10.

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2. CONSULTATION HISTORY

On July 18, 1988, the USFWS published a final rule designating Lost River suckers (LRS; *Deltistes luxatus*) and shortnose suckers (SNS; *Chasmistes brevirostris*) as endangered species, which implemented protection provided by the ESA of 1973, as amended. Reclamation began consultations the next year on the effects of aquatic herbicide use within the Project on these species. On August 14, 1991, Reclamation completed the first consultation on the effects of Project operations on all federally-listed species. On January 6, 1992, Reclamation finished another consultation, specific to LRS and SNS. On December 11, 2012, the USFWS published a final rule designating critical habitat for the LRS and SNS. The designation included two critical habitat units for each species. Additional consultations have occurred since then, the most recent being in May of 2013 (Table 2-1).

On May 6, 1997, NMFS listed the SONCC coho salmon *(Oncorhynchus kisutch)* Evolutionarily Significant Unit (ESU) as threatened. NMFS designated critical habitat for the SONCC coho population on May 5, 1999. On March 9, 1999, Reclamation requested formal section 7 consultation under the ESA on the effects of its Project operations on SONCC coho salmon. On July 12, 1999, NMFS issued a final BiOp (effective through March 2000) which concluded that the proposed one-year operation of the Project was not likely to jeopardize the continued existence of SONCC coho salmon or adversely modify designated critical habitat. Since 1999, NMFS and Reclamation have conducted five section 7 consultations regarding the potential effects of Reclamation's proposed Project operations on SONCC coho salmon and its designated critical habitat (1999, 2001, 2002, and 2010, 2012). In 2001 and early 2002, a series of consultations were completed with NMFS and USFWS, which resulted in the curtailment of Project deliveries in 2001. In May 2002, consultations with the Services covering Project operations into 2012 were completed.

In October 2007, Reclamation initiated consultations with both NMFS and USFWS, related to Project operations between 2008 and 2018. On April 2, 2008, USFWS issued a final BiOp addressing Project operations through 2018. USFWS' 2008 BiOp concluded that the Project was not likely to jeopardize the continued existence of the endangered suckers or to adversely modify their critical habitat. On March 15, 2010, NMFS issued a final BiOp, covering the time period 2010 to 2018, which concluded Reclamation's PA was likely to jeopardize the continued existence of SONCC coho salmon and likely to result in the destruction or adverse modification of its designated critical habitat.

In December 2012, Reclamation formally re-initiated consultation with the Services, pursuant to section 7(a)(2) of the ESA, related to the potential effects of proposed Project operations between April 1, 2013 and March 31, 2023 on federally-listed threatened and endangered species. Reclamation's BA concluded that the PA was likely to adversely affect the LRS and SNS and SONCC coho salmon and their critical habitat. The Services Final Joint BiOp was issued in May 2013 and concluded that the continued operation of the Project for a 10-year term is not likely to jeopardize the continued existence of the LRS and SNS, or the SONCC coho salmon evolutionarily significant unit (ESU), nor result in the destruction or adverse modification of their critical habitat.

This BA is part of a new coordinated consultation that has been undertaken between Reclamation, and the Services that began in January 2017. The consultation covers the potential effects of Project operations on ESA-listed species based on an adjusted water management approach for continued operations of the Project and new scientific information related to the effects of Project operations on listed species. The table below summarizes the history of ESA consultations undertaken by Reclamation since the listing of the suckers in 1988.

Table 2-1. History of Endangered Species Act Consultations Undertaken by the Bureau of Reclamation since 1988.

Date	USFWS	NMFS	Subject of Consultation	Determination
7/18/1988	X		Endangered and Threatened Wildlife and Plants; Determination of Endangered Status for the LRS and SNS.	Endangered status was determined for the LRS and SNS. This rule implemented listing and protection provided by ESA.
6/14/1989 (superseded by 1995 BiOp)	X		Formal Endangered Species Consultation on the Use of Acrolein (Magnicide H) in Canals and Drainage Ditches Within the Project Service Area in Klamath County, Oregon, and Siskiyou County, California.	The continued use of acrolein in Project canals and drainage ditches, as traditionally applied, is likely to jeopardize the continued existence of the SNS and LRS.
8/14/1991 (superseded by 2008 BiOp)	X		Formal Consultation on the Effects of the 1991 Operation of the Project on the LRS and SNS, Bald Eagle, and American Peregrine Falcon.	The proposed 1991 drought operation of the Project was likely to jeopardize the continued existence of LRS and SNS but would not jeopardize the continued existence of the Bald Eagle. The American Peregrine Falcon was not likely to be affected and was not addressed in the consultation.
1/6/1992 (superseded by 2008 BiOp)	X		Formal Consultation on the Effects of the 1992 Operation of the Project on the LRS and SNS, Bald Eagle, and American Peregrine Falcon.	The operation of the Project was not likely to jeopardize the continued existence of the LRS and SNS or the Bald Eagle. The American Peregrine Falcon was not likely to be affected and was not addressed in the consultation.
3/27/1992 (superseded by 2008 BiOp)	X		Reinitiation of Formal Consultation on the Effects of the 1992 Operation of the Project on the LRS and SNS, Bald Eagle, and American Peregrine Falcon.	The proposed 1992 operation of the Project was likely to jeopardize the continued existence of the LRS and SNS, but not likely to jeopardize the continued existence of the Bald Eagles. The American Peregrine Falcon was not likely to be affected and was not addressed in the consultation.
5/1/1992 (superseded by 2008 BiOp)	X		Reinitiation of Formal Consultation on the Effects of the 1992 Operation of the Project at Clear Lake Reservoir on the LRS and SNS, Bald Eagle, and American Peregrine Falcon.	The proposed 1992 operation of the Project at Clear Lake Reservoir was likely to jeopardize the continued existence of the LRS and SNS, but not likely to jeopardize Bald Eagles. The American Peregrine Falcon was not likely to be affected and was not addressed in the consultation.

Date	USFWS	NMFS	Subject of Consultation	Determination
7/22/1992 (superseded by 2008 BiOp)	X		Formal Consultation on the Effects of the Long-Term Operation of the Project on the LRS and SNS, Bald Eagle, and American Peregrine Falcon.	The long-term operation of the Project was likely to jeopardize the continued existence of the LRS and SNS, but not likely to jeopardize the continued existence of the Bald Eagle. The American Peregrine Falcon was not likely to be affected and was not addressed in the consultation.
2/22/1993 (superseded by 2008 BiOp)	X		Reinitiation of Formal Consultation on the BiOp for the Long-Term Operation of the Project - UKL Operations.	One-year modification of lake elevation. Reclamation was released from the March 1, 1993 requirement of a maintaining a 4,141-foot surface elevation for 1993 only.
8/11/1994 (superseded by 2008 BiOp)	X		Reinitiation of Formal Consultation on the Long-Term Operation of the Project, with Special Reference to Operations at Clear Lake Reservoir on the LRS and SNS, Bald Eagle, and American Peregrine Falcon.	The proposed long-term operation of the Project was likely to jeopardize the continued existence of the LRS and SNS, but not likely to jeopardize the continued existence of the Bald Eagle. The American Peregrine Falcon was not likely to be affected and was not addressed in the consultation. RPAs were specified in the BiOp for Clear Lake and a new minimum elevation for Clear Lake Reservoir was established.
2/9/1995	X		Final BiOp on the Use of Pesticides and Fertilizers on Federal Lease Lands and Acrolein and Herbicide Use on the Project Rights-of-Way (Reinitiation of Consultation on the Use of Acrolein for Aquatic Weed Control in Reclamation Canals and Drains).	The use of pesticides and fertilizers on federal lease lands and acrolein and herbicide use on the Project rights-of way was not likely to jeopardize the continued existence of the LRS and SNS and may affect, but not likely to adversely affect the Bald Eagle, or Applegate's milk-vetch, and not likely to affect the American Peregrine Falcon.
2/2/1996 (not superseded by 2008 BiOp)	X		Reinitiation of Formal Consultation on the Use of Pesticides and Fertilizers on Federal Lease Lands and Acrolein and Herbicide Use on the Project Rights-of-Way Located on the Project.	Use of Metam-Sodium, Lorsban, Pounce, and Disyston on Project lands as described under the Description of the PA was not likely to jeopardize the continued existence of the Bald Eagle, American Peregrine falcon, LRS and SNS, or adversely modify the LRS and SNS proposed critical habitat.
7/15/1996 (superseded by 2008 BiOp)	X		Formal Consultation on PacifiCorp and The New Earth Corporation Operations, as Permitted by Reclamation, for the LRS and SNS.	The PA was not likely to jeopardize the continued existence of the LRS and SNS and was not likely to adversely modify or destroy proposed critical habitat.
5/6/1997		X	Endangered and Threatened Species; Threatened Status for SONCC ESU of Coho Salmon.	The SONCC ESU of coho salmon was determined to be a “species” under the ESA of 1973, as amended, and was listed as threatened. Critical habitat was not designated.
4/2/1998 (superseded by 2008 BiOp)	X		Amendment to the 1992 BiOp Dealing with A-Canal Sucker Entrainment Reduction.	Reclamation was granted a 5-year extension (to 2002) to implement entrainment reduction measures for all life stages of LRS and SNS into A-canal. The date for completion of A Canal screen was extended until 2002. Not likely to jeopardize species.

Date	USFWS	NMFS	Subject of Consultation	Determination
4/20/1998	X		Amendment to the 1992 BiOp to Cover Operation of Agency Lake Ranch Impoundment.	The action was not likely to jeopardize the continued existence of LRS and SNS.
4/21/1998 (superseded by 2008 BiOp)	X		Amendments to the August 27, 1996, BiOp on PacifiCorp and New Earth Operations, as Permitted by Reclamation, for the LRS and SNS.	Five amendments regarding sampling dates, report consolidation and due date extension, extension of incidental take coverage, and monitoring fulfillment. Not likely to jeopardize species.
6/2/1998		X	Reclamation transmitted a BA to NMFS on 1998 Project operations and Requested Formal Consultation.	NMFS deferred consultation until the following year (1999).
7/13/1998 (superseded by 2008 BiOp)	X		An Amendment to the Revised July 22, 1992 Project Long-Term Operations BiOp, Dealing with Anderson-Rose Releases. The purpose of this amendment is to adjust requirements for release of spawning flows from Anderson-Rose Dam on the Lost River.	USFWS concurred with Reclamation's recommended RPA changes. Not likely to jeopardize species.
3/9/1999		X	Project operations 1999 BiOp. Reclamation provided the Draft Project 1999 Annual Operations Plan Environmental Assessment and requested NMFS use the 1998 BA as the basis for preparing the 1999 BiOp.	Reclamation requested formal consultation with NFMS regarding the 1999 Annual Operations Plan.
4/15/1999	X		Amendment to the 1996 BiOp. Incidental Take of LRS and SNS Owing to Lowered Water Levels in UKL by a Change in Operation of LRD to Reduce Risk of Flooding During the Spring 1999 Runoff Period.	The Service concurred with Reclamation’s determinations of “may affect, likely to adversely affect,” and it was determined that the action was not likely to jeopardize the continued existence of LRS and SNS.
5/5/1999		X	Designated Critical Habitat; Central California Coast and SONCC Coho Salmon.	Critical habitat was designated for two ESUs of coho salmon pursuant to the ESA.
6/18/1999		X	Reclamation letter regarding Draft BiOp for Project operations 1999 (Dated April 22,1999).	Reclamation reviewed draft BiOp and proposed to modify project operations described in the 3/9/1999 draft Environmental Assessment.
7/12/1999		X	NMFS BiOp on Project operations through March 2000.	Not likely to jeopardize SONCC coho salmon or adversely modify designated critical habitat.
8/18/1999	X		One-year, Emergency Amendment to the 1995 BiOp, Use of Pesticides and Fertilizers on Leased Lands and Use of Acrolein in Project Canals and Drains.	The LVID-operated canal system was exempt from the prohibitions of Section 9 of the ESA. Incidental take covered by amendment for SNS in LVID-operated irrigation canal system. The amendment included RPMs to be implemented by LVID to minimize take.
9/10/1999 (superseded by 2008 BiOp)	X		Revised Amendment to the 1992 BiOp to Cover Operations and Maintenance of Agency Lake Ranch Impoundment.	Service concurred with Reclamation’s determination of “may affect, likely to adversely affect” and determined the action was not likely to jeopardize the continued existence of LRS and SNS.

Date	USFWS	NMFS	Subject of Consultation	Determination
4/4/2000		X	NMFS letter advised Reclamation to request initiation of consultation pursuant to section 7(a)(2) of the ESA on Project operations.	1999 BiOp and associated Incidental Take Statement expired on 3/31/2000.
4/26/2000		X	Klamath River Flows Below IGD-2000 Operation Plan-Project.	Proposed flows were both sufficient and necessary to avoid possible 7(d) foreclosures and fulfill obligation to protect Tribal trust resources.
1/22/2001		X	Reclamation's BA of the Project's Continuing Operations on SONCC ESU Coho Salmon and their Critical Habitat.	Requested initiation of formal ESA section 7 consultation. BA provided description of the effects on federally-listed species and its designated critical habitat from on-going operation of the Project based on historic operations.
4/5/2001	X		BiOp Regarding the Effects of Operation of Reclamation's Project on the Endangered LRS and SNS, Threatened Bald Eagle, and Proposed Critical Habitat for the LRS and SNS.	Likely to jeopardize the LRS and SNS and adversely modify proposed critical habitat. Not likely to jeopardize the continued existence of the Bald Eagle.
4/6/2001		X	2001 BiOp on Ongoing Project operations.	Likely to jeopardize SONCC coho salmon and likely to adversely modify designated critical habitat.
4/13/2001 (superseded by 2008 BiOp)	X		Concurrence Memorandum Responding to Reclamation's Request to Postpone Spawning Releases at Anderson Rose Dam for 2001.	Not likely to jeopardize sucker species; USFWS concurred with drought year assessment.
8/22/2001 (superseded by 2008 BiOp)	X		Amendment to the April 5, 2001 BiOp on Project operations to Cover Safety of Dams Modification of the Clear Lake Dam.	Not likely to jeopardize the continued existence of the LRS and SNS and will not likely adversely modify proposed critical habitat.
9/12/2001 (superseded by 2008 BiOp)	X		Amendment to the April 5, 2001 BiOp on Project operations to Cover Link River Topographic Survey Fish Passage Assessment.	Not likely to jeopardize the continued existence of the LRS and SNS and will not likely adversely modify their proposed critical habitat.
9/19/2001	X		Amendment to the November 27, 2000 BiOp for the Airport Runway Extension Project and the April 5, 2001 BiOp on Project operations to Cover Salvage in LRDC and for the Station 48 Maintenance Project.	Not likely to jeopardize the continued existence of LRS and SNS and will not likely adversely modify their proposed critical habitat.
9/28/2001		X	Amendment to the April 6, 2001 BiOp and RPA for Reclamation's Project operations.	Provided minimum IGD flows for Oct to Dec 2001.
12/28/2001		X	Amendment to the April 6, 2001 BiOp and RPA for Reclamation's Project operations.	Provided minimum IGD flows for Jan to Feb 2002.
2/27/2002	X	X	Reclamation's Final BA on Effects of PAs Related to Project operations (April 1, 2002-March 31, 2012).	Requested initiation of formal ESA section 7 consultation.
3/28/2002 (superseded by 2008 BiOp)	X		Biological/Conference Opinion Regarding the Effects of Operation of Reclamation's Project During the Period April 1, 2002, Through May 31, 2002 on the Endangered LRS and SNS, Threatened Bald Eagle, and Proposed Critical Habitat for the LRS and SNS.	Not likely to jeopardize the continued existence of the LRS and SNS or Bald Eagle.

Date	USFWS	NMFS	Subject of Consultation	Determination
5/16/2002		X	NMFS draft BiOp on Project operations between April 1, 2002, and March 31, 2012.	Likely to jeopardize the continued existence of SONCC coho salmon and adversely modify critical habitat.
5/31/2002		X	BiOp on Project operations and the Project's effects on the SONCC coho salmon.	Likely to jeopardize the continued existence of SONCC coho salmon and likely to adversely modify critical habitat.
5/31/2002 (superseded by 2008 BiOp)	X		BiOp on the 10-year (June 1, 2002, through March 31, 2012) Operation Plan for the Project.	Likely to jeopardize the continued existence of the LRS and SNS, and in part, the adverse modification of their proposed critical habitat. Not likely to jeopardize the continued existence of the Bald Eagle.
7/24/2002 (not superseded by 2008 BiOp)	X		Biological/Conference Opinion Regarding the Effects of Construction of the A-Canal Fish Screen and Link River Fish Ladder, Reclamation – Project and its Effect on the Endangered LRS and SNS and Proposed Critical Habitat for LRS and SNS.	Not likely to jeopardize the continued existence of SNS and LRS.
3/4/2003 (superseded by 2008 BiOp)	X		Amendment to the 2002 BiOp on the Effects of the 10-Year Operations Plan for the Project as it Relates to Operation of Clear Lake and Gerber Reservoir.	No effects to LRS and SNS different from those analyzed in the 2002 BiOp.
5/31/2007 (not superseded by 2008 BiOp)	X		BiOp Regarding the Effects on Listed Species from Implementation of the Pesticide Use Program on Federal Leased lands, Tule Lake and LKNWRs, Klamath County, Oregon, and Siskiyou and Modoc Counties, California.	Not likely to adversely affect the Bald Eagle, LRS and SNS, and therefore will not likely jeopardize their continued existence.
10/1/2007	X		Reclamation's BA on The Effects of the PA to Operate the Project from April 1, 2008 to March 31, 2018.	May affect, and is likely to adversely affect coho salmon, LRS and SNS, and may adversely modify critical habitat for coho salmon, LRS and SNS. No effect on Applegate's milk-vetch.
4/2/2008	X		Biological/Conference Opinion Regarding the Effects of Reclamation's Proposed 10-Year Operation Plan (April 1, 2008-March 21, 2018) for the Project and its Effects on LRS and SNS.	Not likely to jeopardize the continued existence of the LRS and SNS and is not likely to destroy or adversely modify proposed critical habitat for these species.
3/15/2010		X	NMFS BiOp on Operation of the Project Between 2010 and 2018.	Likely to jeopardize the continued existence of SONCC coho salmon and is likely to destroy or adversely modify SONCC coho salmon designated critical habitat.
12/11/2012	X		Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for LRS AND SNS.	Two units of critical habitat for the LRS and SNS were designated under ESA.

Date	USFWS	NMFS	Subject of Consultation	Determination
5/31/2013	X	X	Joint BiOp on the Effects of Proposed Project operations from May 31, 2013, through March 31, 2023, on Five Federally Listed Threatened and Endangered Species.	May affect but is not likely to adversely affect the southern Distinct Population Segment (DPS) of green sturgeon, the southern DPS of Pacific eulachon, or both their critical habitat. Not likely to jeopardize the continued existence of the SONCC coho salmon ESU, the LRS and SNS, nor likely to result in the destruction or adverse modification of their critical habitat.

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3. ANALYTICAL APPROACH

3.1. Analytical Approach

Project operations have been continually adjusted to comply with ESA requirements since the 1980s, when the first consultations (for SNS and LRS) occurred. To improve the coordination between Reclamation and the Services, extensive coordination has occurred in development of the PA and this BA. The coordination has included Agency Coordination Team (ACT) meetings, Tri-agency[4] Hydrology (Hydro) Team meetings, Tri-agency Biology (Bio) Team meetings, and other meetings between Reclamation and the Services scheduled since January 2017. The goal of the collaborative efforts for this consultation was to develop an improved and common understanding of the available information and analytical tools, and to facilitate a continuous information sharing process. The general analytical approach used by Reclamation in the development of this BA has been framed by this collaboration and by the factors discussed below.

3.2. Legal, Analytical, and Ecological Framework

Pursuant to section 7(a)(2) of the ESA ,federal agencies must ensure that their activities are not likely to jeopardize the continued existence of any listed species or result in the destruction or adverse modification of critical habitat. The analytical framework associated with this BA is outlined below. The ecological framework within the Effects Analysis for suckers is based on lake elevations and habitat, whereas the Effects Analysis for coho salmon are based upon river flows below IGD. Therefore, the analyses have been conducted differently and the ecological approach is detailed in Parts 7 and 8. Additionally, the effects analysis for SRKW is based on a suite of population modeling and other analytic tools and is detailed in Part 9.

Section 7(a)(2) of the ESA and implementing regulations (50 C.F.R. Part 402), and associated guidance materials (e.g., Endangered Species Consultation Handbook, 1998) suggest that BAs present the following:

1. A description of the action being considered (PA).

2. A description of the specific area that may be affected by the action (Action Area).

3. A description of any listed species or critical habitat that may be affected by the action.

4. A description of the manner in which the action may affect any listed species or critical habitat, and an analysis of any cumulative effects (Effects Analysis).

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[4] Where the term Tri-agency is used it refers to Reclamation and the Services.

5. Relevant reports, including any environmental impact statements, environmental assessments, BAs, or other analyses prepared on the proposal.

6. Any other relevant studies or other information available on the action, the affected listed species, or critical habitat.

The Project has a unique mix of factors that are considered in operational decisions, even if not directly related to a section 7 consultation, including:

Limited Carry-Over Water Storage Capacity.
UKL, the largest Project water source, is relatively shallow and has limited storage capacity (approximately, 562 (thousand acre-feet; TAF)). As a result, it cannot store large quantities of spring runoff and lacks storage capabilities in wet years to carryover volumes that could help meet all water needs in subsequent dry years, unlike Clear Lake and Gerber reservoirs in the Lost River Basin.

Dependency upon Forecasted Streamflows for Water Management Decisions.
As a consequence of limited storage in UKL, Reclamation must base its various water management decisions each year on stream inflow forecasts issued by the Natural Resources Conservation Service (NRCS) between January and June. Reclamation makeswater management decisions and the March 1 initial allocations between the Project, and the Klamath River (Environmental Water Account [EWA] supply) and UKL (UKL reserve) based on the March – September NRCS inflow forecast. The final forecast (generally the most accurate, but still subject to error) is released in June and can result in adjustments to the allocations made on April 1; the EWA supply and UKL reserve can be both increased or decreased with the June 1 inflow forecast, whereas Project Supply cannot decrease below the April 1 allocation with the issuance of the May and June inflow forecast. The final determination for Project Supply is made in June and is then fixed through the end of September. It is important to note that *delivery* of the “fixed” Project Supply is not guaranteed; Reclamation retains discretion to curtail deliveries from UKL to comply with unforeseeable legal requirements and hydrologic conditions as necessary.

Multiple Legal Responsibilities. The Secretary, through Reclamation, must manage and operate the Project pursuant to various legal responsibilities, including the Reclamation Act, the Kuchel Act, ESA, and the federal trust responsibility to Indian tribes. These independent acts and mandates can have differing requirements.

A Highly Variable Natural Hydrologic System.
The Klamath Basin has demonstrated a wide range of variable water conditions, from extreme drought conditions to extreme flood flow, sometimes within the span of a couple years. Recent precipitation and stream flow trends (within the last 20 years) have been drier than the median for the Period of Record (POR; Water Years [WY] 1981 to 2016) used in this analysis, but such fairly short-term trends can, and have, reversed within the Basin making any long-term forecasting difficult. For example, Klamath Falls rain gage data from WYs 1911 to 2018 shows that the ten driest years on record were, in order, 1926, 2010, 1924, 1992, 1955, 2012, 1994,

1920, 1929, and 1931. The ten wettest years, in order, were 1956, 1958, 1993, 1982, 1996, 1965, 1927, 1940, 1952, and 1971. (The years 1998 to 2001 were excluded due to numerous missing data points.) The 1980's were a wetter than average decade, making the last two decades appear even drier by comparison. Reclamation believes that the POR used in this analysis contains a reasonable range of hydrologic conditsions likely to be experienced over the next 10 years. If the trend in recent declining inflows continues, it could reduce available water for all resource needs in the Klamath Basin, in the manner defined by the PA.

3.3. Use of Best Available Science

The ESA requires that the action agency, in any request of formal consultation, provide "the Service with the best available scientific and commercial data available, or that can be obtained during the consultation for an adequate review of the effects that an action may have upon listed species or critical habitat" (50 C.F.R. § 402.14(d)). Additionally, U.S. Department of the Interior Policy (305 Department Manual 3) states that "Scientific and scholarly information considered in Departmental decision making must be robust, of the highest quality, and the result of as rigorous scientific and scholarly processes as can be achieved." Finally, Reclamation has an agency specific scientific integrity policy (CMP-P13) further defining required practices relating to the use of scholarly and scientific information.

Reclamation has prepared this BA using the best available scientific and commercial data available as required by law and policy. Reclamation has included references to all documentation and information that was reviewed and/or referenced in preparation of this BA.

3.4. Water Resource Integrated Modeling System

Reclamation used results generated by the Water Resource Integrated Modeling System (WRIMS) to identify the Klamath River and UKL hydrographs that are likely to occur as a result of implementing the PA. WRIMS is a generalized water resources modeling system, broadly accepted by the hydrologic community, for evaluating operational alternatives of large, complex river basins. WRIMS integrates a simulation language for flexible operational criteria specification, a linear programming solver for efficient water management decisions, and graphics capabilities for ease of use. These combined capabilities provide a comprehensive and powerful modeling tool for water resource systems simulation. Reclamation has worked closely with the Services' hydrologists to develop a WRIMS model specific to the Klamath Basin for this consultation, referred to as the Klamath Basin Planning Model (KBPM) hereafter.

Data files generated by the WRIMS model include daily modeled output. The daily modeled outputs can be summarized by week, month, or WY. For ongoing analysis, Reclamation will also use exceedance tables created by WRIMS results. Exceedance tables are developed through data analysis of historical hydrological conditions. Exceedance tables depict the probability that specific hydrologic conditions will be met or exceeded during a given time. For example, a 95 percent exceedance value would represent relatively dry conditions, because actual hydrological conditions can be expected to meet or exceed that value in 95 out of 100 years. Conversely, a 5 percent exceedance value would represent a period of unusually high precipitation, given that conditions can only be expected to meet or exceed that value in 5 years out of 100. A 50 percent exceedance value represents median hydrological conditions. It is important to note that within a WY hydrologic conditions, as represented by the exceedance value, are likely to vary between and within months.

3.5. Period of Record Hydrograph

For UKL and the area within the Project served from that source (excluding Tule Lake), the ACT recommended using October 1, 1980 to November 30, 2016 for the POR from which to run the daily time step WRIMS model. This time period, October 1, 1980 to November 30, 2016, incorporates daily inflows into UKL; including years (2013 through 2016) when the Project was being operated under the criteria identified in the 2013 BiOp; and contains a reasonable, adequate distribution of dry, average, and wet years, including the two driest years for which complete, quality assurance/quality controlled (QA/QC'ed) data exists, 1992 and 1994. With this range of data, the WRIMS model can evaluate a particular water operation strategy across the full range of reasonably foreseeable annual precipitation and hydrologic patterns. Reclamation's analysis used WRIMS to estimate mainstem Klamath River flows at IGD and UKL elevations that would likely be realized through implementation of the PA during the POR. Reclamation considers the resulting model outputs to reflect the range of flows reasonably expected to occur during the 10-year period of the PA (April 15, 2019 through March 31, 2029). However, it is important to note that each year in the POR has unique hydrological and climatological characteristics that only occur in that year. While the hydrology observed in the POR captures the range of conditions, the unique sequencing and patterns of climatological and hydrological events that will occur in the future cannot be predicted. As such, unique climatological and hydrological events not captured in the POR may occur, resulting in conditions not simulated by the KBPM.

For Clear Lake and Gerber reservoirs, Reclamation identified a different POR as representative given the quality and availability of relevant hydrologic data, which differed for UKL. In arriving at the applicable POR for each reservoir, Reclamation examined all available hydrologic records. For both Clear Lake and Gerber reservoirs, Reclamation uses the POR of WY 1986 through to 2016.

While the 36-year POR used for UKL analysis purposes reflects a range of wet and dry WYs, actual conditions may deviate from the representative trend in future years, possibly due to climate change. However, there is currently a lack of reliable forecasting tools available to precisely quantify the influence of global climatic changes on local hydrologic conditions. Therefore, the effects of possible future climate change, and the associated impacts on species and hydrology, are not explicitly incorporated into the analyses.

3.6. Uncertainties and Unknowns

In any ecosystem, there are always unknowns and uncertainties. This fact is especially true of aquatic ecosystems. In the Klamath Basin, these uncertainties and unknowns exist for all federally-listed species. The following describes some of the key issues where uncertainties and unknowns exist:

3.6.1. General

1. Uncertainties exist in all models. Models are a simplification and a simulation of complex ecologic and/or hydrologic processes. All models are approximations of actual conditions, and include assumed values, or computed values that are based upon uncertain data or information. As a result, lake elevation and river flow output should be considered an approximation of what would have occurred had the hydrologic conditions in the POR manifested while operating under this PA. Uncertainties associated with the WRIMS model (and submodels) are further discussed in Appendix 4.

2. Uncertainties exist in all measurements. For example, United States Geological Survey (USGS) gages have some amount of error that can vary by specific gage, season, and flow rate. Estimated numbers of fish abundance, disease prevalence and mortality, and habitat preference contain inherent uncertainty. This analysis uses numbers to determine relative effect rather than absolute values. To address this uncertainty, at IGD, for example, Reclamation allows a maximum of a 5 percent reduction in flows below the minimum daily average flows at IGD, not to exceed 72 hours in duration.

3. Uncertainties exist within the underlying datasets contained within the KBPM, as is common for complex datasets. While most uncertainties are not specifically known, specific concerns have been raised regarding the accuracy of the UKL bathymetric layer utilized in the KBPM to model this PA. However, it is the best information currently available and it is unclear and to what extent (if any) a revised bathymetric surface will have on the existing area capacity curves.

3.6.2. Suckers

1. Specific reasons for the loss of juvenile suckers (of both species) during their first year in UKL are largely unknown. This represents a “Baseline Condition” and there is no available evidence linking this loss to Project operations.

2. Suckers are entrained at Project facilities. It is unknown whether entrainment within the Project is compensatory or additive mortality to sucker populations, particularly at UKL (A Canal), and Clear Lake and Gerber reservoirs. The Baseline and analysis sections discuss entrainment as both compensatory mortality (sucker mortality would occur even without entrainment) and additive mortality (mortality occurs as a result of entrainment) within a population. The analysis section considers entrainment, which may result in either compensatory or additive mortality within a population, an adverse effect to the entrained individual and to the population from which they are entrained or emigrate.

3. Taxonomic status of sucker species is uncertain, particularly SNS in the Lost River Basin such as Clear Lake and Gerber reservoirs. Researchers have consistently concluded that the shortnose-like suckers in both Clear Lake and Gerber reservoirs are federally-listed SNS (Scoppettone et al. 1995, Perkins and Scoppettone 1996, Barry et al. 2007).

4. The recovery of passive integrated transponder (PIT) tags at fish-eating bird colonies in the Upper Klamath Basin indicates bird predation occurs at UKL and Clear Lake Reservoir. Factors influencing bird predation are currently unknown. This represents a Baseline condition and Reclamation has no evidence linking this mortality to Project operations.

3.6.3. Coho Salmon

1. Little is known about juvenile coho salmon movement into, out of, and within the mainstem of the Klamath River. The analysis for this BA assumes similar movement patterns as nearby drainages, where data is available.

2. Salmonids in the Klamath Basin are exposed to a number of pathogens and diseases that can impact all life stages. New science indicates that water temperature and flow regime influence infectious dose and mortality of fish, though the effect varies annually. The PA specifically includes flow management below IGD in an attempt to address identified disease issues and continued support of monitoring and research of disease issues below IGD.

3. Uncertainty exists concerning the interrelationship of hatchery produced fish with the naturally produced coho salmon when both are present in the natural environment (i.e., after the hatchery fish are released into the Klamath River). This includes the role of hatchery-produced salmon in the spread and proliferation of fish disease. The effects of hatchery operations are included as a Baseline condition.

4. Marine salmon survival during ocean rearing is an uncertainty that depends on a number of interacting factors, including the abundance of prey, density of predators, the degree of intra-specific competition (including that from hatchery fish), and fisheries. The importance of these factors in turn depends on ocean conditions. Even relatively small changes in local and annual fluctuations in marine water temperatures can be related to changes in salmon survival rates. These drastic, and unpredictable, changes in annual ocean productivity are considered a Baseline condition.

3.6.4. Southern Resident Killer Whales

1. The diet of SRKWs in the southern part of their range is poorly known compared to their diet in the Salish Sea. The effects analysis assumes the preferred diet is similar throughout their range.

2. Marine survival, distribution, and the factors affecting them (including climate change and competing predators) are poorly known for Klamath River Chinook, estimated to be the preferred food for SRKW when in the vicinity of the Klamath River. These are variable from year to year, leading to uncertainty in actual prey availability based on smolt production alone. The SRKW effects analysis will focus on Chinook habitat as an indication of the PA

effects upon their primary food source and not attempt to define actual numbers of Chinook salmon due to the uncertainty and unknowns involved.

3. The importance of Klamath River Chinook to SRKW will vary to some degree with the health of Chinook populations throughout their range. Future coast-wide abundance is unknown, leading to uncertainty in the future significance of Klamath River Chinook. This uncertainty is considered a Baseline condition for west coast chinook populations.

4. While the relative importance of prey availability, disturbance, and toxins to SRKW population dynamics has been modeled, there are uncertainties in how well models reflect the real world. This is an inherent uncertainty in all models, as mentioned above.

While this list of uncertainties and unknowns is not exhaustive, Reclamation has coordinated with the Services to identify these uncertainties and unknowns, given our current scientific understanding and how those uncertainties are resolved in this analysis.

3.7. Other Existing and Future Actions in the Action Area Not Included in the Environmental Baseline or Cumulative Effects

3.7.1. Klamath Agreements – Dam Removal

In 2010, representatives of 45 organizations, including federal agencies, the states of California and Oregon, Indian tribes, counties, irrigators, and conservation and fishing groups of the Klamath Basin negotiated the Klamath Basin Restoration Agreement (KBRA) to address the long-term needs of the Basin. The agreement, which is not included in this analysis, intended to:

1. Restore and sustain natural production and provide for full participation in harvest opportunities of fish species throughout the Klamath Basin.

2. Establish reliable water and power supplies which sustain agricultural uses and communities and NWRs.

3. Contribute to the public welfare and the sustainability of all Klamath Basin communities[5].

The KBRA required Congressional approval to provide legal authority and funding. However, legislation never became law and the KBRA subsequently expired in 2015. An Upper Klamath Basin Comprehensive Agreement was signed in 2014 to address KBRA commitments regarding tributaries to UKL, but this agreement was terminated in 2017 due to the failure of the KBRA.

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[5] *See* Klamath Basin Restoration Agreement for the Sustainability of Public and Trust Resources and Affected Communities. (2010).

Separately, many of the same organizations negotiated with PacifiCorp, (not a party to the KBRA), to arrive at the 2010 Klamath Hydroelectric Settlement Agreement (KHSA). The KHSA addressed the interim operations of the four PacifiCorp owned dams downstream of the Project and established a framework for facilities removal. Activities undertaken as a precursor to dam removal have included establishment of the Klamath River Renewal Corporation (KRRC) as the designated Dam Removal Entity and separating the Klamath Hydroelectric Project's FERC license to isolate the four dams in preparation for their transfer to the KRRC.

Although efforts continue with dam removal currently slated to occur in 2021, this activity is under the jurisdiction of FERC and FERC will consult with the appropriate fisheries agencies under section 7 of the ESA regarding effects to listed species of any action taken by FERC related to dam removal. As of this time FERC has not taken any action and therefore the associated private action of dam removal is currently not reasonably certain to occur. As such, under 50 C.F.R. 402.02 it is not required to be included in the cumulative effects discussion of this BA. However, awareness of the proposed dam removal and basin-wide settlement efforts is important to recognize as part of the overall context of this consultation. Many of the interim actions defined in the KHSA and the HCPs are included in the Environmental Baseline used for this BA.

3.7.1.1. Dam Removal – Point of Compliance

The KBPM does not currently account for the potential removal of four mainstem Klamath River developments in the Klamath Hydroelectric Project (JC Boyle, Copco 1 and 2, and Iron Gate). On September 23, 2016, PacifiCorp and the Klamath River Renewal Corporation (KRRC) submitted an application to the FERC to amend the existing license for the Klamath Hydroelectric Project, establish an original license for the Lower Klamath Project consisting of four developments, and transfer the original license for the Lower Klamath Project to the KRRC. At that time, the KRRC also applied to surrender the license for the Lower Klamath Project, including removal of the four developments. On October 5, 2017 FERC issued notice of the application for amendment and transfer of the license and soliciting comments, motions to intervene, and protests. However, FERC indicated that it was not requesting comments at that time on the surrender application, and it will issue a notice requesting comments, protests and motions to intervene on the surrender application after receiving a supplemental filing regarding a decommissioning plan. FERC still has not issued such a notice on the surrender application yet.

According to a Definite Plan that the KRRC submitted to FERC on June 28, 2018, decommissioning of the four developments is expected to commence on January 1, 2021. However, FERC has not yet submitted a biological assessment or requested initiation of formal consultation under Endangered Species Act section 7 with the Services on any federal action that it would take to decide whether to approve decommissioning of the four developments. Therefore, the effects of FERC's action deciding whether to decommission the four developments is not part of the Environmental Baseline considered with this PA (*see* the definition of "Effects of the action" in 50 C.F.R. 402.02 ("The Environmental Baseline includes … the anticipated impacts of all proposed federal projects in the action area that have already undergone formal or early section 7 consultation ….").

Indeed, KBPM explicitly assumes a control point at LRD and a measurement/compliance point at IGD. If FERC approves decommissioning the four developments described above and the developments are decommissioned, Keno Dam would be expected to become the compliance point for ESA releases to the Klamath River; LRD would remain the control point. Reclamation did not attempt to model a compliance point at Keno Dam in this PA. This process would require iterative modeling to arrive at new release guidelines (including new minimums) that would be appropriate for listed coho. Note that this process is necessary given that Keno Dam is not currently operated strictly as a run-of-the-river dam, meaning that there is not a clear relationship between Keno Dam and IGD releases (i.e., Copco and JC Boyle reservoirs may confound the flow relationship between Keno Dam and IGD), particularly in the late spring and summer.

Given the potential that decommissioning of the four dams described above will occur within the lifespan of this PA, the need to modify the location of the compliance point will need to be moved to Keno Dam. As such, upon FERC's final action authorizing removal, Reclamation will coordinate with the Services to identify a methodology to back calculate flow requirements measured at Iron Gate Dam under the PA to what the flow requirements that would need to be measured at Keno Dam to ensure consistency prior to decommissioning. This process would include close coordination with the Services to ensure that the point of compliance shift would not result in effects outside those analyzed by the Services in their forthcoming Biological Opinions.

3.7.2. Klamath Agreements – Keno Dam Acquisition

Along with the KHSA, a Klamath Power and Facilities Agreement (KPFA) was signed in 2016 to mitigate impacts to irrigated agriculture due to increased power rates and potential impacts due to return of anadromous fish to the Upper Klamath Basin. Collectively, the two agreements commit the Department of the Interior to acquire Keno Dam from PacifiCorp, operate it consistent with historic practices, and to evaluate and construct fish entrainment alleviation facilities at Project diversions along the Klamath River upstream.

3.7.3. Klamath Basin General Stream Adjudication

Since 1975, the State of Oregon has been in the process of adjudicating all pre-1909 and federally-reserved water rights to water from the Klamath River and its tributaries in the State of Oregon, including the rights associated with the Project. This process, generally known as the Klamath Basin General Stream Adjudication, will eventually result in a final determination of the nature and relative priority of water rights for the Project to water from the Klamath River and its tributaries, including UKL. *See* Part 1.3.2. for more information on the Klamath General Stream Adjudication.

In 2013 the State of Oregon issued a Findings of Fact and Order of Determination, which has since been amended and corrected (ACFFOD*)*. Under Oregon law, the ACFFOD is subject to judicial review, but is enforceable unless stayed by the court. These proceedings are ongoing in Klamath County Circuit Court and is likely to result in changes to the ACFFOD and the nature of the water rights determined therein.

Enforcement of water rights in the ACFFOD since 2013, particularly The Klamath Tribes instream flow water rights to tributaries to UKL, has resulted in significant changes in hydrology in the Upper Klamath Basin. At times, all irrigation diversions in certain stream reaches have been completely curtailed by calls on the water rights held by the BIA on behalf of The Klamath Tribes. Given the effect of the Klamath Basin General Stream Adjudication and enforcement of associated water rights on stream flows in the Upper Klamath Basin, they fall within the Environmental Baseline for this consultation (*see* Part 6.2). But the potential changes to ACFFOD through the judicial review process, and their effects on hydrology in the Upper Klamath Basin, are not reasonably foreseeable.

3.8. Key Consultation Considerations

Reclamation has participated in extensive consultation with the Services in preparation of this BA. This effort has involved the dedication of many hours of staff and management time resulting in an improved working relationship among agency staff and members of the ACT. Reclamation made efforts to provide the Services with an opportunity to review drafts of the document and worked diligently to respond to the comments received. The final content of the BA is Reclamation's responsibility and has been prepared in compliance with section 7 of the ESA and associated implementing regulations. *See* Table 3-1 for a list of meetings and work sessions held between Reclamation and the Services.

Reclamation invited the Klamath Water Users Association (KWUA), irrigation and/or drainage districts, the Klamath Basin NWR Complex, PacifiCorp, the BIA, the Yurok, Hoopa Valley, Karuk, Quartz Valley tribes, The Klamath Tribes, including the Resighini Rancheria (collectively, Tribal and Key Stakeholders) to participate in the consultation effort. *See* Table 3-1 for a list of Tribal and Key Stakeholder meetings and workshops with Reclamation and the Services.

The PA is modeled, and the model outputs are used to define key parameters such as Project/NWR water availability, UKL elevations, and Klamath River flows. The hydrologic model includes all current hydrologic features in the Klamath River in the Environmental Baseline (e.g., PacifiCorp owned hydroelectric facilities and both federal/non-federal diversion systems, etc.). These modelled results are the simulated direct and indirect effects that result from the implementation of the PA and are added to the Environmental Baseline, as indicated in the definition of "Effects of the action" (50 C.F.R. 402.02).

Table 3-1. Chronology of meetings held for development of Reclamation's Proposed Action, January 2017 to November 2018.

Meeting Type	Date Held	Location
Reclamation and the Services Meetings and Work Sessions		
ACT	1/31/2017	webinar/teleconference
ACT	2/15/2017	Ashland, OR
ACT	4/5/2017	Ashland, OR
ACT	5/24/2017	webinar/teleconference
ACT	6/12/2017	webinar/teleconference
ACT	7/6/2017	webinar/teleconference
ACT	7/12/2017	webinar/teleconference
ACT	8/1/2017	webinar/teleconference
ACT	8/22/2017	Medford, OR
ACT	9/27/2017	Klamath Falls, OR
ACT	10/20/2017	webinar/teleconference
ACT	11/30/2017	webinar/teleconference
ACT	12/14/2017	webinar/teleconference
ACT	2/20/2017	webinar/teleconference
ACT	4/17/2018	webinar/teleconference
ACT	5/15/2018	Grants Pass, OR
ACT	6/22/2018	webinar/teleconference
ACT	7/25/2018	webinar/teleconference
ACT	8/7/2018	webinar/teleconference
ACT	8/23/2018	webinar/teleconference
ACT	9/21/2018	Selma, OR
ACT	10/24/2018	webinar/teleconference
ACT	11/27/2018	webinar/teleconference
Tri-Agency Hydro Team	10/11/2017	webinar/teleconference
Tri-Agency Hydro Team	11/2/2017	webinar/teleconference
Tri-Agency Hydro Team	11/30/2017	webinar/teleconference
Tri-Agency Hydro Team	12/4/2017	webinar/teleconference
Tri-Agency Hydro Team	12/12/2017	webinar/teleconference
Tri-Agency Hydro Team	1/11/2018	webinar/teleconference
Tri-Agency Hydro Team	1/29/2018	webinar/teleconference
Tri-Agency Hydro Team	2/5/2018	Ashland. OR
Tri-Agency Hydro Team	2/21/2018	webinar/teleconference
Tri-Agency Hydro Team	4/17/2018	webinar/teleconference
Tri-Agency Hydro Team	4/24/2018	Ashland, OR
Tri-Agency Hydro Team	4/25/2018	Ashland, OR
Tri-Agency Hydro Team	5/14/2018	webinar/teleconference
Tri-Agency Hydro Team	6/8/2018	webinar/teleconference
Tri-Agency Hydro Team	6/21/2018	Klamath Falls, OR
Tri-Agency Hydro Team	7/11/2018	webinar/teleconference

Meeting Type	Date Held	Location
Tri-Agency Hydro Team	7/16/2018	webinar/teleconference
Tri-Agency Hydro Team	7/24/2018	webinar/teleconference
Tri-Agency Hydro Team	8/6/2018	Klamath Falls, OR
Tri-Agency Hydro Team	8/16/2018	Klamath Falls, OR
Tri-Agency Hydro Team	8/22/2018	webinar/teleconference
Tri-Agency Hydro Team	8/28/2018	Ashland, OR
Tri-Agency Hydro Team	8/29/2018	Ashland, OR
Tri-Agency Hydro Team (with Agency Managers and Biologists)	8/30/2018	Ashland, OR
Tri-Agency Hydro Team	9/11/2018	Klamath Falls, OR
Tri-Agency Hydro Team	9/12/2018	Klamath Falls, OR
Tri-Agency Hydro Team	9/19/2018	webinar/teleconference
Tri-Agency Hydro Team	9/24/2018	webinar/teleconference
Tri-Agency Hydro Team	10/3/2018	webinar/teleconference
Tri-Agency Hydro Team	10/4/2018	webinar/teleconference
Tri-Agency Hydro Team	10/11/2018	webinar/teleconference
Tri-Agency Hydro Team	10/25/2018	webinar/teleconference
Tri-Agency Bio Team	8/15/2017	Teleconference
Tri-Agency Bio Team	11/1/2017	Teleconference
Tri-Agency Bio Team	6/18/2018	Teleconference
Tri-Agency Bio Team	6/20/2018	Teleconference
Tribal and Key Stakeholder Workshops and Meetings		
Tribal and Key Stakeholder Policy Workshop	7/24/2017	Klamath Falls, OR
Tribal and Key Stakeholder Policy Workshop	7/25/2017	Klamath Falls, OR
Tribal and Key Stakeholder Policy Workshop	9/27/2017	Klamath Falls, OR
Tribal and Key Stakeholder Policy Workshop	12/5/2017	webinar/teleconference
Tribal and Key Stakeholder Policy Workshop in the Morning with Individual Tribal and Key Stakeholder Meetings in the Afternoon	11/13/18	Klamath Falls, OR
Tribal and Key Stakeholder Technical Team (Hydro Members only)	10/17/2017	webinar/teleconference
Tribal and Key Stakeholder Technical Team	11/13/2017	Klamath Falls, OR
Tribal and Key Stakeholder Technical Team	12/15/2017	webinar/teleconference
Tribal and Key Stakeholder Technical Team	1/9/2018	Redding, CA
Tribal and Key Stakeholder Technical Team	2/6/2018	Ashland, OR
Tribal and Key Stakeholder Technical Team	11/8/18 and 11/9/18	webinar/teleconference

4. PROPOSED ACTION

4.1. Action Area

The Action Area includes "all areas to be affected directly or indirectly by the federal action and not merely the immediate area involved in the action" (50 C.F.R. § 402.02). Project lands are identified in Figure 4-1.

The Action Area extends from UKL, in south central Oregon, and Gerber Reservoir and Clear Lake Reservoir in the Lost River drainage in southern Oregon and northern California, to approximately 254 miles downstream to the mouth of the Klamath River at the Pacific Ocean, near Klamath, California (Figure 4-2).

Within the Upper Klamath Basin, the Action Area includes Agency Lake, UKL, Keno Impoundment (Lake Ewauna), Lost River including Miller Creek, and all Reclamation-owned facilities including reservoirs, diversion channels and dams, canals, laterals, and drains, including those within Tule Lake and Lower Klamath NWRs, as well as all land, water, and facilities in or providing irrigation or drainage for the service area of the Project.

Direct effects of the PA are those effects that occur as a result of implementation of the PA. Indirect effects are those effects that are caused by or will result from the PA and are later in time but are still reasonably certain to occur (50 C.F.R. § 402.02). This BA considers both direct and indirect effects for the purpose of analyzing potential species impacts.

The direct effects of Project operations extend downstream from UKL to the KSD, which is the most downstream Project feature that enters the Klamath River upstream of Keno Dam, Oregon. There is a potential for direct effects on listed suckers to occur throughout the Action Area above IGD, although measures such as fish screens at the A Canal and Clear Lake Dam, and a fish ladder at the LRD reduce these effects.

Effects on suckers continue beyond the location of the Project (*see* Part 1.2 for a description and map), including the entirety of UKL, Clear Lake Reservoir, Gerber Reservoir, and Lake Ewauna, into a series of hydroelectric dams and reservoirs (Keno, J.C. Boyle, Copco I, Copco II, and IGD) owned and operated by PacifiCorp. Effects on coho salmon occur downstream of the hydroelectric dams owned by PacifiCorp and continue to some extent to the mouth of the Klamath River at the Pacific Ocean (*see* Part 8.3.2, Table 8-3 for the relative influence of Project operations [IGD releases] below IGD). The effects of Project operations (IGD releases in this case) diminish with increasing distance downstream as the Klamath River volume increases with water from the Scott, Shasta, Salmon and Trinity rivers, and numerous other tributaries, seeps, and springs (*see* Part 8.3.2, Table 8-3). Figure 4-3 describes average annual flow volumes (in AF; from WY 2001 to 2017) contributed to the mainstem Klamath River by these tributaries, illustrating the diminishing direct effect. Figure 4-3 does not include average annual Project diversions via the A Canal that may impact the volumes available for release at the LRD. Note that there may be other effects of Project operations on Klamath River conditions (e.g., water quality, water temperature, etc.) and these are addressed in Part 8.

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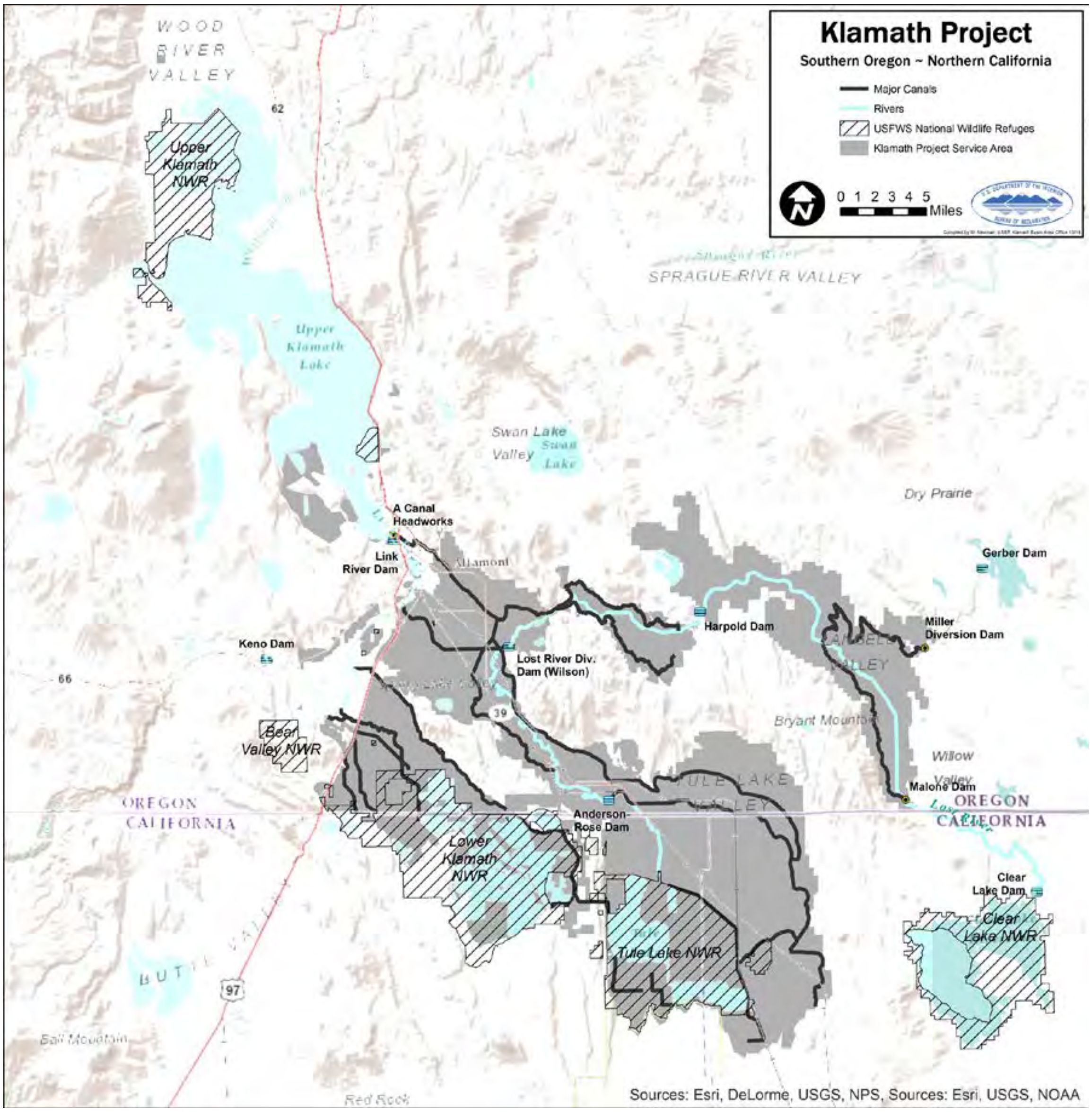


Sources: Esri, DeLorme, USGS, NPS, Sources: Esri, USGS, NOAA

Figure 4-1. Upper Klamath Basin of Oregon and California. Klamath Project lands are shown as shaded area on the map.
Source: Bureau of Reclamation 2018

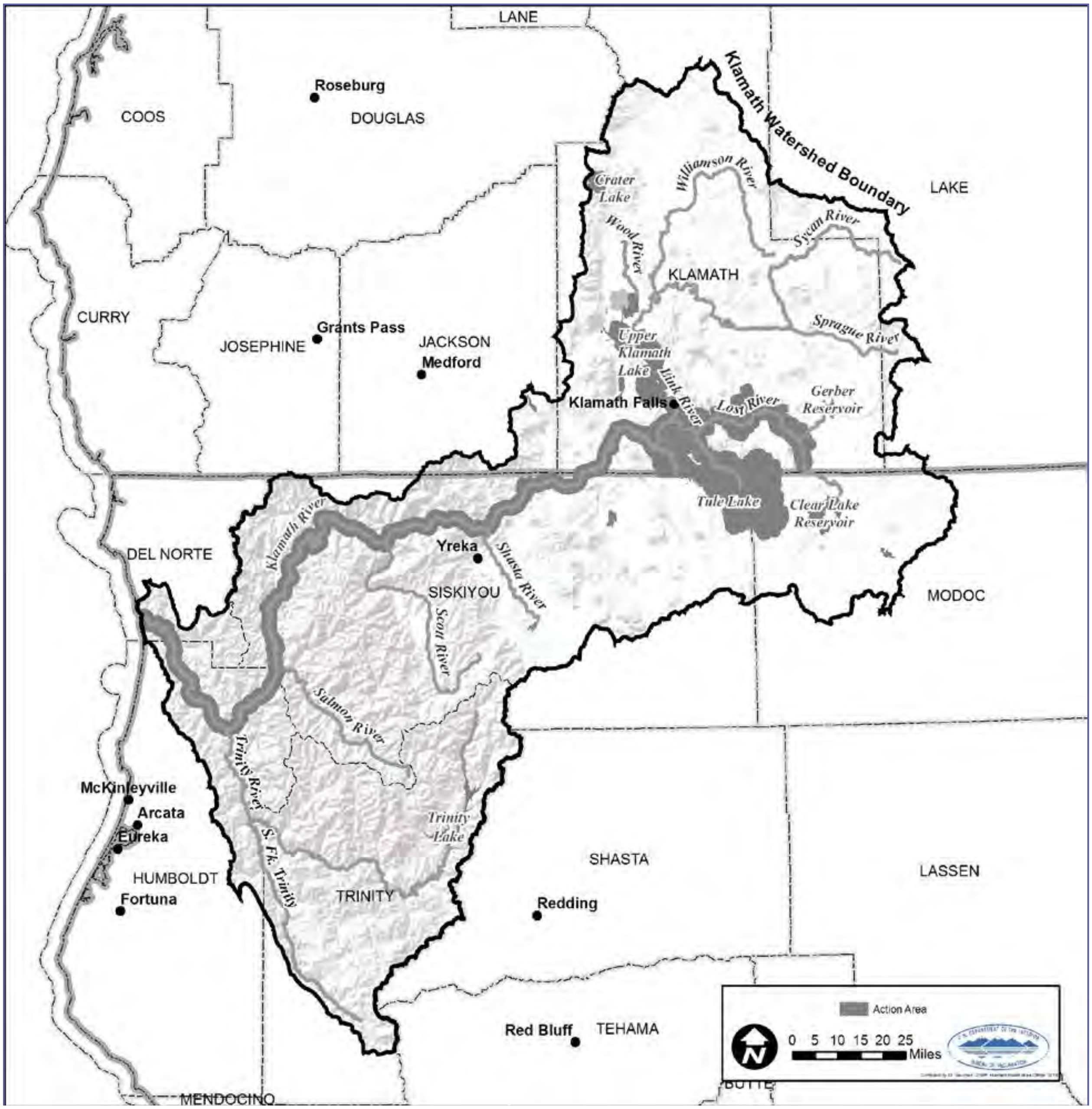


Figure 4-2. Map of the Action Area.
Source: Bureau of Reclamation 2018.

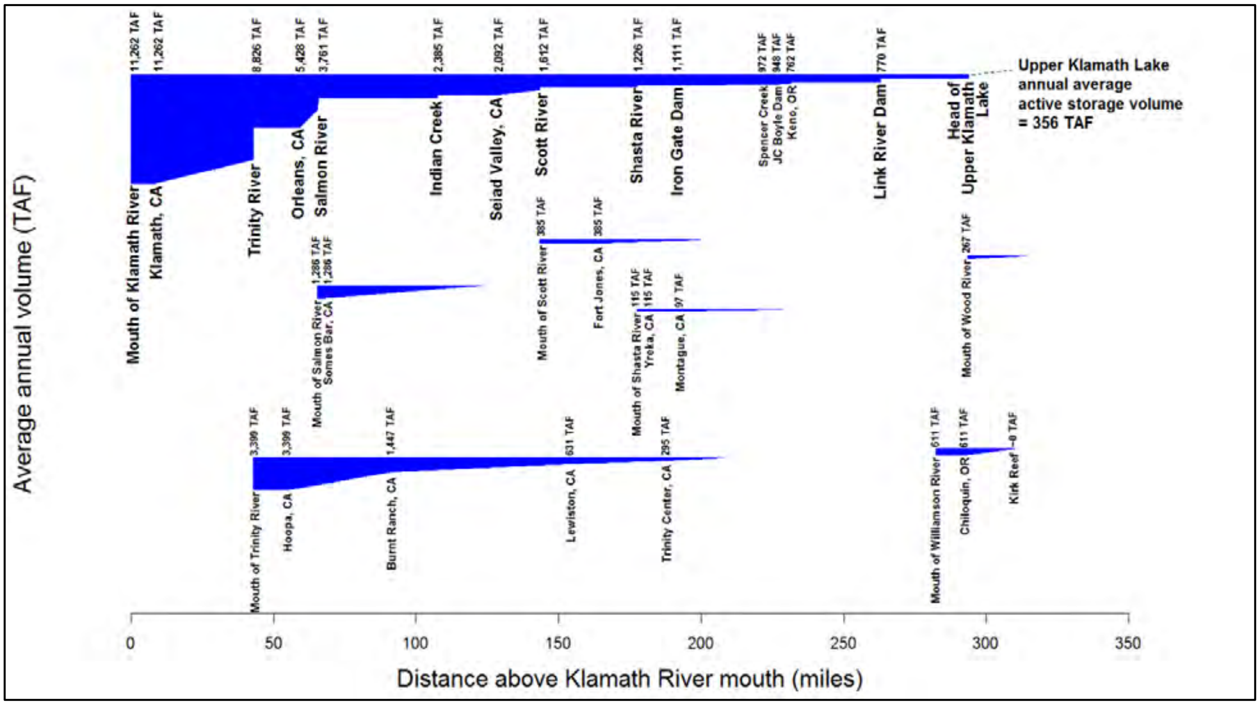


Figure 4-3. Annual volumes (thousand acre-feet [TAF]; water years 2001 to 2017) flowing through the Klamath River at major confluences and landmarks from the Project to mouth of the Klamath River.
Source: Bureau of Reclamation 2017.

There is a separate Action Area specific to the SRKW as there are no effects of flow management that affect SRKW. Rather there is an indirect link to SRKW from Chinook spawning and rearing habitat in the Klamath River, and Chinook are a primary prey for SRKW. This indirect link results in effects that extend out into the Pacific Ocean where SRKW feed on concentrations of adult Chinook salmon (*see* Part 9.1.2. for more detail). This separate Action Area extends, for SRKW only, to that section of the ocean where there is species overlap between Chinook salmon and SRKW. The exact boundaries of this area cannot be defined based upon current information.

4.2. Background

Reclamation has managed minimum UKL elevations (since 1991) and Klamath River flows at IGD (since 2001) in accordance with a series of BiOps from the Services.

For the 2012 BA, Reclamation – in consultation with USFWS and NMFS – used the 1981 through 2011 historical hydrology and revised NRCS forecasts for UKL net inflows as the most complete set of daily data available for development of the PA. To prepare for the current consultation effort, since issuance of the 2013 BiOp, Reclamation has reviewed data updates and refinements, including: new data to expand the POR through 2016 (i.e., 1981 to 2016), a new UKL bathymetric layer, updated UKL net inflow estimates for the POR, and updated daily Project diversion data and return flows for the POR. The 36-year POR includes a broad range of hydrologic conditions that likely represent the range of future conditions within the timeframe covered by the PA. It is important to note that the full effects of climate change during the term of the BA are not fully understood. However, Reclamation believes that the POR includes a climate change signal to some extent, given that trends expected to continue into the future have been observed in the Pacific Northwest over the past several decades (Mote 2003).

4.2.1. Proposed Action Model Development

Reclamation incorporated the 1981 through 2016 dataset into WRIMS to assess the effects of the PA. WRIMS is a generalized water resources modeling system for evaluating operational alternatives of large, complex river basins and is essentially a mass balance model. As described above, historical daily data for this POR was reviewed and updated by comparing values recorded by Reclamation with other data sources, adding data from 2011 through 2016, recalculating computed values, and revising UKL bathymetry using a more current and complete dataset (termed “Reclamation 2017 bathymetry” and described in Reclamation 2017). The final data set used for the analysis was collaboratively developed and reviewed by Reclamation and the Services. Finally, concerns have been raised regarding the accuracy of the UKL bathymetric layer utilized in the KBPM to model this PA; however, it is the best information currently available and it is unclear and to what extent (if any) a revised bathymetric surface will have on the existing area capacity curves. S*ee* Part 6.3.1 for additional discussion about UKL bathymetry.

The working version of WRIMS that was used to simulate operations of the Project is referred to as the KBPM. The KBPM encompasses the areas of the Project served by UKL and the Klamath River and extends from UKL to IGD. KBPM does not model the portion of the Project served by Clear Lake and Gerber reservoirs, although the net effects of conditions on this portion of the Project on the Klamath River are included in the model via the gains (i.e., accretions to the Klamath River) and losses (i.e., Project diversions) within the LRDC. The KBPM also does not model explicit operational details for many facilities within the Project (e.g., Pumping Plant D) and on the Klamath River such as IGD or other reservoirs owned and operated by PacifiCorp; however, reservoir storage on the Klamath River is considered in broad terms to ensure there is sufficient time to fill reservoirs to spillway elevation prior to IGD releases requiring spill. Operation of Project facilities that store and divert water from UKL and the Klamath River was simulated over a range of hydrologic conditions using daily input data to obtain daily, weekly, monthly, and annual results for river flows, UKL elevations, and Project diversions (including deliveries to the LKNWR). Reclamation modeled the effects of the potential management action of operation of Project facilities that store and divert water from UKL and the Klamath River on UKL elevations and Klamath River flows for the period of October 1, 1980 through November 30, 2016. The resulting simulated hydrology represents the water supply available from the Klamath River system (including UKL) at the current level of development.

The KBPM is a planning tool that assisted in the development of the PA and not all the processes built into the model can be implemented during actual operations. In addition, there are many assumptions associated with modeling efforts of this nature, and it is important to be aware of the critical assumptions that are incorporated into the KBPM. Listed below are the critical assumptions that have been identified for the KBPM. This list provides examples of how some of the processes built into the KBPM cannot be, and are not intended to be implemented, during real-time operations.

Critical KBPM assumptions include:

- The upper Klamath River basin will experience WY types within the range observed in the POR.
- UKL inflows will be within the range observed in the POR.
- NRCS inflow forecasts will be within the range and accuracy of historical inflow forecasts.
- UKL bathymetry in the model is reasonably representative of actual UKL bathymetry and therefore accurately represents UKL storage capacity.
- Water deliveries to the Project will be consistent with distribution patterns analyzed for the KBPM.
- Accretions from LRD to IGD will be consistent with accretion timing, magnitude, and volume assumed in the KBPM.
- Accretions from LRD to IGD will be routed through PacifiCorp's hydroelectric reach in a manner that is consistent with the KBPM model results for the POR.
- Facility operational constraints and limitations, and/or associated maintenance activities, will be within the historical range for the POR.
- Implementation of the proposed action will not exactly replicate the modeled results, and actual IGD flows and UKL elevations will differ during real-time operations.

Additionally, the KBPM is a tool and model outcomes are not prescriptive. Similarly, the occurrence of a condition that does not conform to an assumption is not inconsistent with the PA and does not necessarily trigger a duty to re-initiate consultation.

A detailed description of the WRIMS model can be found in Appendix 4.

4.2.2. Water Supply Forecasts

Annual planning relies heavily on seasonal water supply forecasts provided by the NRCS in the form of net inflow forecasts for UKL. The water supply forecasts are developed based on antecedent streamflow conditions, precipitation, snowpack, groundwater, current hydrologic conditions, a climatological index, and historical streamflow patterns (Risley et al. 2005). NRCS updates the forecasts for the season at the start of each month from January to June, with additional unofficial forecasts provided mid-month from March through June. The official (i.e., first of the month) UKL inflow forecasts are used to estimate the seasonal net inflow to UKL through September, which is used to determine the volume of water to be reserved in UKL for the federally-listed suckers, an estimate of water supply for the Project, and an estimate of the

March through September Klamath River EWA volume for federally-listed coho salmon (discussed further in Part 4.3.2.2., Operational Approach). It's important to note that the NRCS UKL inflow forecasts are seasonal volumetric estimates and actual observed inflow volumes and timing can vary substantially from the forecasted inflow, especially over shorter time periods.

Upon request, in 2017, the NRCS used revised inflow data provided by Reclamation to reconstruct forecasts for 1981 to 2016. The results, shown in Table 4-1, appear similar in forecast accuracy to forecasts utilized in development of the 2013 BiOp. Forecast values ranged from 160,419 AF during 1991 to 1,070,129 AF during 1999. These volumes range from 26 to 171 percent of average values for the March through September time period (average March through September inflow for the POR is 620,667 AF). Table 4-1 also shows observed annual inflows from 1981 to 2016. On average, the forecast values were 102 percent of the historical values (98 percent of median). Values for individual years ranged from 63 to 217 percent of observed inflows (as compared to 68 to 223 percent during the 2013 BiOp analysis). A detailed description of the NRCS inflow forecasting procedures is available at https://www.wcc.nrcs.usda.gov/about/forecasting.html.

Table 4-1. Reconstructed Natural Resources Conservation Service March 1st 50 percent exceedance Upper Klamath Lake inflow forecasts for March through September from 1981-2016.

Year	Forecasted UKL Inflow (Acre-Feet)	Forecast Percent of Average (Avg = 620,667 AF)	Observed UKL Inflow (AF)	Observed Percent of Forecast
1981	396,563	64	366,269	92
1982	889,637	143	994,348	112
1983	1,025,671	165	1,223,989	119
1984	878,857	142	1,140,831	130
1985	795,367	128	779,262	98
1986	782,212	126	850,485	109
1987	544,961	88	519,134	95
1988	503,026	81	402,542	80
1989	743,544	120	868,712	117
1990	395,015	64	431,831	109
1991	160,419	26	348,450	217
1992	296,882	48	222,549	75
1993	945,809	152	961,351	102
1994	395,188	64	254,346	64
1995	586,569	95	712,330	121
1996	735,470	118	796,772	108
1997	900,855	145	648,847	72
1998	824,676	133	960,304	116
1999	1,070,129	172	1,027,319	96
2000	867,994	140	723,171	83
2001	407,045	66	338,805	83
2002	693,201	112	438,677	63
2003	425,598	69	474,347	111

Year	Forecasted UKL Inflow (Acre-Feet)	Forecast Percent of Average (Avg = 620,667 AF)	Observed UKL Inflow (AF)	Observed Percent of Forecast
2004	730,808	118	459,119	63
2005	456,372	74	454,378	100
2006	963,272	155	917,206	95
2007	530,635	85	526,490	99
2008	692,028	111	623,985	90
2009	514,632	83	507,524	99
2010	509,953	82	422,643	83
2011	625,019	101	808,304	129
2012	392,468	63	566,090	144
2013	519,560	84	415,096	80
2014	241,474	39	339,015	140
2015	315,982	51	293,794	93
2016	587,124	95	506,882	86

4.3. Proposed Action

The PA for 2019 to 2029 consists of three major elements to meet authorized Project purposes, satisfy contractual obligations, and address protections for listed species and certainty for Project irrigators:

1. Store waters of the Upper Klamath Basin and Lost River.

2. Operate the Project, or direct the operation of Project facilities, for the delivery of water for irrigation purposes or NWR needs, or releases for flood control purposes, subject to water availability; while maintaining conditions in UKL and the Klamath River that meet the legal requirements under section 7 of the ESA.

3. Perform O&M activities necessary to maintain Project facilities.

Each of the elements of the PA is described in greater detail in the following sections. The three major elements of the Proposed Action have not changed relative to the 2012 BA.

4.3.1. Element One

Store waters of the Upper Klamath Basin and Lost River.

4.3.1.1. Annual Storage of Water

Reclamation operates three reservoirs for the purpose of storing water for delivery to the Project's service area – UKL and Clear Lake and Gerber reservoirs.

Bathymetric data compiled by Reclamation in 2017 (including nearshore areas such as Upper Klamath NWR, and Tulana and Goose Bays), indicated an "active" storage volume of 562,000 AF between the elevations of 4,136.0 and 4,143.3 feet above sea level (USBR datum), which is the historical range of water surface elevations within which UKL has been operated. *See* Part 6.3 for additional details regarding historical conditions in UKL.

Clear Lake Reservoir has an active storage capacity of 513,330 AF (between 4,515.6 and 4,543.0 feet above sea level, Reclamation datum), of which 139,250 AF is exclusively reserved for flood control purposes (between 4,537.4 and 4,543.0 feet above sea level, USBR datum).

Gerber Reservoir has an active storage capacity of 94,270 AF (between 4,780.0 and 4,835.4 feet above sea level, Reclamation datum). No storage capacity in Gerber Reservoir is exclusively reserved for flood control purposes.

Reclamation proposes to store water in UKL and Clear Lake and Gerber reservoirs year-round with a majority of the storage occurring from October through April. In some years of high net inflows or non-typical inflow patterns (i.e., significant snowfall or other unusual hydrology in late spring/early summer), contributions to the total volume stored can also be significant in May and June. Most water delivery from storage occurs during March through September, although storage releases for irrigation purposes occur year-round. Storing water through the winter raises lake elevations which usually peak between March and May. Flood control releases may occur at any time of year, as public safety, operational, storage, and inflow conditions warrant.

4.3.2. Element Two

> *Operate the Project, or direct the operation of the Project, for the delivery of water for irrigation purposes or NWR needs, subject to water availability, and consistent with flood control purposes, while maintaining conditions in UKL and the Klamath River that are protective of ESA-listed species.*

Consistent with Reclamation Manual Policy "Water-Related Contracts and Charges – General Principles and Requirements" (PEC P05) and as applicable to the Klamath Project, the term "Project water" encompasses surface water, including Project seepage and return flows, that is developed by, pumped or diverted into, and/or stored based on the exercise of water rights that have been appropriated or acquired by the United States or others, or that have been decreed, permitted, certificated, licensed, or otherwise granted to the United States or others, for the Klamath Project. Consistent with state water law and as applicable to the Klamath Project, the term "live flow" encompasses surface water in natural waterways that has not otherwise been released from storage (i.e., "stored water"). Live flow can consist of tributary runoff, spring discharge, return flows, and water from other sources (e.g., municipal or industrial discharges).

Project water, both stored and from live flow, is used to meet irrigation needs within the Project service area. Live flow is diverted from UKL, the Klamath River, and the Lost River for irrigation purposes. Generally, when live flow is insufficient to meet irrigation demands, stored water is released from UKL and Clear Lake and Gerber reservoirs to meet those needs.

Water supply contracts and other agreements between Reclamation and district entities or individuals, coupled with water rights (e.g., as currently determined in the ACFFOD), govern the distribution and use of Project water supplies (*see* Part 1.3.2, regarding Project water rights, and Part 1.3.3, regarding water supply contracts).

Altogether, the Project provides water for irrigation purposes to approximately 230,000 acres of land, including federally-owned lands within Lower Klamath and Tule Lake NWRs (*see* Part 1.3.6, regarding NWRs and associated acreages within the Project). Approximately 200,000 acres are primarily served from UKL and the Klamath River. Approximately 20,000 acres are served from Clear Lake and Gerber reservoirs, although as noted elsewhere, stored water from these reservoirs can be used under certain circumstances to meet irrigation demands in portions of the area served from UKL and the Klamath River.

In addition to the above acreages, live flow from the Lost River is exclusively used for irrigating approximately 10,000 acres, mostly located immediately upstream and downstream of Harpold Dam (i.e., Yonna and Poe valleys). Live flow from the Lost River is also used as a supplemental irrigation source for the area of the Project served from UKL and the Klamath River.

4.3.2.1. Operation and Delivery of Water from UKL and the Klamath River

The portion of the Project served by UKL and the Klamath River consists of approximately 200,000 acres of irrigable land, including areas around UKL, along the Klamath River (from Lake Ewauna to Keno), Lower Klamath Lake, and from Klamath Falls to Tulelake. Most irrigation deliveries occur between April and October, although water is diverted year-round for irrigation use within the Project.

Stored water and live flow in UKL are directly diverted from UKL, via the A Canal and smaller, privately-owned diversions. The A Canal (1,150 cubic feet per second [cfs] capacity) and the connected secondary canals it discharges into (i.e., the B, C, D, E, F, and G canals) serve approximately 71,000 acres within the Project. In addition to the A Canal, there are approximately 8,000 acres around UKL that are irrigated by direct diversions from UKL under water supply contracts with Reclamation.

In addition to direct diversions from UKL, stored water and live flow is released from LRD, for re-diversion from the Klamath River between Klamath Falls and the town of Keno. PacifiCorp currently operates LRD under guidance from Reclamation to achieve certain flows at IGD (*see* Part 1.3.5, regarding Reclamation's relationship with PacifiCorp and its predecessors).

Water released from LRD flows into the Link River, a 1.5-mile waterbody that discharges into Lake Ewauna, which is the start of the Klamath River. The approximately 16-mile section of the Klamath River between the outlet of Link River and Keno Dam is commonly referred to as the Keno Impoundment or Keno Reservoir (referred to as the Keno Impoundment herein).

There are three primary points of diversion along the Keno Impoundment that are used to re-divert stored water and live flow released from UKL via the LRD. Approximately three miles below the outlet of Link River, water is diverted into the LRDC, where it can then be pumped or released for irrigation use. Pumping from the LRDC primarily occurs at the Miller Hill Pumping Plant (105 cfs capacity), which is used to supplement water in the C-4 Lateral for serving lands within KID that otherwise receive water through the A Canal. KID operates and maintains the Miller Hill Pumping Plant. In addition to the Miller Hill Pumping Plant, there are other smaller, privately-owned pumps along the LRDC that serve individual tracts within KID.

Water re-diverted into the LRDC can also be released through Station 48 (650 cfs maximum capacity), where it is then discharged into the Lost River below the Lost River Diversion Dam for re-diversion and irrigation use downstream. TID makes gate changes at Station 48 based on irrigation demands in the J Canal system, which serves approximately 62,000 acres within KID and TID. To the extent that live and return flows in the Lost River at Anderson-Rose Dam and the headworks of the J Canal (810 cfs capacity) are insufficient to meet associated irrigation demands, water is released from Station 48 to augment the available supply.

The other two primary points of diversion along the Keno Impoundment that re-divert stored water and live flow from UKL are the North and Ady canals (200 cfs and 400 cfs capacity, respectively), which are owned and operated by KDD. In addition to lands within the boundaries of KDD, the Ady Canal also delivers water to the California portion of LKNWR. Together, the North and Ady canals deliver water to approximately 45,000 acres of irrigable lands in the Lower Klamath Lake area, including lands in KDD.

In addition to the lands served by the LRDC and Ady and North canals, Reclamation has entered into water supply contracts covering approximately 4,300 acres along the Keno Reservoir, including lands on the west side of the Klamath River and on Miller Island. Privately-owned pumps are generally used to serve these lands. Refer to Figures 1-1, 4-1, and Appendix 1A for maps showing the location of the facilities referenced above.

Demands for irrigation supply and refuge deliveries over the proposed lifetime of this BA are assumed to be similar to those that have occurred in the 36-year POR for water-year 1981 through 2016. However, continued improvements in irrigation infrastructure and equipment combined with advances in irrigation practices and technology will likely help to reduce Project irrigation demand in the future. The irrigation "demand" is the amount of water required to fully satisfy the irrigation needs of the Project. While these historical demands are retained for analysis and comparison purposes, irrigation deliveries to the Project within this PA were modeled using the Agricultural Water Delivery Sub-model (Part 4.3.2.2.2.2.; Appendix 4, section A.4.4.4). This sub-model includes variables such as deliveries during the previous timestep, meteorological conditions, and soil moisture to predict irrigation deliveries on a 5-day timestep, scaled to Project Supply (water available to the Project from UKL; *see* definition and additional details in Part 4.3.2.2.2.1) and water available from the LRDC and KSD. Modeled deliveries during this 36-year POR generally fall within the range of historical Project deliveries. In addition, the POR exhibits a large range of hydrologic and meteorological conditions, and the various modeled deliveries during this period are reasonably expected to cover the range of conditions likely to occur during the proposed term of this BA.

4.3.2.2. Operational Approach

This section of the PA provides a general overview of the operational approach for the PA; additional details regarding the fall/winter and spring/summer operational periods are discussed below in their respective sections and in Appendix 4.

Water management in the fall/winter operations period (November 1 – February 28/29 for the Project and from October 1 – February 28/29 for the Klamath River), employs a formulaic management approach focused on maintaining conditions in UKL and the Klamath River that meet the needs of the ESA-listed species as described in this BA and provide fall/winter water deliveries to the Project and LKNWR. This approach attempts to ensure appropriate water storage and sucker habitat in UKL (*see* Part 7 for details regarding sucker habitat) while providing Klamath River flows that mimic natural hydrologic conditions based on current conditions in the upper Klamath Basin. *See* Part 4.3.2.2.1 and Appendix 4, Section A.4.4.2 in-depth details regarding the fall/winter water management approach.

Water management in the spring/summer operational period includes March 1 – November 30 for Area A1 and March 1 – October 31 for Area A2. Limited overlap between spring/summer operations in Area A1 and fall/winter operations in October and November remains; in other words, as in the 2012 BA and 2013 BiOp, Area A1 may continue diverting spring/summer water (i.e., Project Supply) after October 1, when the fall/winter period begins (*see* Parts 4.3.2.2.1 and 4.3.2.2.2 for additional details). Note that Area A1 includes Project lands served by A Canal and the LRDC including KID, TID, and water supply contracts and Districts served by KID. Area A2 includes KDD and LKNWR served by the Ady and North canals.

Generally, Reclamation proposes to determine the total available UKL Supply, accounting for sucker needs [as outlined in Part 7] through the spring/summer period; (*see* Part 4.3.2.2.2.1), and then distribute this supply between the Project (Project Supply; water available to the Project from UKL; *see* definition and additional details in Part 4.3.2.2.2.1) and the Klamath River EWA (*see* Part 4.3.2.2.2.3 for definition and additional details). The division of the total available UKL water supply between EWA and Project Supply was determined through the iterative modeling process, relying on the expert opinion of Reclamation and, informally, the Services.

The management approach employed by Reclamation in this PA attempts to optimize the ecologic benefit of the available water supply, resulting in the ability to maximize the amount of remaining water available for the Project. In some instances, dry hydrologic conditions characterized by limited precipitation, runoff, and inflows to UKL may create shortages in the total available UKL water supply, which can result in a Project Supply that is less than the full irrigation demand. *See* Part 4.3.2.2.2. and Appendix 4, Section A.4.4.3 for in-depth details regarding the spring/summer operational approach.

The PA management approach has two major components:

1. UKL elevations and storage, specifically the UKL control logic and UKL Credit, to protect sucker habitat and ensure adequate storage to meet the needs of listed species in UKL and the Klamath River and water supply for the Project; and

2. Klamath River flows, specifically EWA to support coho needs and to produce flows for disease mitigation or protection of coho habitat during the spring/summer operational period (between March 1 and September 30), and a formulaic approach for calculating IGD releases in the fall/winter (October 1 – February 28/29).

Upper Klamath Lake

This operational approach seeks to fill UKL during the fall/winter to increase the volumes available for the EWA (including disease mitigation flows), UKL, and Project Supply during the spring/summer operational period. The PA also includes a "UKL control logic" that regulates certain releases (as described below) relative to UKL storage and recent hydrologic conditions in a manner that maintains UKL elevations important for suckers, and a "UKL Credit" that buffers UKL against uncertainties associated with NRCS forecast error and other factors affecting UKL inflow available for subsequent diversion.

The UKL control logic helps to manage UKL elevations for endangered suckers while ensuring adequate storage in UKL for both Klamath River and Project releases, utilizing a "central tendency." The central tendency is based on user-defined end-of-month UKL elevations which are subsequently interpolated to daily values (this is termed the generic or default central tendency). This results in a generic annual hydrograph that accounts for seasonal needs of suckers, seasonal water demand for the Klamath River and Project, and end-of-season elevations intended to result in (after winter inflows) storage volumes appropriate to meet the next year's demands on UKL. This generic hydrograph is then adjusted daily, based on a normalized 60-day trailing average of net inflow to UKL. If UKL elevations drop below the adjusted central tendency, then releases to the Klamath River (subject to IGD minimums described in Appendix 4, Section A.4.4.2, Table A.4.4.2.2) and winter deliveries to Area A2 are reduced until UKL elevations equal or exceed the adjusted central tendency line. The adjusted central tendency is not a target to which UKL should be managed, but rather a guideline that maintains UKL elevation in line with both hydrologic conditions and the multiple demands placed upon UKL storage throughout the year. Finally, note that the generic central tendency end-of-month UKL elevations were arrived at through the iterative modeling process and are not intended to change during operations under this PA. *See* Appendix 4, Section A.4.4.1.1 for technical details regarding the UKL control logic.

The purpose of the UKL Credit is to hold water in UKL to facilitate establishing a minimum Project Supply on April 1 with no later reduction, and the possibility of an increase in subsequent May 1 and June 1 allocations. Accrual of UKL Credit provides a volume of water in UKL that can be drawn upon in the case of an early season over-forecast of seasonal inflow to UKL. Any UKL Credit accrued in UKL above and beyond that necessary for full delivery of Project Supply will remain in UKL to facilitate refill of UKL in the ensuing fall/winter period. There is no carryover of accrued UKL Credit from season to season. UKL Credit can only be accrued from March 1 – September 30 during controlled flow conditions (i.e., not during flood control operations), and is accumulated when LRDC flows and KSD discharges in excess of direct diversions for irrigation are utilized to meet IGD flow targets, resulting in a reduction in LRD releases. In other words, when Project irrigators do not divert LRDC flow or KSD return flows and these unused volumes are utilized to offset LRD releases, a volume of water (the UKL Credit, equal to the reduction in LRD releases) is stored in UKL. As with current operations, Reclamation anticipates that PacifiCorp will adjust LRD releases as appropriate to meet IGD targets, accounting for these specific accretions to the Klamath River (i.e., if LRDC and KSD accretions increase, PacifiCorp would decrease LRD releases such that IGD targets are still met, but not exceeded). S*ee* Part 4.3.2.2.2. for additional details.

For several graphical examples of the anticipated UKL elevations, *see* Appendix 4, Section B. The model output graphs provided in Appendix 4, Section B provide examples of how the annual hydrographs might look. Real-time operations will not exactly replicate the modeled results and actual flow and elevation variability will differ during real-time operations.

Klamath River

Reclamation is proposing to distribute EWA from UKL based on the EWA allocation, UKL control logic, UKL net inflow, and NRCS-forecasted March – September net inflow (50 percent exceedance) from March 1 – September 30. From July 1 – September 30, Reclamation proposes to distribute EWA from UKL based on remaining EWA and UKL control logic. Reclamation also proposes to retain IGD as a compliance point for Klamath River flows (though *see* Part 3.7.1 for details about dam removal and associated implications for this BA). Finally, the PA incorporates into the EWA the augmented April, May, and June IGD minimums called out separately in the 2013 BiOp (*see* Appendix 4, A.4.4.6.1 for IGD minimums), and explicitly provides additional water to mitigate disease and habitat issues in years with below average hydrology (Part 4.3.2.2.2.4.).

As in the 2013 BiOp, IGD targets in the fall/winter and a portion of the spring/summer period are calculated using a hydrologic indicator of upper Klamath Basin conditions. Specifically, Reclamation proposes to utilize the net inflow to UKL to calculate IGD targets throughout the fall/winter period and for part of the spring/summer period (March 1 – June 30; note that from July 1 – September 30, EWA distribution is based on EWA allocation and UKL control logic as described above and in Part 4.3.2.2.2.3.). The intent of this method is to create a hydrograph downstream of IGD that approximates a natural flow regime reflective of actual hydrologic conditions and variability occurring in the upper Klamath Basin. Net UKL inflow was chosen over the previously-utilized Williamson River discharge because Williamson River flow is only reflective of hydrology in a portion of the UKL watershed, namely the ground-water dominated north-central portion. UKL net inflow is preferable given that it also accounts for hydrologic dynamics in the groundwater-dominated Wood River and snowmelt-runoff dominated tributaries originating in the Cascade Mountains. Additionally, UKL net inflow is calculated daily using a number of gages maintained by the USGS with consistent and reliable datasets over the POR. These gages are expected to remain in operation and the continued reliability of this hydrologic data is an important consideration to retain the ability to implement the PA in the future.

Utilizing UKL net inflow as the hydrologic proxy is expected to result in flows of a similar timing and shape observed under the 2013 BiOp, with the exception that there is also sufficient EWA volume to implement disease mitigation or coho habitat-supporting flows in the Klamath River (*see* Part 4.3.2.2.2.4. for additional details). IGD targets may also now be adjusted based on the UKL control logic (*see* Parts 4.3.2.2.1. and 4.3.2.2.2.3. for additional details).

For several graphical examples of the anticipated IGD hydrograph, *see* Appendix 4, Section B. The model output graphs provided in Appendix 4, Section B provide examples of how the annual hydrographs might look. Real-time operations will not exactly replicate the modeled results and actual flow and elevation variability will differ during real-time operations. The daily IGD target flows will be implemented three days after the hydrologic conditions are observed in the upper Klamath Basin. The actual transit time may be more or less than three days depending on the magnitude of the flow rate, elevation of UKL, and the hydrologic conditions downstream of UKL. No attempt was made to calculate transit time and the three-day delay is not intended to precisely replicate flow conditions in the Klamath River. Rather, the three-day lead time is needed for IGD flow schedule planning purposes to accommodate PacifiCorp's operation of the Klamath Hydroelectric Project.

In the event of gage failure, professional judgment will be used in combination with all relevant hydrologic data to estimate UKL elevation and inflow, IGD releases, and/or LRD to IGD accretions. USGS gage failures occur infrequently and every attempt will be made to coordinate with USGS to appropriately estimate flow and/or elevation values whenever a gage failure occurs.

Finally, PacifiCorp's operation of the Klamath Hydroelectric Project will influence the timing and magnitude of the hydrograph downstream of IGD due to water travel time through the reservoirs and due to facilities operations. Under normal operating conditions, these influences are expected to be minimal because PacifiCorp manages hydroelectric operations to meet IGD targets.

4.3.2.2.1. Fall/Winter Operations

The fall/winter operational period extends from November 1 – February 28/29 for the Project and from October 1 – February 28/29 for the Klamath River (i.e., EWA no longer applies after September 30). Note that there is often overlap between the spring/summer and fall/winter operations in October and November because Area A1 and the LKNWR will likely divert a portion of the spring/summer Project Supply during these months, while EWA accounting ends on October 1. Spring/summer and fall/winter diversion accounts must be kept separate during the overlap period.

The fall/winter Project operational procedure distributes the available fall/winter UKL inflows among the following:

1. UKL:
   a. Increase UKL elevation to meet sucker habitat needs (as outlined in Part 7) throughout the fall/winter period and the following spring/summer period, as well as increase storage for spring/summer EWA releases and irrigation deliveries.
   b. This is achieved through a fall/winter UKL refill rate and the UKL control logic.

2. Klamath River:
   a. Release sufficient flow from IGD to meet ESA-listed species needs in the Klamath River downstream of IGD; this includes flows to support coho spawning from October 1 – November 15.
   b. This is achieved through the formulaic approach to calculating IGD targets.

3. Project:
   a. KDD (Area A2 – served by North Canal and Ady Canal)
   b. Lease Lands in Area K (Area A2 – served by Ady Canal)
   c. LKNWR (Area A2 – served by Ady Canal)

Additionally, sufficient flood pool capacity must be maintained in UKL to balance refilling UKL to meet legal requirements with flood-related public safety issues.

To satisfy these objectives, Reclamation proposes to calculate IGD target flows by means of a series of context-based real-time equations using the net UKL inflow as a hydrologic indicator. Specific steps for calculating IGD target flows include:

1. Determine the LRD flow target, which is the maximum of either the minimum LRD flow target (look up table) or the LRD release target to support IGD target flows (calculated as follows)
    a. October 1 – November 15
        i. Refer to step 2a
    b. November 16 – February 28/29
        i. Determine yesterday's smoothed UKL net inflow
        ii. Subtract 1.5 times the average daily UKL fill rate necessary to attain a UKL elevation of 4,143 feet on February 28/29
    c. Adjust based on the difference in UKL storage between the UKL adjusted central tendency and UKL elevation
    d. Constrain by the maximum LRD release capacity, if applicable

2. Determine the IGD flow target, which is the maximum of either the minimum IGD flow requirement (look up table; Appendix 4, Section A.4.4.2, Table A.4.4.2.2) or the IGD flow target (calculated below)
    a. October 1 – November 15
        i. Determine the IGD target necessary for coho spawning flows
    b. November 16 – February 28/29
        i. To the LRD flow target calculated in step 1, add LRD to Keno Dam accretions from three days prior (i.e., this step relies on the accretion that occurred in a single day three days ago)
        ii. Add the value for today's Keno Dam to IGD accretions that was forecast three days ago (i.e., this step relies on the accretion forecast for the current day that was issued three days ago)
        iii. Add KSD discharge (assumes three-day lag)
        iv. Add the maximum of either LRDC flow towards the Klamath River minus diversion of LRDC water to North and Ady canals (assumes three-day lag), or zero

Note that it is operationally possible to reduce LRD flows below the flow 'minimums' referred to above (and further described in Appendix 4, Section A.4.4.2), but this requires Reclamation to conduct a fish stranding assessment below LRD (and possibly below Keno Dam). This requires additional personnel and other resources and Reclamation will weigh the benefit of flows below LRD minimums against the personnel, resource and safety requirements necessary for completion of the stranding assessments. If a reduction below LRD "minimum" flows is desired, Reclamation retains discretion in weighing the benefits of such an action against the issues described above. Additionally, note that the LRD target flow is not adjusted to account for the fill trajectory in UKL until November 16. October 1 through November 15 is a period of transition in Klamath Basin hydrology (i.e., UKL elevation transitions from decreasing to increasing), is a biologically sensitive time downstream of IGD (e.g., Chinook spawning and egg incubation) and is subject to highly variable accretions between LRD and IGD. Therefore, no adjustments beyond those of the UKL control logic are made to enhance UKL refill during this period.

Relative to fall/winter irrigation needs, up to 28,910 and 11,000 AF of fall/winter water is made available to KDD and LKNWR, respectively, subject to the UKL control logic. Specifically, if UKL elevation is at or above the adjusted central tendency throughout the fall/winter period, the only modeled constraints to delivery would be the delivery cap (28,910 and 11,000 AF for KDD and LKNWR, respectively), conveyance capacity, and demand. However, if UKL elevation is below the adjusted central tendency, daily deliveries to KDD and LKNWR will be reduced incrementally by up to 80 percent. Fall/winter water available for delivery to KDD and LKNWR will be assessed every 5 days, when the ratio determining the delivery adjustment (termed the "storage difference ratio") is calculated. Similarly, LRD releases can be reduced by up to 80 percent (possibly resulting in up to an 80 percent decrease at IGD, though IGD releases cannot drop below the IGD minimum flow requirements specified in the 2013 BiOp) when UKL elevation is below the adjusted central tendency; the maximum reduction occurs when UKL elevations approach the lower bound of the central tendency "envelope" as described in Appendix 4, Section A.4.4.1.1. *See* Appendix 4, Section A.4.4.1.1 for additional details.

It is possible to deviate from the fall/winter formulaic approach to calculating IGD flow targets. For instance, real-time hydrologic conditions, such as high flow events or emergency situations, or USGS rating curve adjustments may warrant the need to deviate from this formulaic approach. In addition, there may be specific ecologic objectives that water resource managers may want to address that can only be achieved by deviating from the formulaic approach to calculating IGD targets. Any time a deviation from the formulaic approach occurs, either by necessity or to address a specific ecologic objective, or if it is determined that the formulaic approach results in conditions that are not consistent with the intent of the PA, the process detailed in Part 4.3.2.2.3. will be followed. However, the formulaic approach for calculating IGD targets considered in this PA was designed to meet the key ecologic objectives for UKL and the Klamath River (with the exception of disease mitigation and habitat flows described in Part 4.3.2.2.2.4). Therefore, Reclamation anticipates that implementation of the formulaic approach will address these ecologic objectives, and only infrequent deviations from this approach are expected to be necessary.

Finally, it is important to note that real-time hydrologic conditions will be closely monitored during the fall/winter to ensure that flood control elevations for UKL are not exceeded and adequate capacity remains in UKL to accommodate high runoff events, especially during rain on snow events. During high runoff events, deviations from the fall/winter management procedure may be required in order to protect public safety and the levees surrounding UKL. In addition, other unforeseen emergency and/or facility control issues could arise that would require deviations from the fall/winter management procedure. In such cases, Reclamation will return to the fall/winter management procedure as soon as the emergency or facility control issue is resolved, but Reclamation retains ultimate discretion regarding the timing of a return to the formulaic approach. *See* Part 4.3.2.2.4. for additional details regarding flood control for UKL.

4.3.2.2.2. Spring/Summer Operations

The previous section described the fall/winter operations which are the first half of each WY, while this section describes the second half of each WY, covering the irrigation season. The Project irrigation season is defined as March 1 – November 30 for Area A1 and March 1 – October 31 for Area A2.

The specific objectives during the spring/summer operational period include:

1. Provide irrigation deliveries to lands within the Project, including TLNWR and LKNWR, with a reasonable level of certainty; and

2. Maintain conditions in UKL and the Klamath River that meet legal requirements under section 7 of the ESA.

The irrigation season operations are controlled by defining the available UKL Supply, which is computed from end of February storage in UKL, observed (since March 1) and forecasted monthly UKL inflows (March-September) and an end of September storage target (*see* Part 4.3.2.2.2.1 for additional details). Division of this supply between the Klamath River (EWA) and Project (Project Supply; water available to the Project from UKL) is dependent on the size of UKL Supply. Any UKL inflow that is not delivered to the Project or released for Klamath River flows (EWA) will remain in UKL as storage. All water that leaves UKL through either LRD or the A Canal is accounted for against one of these two identified volumes; this includes flood control releases (but does not include spill of UKL credit, which is the first volume of water to spill during flood control operations). *See* Figure 4-4 for a schematic illustrating the division of UKL Supply.

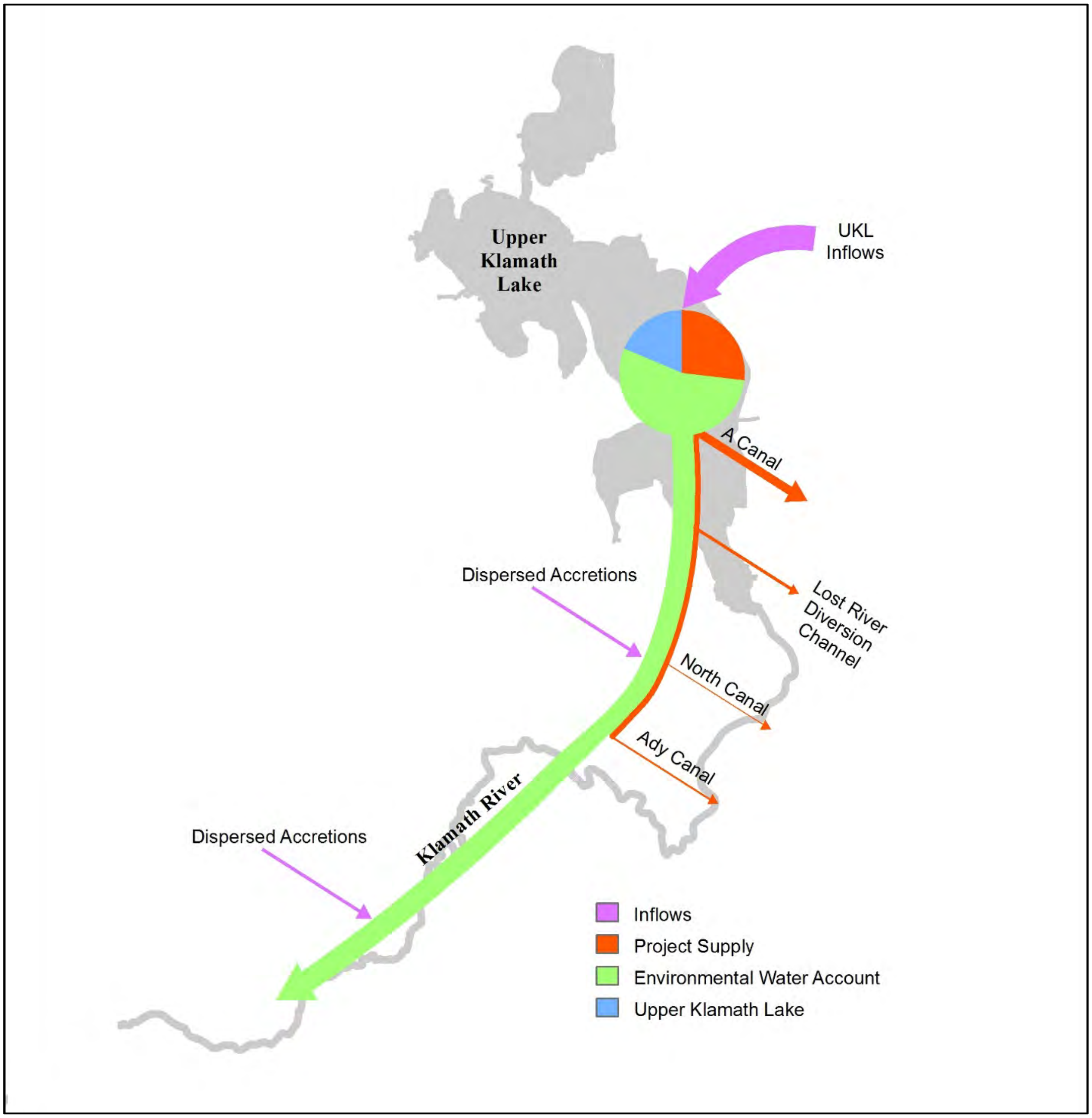


Figure 4-4. Schematic of spring/summer EWA, Project Supply, and volume remaining in UKL (i.e., the end of September storage target). The size of the pie chart and lines are proportional to average volumes of water modeled over the Period of Record. Project Supply includes both irrigation supply and a supply for Lower Klamath National Wildlife Refuge (LKNWR) deliveries; this figure does not include LKNWR deliveries associated with transferred water rights.
Source: Reclamation 2018.

Throughout the spring/summer operational period, Reclamation will track EWA, Project deliveries, remaining Project Supply, UKL elevation relative to the adjusted central tendency, LKNWR deliveries, and the anticipated remaining LKNWR deliveries every 5 days (corresponding to the 5-day time step for recalculation of the storage difference ratio; *see* below for details) and adjust releases as necessary to maintain operations consistent with this PA.

See Appendix 4, Section B for examples of how the annual hydrographs might look. Actual flow and elevation variability will differ during real-time operations as a result of hydrologic conditions specific to the current period of operation. Details regarding the accounting for EWA releases, as well as Project and LKNWR deliveries, are provided below.

4.3.2.2.2.1. UKL Supply

UKL Supply is calculated on the first of each month (or when Reclamation receives the NRCS UKL inflow forecast) from March – June. UKL Supply is calculated by adding the Mar50vol (50 percent exceedance volume) to the end of February UKL storage, and then subtracting the end of September UKL storage target. The specific steps for calculating UKL Supply and Mar50vol are detailed below.

First calculate the "Mar50vol," a combination of forecasted and observed March – September UKL inflow. For each month, Mar50vol is calculated as follows:

1. March 1
    a. Equal to the March 1 NRCS 50 percent exceedance March – September UKL inflow forecast

2. April 1
    a. April 1 NRCS 50 percent exceedance April – September UKL inflow forecast, plus
    b. Measured March net inflows

3. May 1
    a. May 1 NRCS 50 percent exceedance May – September UKL inflow forecast, plus
    b. Measured March net inflows, plus
    c. Measured April net inflows

4. June 1
    a. June 1 NRCS 50 percent exceedance June – September UKL inflow forecast, plus
    b. Measured March net inflows, plus
    c. Measured April net inflows, plus
    d. Measured May net inflows

Next, calculate the end of September UKL storage target. This target is dependent on the default end of September UKL central tendency elevation (4,139.1 feet), the end of September "envelope" around the UKL central tendency (+/- 0.4 feet), and the Mar50vol (*see* Appendix 4, Section A.4.4.3 for specific details). The purpose of the end of September UKL storage target in determining UKL Supply is to constrain the amount of UKL storage used in a given year. Such constraint is necessary to balance near-term demand for irrigation diversion or river flow with the uncertainties associated with future hydrologic conditions (e.g., the consequences of the upcoming winter being drier than normal). Note that the end of September UKL storage target is a mathematical term (and the name of this model variable is a legacy of the 2012 BA) and is not a management target. It is effective in "constraining" use of UKL storage since it is not mathematically allocated to EWA or Project Supply during the March 1 – June 1 spring/summer supply calculations.

4.3.2.2.2.2. Project Supply

As in the 2012 BA/ 2013 BiOp, Project Supply is calculated on the first of each month from March – June, after volumes have been set aside for coho (EWA, *see* Part 4.3.2.2.2.3.) and suckers (end of September target, *see* Section 4.3.2.2.2.1). To provide early-season certainty for Project irrigators, the calculated April 1 Project Supply is "locked in" such that Project Supply may go up as a result of increased NRCS UKL inflow forecasts on May 1 and June 1 but cannot drop below the April 1 calculation. In the event that the NRCS inflow forecasts are substantially lower in May and June, relative to the April forecast, UKL storage volume will be utilized to deliver the "locked-in" April 1 Project Supply. The UKL Credit as described above in Part 4.3.2.2. was specifically designed to help offset any negative effects to UKL storage and listed suckers (by increasing UKL elevation above what it otherwise would have been) potentially resulting from this scenario. Further, because UKL storage is utilized to offset NRCS forecast error, there is no direct effect on EWA calculations in a given WY (*see* below for additional details).

Maximum Project Supply is 350,000 AF, which occurs when UKL Supply is greater than 1,035,000 AF (which occurs in 30 percent of simulated years). When UKL Supply is less than 1,035,000 AF, Project Supply is equal to UKL Supply minus EWA (*see* below for additional details). The final determination for Project Supply is made in June and is then fixed through the end of September. It is important to note that *delivery* of the "fixed" Project Supply is not guaranteed; Reclamation retains discretion to curtail deliveries from UKL to comply with unforeseeable legal requirements and hydrologic conditions as necessary. Finally, the UKL control logic does not directly affect spring/summer Project deliveries, except delivery of Project Supply to LKNWR in the August – November period (which can be decreased by as much as 50 percent based on the UKL control logic).

Project Supply is only the supply of water to be made available to the Project and LKNWR from UKL and does not take into account diversions of discharge in the LRDC and return flows from the KSD. In other words, any water diverted from the LRDC or KSD for irrigation does not count against the Project Supply from UKL. Since only the water originating from UKL counts towards the Project Supply, Project diversions of LRDC discharge and KSD return flows will be evaluated on a daily basis and subtracted from the total Project diversion to compute the daily Project Supply usage. As discussed above, any portion of LRDC or KSD return flows not diverted by the Project (that directly support IGD targets and result in a reduction in LRD releases) accrue as UKL Credit that remains in UKL to buffer against NRCS inflow forecast error.

In order to realistically distribute Project Supply over the irrigation period in the KBPM, which is critical in evaluating the effects of Project operations on listed species at specific times of the spring/summer period, Reclamation developed an Agricultural Water Delivery sub-model. The Agricultural Water Delivery sub-model simulated delivery of irrigation water on a 5-day timestep based on variables such as meteorological conditions, soil moisture, water availability, and deliveries in the previous 5-day timestep, scaled to Project Supply. To ensure that the sub-model would adequately simulate Project deliveries under this PA, the sub-model was first tested against historical Project deliveries and performed relatively well. This sub-model is a substantial improvement over past representations of agricultural deliveries in the KBPM. *See* Appendix 4, Section A.4.4.4 for a detailed description of the sub-model, sub-model development, and statistical analysis of sub-model performance.

Finally, Reclamation proposes to deliver Project Supply to LKNWR (not inclusive of Area K [Project Lease Lands served by Ady Canal which are served out of Project Supply]) in the spring/summer operational period. Proposed spring/summer LKNWR deliveries are likely to include a combination of water available from Project Supply and stored water from UKL available in wet years, as further described below.

Reclamation, and USFWS, in coordination with Project irrigators and other stakeholders, are currently undertaking a process to identify the relative priority of lands within LKNWR to available Project water, and to develop a shortage sharing agreement (pursuant to a 2017 memorandum from the Deputy Secretary of the Interior) to address delivery shortages to LKNWR. As that process is still on-going, the outcome from this process is not included in Reclamation's PA. However, because any volume identified for delivery to LKNWR through that process will not increase Project Supply (which is already modeled as coming from UKL in the KBPM), Reclamation has concluded that the distribution of Project Supply will generally remain consistent with the simulated distribution pattern and magnitude will not alter the effects of Project operations on ESA-listed species described herein. In other words, if in the future a shortage sharing agreement is finalized and deliveries to LKNWR are part of Project Supply, the effects of that delivery to listed species should be no different than under the PA analyzed in this BA and therefore reinitiation of consultation should not be required under 50 CFR 402.16(a) or (c).

Until the process described above is complete, Reclamation proposes to coordinate with USFWS and other Project water users to determine when Project Supply during the spring/summer operational period can be made available to LKNWR consistent with Reclamation's and delivery agencies' contractual and other legal obligations. When Reclamation determines that there is Project Supply not needed to meet other Project demands, such water can be delivered to LKNWR, as the model assumes delivery of the full Project Supply allocation in all years. *See* Part 4.3.2.2.8. and Appendix 4, Section A.4.4.9 for additional details regarding LKNWR operations.

In addition to a portion of Project Supply, LKNWR may also receive spring/summer deliveries in June and July if Project Supply is 350,000 AF and UKL elevations are above 4,142.5 and 4,141.5 feet, respectively, on the first of each month; daily values to be exceeded are linearly interpolated thereafter. When these conditions were met in the modeled POR (11 of the 36 years), a maximum of 3,000 AF was made available to LKNWR from this source. Note that this water is not considered Project Supply.

4.3.2.2.2.3. Environmental Water Account

Similar to IGD flow targets in the fall/winter period, EWA (the volume of water used to meet IGD flow targets in spring/summer) distribution is based on a spring/summer formulaic approach for calculating IGD flow targets. The spring/summer formulaic approach is based on the EWA allocation, UKL control logic, UKL net inflow, and NRCS-forecasted March – September net inflow (50 percent exceedance) from March 1 – June 30. From March 1 – June 30 there is also a correction applied that accelerates EWA release if there was under-release in previous days (e.g., due to UKL control) and decelerates EWA release if there was an over-release in previous days (e.g., due to flood control or disease mitigation flows). From July 1 – September 30, EWA distribution is based on remaining EWA and UKL control logic. EWA releases for disease mitigation/habitat flows (as defined in Part 4.3.2.2.2.4. and Appendix 4, Section A.4.4.7), minimum required IGD flows (Appendix 4, Section A.4.4.7, Table A.4.4.6.1), and IGD ramping flows (Part 4.3.2.2.5.) are not subject to reduction under UKL control logic. Finally, LRDC discharge and KSD return flows are no longer considered accretions upon which EWA releases rely, which is a change from the 2013 BiOp. In the spring/summer, any return flows from these sources not used by the Project contribute to the UKL Credit during controlled flow conditions (and when LRD releases are above the minimum flow targets).

The specific steps for calculating IGD target flows in the spring/summer include:

1. Determine the LRD flow target as follows:
    a. March 1 – June 30
        i. Determine the release adjustment factor (termed “in_pct_Mar50vol”) that combines observed and forecasted net inflow, NRCS forecast error, and UKL Supply
        ii. Multiply by the calculated EWA allocation, minus the 130,000 AF EWA volume reserved for the July to September baseflow period (137,000 AF in Boat Dance years), minus the release correction that accounts for the difference between the previous day’s actual and calculated LRD releases (termed “Link_release_ss_diff”)
    b. July 1 – September 30
        i. Divide the volume of EWA remaining for the current month by the number of days in the current month
    c. Adjust based on the difference in UKL storage between the UKL adjusted central tendency and UKL elevation
    d. Constrain by the maximum LRD release capacity, if applicable

2. Determine the IGD flow target, which is the minimum of either the maximum IGD flow (look up table) or the IGD flow target (calculated below)
    a. To the LRD flow target calculated in step 1, add LRD to Keno Dam accretions from three days prior (i.e., this step relies on the accretion that occurred in a single day three days ago)
    b. Add today’s forecasted Keno Dam to IGD accretions from three days prior (i.e., this step relies on the accretion forecast for the current day that was issued three days ago)
    c. Increase to the minimum IGD flow requirement (Appendix 4, Section A.4.4.6, Table A.4.4.6.1), if applicable

The EWA volume is calculated on the first of each month from March – June as a portion of UKL Supply. Minimum EWA is 400,000 AF, which occurs when UKL Supply is less than 660,000 AF. When UKL Supply is greater than 1,035,000 AF, EWA is calculated as UKL Supply minus the maximum Project Supply (350,000 AF). When UKL Supply is between 660,000 AF and 1,035,000 AF, EWA is calculated as described in Appendix 4, Section A.4.4.3. Note that EWA is increased by 7,000 AF in even years to augment IGD releases for the Yurok Boat Dance ceremony, typically occurring in late August or early September. The EWA volume calculated from the June 1 UKL inflow forecast is the final EWA volume for the year. Finally, it is possible that the spring/summer formulaic approach to calculating IGD targets described above will result in an "overspend" (i.e., formulaic approach required more volume than was calculated for EWA, particularly if the Klamath River is at minimums) or an "underspend" (i.e., formulaic approach required less volume than was calculated for EWA) between March 1 - September 30. Regardless of the calculated EWA volume, IGD releases will reflect calculated IGD targets. If EWA is overspent, UKL storage will be utilized to continue meeting IGD targets through September 30. If EWA is underspent, the unused EWA volume remaining on September 30 will remain in UKL. There is no inter-annual carryover of EWA.

The EWA is accounted for through both releases for the Klamath River through LRD and releases during flood control operations. In other words, all LRD releases between March 1 and September 30 that are not diverted to the Project and/or LKNWR are counted as EWA. Conversely, all stored water and live flow that is released from UKL via LRD and re-diverted at the A Canal, LRDC, North Canal, and Ady Canal during the spring/summer period will count towards use of the Project Supply. Measurements for these diversions will be obtained at the point of diversion or measure location identified in the ACFFOD. For the measurement of these diversions below LRD, the UKL contribution will be the overall measurement less any flows from the LRDC and KSD. Any flow released from LRD during the spring/summer period (March 1 – September 30), that is not diverted into the LRDC, North Canal, or Ady Canal, is considered an EWA release and is counted towards the EWA. Furthermore, during IGD controlled flow conditions (e.g., minimum required flows, IGD targeted flows, ramping flows), contributions to IGD flow from LRDC discharge and KSD return flows are counted as EWA releases when they result in an equivalent reduction in LRD releases to support Klamath River flows (i.e., when UKL Credit is accrued). This does not happen when UKL is in flood control.

When releases are made for flood control, which occur any time UKL elevation exceeds the allowable flood control elevations (*see* Part 4.3.2.2.4.), they are counted as EWA and factored into future EWA releases. In some cases, the flood control releases can be so large that the remaining EWA volume would not be considered adequate to provide acceptable fish habitat for the remainder of the spring/summer period. In order to protect against this scenario, a measure was added to the PA to ensure that the remaining EWA is sufficient to accommodate minimum IGD flow requirements. This protection is considered and will be implemented whenever the total flood control releases have exceeded 22 percent of the total EWA from June 1 to the end of September. *See* Appendix 4, Section A.4.4.8 for specific details

As with fall/winter operations, close coordination and communication between Reclamation and PacifiCorp on the operation of the Klamath Hydroelectric Project will be required to efficiently implement any EWA flow schedule. PacifiCorp will implement releases downstream of IGD based on target flows provided by Reclamation. Reclamation will calculate those target flows according to the EWA distribution formula starting on March 1 of each year. Once implementation of the formulaic approach to EWA distribution is initiated, Reclamation will monitor IGD flows to ensure that the actual observed flows are consistent with the EWA flow schedule. *See* Part 4.3.2.2.6. for additional information regarding coordination with PacifiCorp.

As described above, EWA distribution will follow the spring/summer formulaic approach for calculating IGD target flows. However, in addition to the opportunity for disease mitigation/habitat flows using a total volume of around 50,000 AF when EWA is less than 575,000 AF (*see* Part 4.3.2.2.2.4.), it is possible to deviate from the spring/summer formulaic approach to EWA distribution. Specifically, real-time hydrologic conditions, such as high flow events or emergency situations, may warrant the need to deviate from this formulaic approach. In addition, there may be specific ecologic objectives that water resource managers may want to address that can only be achieved by deviating from the formulaic approach to EWA distribution. Any time a deviation from the formulaic approach occurs, either by necessity or to address a specific ecologic objective, or if it is determined that the formulaic approach results in conditions that are not consistent with the intent of the PA, the process detailed in Part 4.3.2.2.3. will be followed. However, the formulaic approach for EWA distribution considered in this PA was designed to meet the key ecologic objectives for UKL and the Klamath River. Therefore, Reclamation anticipates that implementation of the formulaic approach will address these ecologic objectives, and frequent deviations from this approach are not expected to be necessary, aside from those anticipated for disease mitigation/habitat flows (*see* Part 4.3.2.2.2.4.).

4.3.2.2.2.4. Disease Mitigation and Habitat Flows

Reclamation proposes to deliver the EWA based on the formulaic approach described above. However, the PA provides flexibility to deviate from the formulaic approach in the spring/summer operational period to deliver:

1. Approximately 50,000 AF of EWA in a manner that best meets coho needs (i.e., disease mitigation, habitat, etc.) in dry years (as defined below) or

2. An “opportunistic” surface flushing flow in average to wet years (as defined below) if hydrologic conditions allow.

As described below, Reclamation has modeled use of the approximately 50,000 AF of EWA in dry years as a surface flushing flow. Additionally, implementation of approximately 50,000 AF of EWA described above must not result in impacts to suckers in UKL outside of those analyzed in this document; if Reclamation believes implementation of this volume may result in impacts to suckers outside of those analyzed here, Reclamation will coordinate with USFWS.

Dry Years (March/April 1 EWA less than 575,000 AF)

As part of the PA, approximately 50,000 AF of EWA was modeled as available to meet coho needs in the form of a “forced” surface flushing flow, as requested by the Services. Given agreement by the Tri-Agency Hydro Team to model this volume of water as a surface flushing flow, the below narrative reflects what was implemented in the KBPM. These assumptions do not limit NMFS’s ability to request implementation of this volume in a different manner or request that Reclamation utilize this volume only for a surface flushing flow. Reclamation has not attempted to develop implementation criteria for other potential uses of the approximately 50,000 AF. However, Reclamation is proposing that the criteria outlined below be utilized if a surface flushing flow is determined by NMFS to be the appropriate use of the approximate 50,000 AF.

Specific criteria for implementing a forced surface flushing flow include all the following:

1. Date is between March 1 and April 15;

2. EWA is less than 575,000 AF;

3. There is sufficient head behind LRD to produce 6,030 cfs for 72 hours at IGD; and

4. The previous day's UKL elevation is greater than 4,142.4 feet.

If a flushing flow has not been implemented by April 15, a flushing flow (maximum discharge possible, up to 6,030 cfs, release for 72 hours) is attempted regardless of UKL elevation, maximum LRD capacity, or IGD flow.

See Part 4.3.2.2.3. for information regarding the process to assist in determining the appropriate use of the approximately 50,000 AF of EWA in dry years.

Average/Wet Years (March/April 1 EWA greater than or equal to 575,000 AF)
Reclamation proposes implementation of an opportunistic surface flushing flow in average/wet years.

Specific criteria for implementing an opportunistic surface flushing flow include all of the following:

1. Date is between March 1 and April 15;

2. EWA is equal to or greater than 575,000 AF;

3. There is sufficient head behind LRD, and accretions between LRD and IGD, to produce 6,030 cfs for 72 hours at IGD;

4. The previous day's UKL elevation is greater than 4,142.4 feet; and

5. The previous day's IGD flow is greater than 3,999 cfs.

General Surface Flushing Flow Details
Surface flushing flows are subject to ramping rates outlined in Part 4.3.2.2.5. Flows that occur outside of the March 1 to April 15 window, but which otherwise met the KBPM criteria for a surface flushing flow, are not considered a surface flushing flow by the KBPM. All surface flushing flow releases are counted against the EWA.

The specific objective of the surface flushing flows is to disturb surface sediment along the river bottom and disrupt the life cycle of *Manayunkia speciosa* (a polychaete), which is a secondary host for the *Ceratonova shasta* parasite central to salmonid disease dynamics in the Klamath River. The surface flushing flow constitutes a release of at least 6,030 cfs from IGD for at least 72 consecutive hours. Surface flushing flows in the KBPM reflect those described as Disease Management Guidance #1 in the Disease Management Guidance document (Hillemeier et al., 2017).

See Appendix 4, Part A.4.4.7 for additional information regarding implementation of surface flushing flows in the KBPM.

Deep Flushing Flows
Finally, Reclamation has not explicitly modeled a deep-flushing flow, as defined in the Disease Management Guidance document (11,250 cfs for 24 hours; Hillemeier et al., 2017). However, Reclamation will attempt to implement such a flow when hydrologic conditions and public safety allow. Specifically, infrastructure limitations and public safety issues (particularly release capacity at LRD and flood concerns in the middle and lower Klamath Basins) are such that a suite of conditions must be present in order to implement this flow. These conditions include, but are not limited to, UKL storage to allow for sufficient LRD release capacity, UKL storage sufficient to protect sucker needs, substantial accretions, and Klamath River tributary discharge that does not result in flooding concerns down river. Typically, this suite of conditions occurs when UKL is at flood curve in the late winter or early spring and there is a rain-on-snow hydrologic event. Maximum LRD capacity at the maximum allowable UKL elevation under the current flood curve (4,143.3 feet) is approximately 8,600 cfs, meaning that additional accretions of up to approximately 2,650 cfs for 24 hours would be necessary to achieve 11,250 cfs from IGD at full UKL storage under this PA; as such, even larger accretions are necessary if UKL elevation is less than 4,143.3 feet. Implementation of a deep flushing flow will require coordination with PacifiCorp and numerous public safety entities.

4.3.2.2.3. Flow Account Scheduling Technical Advisory (FASTA) Team and the Flow Management Process

As discussed above, there may be opportunities to benefit coho through deviations from the formulaic approach to IGD targets in the fall/winter and EWA distribution in the spring/summer. Additionally, NMFS has recommended that Reclamation retain flexibility in shaping approximately 50,000 AF of EWA in years with March/April 1 EWA volumes less than 575,000 AF (*see* Part 4.3.2.2.2.4.). Reclamation, in coordination with the Services, will consider input from Klamath Basin technical experts relative to these actions and opportunities. Reclamation therefore proposes that the Flow Account Scheduling Technical Advisory (FASTA) Team be the venue in which these technical experts provide input on flow management options.

The primary purpose of the FASTA Team is to share information on hydrologic, meteorological, disease, and other conditions among Klamath Basin technical experts. However, an important secondary function will be to serve as a venue for input on flow management options, including input regarding the shaping of approximately 50,000 AF of EWA for disease mitigation or habitat improvement/protection in years with March/April 1 EWA volumes less than 575,000 AF (*see* Part 4.3.2.2.2.4.). Participants in the FASTA Team are technical specialists focused on meaningful participation, facilitating timely implementation of the flow input process (described below), and providing input to Reclamation and the Services. Operational or compliance decisions will not be made by the FASTA Team or during FASTA Team calls or meetings.

Reclamation retains decision-making authority relative to flow management and operations on and related to the Project, though Reclamation encourages input and feedback from the FASTA Team. Reclamation also retains discretion regarding FASTA Team participants. Finally, the FASTA Team was created under a previous BiOp with a slightly different purpose in mind; Reclamation is choosing to retain the previous name for consistency, but the name itself does not convey additional purpose beyond that described here.

Ultimately, Reclamation, acting under the authority of the Secretary of the Interior, makes flow management decisions affecting UKL and the Klamath River; the process outlined below does not relinquish this Secretarial responsibility. Additionally, Reclamation determines whether proposed flows are consistent with flood control, public safety, and operational constraints for UKL and the Klamath Project.

The specific process for providing flow management input via the FASTA Team is as follows:

1. A FASTA Team member provides input regarding flow management during a FASTA Team call, or via email or call directly to the Klamath River Manager.
    a. If the input is provided outside of a FASTA Team call, the Klamath River Manager may choose to schedule a call or otherwise discuss the input with other FASTA Team members prior to moving to step two.

2. The Klamath River Manager initiates internal Reclamation discussions to determine if the proposed flows are operationally feasible. Specifically, this will include evaluating whether:
    a. The proposed flows are feasible given Reclamation infrastructure and operations, public safety, flood control, and other operational constraints;
    b. Evaluating whether the proposed flows comply with applicable state and federal law; and
    c. Evaluating whether the proposed flows are consistent with the PA.
    d. If the proposed flows are determined by Reclamation to not be operationally feasible for the Klamath Project, no further action is necessary.

3. If Reclamation determines the proposed flows are operationally feasible, Reclamation will initiate conversations with PacifiCorp to determine if the proposed flows are operationally feasible for PacifiCorp's Klamath Hydroelectrical Project (additional information relative to coordination expectations is described in Part 4.3.2.2.6.)
    a. If the proposed flows are determined by Reclamation and/or PacifiCorp to not be operationally feasible, no further action is necessary.

4. If the proposed flows are operationally feasible for both Reclamation and PacifiCorp, Reclamation will initiate conversations with the Services to determine if the proposed flows provide additional ecological benefit to coho, while maintaining UKL elevations/conditions necessary for listed suckers.

   a. If the proposed flows are determined by Reclamation and/or Services to not provide additional ecological benefit, no further action is necessary.

5. If the Services determine that the proposed flows are likely to result in benefit to coho and would not adversely affect listed suckers, then Reclamation will take steps to implement the proposed flows. Reclamation will be responsible for implementing the proposed flows, coordinating with PacifiCorp, issuing public safety notices, and any other coordination required to implement in a timely manner.

Reclamation retains discretion to deviate from the steps outlined above when considering flow management input. Additionally, Reclamation will communicate with FASTA Team members the outcome of the steps above, when possible and appropriate.

Finally, the Klamath River Manager is the individual responsible for scheduling and holding FASTA Team calls (as needed, but typically weekly or every other week) and distributing relevant information (as needed, but typically weekly, typically in the form of a slide presentation). Weekly updates will typically include information such as EWA use, Project deliveries, remaining Project Supply, UKL elevation, LKNWR deliveries, projected IGD target flows, meteorological information, etc. Reclamation retains discretion regarding the content of the FASTA slides and any other information made available to the FASTA Team, and the timing and frequency of FASTA Team calls.

4.3.2.2.4. Flood Control Operations

Maximum UKL flood control elevations are utilized as a guideline in an attempt to provide adequate storage capacity in UKL to capture high runoff events, to avoid potential levee failure due to overfilling UKL, and to mitigate flood conditions that may develop in the Keno plain upstream of Keno Dam. The general process of flood control consists of spilling water from UKL when necessary to prevent elevations from increasing above flood pool elevations, which change throughout the year in response to inflow forecasts and experienced hydrology. Flood pool elevation is calculated each day to create a smooth UKL operation, allowing UKL to fill (i.e., approach 4143.3 ft) by the end of March in drier years and by the end of April in wetter years. The UKL flood control elevations are intended to be used as guidance, and professional judgment will be utilized in combination with hydrologic conditions, snowpack, forecasted precipitation, public safety, and other factors in the actual operation of UKL during flood control operations.

The flood control elevations are set at 4,141.4 feet in September and October and then increase from 4,141.4 to 4,141.8 feet from November 1 through December 31 (daily values are obtained through interpolation). In most years, there are no flood control releases during these months.

From January 1 through April 30, the UKL flood control elevations are determined based on the forecasted inflow and the day of the month. The NRCS UKL net inflow forecast is used to determine the end of month flood control elevation (Appendix 4, Section A.4.4.10, Table A.4.4.10.1) and the daily flood control elevation is linearly interpolated between the current end of month elevation and the previous month’s end of month flood control elevation.

Additionally, UKL flood control elevations vary between wet and dry year types. The distinction is based on the NRCS March through September 50 percent exceedance forecast for UKL net inflow issued in January, February, and March. The forecast issued in March is used for both March and April. If the forecast March through September net UKL inflow is greater than 710,000 AF, the year is considered wet; the WY is considered dry if the forecast net inflow is equal to or less than 710,000 AF. It is important to note that the flood control curve and flood control operations are consistent with what has been implemented under the 2013 BiOp. *See* Appendix 4, Section A.4.4.10 for details.

Reclamation retains sole discretion to determine when to initiate or cease flood control operations.

4.3.2.2.5. Flow Ramping

Ramping rates limit rapid fluctuations in streamflow downstream of dams. Reclamation proposes a ramping rate structure that varies by release rate at IGD. The ramp rates proposed below are as measured at the USGS gaging station located immediately downstream of IGD (USGS Station ID#: 11516530). IGD is owned and operated by PacifiCorp and the ramp down rates will be implemented by PacifiCorp as part of IGD operations. Reclamation will coordinate with PacifiCorp as appropriate on the implementation of the ramp down rates.

The target ramp down rates at IGD, when possible, are as follows:

- When IGD flows are greater than 4,600 cfs: decreases in flows of no more than 2,000 cfs per 24-hour period, and no more than 500 cfs per six-hour period.
- When IGD flows are greater than 3,600 cfs but equal to or less than 4,600 cfs: decreases in flows of 1,000 cfs or less per 24-hour period, and no more than 250 cfs per six-hour period.
- When IGD flows are greater than 3,000 cfs but equal to or less than 3,600 cfs: decreases in flows of 600 cfs or less per 24-hour period, and no more than 150 cfs per six-hour period.
- When IGD flows are above 1,750 cfs but equal to or less than 3,000 cfs: decreases in flows of 300 cfs or less per 24-hour period, and no more than 125 cfs per four-hour period. (Note that ramp rates can be slower, such as 75 cfs per six-hour period, if Reclamation and PacifiCorp agree on a schedule).
- When IGD flows are 1,750 cfs or less: decreases in flows of 150 cfs or less per 24-hour period and no more than 50 cfs per two-hour period.

Upward ramping is not restricted. Additionally, NMFS concluded in their 2002 BiOp that ramp down rates below 3,000 cfs, as outlined above, adequately reduce the risk of stranding juvenile (and fry) coho salmon (p. 111, NMFS 2010a).

Facility control limitations and stream gage measurement error limit the ability to accurately manage changes in releases from IGD at a fine resolution. In addition, facility control emergencies may arise that warrant the exceedance of the proposed ramp down rates. Therefore, Reclamation recognizes that minor variations in ramp rates (within 10 percent of targets) will occur for short durations and all ramping rates proposed above are targets and are not intended to be strict maximum ramp rates. Reclamation expects significant exceedance of the proposed ramp rates due to facility control limitations, stream gage error, and/or emergency situations will occur infrequently and will be corrected as soon as possible when they do occur.

Under some circumstances (based on presence and abundance of ESA-listed species, life cycle stage, hydrologic conditions in the Klamath River and tributaries, and other considerations) the proposed ramp rates may be more stringent than necessary to prevent the stranding of ESA-listed species downstream of IGD. Reclamation, in coordination with NMFS, may explore more flexible ramping rates to determine under what conditions those rates would be appropriate to implement.

IGD is a PacifiCorp facility and Reclamation does not have control over the implementation of ramp down rates and operations at IGD. However, Reclamation will coordinate with PacifiCorp as appropriate to ensure that implementation of the ramp down rates is consistent with those proposed herein and required by PacifiCorp's Interim Operation Habitat Conservation Plan for Coho Salmon (HCP) (PacifiCorp 2012).

4.3.2.2.6. Coordination with PacifiCorp

PacifiCorp is required by its 2012 Biological Opinion (PacifiCorp 2012) to implement flow-related operations consistent with Reclamation's BiOp requirements. This, combined with the fact that Reclamation's PA includes IGD as a compliance point, means close coordination between Reclamation and PacifiCorp is necessary for implementation of the PA and corresponding BiOps.

All IGD target flows will be determined and coordinated with PacifiCorp three days in advance. Reclamation will also provide an IGD target forecast for an additional 11 days using projections based on NRCS UKL inflow forecasts (if available), California Nevada River Forecast Center hydrologic forecasts (namely, for accretions and some UKL tributaries), meteorological forecasts, measured flows, historical patterns, and professional judgement. If these information sources do not adequately predict flows for ongoing operations, Reclamation may ask PacifiCorp to provide accretion estimates between Keno and Iron Gate as they have since the 2013 BiOp. This additional 11 days of forecasted IGD flow targets is intended to provide additional advanced planning opportunities for resource managers and PacifiCorp. However, provisional flow targets provided for these additional 11 days are estimates and the actual IGD target flows will be determined after the upper Klamath Basin hydrologic conditions and LRD to IGD accretions are actually observed.

PacifiCorp has successfully coordinated with Reclamation to implement the requirements associated with the 2013 BiOp for the last five years and Reclamation expects this close coordination to continue for the implementation of Project operations resulting from this consultation. In addition, emergencies may arise that necessitate PacifiCorp to deviate from the IGD release target. These emergencies may include, but are not limited to, flood control, and facility and regional electrical service emergencies. Reclamation will closely coordinate with PacifiCorp should the need to deviate from the IGD flow target be identified due to an emergency. Such emergencies occur infrequently and are not expected to significantly influence flows downstream of IGD.

On a weekly basis, Reclamation will assess how the actual observed IGD flows compare to the target flows and communicate any necessary adjustments of LRD releases to PacifiCorp. During periods of rapid hydrologic change and/or during an urgent in-season flow schedule adjustment, it may be necessary to coordinate with PacifiCorp more frequently. PacifiCorp will make every attempt to follow the flow schedule provided by Reclamation (and based on the EWA distribution/IGD formulaic approach described in Parts 4.3.2.2.1. and 4.3.2.2.2.3.) as closely as possible within the operational constraints of the Klamath Hydroelectric Project facilities and based upon their obligations under the existing HCP (PacifiCorp 2012), except when requested otherwise by Reclamation for events such as flushing flows. If Reclamation determines that actual mean daily flows deviate from the flow schedule above the percentages described in Part 3.6.1., Reclamation may need to coordinate with PacifiCorp, the FASTA Team, and Klamath Basin Area Office (KBAO) Area Manager to take corrective action, which may result in the need for a formal in-season deviation from the formulaic approach for IGD targets and EWA distribution. The relative effect of deviating from the flow schedule depends on many hydrologic, climatologic, and ecologic factors, and the same amount of deviation from the flow schedule does not warrant the same response in all situations. For example, a deviation of 100 cfs downstream of IGD when flows are in excess of 3,000 cfs doesn’t require the same consideration as a deviation of 100 cfs when IGD flows are at 900 cfs. Each instance will need to be considered on a case-by-case basis.

Relative to the process laid out in Part 4.3.2.2.3., Reclamation will provide PacifiCorp with adequate lead time when implementing deviations from the formulaic approach. Reclamation will make every attempt to provide two weeks advanced notice to PacifiCorp when requesting flow schedule adjustments. In some circumstances Reclamation may request PacifiCorp to respond in less than two weeks if the adjustment to the flow schedule is urgent due to the need to respond to real-time and/or emergency conditions that warrant rapid response (i.e., fish disease, fish die-off, poor water quality, unexpected hydrologic conditions, imminent flooding or other health and safety issues, etc.). Finally, this section is not inclusive of all possible Reclamation-PacifiCorp coordination needs and processes. Additional coordination details regarding specific management actions (i.e., ramping rates) are contained within sub-sections of Part 4.3.2.2.

4.3.2.2.7. Tule Lake Sump operations

The proposed minimum elevations for Tule Lake Sump 1A are described below. Tule Lake National Wildlife Refuge (TLNWR) deliveries are outlined in Part 4.3.2.2.8. Actual water availability and TID return flows will determine the amount of water available for TLNWR including federal lease lands. Reclamation proposes to maintain minimum elevations in Tule Lake Sump 1A (Table 4-2).

During excessively dry periods when the UKL Supply is inadequate to meet Project demands, it may not be possible to maintain Tule Lake Sump 1A elevations due to decreased runoff to Tule Lake Sump 1A. This condition would be outside of Reclamation’s control and the proposed minimum elevations would not apply. In the event that surface water supply is estimated to be unavailable or is insufficient to maintain biological minimum elevations of Tule Lake Sump 1A (e.g., greater than 95 percent exceedance inflow years such as 1992 and 1994), Reclamation proposes to coordinate with USFWS as early as is possible to determine if relocation of adult suckers from the sumps to more permanent bodies of water within the species range is prudent.

Table 4-2. Minimum Sump 1A Elevations (Reclamation Datum).

Time Period	Elevation (feet)
April 1 through September 30 (each year)	4,034.6
October 1 through March 31 (each year)	4,034.0

During dry winter conditions, Reclamation will initiate discussions with USFWS to determine the best course of action, including the likelihood of a sucker relocation effort from Tule Lake. If Reclamation and USFWS deem it necessary to relocate suckers from Tule Lake during these discussions, Reclamation, in coordination with the USFWS, will develop a proposal that Reclamation will employ to relocate suckers from the Tule Lake Sumps before seasonally stressful conditions develop. The proposal will describe methods for capture and transport of fish, release sites, fish handling techniques, and the appropriate level of effort expected to relocate suckers (*See* Appendix 4 for example).

4.3.2.2.8. Other Refuge Deliveries

Federally-owned lands within TLNWR and LKNWR receive and use Project water from multiple sources, in a variety of ways as described below.

For TLNWR, irrigated agricultural lands generally obtain water for irrigation and refuge use from return flows from irrigated lands within the Project. These return flows accumulate in the Tule Lake Sumps and are diverted via the R and Q canals or are pumped into the N Canal from drains serving private lands in TID.

Generally, irrigation return flows and tributary runoff are adequate to meet irrigation and refuge demands within TLNWR, limiting the need for direct deliveries from UKL and the Klamath River. When irrigation demands are high, Project Supply during the spring/summer period (i.e., water from UKL and the Klamath River) may be needed for irrigation use within TLNWR. All deliveries to TLNWR are coordinated between TID and USFWS, Reclamation, or the individual lessee of the lands, consistent with Reclamation's water supply contract with TID.

LKNWR deliveries proposed as part of this PA are discussed in Parts 4.3.2.2.1. and 4.3.2.2.2. above. In addition to the proposed fall/winter and spring/summer deliveries, Reclamation also anticipates that from April 1 – September 30 LKNWR *may* exercise a water right temporarily transferred from the Agency Lake and Barnes Ranch properties to irrigable lands in LKNWR (*see* Part 1.3.6 for further information on the current transfer order applicable to these water rights). In the State of Oregon, a valid water right, such as those appurtenant to the Agency Lake and Barnes Ranch properties, can be exercised at any time for the authorized beneficial purpose within the authorized period of use, to the extent is water physically available at the point or points of diversion and the water right is not otherwise subject to regulation based on a call by a senior water rights holder (*see* Part 1.3.2., for background information on the prior appropriation doctrine as applicable in the State of Oregon).

Collectively, the transferred water right from the Agency Lake and Barnes Ranch properties allows for diversions at the Ady Canal of up to approximately 31 cfs and 11,200 AF in total annually. This transferred water right has a priority date of September 13, 1920 and is potentially subject to water rights regulation in the Upper Klamath Basin based on calls by senior water rights holders, including potentially a call made on behalf of the water rights for the Project. In the event of call by the Project or other senior water rights holders, USFWS may not be able to exercise this transferred water right due to regulation by OWRD. For purposes of this PA, the KPBM assumes that diversions at the Ady Canal associated with this transferred water right will be approximately 11,000 AF.

Water diversions by the USFWS to the Ady Canal pursuant to the water right transferred from the Agency Lake and Barnes Ranch properties are not subject to UKL control logic, given that in approving this transfer, OWRD determined that this water would have historically been diverted and consumed upstream of UKL.

In addition to water from the Project, water associated with the transferred water right from the Agency Lake and Barnes Ranch properties, local tributary runoff (e.g., Sheepy Creek), and groundwater sources operated by the USFWS (all when available), LKNWR receives water from the Tule Lake Sumps via the Tule Lake Tunnel and Pumping Plant D, which are all Project facilities.

TID operates and maintains the Tule Lake Sumps, Pumping Plant D, and the Tule Lake Tunnel. Generally, Pumping Plant D is operated as necessary to maintain water surface elevations in the Tule Lake Sumps consistent with rules and regulations issued by Reclamation (primarily for flood control purposes), levels to meet USFWS migratory bird/wildlife needs, and ESA requirements (*see* Part 4.3.2.2.7).

Deliveries to LKNWR via Pumping Plant D have significantly decreased in recent years due to drought, regulatory limitations on Project diversions, and increases in power costs associated with pumping. These factors have resulted in decreased pumping from Tule Lake to LKNWR through Pumping Plant D. The historical average annual volume pumped dating back to 1941 is approximately 70,000 AF. Over the last ten years the annual average volume has been under 20,000 AF. Regardless, these pumping activities are not part of Reclamation’s PA and are not modeled in the KBPM, which focuses on UKL and the Klamath River.

4.3.2.2.9. Deliveries of Stored Water from Clear Lake and Gerber Reservoirs

Clear Lake and Gerber reservoirs are used to store seasonal runoff to meet irrigation needs of the Project and to prevent flooding in and around Tule Lake. Stored water from Clear Lake and Gerber reservoirs is generally used for irrigation purposes within LVID, Horsefly Irrigation District (HID), and for lands covered by individual contracts; however, Reclamation can and historically has at times released water from both reservoirs for use for irrigation purposes within KID and TID (*see* Part 1.3.3., regarding Reclamation’s water supply contracts with KID and TID).

Stored water released from Clear Lake Reservoir is generally diverted at Malone Diversion Dam into either the West Canal or East Malone Lateral. The East Malone Lateral serves approximately 1,800 acres on the east side of the Lost River. The West Canal serves approximately 6,750 acres within LVID. The West Canal also has a spill structure at its terminus, so that water can be discharged into the Lost River for re-diversion and use within HID. Stored water from Clear Lake Reservoir can also be released through the spillway gates on Malone Diversion Dam, for use within LVID, HID, KID, and TID.

Stored water released from Gerber Reservoir is generally diverted at Miller Creek Diversion Dam into the North Canal, for irrigation use within LVID. The North Canal serves approximately 9,550 acres within LVID.

In addition to irrigation deliveries, Reclamation makes flood control releases from Clear Lake and Gerber reservoirs, when conditions necessitate.

Reclamation proposes to operate the portion of the Project served by Clear Lake and Gerber reservoirs as described below.

4.3.2.2.9.1. Clear Lake Reservoir Operations

Under the PA, Clear Lake Reservoir will provide a range of water supplies consistent with historical operations necessary to meet demand throughout the period covered by this BA. Reclamation proposes to operate Clear Lake Reservoir to meet the full irrigation demand of the Project, while maintaining the end of September minimum elevation. Historical annual releases vary based on available water supply and demand, with an average release of approximately 35,000 AF, based on the POR for which adequate data is available (1986-2016). With 35,000 AF being the approximate average annual release from Clear Lake Reservoir, a volume greater than 35,000 AF will be released in approximately half of years. Historical releases from Clear Lake Reservoir have ranged from zero AF, when no irrigation water supply was available, to more than 115,000 AF when flood control operations occurred. Water supply for irrigation purposes is generally used from April 15 – September 30 of each year. The outlet at Clear Lake Dam is generally opened on April 15 and closed by October 1, although slight deviations have occurred in the 1986-2016 POR. The typical release rate during irrigation season is approximately 120 cfs, with a typical maximum irrigation release of approximately 170 cfs. Releases can be greater during flood control operations and when irrigation demand is high. Table 4-3 summarizes monthly releases from Clear Lake Reservoir by month for the April through October time period. Some releases have also historically occurred during the months of February and March, primarily for flood control, and are not included in the table below.

Table 4-3. Summary of monthly 1986-2016 Clear Lake Reservoir releases (thousand acre-feet).

	April	May	June	July	August	September	October
Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Median	0.22	5.22	6.10	7.68	7.34	5.56	0.00
Average	2.58	5.45	6.41	6.99	6.54	4.71	0.04
Maximum	31.27	29.20	16.32	15.73	18.68	27.44	0.42

Available water supply from Clear Lake Reservoir is estimated annually using a seasonal forecasting model (*see* Appendix 4, Section D). The model allows Reclamation to estimate available water supplies and provide insight on appropriate deliveries that will provide elevations greater than the end of September minimum reservoir elevation, while taking into account projected inflows, typical delivery patterns, seepage, and evaporation. Changes in releases during the irrigation season are largely dictated by irrigation demand throughout the spring/summer period. Table 4-4 lists the end of September minimum proposed elevation for Clear Lake Reservoir.

Table 4-4. Minimum Clear Lake Reservoir end of September elevation (Reclamation Datum).

Water Body	Elevation (feet)
Clear Lake Reservoir	4,520.6

4.3.2.2.9.2. Gerber Reservoir Operations

Under the PA, Gerber Reservoir will provide a range of water supplies consistent with historical operations that are necessary to meet demand throughout the period covered by this BA. Reclamation proposes to operate Gerber Reservoir to meet the full irrigation demand of the Project, while maintaining the end of September minimum elevation. Historical annual releases vary based on available water supply and demand, with an average of approximately 35,000 AF, based on the POR for which adequate data is available (1986 through 2016). With 35,000 AF being the approximate average annual release from Gerber Reservoir, a volume greater than 35,000 AF will be released in approximately half of years. Historical releases from Gerber Reservoir have ranged from approximately 1,000 AF, when little irrigation water supply was available, to almost 95,000 AF when flood control operations occurred. Water supply for irrigation purposes is generally used from April 15 to September 30 each year. The outlet of Gerber Dam is generally opened on April 15 and closed on October 1, although slight deviations have occurred in the 1986 through 2016 POR. The typical release rate during irrigation season is approximately 120 cfs with a typical maximum irrigation release of approximately 170 cfs. Releases can be greater during flood control operations and when irrigation demand is high. Table 4-5 summarizes monthly releases from Gerber Reservoir by month for the April through October time period. Some releases have also historically occurred during the months of November through March, primarily for flood control, and are not included in the table below.

Table 4-5. Summary of monthly 1986 through 2016 Gerber Reservoir releases (thousand acre-feet).

	April	May	June	July	August	September	October
Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Median	0.10	5.56	6.76	7.87	7.53	6.08	0.00
Average	1.46	4.88	6.44	7.22	6.58	5.39	0.07
Maximum	17.03	7.85	8.63	8.94	8.35	7.34	0.80

Historically, approximately two cfs is bypassed and released into Miller Creek during the winter months to prevent a valve in the dam from freezing and improve conditions for ESA-listed suckers that may be present in pools below the dam when irrigation deliveries are not occurring.

This bypass has typically occurred in late October or early November until the beginning of the following irrigation season, although it has occurred as early as July. Reclamation intends to continue the two cfs bypass from Gerber Reservoir as part of operations in this PA. In the event of a mid-irrigation season shut off (as occurred in 2015), or concerns about meeting minimum lake elevations, Reclamation will coordinate with the USFWS on whether or not opening the frost valves is warranted.

Available water supply from Gerber Reservoir is estimated annually with a seasonal forecasting model (*see* Appendix 4, Section D). The model allows Reclamation to estimate available water supplies and provide appropriate deliveries that will provide elevations greater than the established end of September minimum lake elevation while taking into account projected inflows, typical delivery patterns, seepage, and evaporation. Changes in releases during the irrigation season are largely dictated by irrigation demand throughout the spring/summer period. Table 4-6 lists the end of September minimum proposed elevation for Gerber Reservoir.

Table 4-6. Minimum Gerber Reservoir end of September elevation (Reclamation Datum).

Water Body	Elevation (feet)
Gerber Reservoir	4,798.1

4.3.2.2.10. Diversions of Live Flow from the Lost River

In addition to stored water from Clear Lake and Gerber reservoirs, live flow in the Lost River is used for irrigation within portions of HID, LVID, Poe Valley Improvement District (PVID), and for lands covered under individual contracts in the south end of Langell Valley. The live flow from the Lost River generally consists of natural accretions and tributary runoff, particularly discharges from the Bonanza Big Springs, as well as return flows from irrigation.

Whereas LVID primarily relies upon gravity diversions of stored water, HID, PVID, and other individual landowners are primarily dependent upon pumping water (live flow and stored) from the Lost River. To facilitate its pumping operations, HID operates Harpold Dam and a series of small dams in the Lost River near Bonanza to maintain upstream water levels. Similar private dams and other structures, including private pumps, exist in the Lost River downstream of Harpold Dam.

Downstream of Poe Valley and the Olene Gap, absent significant precipitation or other operational requirements (e.g., maintenance), all flow in the Lost River is diverted at the Lost River Diversion Dam into the LRDC, where the water can be exported to the Klamath River. The LRDC has a capacity of approximately 3,000 cfs. During the irrigation season, live flow from the Lost River diverted into the LRDC (in addition to any direct storage releases from Clear Lake or Gerber reservoirs) is re-diverted for irrigation purposes prior to reaching the Klamath River (at Station 48, the Miller Hill Pumping Plant, or the various private pumps that exist along the LRDC).

Generally, there is always some water from the Lost River flowing into the LRDC, although during the spring/summer irrigation season, water from this source is relatively small compared to the amount from UKL and the Klamath River simultaneously being diverted into the LRDC for delivery through the Miller Hill Pumping Plant, Station 48, and private pumps along the LRDC.

During high flow events, the entire capacity of the LRDC (approximately 3,000 cfs) is used for diverting water from the Lost River to the Klamath River for flood control purposes. Any water in the Lost River in excess of LRDC capacity must be released through Lost River Diversion Dam and at least temporarily stored in the Tule Lake Sumps. Through Pumping Plant D, the Tule Lake Tunnel, the P Canal, and finally the KSD, such water can be exported to the Klamath River, in order to limit flooding of lands in and around Tule Lake.

4.3.2.2.11. Water Rights Regulation in the Upper Klamath Basin

The KBPM does not separately account for additional inflows to UKL that occur due to enforcement of water rights by OWRD in the Upper Klamath Basin. *See* Part 1.3.2., regarding the ACFFOD, the doctrine of prior appropriation as applied in the State of Oregon, and water rights enforcement by OWRD. The KBPM treats all inflow the same for purposes of the PA, regardless of whether that inflow has been altered by upstream tributary water diversions (or the lack thereof).

Consistent with the laws of the State of Oregon, live flow that is physically available at the established point or points of diversion for a water right is subject to appropriation for beneficial use, subject to any restrictions that may exist on the exercise of that water right as a matter of state and/or Federal law. Accordingly, additional inflow to UKL resulting from water rights regulation in the Upper Klamath Basin is available for appropriation and beneficial use within the Project, just like any other live flow that may exist in UKL. However, as noted above, state and Federal law, including the ESA, may nevertheless limit the extent to which this water can be appropriated and applied to beneficial use. Accordingly, additional inflow to UKL due to water rights regulation in the Upper Klamath Basin is subject to the same operational regime as outlined in this PA, with respect to ESA requirements, as all other water in UKL.

There is one notable exception to this aspect of the PA, necessitated by Oregon law. As discussed in Part 1.3.2., Project water rights recognized in the ACFFOD are currently enforceable, absent a judicial stay. In accordance with the doctrine of prior appropriation, when the amount of live flow available for appropriation in UKL and the Klamath River is insufficient to meet the actual beneficial irrigation demands within the Project, a call may be made on the Project water rights determined in the ACFFOD. However, OWRD's administrative rules provide that an otherwise enforceable call may be disregarded if the water made available due to enforcement is not available for use or is not otherwise being used by the senior rights holder making the call. *See* Or. Admin. R. §690-250-020. Accordingly, as part of this PA, to the extent a call is made on Project water rights, the additional inflow to UKL resulting from the call will be delivered for irrigation purposes within the Project and in addition to the Project Supply identified above in section 4.3.2.2.2.2.

In the event of a Project call, for purposes of this PA and overall compliance with the ESA, Reclamation proposes the following process to quantify and deliver for irrigation purposes available UKL inflow resulting from a Project call:

1. Reclamation will quantify inflow to UKL as a result of a Project call. Reclamation retains discretion regarding the quantification method.

2. Reclamation will review with the Services the quantification method and UKL inflow rates and volumes resulting from a Project call.

3. Reclamation will make the final determination whether and to what extent the additional water resulting from a Project call can be delivered from UKL for irrigation use within the Project consistent with Reclamation's obligations under the ESA.

4. Reclamation will continue to monitor deliveries of Project Supply, including any deliveries as a result of a Project call for consistency with the PA and BiOp, including potentially adjusting UKL central tendency to account for these inflows.

The OWRD is responsible for regulating water rights in the State of Oregon. Reclamation has no role in this process except to the extent of making a call on Project water rights when the amount of water physically available at the designated points of diversion for the Project is inadequate to meet beneficial irrigation demands within the Project. The above described process explains how and to what extent Reclamation will determine and make additional water available to the Project due to water rights regulation, consistent with ESA.

4.3.3. Element Three

Perform the O&M activities necessary to maintain Project facilities.

This section outlines the O&M activities that are performed on Reclamation's various features within the Project. These activities have been on-going throughout the history of the Project and have been implicitly included in previous consultations with the USFWS on Project operations (*See* Part 2, Consultation History). No new maintenance activities are being proposed, rather these are only included in detail in this consultation to provide a more complete, explicit description of Project maintenance activities so that the potential effects of these actions on listed species can be more specifically analyzed. Reclamation has attempted to include all maintenance activities necessary to maintain Project facilities and to continue proper long-term functioning and operation. Reclamation also recognizes that this is not an exhaustive list and that there may be items that were inadvertently omitted. However, Reclamation believes that any omitted activities are similar in scope and are not outside the effects analyzed for the activities included in the following sections.

O&M activities are carried out either by Reclamation or through contract by the appropriate irrigation district according to whether the specific facility is a reserved or transferred work, respectively.

4.3.3.1. Dams and Reservoirs

4.3.3.1.1. Exercising of Dam Gates

The gates at Gerber, Clear Lake, Link River, and Lost River Diversion dams are exercised bi-annually, before and after each irrigation season to be sure they properly operate. The approximate dates the gates are exercised are March to April 15 and October 15 to November 30, and potentially in conjunction with any emergency or unscheduled repairs. The need for unscheduled repairs is identified through site visits. Once identified, the repair need is documented and scheduled. Exercising gates requires anywhere from 10 to 30 minutes depending on the facility. The gates at Gerber, Link River, and Lost River Diversion dams are opened, and water is discharged during the exercising process. Additional information that describes associated maintenance activities performed when exercising gates at specific facilities is included as follows:

1. LRD is operated by PacifiCorp who does not schedule when gate exercise occurs. The dam is operated continuously due to the flows required from UKL to the Klamath River. As such, the gates are considered exercised whenever full travel of the gates and a minimum flow of 250 cfs is achieved; PacifiCorp documents these occurrences. The stoplog gates at LRD are not exercised annually and are typically only removed under flood control operations and during infrequent stoplog replacement. A Review of O&M inspection should be performed every six years.

2. Clear Lake Dam gate exercise activities include exercising both the emergency gate and the operation gate. Depending on water conditions, some water may be allowed to discharge in order to allow for sediment flushing. Flushing requires a release of flows that must be near 200 cfs for approximately 30 minutes. This activity occurs once a year generally between March and April and is contingent on Clear Lake Reservoir surface water level elevations.

3. The frost valves at Gerber Dam are exercised annually in order to prevent freezing of dam components. Valves are opened in the fall, at the end of irrigation season, at a flow rate of approximately two cfs and closed in the spring once persistent freezing temperatures have ceased.

4.3.3.1.2. Stilling Well Maintenance

Gage maintenance is required at various project facilities to ensure accurate measurement of flows. Gage maintenance generally includes sediment removal from the stilling well, replacement of faulty equipment, modification and/or relocation of structural components, and/or full replacement of the structure, as necessary. Reclamation estimates that every 5 to 10 years, one structure is replaced. Stilling wells are cleaned once a year during the irrigation season which typically runs from April 1 through October 15.

4.3.3.1.3. Other Maintenance

To determine if repair and/or replacement of dam components is necessary, activities may include land-based observation and/or deployment of divers. Divers are deployed at Clear Lake Reservoir, Gerber Reservoir, Lost River Diversion Dam and LRD every six years prior to the Comprehensive Facilities Review for inspection of the underwater facilities. In addition, at Gerber Dam, the adjacent plunge pool is de-watered approximately every eight years for inspection of headgates, discharge works, and other components; fish salvage by Reclamation staff would be conducted for this effort. Through these inspections, if replacement is deemed necessary, Reclamation would evaluate the potential effects to federally-listed species and determine if additional ESA consultation would be required.

At LRD, the replacement of the remaining wood stop logs with concrete stop logs is proposed to occur over the next three to five years. This action may require in-water work as a floating caisson (i.e., a watertight chamber) would be placed in front of the stop log bay and then filled with water in order to submerge and seal the bay. Once sealed, the bay would be de-watered to allow for maintenance and stop log replacement. When work is completed, air would be pumped into the caisson so that it floats to the surface, and the caisson would be moved to another bay to begin work. Appropriate Reclamation staff would be on-site during the de-watering process to conduct fish salvage as needed.

At the LRDC, the removal and rebuild of the headgates is currently required. As no stop log bays exist at the channel headworks, which, if present, could isolate the gates for removal, fabrication of a bay will be necessary. This bay would be created by the installation of structural "C" channel beams in the channel walls and pier noses to allow for placement of a steel bulkhead. With a bulkhead in place, water flow can be controlled and allow for the removal of the gates. No de-watering is necessary for this activity; however, some in-water work will be required.

Design Operation Criteria, which outlines O&M guidelines for facilities maintenance is required at LRD, Clear Lake Dam, Gerber Dam, and the LRDC gates. The Design Operation Criteria is used to develop Standard Operating Procedures for Reclamation facilities. The Standard Operating Procedures outline the maintenance procedures, requirements, and schedule. The activities address the structural, mechanical, and electrical concerns at each respective facility. Some of the components of facilities that require maintenance are typically reviewed outside of the irrigation season and include, but are not limited to, the following:

- Trash racks - Maintained when necessary and are not on a set schedule. Trash racks are cleaned and debris removed daily and is specific to each pump as individual pumps may or may not run year round. Cleaning can take anywhere from one to eight hours.
- Fish screens (Screens at Clear Lake Reservoir are cleaned as described below).
- Concrete repair occurs frequently and as needed (not on a set time schedule). The amount of time necessary to complete repairs to concrete depends on the size and type of patch needed.
- Gate removal and repair/replacement (performed when needed, no set time schedule.) Inspections of gates occur during the dive inspection prior to the Comprehensive Facilities Review every six years. Gates are continually visually monitored.

Boat ramps and associated access areas at all reservoirs must be maintained, as necessary, in order to perform all weather boating access to carry out activities associated with O&M of the Project. If the boat ramp is gravel, it should be maintained on a five-year cycle. If the structure is concrete, it should be maintained on a 10-year cycle. Maintenance can include grading, geotextile fabric placement, and gravel augmentation/concrete placement depending on boat launch type. Reclamation does not perform maintenance of boat ramps on a time schedule, but rather as needed.

4.3.3.2. Canals, Laterals, and Drains

All canals, laterals, and drains are either dewatered after irrigation season (from approximately October 15 through April 15) or have the water lowered for inspection and maintenance every six years as required as part of the Review of O&M or on a case by case basis. Inspection includes checking the abutments, examining concrete and foundations, examining mechanical facilities, pipes, and gates. The amount of time necessary for inspection is based on size and specific facility.

As with other typical facilities, the C Siphon, which replaced the C Flume in 2018, would be operated, maintained, and monitored in a similar manner. Along with the external inspection of the facility, maintenance staff would enter the siphon, when de-watered, to perform an inspection of the siphon's internal features. Additionally, inspections of the concrete piers that support the siphon above the LRDC would be conducted. As necessary, hardware would be replaced throughout the life of the facility.

Historically, dewatering of canals, laterals, and drains has included biological monitoring and (as needed) listed species salvage. This practice would continue under the current PA as described in Part 4.5.1.

The facilities are also cleaned to remove sediment and vegetation on a timeline ranging from annually to every 20 years. Inspections of all facilities take place on an annual basis. Inspections occur year-round or as concerns are raised by Project patrons; cleaning and maintenance takes place year-round on an as-needed basis. Cleaning the facilities may include removing sand bars in canals, silt from drains, or material filling the facilities. Animal burrows that may be impeding the facilities are dug up and compacted in order to repair them. Trees that are deemed to interrupt operations of facilities (and meet criteria outlined in the O&M guidelines) and/or pose a safety threat to the structural integrity of the facilities are removed and the ground returned to as close to previous conditions as practicable.

All gates, valves, and equipment associated with the facilities are to be exercised bi-annually before and after the irrigation season. Any pipes and structures located on dams or in reservoirs that are associated with irrigation facilities are replaced when needed and have an average lifespan of 30 years. Reclamation O&M staff replace approximately 10 sections of pipe per year and attempt to perform this maintenance activity when the canals are dry. Additional information that describes associated maintenance activities performed when exercising gates at specific facilities are included as follows:

1. A Canal headgates include six gates that need to be checked. The A Canal headgates are only operated and exercised when the fish screens are in place. If the breakaway screens were to fail, the A Canal would still be operating until the screen is put back into place. This allows for uninterrupted operation at A Canal in the event that a screen needs to be replaced to their previous position. Screens typically break once or twice a year (during normal operation), and KID is notified through alarm and the screens are repaired at the earliest time practicable.

2. The A Canal headgates are typically exercised in the spring (February through March timeframe) and fall (October through November timeframe). This activity occurs when the bulkheads are in place and the A Canal is drained and empty.

3. The LRDC diagonal gates and banks should be inspected every six years. Review of O&M inspections alternate every six years and take place anywhere from October 15 through March 31. This inspection would require drawdown of the LRDC (i.e., drawdown at least once every six years; however, as maintenance requires, LRDC drawdowns may be more frequent). The drawdown of the LRDC would leave enough water to ensure that fish were not stranded during this activity. The appropriate drawdown level is coordinated by Reclamation O&M and fisheries staff. Biological monitoring would be incorporated, and, if necessary, flows would be increased for fish protection.

4. The gates in the concrete structure in the railroad embankment immediately upstream of the Ady Canal are exercised annually. This activity includes closing and opening the gates and this activity typically occurs in the July to September timeframe. All debris is also removed once a year, generally some time during the June through September timeframe.

4.3.3.3. Fish Screen Maintenance

The A Canal fish screens have automatic screen cleaners. Cleaning is triggered by timing or head difference. When cleaned on a timer, the timing intervals are set at 12 hours, but intervals can be changed at (KID) operator's discretion for a period defined by hours or on a continuous basis.

Fish screens at Clear Lake Dam are cleaned periodically when 6 to12 inches of head differential between forebay one and forebay two is encountered. The need for cleaning the fish screen is dictated by water quality and lake elevation and varies from year to year. For instance, in some years, such as 2009, the screen was cleaned every other day beginning approximately the end of June/early July until it was shut off. Whereas in 2011, no cleaning took place during irrigation season. During irrigation season the head differential never exceeded 0.3 foot. There is an extra set of fish screens that the O&M crew uses during the cleaning process. The extra fish screen is lowered in place behind the first set of screens so that no fish will be allowed to pass. The primary screens are then lifted and cleaned and then placed behind the second pair of screens in the lineup. This process is continued until all screens are cleaned. This process can take up to 10 hours. Upon completion, the remaining set is stored away until the next cleaning which is anytime a head difference of 0.5 foot occurs. During flood releases (when Clear Lake elevations are 4,543.0 feet or above), fish screens would not be in place.

4.3.3.4. Fish Ladder Maintenance

LRD fish ladder gate exercise activities include exercising both the head gate and the attraction flow gate which includes closing and opening the gates and physical inspection of the ladder. This activity occurs twice annually and generally occurs in the February/March timeframe and again in the November/December timeframe. The amount of time necessary for the gates to be exercised is no longer than 15 minutes. This activity includes biological monitoring by Reclamation staff biologists.

4.3.3.5. Roads and Dikes

Road and dike maintenance, including gravel application, grading, and mowing, occurs as necessary from April through October. Pesticides and herbicides are also used on Reclamation managed lands, primarily canal rights-of-way to control noxious weeds. This activity typically occurs annually. The activity of pesticide spraying occurs generally from February through October (in compliance with the Pesticide Use Plan) and is applied according to the label. Vegetation control occurs on facilities where necessary throughout the year. Techniques used to control noxious weeds may include cultural, physical, and chemical methodologies for aquatic and terrestrial vegetation. The effects of these activities have been evaluated in previous section 7 consultations, and incidental take coverage was provided in the USFWS's BiOps 1-7-95-F-26 and 1-10-07-F-0056 dated February 9, 1995 and May 31, 2007, respectively. In both BiOps, the USFWS determined that the maintenance action of pesticide application would not jeopardize the continued existence of LRS and SNS. The products used for this maintenance activity are still being used to minimize take and are in compliance with current Integrated Pest Management Plans required by the Reclamation Manual's Directive and Standard ENV 01-01. At this time, there have been no changes to the action.

4.3.3.6. Pumping Facilities

All pumping plants are monitored yearly by visual evaluation. Dive inspections occur every six years according to the Review of O&M inspection criteria. This activity would include dewatering of the adjacent facility and installation of coffer dams. Dive inspections and dewatering of the facilities typically occurs in the August to December timeframe. Biological monitoring occurs daily during the dewatering of the facility and has historically been, and will continue to be, incorporated into maintenance activities to ensure the protection of fish as necessary. Aquatic weeds that collect on trash racks and around pump facilities are monitored continuously throughout the irrigation season and removed as needed. Weed removal typically occurs on a daily basis for those pumps that are operating continually through the season.

All pumps are greased, oil checked, cleaned, and exercised monthly if they are not in regular use. Pumps used for irrigation are maintained daily during the irrigation season. Drainage pumps would be maintained and operated on a daily basis, year-round. Pumps are greased and oiled according to the pump manufacturer's specifications. Excess grease and oil is removed and cleaned. When oil is being changed oil spill kits are kept on site and used as necessary.

Should a pump require repair, the pump chamber would be isolated from the water conveyance facility by placement of a gate, bulkhead, or coffer dam. The chamber would then be de-watered to allow for maintenance access. Appropriate staff would be on-site to perform fish salvage, as necessary, during the de-watering process.

4.4 Water Shortage Planning

Reclamation generally follows an established process for identifying and responding to the situation where available water supplies are inadequate to meet beneficial irrigation demands within the Project.

During the fall-winter period, Reclamation coordinates directly with KDD and the USFWS regarding Project water availability and demands (for both refuge and irrigation purposes). Reclamation does not make any public announcement of the volume of water available during the fall-winter period for delivery to the Project, including LKNWR.

Near the beginning of the spring-summer irrigation season, Reclamation issues an annual Operations Plan, which identifies the anticipated volume of water available from the various sources utilized by the Project, and the associated operating criteria applicable that year. The Operations Plan is posted on Reclamation's website, a press release is issued, and copies are sent by letter to Project water users and affected Tribes.

In the event of an anticipated shortage in the volume of water available for irrigation use from Clear Lake and Gerber reservoirs, Reclamation coordinates the allocation and delivery of limited supplies with LVID, HID, and others with a contractual right to receive stored water from these reservoirs.

In the event of an anticipated shortage in the volume of water available for irrigation use from UKL and the Klamath River, Reclamation will coordinate with irrigation districts and water users regarding anticipated irrigation demands within the Project. If the volume of water or the timing when it is available is less than the anticipated demands of these two districts, Reclamation may determine it necessary to issue an Annual Drought Plan (Drought Plan), which identifies and explains how water from UKL and the Klamath River is to be allocated among various entities with different contractual priorities to Project water (*see* Part 1.3.3., Reclamation Water Supply Contracts). The Drought Plan is posted on Reclamation's website, a press release is issued, and affected Project water users are provided a copy and notified by letter of the volume of water available under their respective contract.

The Drought Plan will identify an initial allocation for entities and individuals with a secondary priority to Project water from UKL and the Klamath River. Reclamation then updates the allocation (either increasing or decreasing the water available) as the irrigation season progresses and hydrologic conditions change, again notifying affected contractors by letter. Reclamation attends district board meetings, calls contractors by telephone, and answers direct inquiries related to the Drought Plan allocation.

In addition to possibly allocating the available water through the Drought Plan, there are other actions that Reclamation can take or directly facilitate, in response to a shortage in water available from the Project.

Consistent with Reclamation policy, Reclamation may administratively approve the transfer of water between districts and individual water users within the Project. Such transfers do not increase the amount of water available to the Project or expand the Project's service area but rather simply change the place of use within the Project. Prior to approval, Reclamation reviews each application on a case-by-case basis to make sure these basic conditions are met.

These internal transfers are generally used by irrigators to address a shortage in the water available under a given contract, based on the contractual priority it provides to Project water. Overall, these types of transfers promote the efficient and economical use of water.

Internal Project transfers are also available for irrigable lands within Lower Klamath and Tule Lake NWRs, subject to the approval of the USFWS. Water made available to a NWR through an internal transfer approved by Reclamation is separate from any water that may be available for delivery to the NWR consistent with the terms of this PA.

As has occurred in the past, Reclamation may also engage in irrigation demand reduction activities within the Project, on a year-by-year basis. There is no program currently in place for such activities, but such efforts have occurred periodically over the last two decades, subject to proper legal authority and the availability of federal appropriations. In the past, these activities have included agreements with individual landowners to forgo use of Project water or to produce supplemental groundwater.

4.5. Conservation Measures

The term "conservation measure" is defined as an action to benefit or promote the recovery of listed species that are included by the federal agency as an integral part of the PA. These actions will be taken by the federal agency or applicant, and serve to minimize or compensate for, project effects on the species under review. These may include actions taken prior to the initiation of consultation, or action which the federal agency or applicant have committed to complete in a BA or similar document. The conservation measures proposed assist Reclamation in best meeting the requirements under section 7 of ESA by (1) "…utilizing our authorities in furtherance of the purpose of this Act by carrying out programs for the conservation of endangered species…" and (2) avoiding actions that jeopardize the continued existence of listed species.

4.5.1. Canal Salvage

Fish salvage of Project canals occurs when canals are: (1) temporarily dewatered for a discrete action related to maintenance and/or repairs at Project facilities (described in Part 4.3.3), and (2) when canal systems are dewatered at the end of each irrigation season. Under both circumstances fish are salvaged from pools where they are stranded.

Reclamation proposes, in coordination with USFWS, to continue the salvage of suckers both for routine maintenance and repair at Project structures and at conclusion of the irrigation season when Project canals, laterals, and drains are dewatered consistent with past salvage efforts since 2005.

At conclusion of each irrigation season, Reclamation will coordinate fish salvage activities with irrigation districts, principally KID and TID. Future fish salvage of the canal system will include areas where suckers are annually encountered in reliable numbers since 2005, including the A Canal forebay, C4 Canal, D1 Canal, and D3 Canal within the KID and J Canal within the TID. Other locations within the Project canals will be periodically checked during dewatering and fish will be salvaged if deemed feasible and productive. Reclamation will also continue to pursue alternative methods of dewatering canals, laterals, and drains and which could result in less sucker presence within these facilities at the end of the irrigation season. Fish salvage will be coordinated with USFWS each year.

Reclamation will coordinate with USFWS on the disposition of endangered suckers resulting from salvage activities, including release to natural waters or retention for disease treatments, studies, and captive rearing.

4.5.2. Sucker Captive Rearing Program

Since 2000, Reclamation has supported various conservation measures within the upper Klamath Basin which have resulted in significant improvements to the Baseline (including fish screen installation at A Canal and Geary Canal, removal of Chiloquin Dam on the lower Sprague River, fish passage at LRD, increasing wetland and lake habitat at the Williamson River Delta, and annual salvage of suckers from canals). However, there are few, if any, practicable options for reducing incidental take which is an effect of the Project.

Reclamation proposes to continue support of a captive rearing effort by USFWS for LRS and SNS. The intention is to improve the numbers of suckers reaching maturity in UKL. Ultimately, the function of a captive rearing program would be to promote survival and recovery of the sucker populations that suffer losses from entrainment as a result of the Project or other threats. Captive propagation is already an important part of listed fish recovery efforts nation-wide, including at least three sucker species (i.e., June sucker, razorback sucker, and robust redhorse sucker).

The USFWS has already implemented initial efforts to rear LRS and SNS to a size that may increase individual survival. Sucker larvae collected from Williamson River were reared in tanks and holding ponds for approximately two years. Juvenile suckers salvaged from Project canals have also been held prior to release to UKL. Based on these efforts, captive rearing of LRS and SNS appears feasible and practicable. Reclamation envisions that future efforts by USFWS will expand on these initial efforts.

Specifically, Reclamation proposes support of a captive rearing program by providing funding in the amount of $300,000 annually. These funds will be used to cover costs associated with capture, rearing, release, and monitoring of released suckers in UKL. As requested by USFWS, Reclamation staff will provide personnel assistance with the rearing program when not in conflict with other necessary work. The USFWS will have oversight of the rearing program. Reclamation's support of the captive propagation program would be for the period of this consultation (April 1, 2019 to March 31, 2029) and adhere to regulations of an interagency agreement between USFWS and Reclamation. The program is envisioned as having a positive effect on the species that offsets impacts due to entrainment at LRD, A Canal, and other Project facilities. Monitoring will determine the actual effectiveness and the program's continuation will be coordinated between Reclamation and USFWS.

4.5.3. Sucker Monitoring and Recovery Program Participation

Since about 2000, Reclamation has funded monitoring of sucker populations in the lakes and reservoirs of the Upper Klamath Basin. Reclamation has also funded projects identified through USFWS' Sucker Recovery Implementation Team since 2013 and participated in the Recovery Implementation Team discussions and project identification. In coordination with USFWS, Reclamation proposes to continue efforts to monitor adult suckers in UKL, Clear Lake and Gerber Reservoirs, monitor juvenile suckers in UKL and Clear Lake, and fund sucker research, restoration and recovery actions throughout the Upper Klamath Basin. Contingent upon Reclamation's annual budget process and appropriations, Reclamation anticipates annual funds of approximately $1.5 million base funding annually with an additional $700,000 for the first two years (fiscal year 2019 and 2020) for UKL adult monitoring, Clear Lake adult monitoring, and juvenile cohort monitoring, research, and recovery projects. Funding in fiscal years beyond 2020 will be supplemented with $700,000 should appropriations materialize. Reclamation envisions that monitoring and research projects funded through the Recovery Program will answer questions about sucker recruitment in UKL and sucker population trends in both UKL and Clear Lake Reservoir. Reclamation also envisions that projects under a sucker Recovery Program will improve the amount and quality of sucker habitats, sucker passage issues, and sucker survival in the Upper Basin thereby offsetting PA impacts to habitat and entrainment of suckers at UKL, Gerber Reservoir, and Clear Lake Reservoir.

In coordination with USFWS, Reclamation proposes to continue participation in the Klamath Sucker Recovery Program.

4.5.4. Coho Restoration Grant Program

Reclamation will provide $500,000 annually with an additional $700,000 for the first two years (fiscal year 2019 and 2020) for program administration and projects that address limiting factors for SONCC coho salmon in the Klamath Basin contingent upon Reclamation's annual budget process and appropriations. Funding in fiscal years beyond 2020 will be supplemented with $700,000 should appropriations materialize. The program targets projects that have both the greatest impact on promoting survival and recovery and provide sustainable and lasting ecological benefits in the Klamath River Basin for coho salmon. Projects given the highest priority under this program include access improvement and barrier removal, improved habitat and access to coldwater refugia, instream habitat enhancement and protections, and water conservation. Restoration projects minimize habitat related effects of the Project by individually and comprehensively improving critical habitat conditions for coho individuals, populations, and overall.

5. SPECIES STATUS FOR LOST RIVER AND SHORTNOSE SUCKERS AND COHO SALMON

The following discussion on the Status of the Species contains a level of detail beyond what is generally required for a BA. However, select elements of the Status of the Species are discussed in this BA to provide a basis for the Effects Analysis contained in Parts 7 and 8. A more thorough discussion can be found in prior ESA consultation documents (e.g., *NMFS and USFWS joint 2013 BiOps on the Effects of Proposed Klamath Project Operations from May 31, 2013, through March 31, 2023, on Five Federally Listed Threatened and Endangered Species*).

5.1. Shortnose and Lost River Sucker

5.1.1. Description

SNS and LRS are endemic to the Upper Klamath Basin (Moyle 2002). As a member of the genus *Chasmistes*, SNS are closely related to cui-ui (*C. cujus*) of Nevada, the June sucker (*C. liorus*) of Utah, and the recently extinct Snake River sucker (*C. muriei*) of Wyoming (National Reseach Council [NRC] 2004). LRS are currently the only extant species of the genus *Deltistes*. Reclamation recognizes that hybridization is common among Basin suckers, specifically SNS with the Klamath largescale sucker (KLS; *Catostomus snyderi*), one of two non-listed, regional suckers (Dowling 2005, Tranah and May 2006, USFWS 2007a, 2007b). Klamath smallscale sucker (*Catostomus rimiculus*) also co-occur regionally but do not appear to be introgressed with either endangered species (Dowling 2005, Tranah and May 2006, USFWS 2007a, 2007b). The degree of hybridization makes field identification of suckers in the Basin problematic, particularly in certain bodies of water in the Lost River drainage, such as Clear Lake and Gerber reservoirs (Markle et al. 2005, Barry et al. 2007a, Leeseberg et al. 2007). For the purposes of life history and population descriptions at these locations throughout this document, Reclamation has attempted to compile information on only the two endangered sucker species. However, for bodies of water where identification of species has proven difficult, such as the Lost River drainage (including Clear Lake and Gerber reservoirs), this was not always possible, and Reclamation follows the USFWS approach in considering individuals in these populations to be endangered (USFWS 2008a). Thus, SNS identifications in the Lost River drainage are suspect and likely include an unknown number of misidentifications and hybrid suckers with morphological characteristics that are shared by SNS, LRS, and KLS.

5.1.2. Life History and Spawning

LRS and SNS are long-lived, lake-obligate fishes. Annual survival estimates for adults of both species are typically 90 percent, and on average LRS live 20 years while SNS live 12 years. However, there is substantial variation in life expectancy; the oldest aged specimens are 57 years for LRS and over 30 years for SNS (Scoppettone 1988, Buettner and Scoppettone 1990, Terwilliger et al. 2010.) Reproductive maturity is reached between four and nine years for LRS and between four and six years for SNS (Buettner and Scoppettone 1990, Perkins et al. 2000a). Fecundity of females is related to age and size, and other unidentified factors (Perkins et al.

2000a). LRS produce 44,000 to 236,000 eggs per female, whereas SNS produce 18,000 to 72,000 eggs per female (Perkins et al. 2000a).

In UKL there are two main spawning aggregations of LRS; those that spawn in the Williamson and Sprague Rivers (tributary-spawner) and those that spawn at springs emanating from the eastern shoreline of UKL. Presently, known spawning occurs along the shore of UKL at Sucker, Silver Building, Ouxy, and Cinder Flats springs (Figure 6-1; Shively et al. 2000a, Hayes and Shively 2001, Hayes et al. 2002, 2004, Barry et al. 2007b). Both populations of LRS show a high degree of site fidelity though a small amount of mixing does occur (Hewitt et al. 2018). SNS spawn only in the Williamson and Sprague Rivers (Hewitt et al. 2018). Annual spawning migrations for tributary-spawners in UKL are triggered by average daily temperatures; 50 degrees Fahrenheit (ºF; 10 degrees Celsius [ºC]) for LRS, and 54ºF (12ºC) for SNS (Hewitt et al. 2018). Suckers begin spawning immediately after migrating up the rivers and peak egg-drift typically occurs within days of peak adult migration (Hewitt et al. 2011, Ellsworth and Martin 2012). Up to seven males may attempt to spawn with a single female, though two males and one female is most common (Buettner and Scoppettone 1990). Both male and female suckers quiver as females broadcast their eggs and males fertilize the eggs. Spawning typically occurs in water ranging from 0.4 to 2.3 feet (0.12 to 0.70 m) deep (both tributary and shoreline springs populations) over mixed gravel (20 to 64 mm; 0.80 to 2.5 inches) or course cobble (2.5 to 10 inches; 65 to 256 mm). Spawning has been observed in flows ranging from 0.49 to 2.69 feet/sec (15 to 82 cm/sec) in the tributaries. Eggs settle in the interstitial space in the substrate and typically develop in 8 days to 3 weeks. The rate of development is dependent upon temperature but other factors such as light conditions have also been identified as factors that change the rate of development (Ellsworth and Martin 2012, Stone and Jacobs 2015).

Suckers in the Clear Lake (LRS and SNS) and Gerber reservoir (SNS) drainages spawn primarily, if not entirely, in the tributary streams (Koch and Contreras 1973, Buettner and Scoppettone 1991, Perkins and Scoppettone 1996, BLM 2000, Barry et al. 2007a, Leeseberg et al. 2007). Migration of Clear Lake suckers up Willow Creek is initiated when stream temperatures reach or exceed 6°C and when sufficient flows in Willow Creek are available (Hewitt and Hayes, 2013). Spawning has been entirely skipped some years when flows and lake elevations were not sufficient for suckers to access Willow Creek and opportunistic spawning has been observed during high discharge events (Hewitt and Hayes 2013, Burdick et al. 2018).

5.1.2.1. Larvae

Approximately one week after fertilization, eggs develop into larvae, and larvae emerge from gravels about 10 days after hatch (Coleman et al. 1988, Buettner and Scoppettone 1990). Emerging larvae are about a third of an inch long (7 to 9 mm) and are mostly transparent with a small yolk sac (Buettner and Scoppettone 1990). Larval suckers need to begin feeding before they exhaust their yolk, or they will starve (The Klamath Tribes 1996, Cooperman and Markle 2003). Larvae spend relatively little time in the tributaries, and they drift toward the lake shortly after emergence (Buettner and Scoppettone 1990, Perkins and Scoppettone 1996, Cooperman and Markle 2003, Murphy and Ellsworth et al. 2009). The majority of larvae from tributary populations egress from the river toward the lake during dark hours (Buettner and Scoppettone 1990, Cooperman and Markle 2003, Ellsworth and Martin 2013), then exit the river current during daylight hours and move to nearshore shallow habitat (Buettner and Scoppettone 1990, Cooperman and Markle 2003). Diurnal peak egress appears to vary among natal sites (Ellsworth and Martin, 2013). While the majority of larval sucker research has been conducted on tributary populations, it is suspected that larval suckers hatched at shoreline spawning areas also emerge from the gravels in greatest numbers at night.

Seasonal timing of drift varies among natal sites and occurs approximately four weeks after the peak in adult spawning (Hewitt et al. 2018, Ellsworth and Martin, 2013). Shoreline spawned larvae typically emerge in greatest numbers in April whereas the majority of larvae from tributaries emerge in May or June (Ellsworth et al. 2008, Ellsworth et al. 2011, Ellsworth and Martin 2013, Martin et al. 2013). Larval LRS spawned in tributaries typically egress in one large, rapid pulse whereas SNSs egress in three smaller pulses, of which, the second is the largest (Wood et al. 2014). Larvae enter UKL at a slower rate since restoration of the Williamson River Delta began in 2007 (Wood et al. 2014). In 2007 (Tulana) and 2008 (Goose Bay) levees built in 1940s were breached, and effectively changed the mouth of the Williamson River, and attempted to bring the Williamson River wetland back to some semblance of its historic, pre-manipulated condition (Wood et al. 2014).

Larval drift and distribution for all populations of suckers throughout UKL is a function of larval production timing, wind speed and directionality, discharge from the Williamson River, and lake elevation, though other factors also influence distribution (Wood et al. 2014). Generally, the prevailing water current in UKL moves clockwise from the Williamson River Delta, south along the east shoreline, west across the lake north of Buck Island, then north along the west side through the Trench, the deepest location of UKL (Wood et al. 2014). A smaller portion of the current is directed south of Buck Island out of UKL and into the Link River (Wood et al. 2014). Winds typically originate from the west from April to July and the predominant water current is clockwise, though wind directionality and speed varies diurnally, seasonally, and among years (Burdick and Brown 2010, Wood et al. 2014). When prevailing winds originate from the northwest (which is not typical), the east-shore current is more prominent, and larvae exit UKL in larger numbers (Wood et al. 2014). Generally, larval retention (for both tributary and springs populations) in UKL is less when river discharge is high, and higher when river discharge is low (Wood et al. 2014). Lake elevation does not appear to affect larval distribution or retention in UKL except when river discharge is low, and winds are counter-prevailing (from the east; Wood et al. 2014). Based on particle transport models that have been verified with extensive lake-wide larval sampling, the effect of lake elevation on larval distribution is unpredictable and not suspected to be an effective management tool for increasing larval retention (Wood et al. 2014). However, modeled distribution of larvae (based on hydrodynamics models of water currents, wind speed and direction, and lake elevation) failed to predict high densities of larvae captured in the northern part of the lake, suggesting that larval retention may be higher than predicted (Wood et al. 2014). Other factors that may influence larval retention and distribution are changes in lake elevation, the rate lake elevation changes, the initial distribution of larvae, or some other factor (Wood et al. 2014).

Once in UKL, peak larval sucker catches occur in late May or early June (Cooperman and Markle 2000, Simon et al. 1996, 2000, 2009, Burdick et al. 2009). Larval suckers are found throughout UKL however the highest concentrations of larvae are generally near the mouth of the Williamson River, and in emergent wetlands (Simon et al. 1995, 1996, 2009, Burdick et al.

2009, Burdick and Hewitt, 2012). Larval habitat in UKL appears to vary between species; SNS are captured more often along the shoreline and are associated with emergent aquatic vegetation whereas LRS are more common in open-water habitat (Figure 5-1; Burdick and Brown, 2009). Diets of sucker larvae generally consist of pelagic or surface food items including adult chironomids and indigestible pollen (Markle and Clauson 2006).

Larval sucker ecology and habitat use within the Lost River watershed, particularly Tule Lake, Lost River, and both Clear Lake and Gerber reservoirs, have not been directly studied. Given the lack of direct observations, larval sucker ecology in the Lost River watershed is assumed similar to the observations from UKL, except for the use of emergent vegetation in some lake environments as permanent emergent vegetation is generally scarce or absent along the shorelines of Clear Lake and Gerber reservoirs (Reclamation 2002).

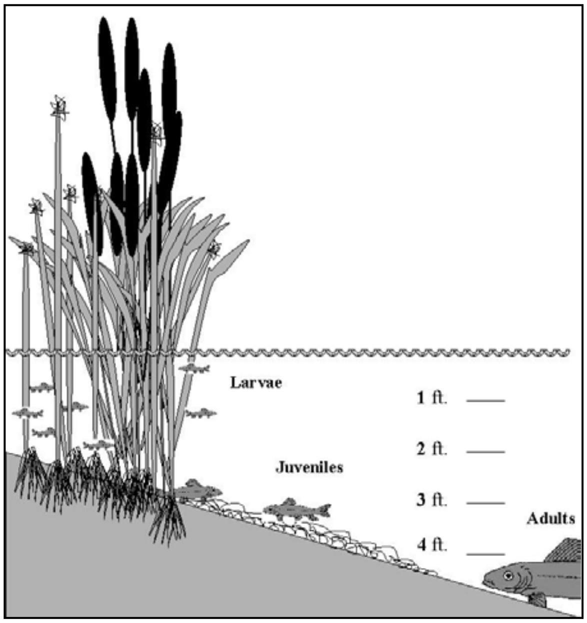


Figure 5-1. Generalized lake habitat utilization by sucker life history stages.
Source: USFWS 2008a.

5.1.2.2. Young-of-the-Year Juveniles

Larvae typically develop into young-of-the-year (YOY) juveniles by mid-summer. Transition from larvae to juvenile includes changes in physiology, diet, behavior, and ecology. Suckers are considered juveniles at about ¾- to 1-inch TL (20 to 30 mm; Markle and Clauson 2006). Very few studies aimed at identifying prey items for larval and juvenile suckers have been conducted, and those that have been conducted are relatively inconclusive. However, juvenile suckers appear to consume more benthic oriented prey items than larvae (predominantly pelagic or surface items), and this change in feeding ecology has been characterized as a developmental milestone (Markle and Clauson 2006). Identifiable prey items of juveniles (longer than 40 mm) include chironomid larvae and pupae, chydorids, ostracods, and harpacticoid copepods (Markle and Clauson 2006). Age-0 juveniles longer than 45mm are habitat generalists and use all available habitat types in UKL; they are found near-shore, off-shore, and in vegetated and open-water habitats (Buettner and Scoppettone 1990, Simon et al. 2000, 2009, Hendrixson et al. 2007a, 2007b Terwilliger et al. 2004, Burdick et al. 2009b, Burdick and Martin 2017).

Although adult LRS are about four times more abundant and are more fecund (females produce more eggs) than SNS, juvenile LRS are not proportionally more abundant. For example, in 2016 juvenile LRS only made up 51 percent of all suckers captured in 2016, 25 percent were SNS, 21 percent had genetic information from both species, and 3 percent were not identified to taxa (Burdick et al. 2018). Catches of age-0 suckers in UKL are typically highest in August when suckers are greater than 45 mm standard length (SL) (Burdick and Martin 2017). Catches generally decline throughout August, September, and October; and very few age-1 and almost no age-2 juvenile suckers are captured each year (Simon and Markle 2001, Terwilliger et al. 2004, Terwilliger 2006, Simon et al. 2009, Korson et al. 2011, Korson and Kyger 2012, Burdick and Martin 2017).

Some of the reduced abundance may be associated with advection from UKL including both emigration and entrainment (Markle et al. 2009). Directed movement patterns from north to south of age-0 juveniles were detected once in 2004 (Hendrixson et al 2007b) but this trend was not apparent in other years (2001 to 2003 and 2005 to 2009; Hendrixson et al. 2007a, 2007b, Bottcher and Burdick 2010, Burdick and Martin 2017). Advection of age-0 suckers from UKL into the Link River is greatest between July and October, generally peaking in August (Gutermuth et al. 1999, 2000a, 2000b, Foster and Bennetts 2006, Tyler 2007, Markle et al. 2009). Advection of suckers from UKL may be a passive act indicative of compromised health. Generally, juvenile suckers (and other fishes) captured from the pumped fish bypass at the A Canal fish screen and headgates (at the southern end of UKL where advection occurs), have higher parasite loads, more disease, and more afflictions than suckers captured elsewhere in UKL (S. Foott; personal communication, August 2018).

The cause(s) of advection of juvenile suckers is not currently understood. Plausible hypotheses include passive movement due to compromised health, natural emigration, avoidance of or impairment from poor water quality events, diminished habitat in the north end of UKL (which may concentrate suckers in the southern end of UKL near the outlet), entrainment, or some other factors (USFWS 2002, 2008a). While entrainment may account for some reductions in abundance; poor juvenile sucker survival (high mortality) appears to be the actual cause of reduced abundance of juvenile suckers (Burdick and Martin 2017). Poor juvenile sucker survival has resulted in essentially no substantial recruitment of juveniles into the adult spawning population since a relatively large cohort born in the early 1990s survived (Burdick and Martin 2017, Hewitt et al. 2018). The cause of widespread juvenile mortality is unknown, but it is likely that some combination of poor water quality, disease, parasites, loss of habitat, non-native species (fish and cyanobacteria), and predation interact to reduce annual survival of juveniles to near zero.

In contrast to UKL, the majority of adult and juvenile suckers in Clear Lake Reservoir are SNS, or introgressed SNS/KLS (Hewitt and Hayes 2013); for example, 80 percent of juveniles captured in 2016 were SNS or SNS/KLS, 17 percent were LRS, and 2 percent were introgressed LRS/SNS (Burdick et al. 2018). As discussed earlier, the differences between KLS and SNS are not visually apparent at this life stage and genetic tools to differentiate between SNS and KLS are not available. Little is known about juvenile sucker distribution and habitat use in Clear Lake Reservoir but when reservoir elevations are high and both lobes have water (the East Lobe may be dry or extremely shallow some years), juvenile suckers are found almost equally in both lobes. For example, in 2016, 56 percent of juvenile suckers were captured in the West Lobe. Interestingly, the majority (77 percent) of juvenile LRS captured in 2016 were in the shallower East Lobe (Burdick et al. 2018).

The abundance of age-0 suckers in Clear Lake Reservoir during any given year is associated, at least in part, with the ability of adult suckers to make a spawning run up Willow Creek (Hewitt and Hayes 2013). Adult suckers in Clear Lake Reservoir have skipped spawning during years when access to spawning tributaries is limited or made smaller runs (fewer individuals) when spring inflows and/or reservoir elevation limited access (Burdick et al. 2018). Recent years that produced larger year classes had lake elevations of at least 4,524 feet (1,378.9 m) during the February to May spawning run (Burdick 2018). Lake elevations or tributary inflows were too low from 2013 to 2015 for adult suckers to make large spawning runs in Willow Creek, thus very few juveniles were present in Clear Lake Reservoir until 2016 (Burdick et al. 2018). In 2016, juvenile suckers were found in both lobes, though sampling in the East Lobe in September was limited due to low lake elevations (Burdick et al. 2018).

5.1.2.3. Older Juveniles

Relatively little is known about habitat use, diet, and ecology of age-1 and older juvenile suckers. A few age-1 suckers are captured each year; they are typically captured in water at least equal to or greater than 3.28 feet (1 m), as this depth is effectively sampled by trap nets. As lake elevations in UKL decline throughout the summer, some areas (like wetlands near the Williamson River Delta) become inaccessible for sampling, which limits researchers' ability to fully assess changes in abundance relative to habitat type and depth in UKL (Burdick 2012a). Captures of juvenile suckers older than age-1 are extremely rare and trends are not discernable from sparse data. However, the real limitation in UKL is poor survival of age-0 and age-1 juveniles. Older juveniles are captured in Clear Lake; however, few extensive studies of juveniles in Clear Lake have been conducted. A consistent juvenile sucker monitoring program began in 2016 but followed several years of limited (2013) or no (2014 and 2015) adult sucker spawning in Willow Creek, an important tributary to Clear Lake for sucker spawning, due to inaccessibility of spawning grounds (Burdick et al. 2018).

Extensive habitat use studies similar to those in UKL have not been conducted in Clear Lake Reservoirs. Unlike UKL, the Clear Lake Reservoir ecosystem is more homogeneous, primarily varying by depth. There are no surrounding wetlands, and there is limited submergent or emergent vegetation. However, juvenile suckers are found throughout Clear Lake Reservoir.

5.1.2.4. Adults

Distribution of adult suckers in UKL varies seasonally. In winter and fall, adult suckers are distributed throughout UKL. In the spring, adult suckers congregate in the north-eastern portion of the lake, staging prior to making their spawning migration (Hewitt et al. 2018). After spawning occurs (described in previous section), suckers return to UKL. As summer progresses and water quality conditions decline, suckers congregate in the northern portion of UKL (Reiser et al. 2001, Banish et al. 2009). When water quality conditions become especially stressful, adult suckers seek refuge in or near Pelican Bay where springs provide cooler water and higher DO concentrations (Banish et al. 2007, 2009). Many suckers moved to the western side of UKL into the Eagle Ridge trench in mid-September (Banish et al. 2007, 2009).

After suckers return from spawning locations in UKL, suckers are found in various depths, but are most often associated with depths greater than 6.56 feet (2 m). Depths greater than 6.56 feet (2 m) are thought to provide adequate cover and protection from avian predators including American white pelicans (*Pelecanus erthrorhynchos*) and provide for adequate food resources (Banish et al. 2007, 2009). In the summer, SNS and LRS prefer depths greater than 6.56 feet (2 m) and 9.84 feet (3 m), respectively, but are not found in the deepest waters of UKL where water depths are greater than 16.4 feet (5 m) (Banish et al. 2007, 2009). When water quality conditions deteriorate, adult suckers may select depths less than 6.56 feet (2 m) near springs where conditions are better (Banish et al. 2007, 2009). Many suckers moved into the deepest part of UKL (up to 49 feet;15 m), the Eagle Ridge Trench, in mid-September (Banish et al. 2007, 2009).

In Tule Lake, where much of the lake is shallower than 3.28 feet (1 m), adult suckers are found primarily in the very limited areas where depths are greater than 3.28 feet (1 m; Hicks et al. 2000, Reclamation 2000).

Adult sucker distribution in Clear Lake Reservoir has not been specifically studied; however, inferences can be made from other fish sampling efforts there. Adult suckers in Clear Lake Reservoir are sampled each fall and are found throughout the West Lobe and in the East Lobe when lake elevations are high enough for safe boat access (B. Hayes, pers. comm., 10/19/2018). Adult suckers appear to exhibit schooling behavior as researchers typically capture many or few suckers in trammel nets (B. Hayes, pers. comm., 10/19/2018). Within the West Lobe, the majority of suckers have been captured in either the north or south, but large numbers of suckers have also been captured in central quadrants (B. Hayes, personal communication, 10/19/2018). Lake level and weather conditions may influence captures and distribution (B. Hayes, personal communication, 10/19/2018).

Relatively little is known about the diets of suckers, however, the terminal mouth morphology and triangle gill rakers of LRS indicates they may be primarily benthic feeders. The subterminal or terminal mouth orientation, and branched gill rakers of SNS may indicate a more pelagic diet that may include filter-feeding zooplankton from the water column (Miller and Smith 1981, Scoppettone and Vinyard 1991).

5.1.3. Distribution

Historically, LRS and SNS occurred throughout the Upper Klamath Basin in suitable aquatic habitats. The higher elevation, cooler temperature tributaries, which are dominated by resident trout, and the upper Williamson River (which is isolated by the Williamson River Canyon) were not inhabited by LRS and SNS (USFWS 2002). The historic range of LRS and SNS was extensively reduced by the loss of major populations in Tule Lake and Lower Klamath Lake, including Sheepy Lake (USFWS 1988). At the time of listing, LRS and SNS reportedly occurred in UKL and its tributaries, the Lost River, Clear Lake Reservoir, the Klamath River, and the three larger Klamath River reservoirs (Copco, Iron Gate, and J.C. Boyle). The current geographic ranges of LRS and SNS have not changed substantially since they were listed. Only two additional populations of SNS and one additional population of LRS have been recognized since 1988. Each additional population occurs in isolated sections of the Lost River drainage, within the historical ranges of the species, and include an isolated population of SNS in Gerber Reservoir and a small group (limited to several hundred adults) of both species in Tule Lake (USFWS 2002). Presently, the Klamath River reservoir populations receive individuals carried downstream from upper reaches of the river, but they are isolated from the Upper Klamath Basin by dams and show no evidence of self-sustaining reproduction (Desjardins and Markle 2000).

5.1.4. Legal Status

The LRS and SNS were federally listed as endangered throughout their entire range on July 18, 1988 (53 Federal Register (FR) 274130). Both species are also listed as endangered in California (1974) and Oregon (1991). In 2007, the status of each of these species was reviewed by the USFWS. It was recommended that no changes be made to the status of the SNS (USFWS 2007b). It was also recommended that LRS be downlisted to threatened (USFWS 2007a); however, recent data on population trends indicate continued decline so it is unlikely LRS will be downlisted.

A revised recovery plan for these species was published by the USFWS in 2012 (USFWS 2012) and included designation of two recovery units for each species: the UKL Recovery Unit which includes individuals in UKL, its tributaries, and any of the reservoirs along the Klamath River, and the Lost River Basin Unit which includes all individuals in lakes and flowing water in the Upper Klamath Basin.

5.1.5. Upper Klamath Lake Species Current Condition

UKL in Oregon supports the largest remaining populations of LRS and SNS in the Klamath Basin (NRC 2004). Adult LRS in UKL appear to consist of two distinct subpopulations, fish that spawn along the eastern shoreline at upwelling areas (hereafter, lakeshore spawners), and fish that spawn in the Williamson and Sprague Rivers (hereafter, tributary spawners; NRC 2004). Mark-recapture data has indicated that the two subpopulations maintain a high degree of fidelity to spawning areas and probably seldom interbreed (Hayes et al. 2002, Barry et al. 2007b, Janney et al. 2008, Hewitt et al. 2012). Tributary spawners make a springtime migration through the lower Williamson River, with most fish entering the lower Sprague River.

Chiloquin Dam, identified as a partial barrier to upstream passage that prevented a portion of the spawning run from migrating further upstream into the Sprague River (Scoppettone and Vinyard 1991, USFWS 1993, NRC 2004), was removed during summer 2008. Adult sucker migrations in the Sprague River have been unimpeded since spring of 2009, after Chiloquin Dam was removed in summer of 2008 (Ellsworth and Martin 2012). However, spawning above the former Chiloquin Dam site is limited. For example, in 2012, 25.5 percent of LRS detected at the weir were also detected at the Chiloquin Dam site however only 4 percent were detected at the Above Dam site 1.6 miles (2.5 kilometers) above the former Chiloquin Dam monitoring site; Hewitt et al. 2014). Of the SNS that were detected at the weir in 2012, 12.1 percent were detected at the Chiloquin Dam site and 6.2 percent were detected at the Above Dam site (Hewitt et al. 2014).

Known areas of concentrated LRS spawning in the Williamson and Sprague Rivers include the lower Sprague River (below the former site of Chiloquin Dam), areas of the lower Williamson

River from the confluence with the Sprague River to immediately downstream of the U.S. Highway 97 bridge, and in the Beatty Gap area of the upper Sprague River (Buettner and Scoppettone 1990, Tyler et al. 2007, Ellsworth et al. 2007).

Currently, SNS in UKL spawn in the lower Williamson and Sprague rivers (Buettner and Scoppettone 1990), principally below the site of former Chiloquin Dam (Tyler et al. 2007, Ellsworth et al. 2007). Few adult SNS are detected or captured at the shoreline spawning areas in UKL (Hayes et al. 2002, 2004, Barry et al. 2007b). While it is possible that spawning occurs near other springs or in other tributaries to UKL, extensive fisheries investigations have not identified other spawning aggregations (Reclamation 2007).

Adult LRS in UKL have relatively high survivorship; however, there has been little to no recruitment of juveniles into adult populations (Hewitt et al. 2018). Mark-recapture analyses of adult LRS from the lakeshore-spawning subpopulation in UKL indicate annual survival from 2000 to 2015 ranged from 88 to 96 percent for females, and 80 to 98 percent for males (Hewitt et al. 2011, 2012, 2018). LRS from the tributary-spawning subpopulation had annual survival ranging from 88 to 95 percent for females, and 70 to 96 percent for males during this same time period. Despite high survival for most years from 1999 to 2015, the abundance of LRS males in the lakeshore-spawning subpopulation declined approximately 64 percent and the abundance of females declined by approximately 56 percent (Hewitt et al. 2018). Preliminary data from USGS reports that lakeshore-spawning LRS have experienced additional declines of approximately 20 percent from 2016 to the spring of 2018. The abundance of tributary-spawning LRS is likely 32 percent of what it was in 1999 (Janney, E. and D. Hewitt, USGS, pers. comm., 16 August 2018). The estimated abundance of lakeshore spawning LRS in UKL is approximately 7,200 individuals (Janney, E. and D. Hewitt, USGS, pers. comm., 16 August 2018). Individuals in this population have exceeded the average life expectancy for the species.

Changes in abundance for LRS in the tributary spawning sub-population is less clear. Current population assessments suggest that minor recruitment events may have occurred for tributary-spawning LRS, but overall, the decline of both LRS spawning groups from 2000 to 2015 is probably greater than 40 or 50 percent (Hewitt et al. 2012). The declines primarily reflect a lack of recruitment of new individuals into the spawning populations, but reduced survival of LRS occurred some years (Hewitt et al. 2012). Preliminary data from USGS reports that tributary-spawning LRS have experienced additional declines of approximately 50 percent from 2016 to the spring of 2018. The abundance of tributary-spawning LRS is likely 30 percent of what it was in 2001 (Janney, E and D. Hewitt, USGS, pers. comm., 16 August 2018). The estimated abundance of tributary-spawning LRS in UKL is approximately 32,000 individuals (Janney, E and D. Hewitt, USGS, pers. comm., 16 August 2018). Individuals in this population have exceeded the average life expectancy for the species.

Annual survival for SNS in UKL has been lower than either population of LRS. Mark-recapture analyses of adult SNS indicate annual survival from 2000 to 2015 ranged from 68 to 95 percent for females, and 74 to 90 percent for males (Hewitt et al. 2011, 2012, 2018). Similar to tributary-spawning LRS, recruitment events of new individuals into the SNS spawning population is less clear. Recruitment events may have occurred in some years though substantial data supporting these events is not comprehensive. The SNS population has declined more than either subpopulation of LRS (Hewitt et al. 2018). Since 2001, the abundance of male SNS declined by 78 percent and the abundance of females declined 77 percent (Hewitt et al. 2018). Preliminary data from USGS reports that SNS have also experienced additional declines of approximately 40 percent from 2016 to the spring of 2018. The abundance of SNS is likely 20 percent of what it was in 2001 (Janney, E and D. Hewitt, USGS, pers. comm., 16 August 2018). The estimated abundance of SNS in UKL is approximately 7,900 individuals (Janney, E and D. Hewitt, USGS, pers. comm., 16 August 2018). Individuals in this population have exceeded average life expectancy and are near the maximum known age for the species (33 years).

Despite relatively high annual survivals from 2000 to 2015 both species have experienced substantial declines in abundance because losses from mortality have not been balanced by recruitment of new individuals (Hewitt et al. 2011, 2012, 2018). All adult sucker populations in UKL appear to be largely comprised of fish that were present in the late 1990s and early 2000s (Hewitt et al. 2011, 2018). Survival analyses show that the two species do not necessarily experience poor survival in the same years and that poor survival on an annual scale is not predictable from fish die-offs observed in the summer and fall (Hewitt et al. 2011). However, little to no recruitment has occurred into these sucker subpopulations in the last 20 years (Hewitt et al. 2011, 2012, 2018).

5.1.6. Clear Lake Reservoir Species Current Condition

LRS and SNS reside in Clear Lake Reservoir (Figure 5-2); however, all studies conducted in Clear Lake have described the morphological characteristics of SNS as introgressed with KLS (Tranah and May 2006, Hewitt and Hayes 2013, Smith et al. 2015, Dowling et al. 2016). Several studies aimed at identifying distinguishable genetic markers between these species throughout the Upper Klamath Basin have been unable to align genetic variation with observed differences in morphology and habitat use (Tranah and May 2006, Smith et al. 2015, Dowling et al. 2016). Thus, the population of SNS in Clear Lake Reservoir (and throughout the Lost River Basin) includes many suckers that are likely hybridized with KLS (Tranah and May 2006, Smith et al. 2015, Dowling et al. 2016).

Fish fauna studies were not conducted prior to the construction of Clear Lake dam but it is likely that suckers were present prior to construction in 1910 because there is no fish passage over the dam (Reclamation 2002). Sucker populations in Clear Lake Reservoir have periodically been sampled; first by Koch et al. (1975) and most recently by USGS (Leeseberg et al. 2007, Barry et al. 2007, Barry et al. 2009, Hewitt and Janney 2011, Hewitt and Hayes 2013). Population assessments have varied from abundant with diverse age classes to in-decline with few age classes (Andreasen 1975, Koch et al. 1975, Buettner and Scoppettone 1991, Reclamation 1994a, Scoppettone et al. 1995). Fish surveys and monitoring from 1989 through 1993 indicate populations of LRS and SNS had low to moderate captures but at least two adult cohorts (often more for SNS), and usually many juvenile suckers (Buettner and Scoppettone 1991, Reclamation 1994a, Scoppettone et al. 1995). USGS began using PIT-tags and remote-monitoring of sucker populations in Willow Creek in 2004 and The Straits in 2014. After several extensive sampling seasons, the population dynamics of suckers in Clear Lake are better understood, and survival and population estimates are more robust and precise (Barry et al. 2007, 2009, Hewitt and Hayes

2013, Hewitt et al. forthcoming). The SNS population is estimated to be at least 20,000 adults, and the LRS population to be at least 11,000 adults (Hewitt et al, forthcoming).

Assessments since 2009 suggest large cohorts have rarely though regularly (at least 1 to 2 times per decade) joined adult spawning populations (Hewitt et al. forthcoming). Unlike UKL, juveniles survive past 1 to 2 years in Clear Lake Reservoir (Barry et al. 2009, Hewitt and Hayes 2013, Burdick et al. 2018, Hewitt et al. forthcoming). In some years, cohorts are small but often disappear from the spawning population after a few years for unknown reasons (Hewitt and Hayes 2013, Burdick et al. 2018, Hewitt et al. forthcoming). Annual success or failure to recruit has often coincided for both LRS and SNS populations in Clear Lake Reservoir's, though LRS cohorts are substantially smaller than SNS cohorts.

Suckers in Clear Lake are only known to spawn in its tributaries; no shoreline spawning has been documented. Consistent monitoring of the adult spawning migration in lower Willow Creek began in 2004 (Hewitt et al. 2013). Willow Creek is Clear Lake Reservoir's primary tributary and sucker spawning is limited by spring-time reservoir elevation and spring flows in Willow Creek (Hewitt et al. 2013, Hewitt et al. forthcoming). When lake elevations are less than 4,524 feet spawning is impeded and suckers are unable to access Willow Creek (e.g., Spring 2014). Additionally, if inflows are too low, suckers do not make spawning migrations. Spawning migrations are triggered by high flows in Willow Creek and increasing temperatures. Clear Lake suckers spawn most years when Willow Creek inflows are at least 40 cfs (Hewitt et al., forthcoming). Both populations appear to make spawning migrations at low but increasing temperatures; 2 to 4°C (Hewitt et al., forthcoming). This contrasts with UKL where spawning migrations are triggered by temperatures of 10 and 12°C for LRS and SNS, respectively (Hewitt et al. 2011). For populations in Clear Lake, spawning can occur as early as the beginning of February or as late as early May, depending on the timing of hydrologic conditions described above (Hewitt and Hayes 2013, Hewitt et al., forthcoming). LRS (especially males) will migrate up Willow Creek at lower flows than SNS but at the expense of increased bird predation (Hewitt et al. forthcoming). Sucker populations have been noted in several small reservoirs on Willow Creek in the Clear Lake Reservoir's subbasin until consecutive drought years in the 1990s (USFWS 2002). However, in summer of 2018, USGS sampled many of these small reservoirs and other locations in the tributaries and found juvenile suckers in some locations despite dry conditions and a small spawning run for adult suckers (S. Burdick, pers. comm., October 16, 2018).

Compared to suckers in UKL, suckers in Clear Lake Reservoir have lower annual survival and are not as long-lived (Hewitt et al. forthcoming). Annual survival ranged from 60 to 89 percent for LRS and from 49 to 89 percent for SNS from 2006 to 2015 (Hewitt et al. forthcoming). Low survival of adult suckers is partially attributed to avian predation by American white pelicans and double-crested cormorants (Evans et al. 2016). The impact of bird predation was particularly apparent in years like 2009 and 2013 when large colonies of American white pelicans were nesting on islands in Clear Lake Reservoir (Evans et al. 2016). The amount of nesting habitat (islands on Clear Lake Reservoir) varies with lake elevation, though climatic conditions contribute to bird abundance and predation risk for suckers (Evans et al. 2016).

The amount of habitat available for suckers in Clear Lake Reservoir varies with lake elevation; and lake elevation can vary by over 20 feet among (but not within) years. Clear Lake Dam's spillway crest elevation is 4,543 feet but lake elevations are typically less than 4,529 feet (Ferrari 2009). Annual changes in elevation are 5 feet or less, though exceptions occur. Clear Lake Reservoir is comprised of two lobes, East and West. The West Lobe is deeper than the East Lobe (dry at 4,520 feet) but Willow Creek flows into the East Lobe via an excavated channel north toward the dam outlet before turning south to the East Lobe. The lobes are connected by a narrow and rocky section called The Strait. The Strait is shallower than either lobe and the lobes become hydrologically disconnected at elevations close to 4,521 feet (Sutton and Ferrari 2010).

When Clear Lake Reservoir elevations are low, adult suckers are limited in their ability or willingness to move between lobes and may be at increased risk of predation. When Clear Lake Reservoir elevations were low in 2015, avian predation was confirmed for 8 percent of radio-tagged suckers (2 LRS, 4 SNS); whereas avian predation was not confirmed as a source of mortality for radio-tagged suckers in 2016 or 2017 when lake elevations were higher (N. Banet, USGS KFFS, personal communication, October 21, 2018). Additionally, when lake elevations were low (e.g., fall 2015) all radio-tagged suckers in Clear Lake Reservoir were found to be in the west lobe (N. Banet, personal communication, October 21, 2018), possibly seeking refuge in deeper water. Suckers were detected on remote detection antennas located in The Strait when lake elevations were 4,522 to 4,523 feet (dam gage), and 4,521 feet (west lobe elevations), apparently staging to spawn in Willow Creek. It is unclear how far spawners are able to move when lake levels are low because antenna arrays at the strait in Clear Lake Reservoir have only been in place since 2014 (Hewitt et al. forthcoming). Some suckers appeared to stage to spawn by entering the Strait in 2014 and 2015 when lake elevations were low (Figures 6-5 and 6-6) but were largely unable to move to spawning grounds in Willow Creek (Hewitt et al. forthcoming). At lower lake elevations, suckers in the West Lobe must navigate through The Strait into the East Lobe, then swim through a channel toward the dam outlet before entering Willow Creek to access spawning grounds in Willow Creek (Figure 6-5 and Figure 6-6) (Figure 5-2). The channel between the dam and the East Lobe is hydrologically disconnected from the remainder of the lake at a surface elevation of about 4,522 feet (Sutton and Ferrari 2009). Suckers appear to be very limited in their ability to access Willow Creek unless lake elevations are 4,524 feet or greater (Hewitt and Hayes 2013, Hewitt et al. forthcoming), likely due to hydrologic constrictions at the Strait or the channel to the dam outlet. Evans et al (2016) concluded that avian predation may be a factor that is limiting the recovery of ESA-listed suckers in Clear Lake Reservoir. Predation of suckers by avian predators in Clear Lake varied among years, bird colony size, sucker species, sucker size, and sucker age-class (Evans et al. 2016). The amount of bird nesting habitat and loafing areas (islands) also varies with lake elevation (Moreno-Matiella and Anderson 2005) which may contribute to avian predation. The specific relationship among many variables including lake elevation, nesting habitat, nesting success, avain predation, and sucker survival, is not fully understood, though avian predation has been documented as a (proportionally) large source of annual mortality for juvenile and adult suckers in Clear Lake Reservoir (Evans et al. 2016).

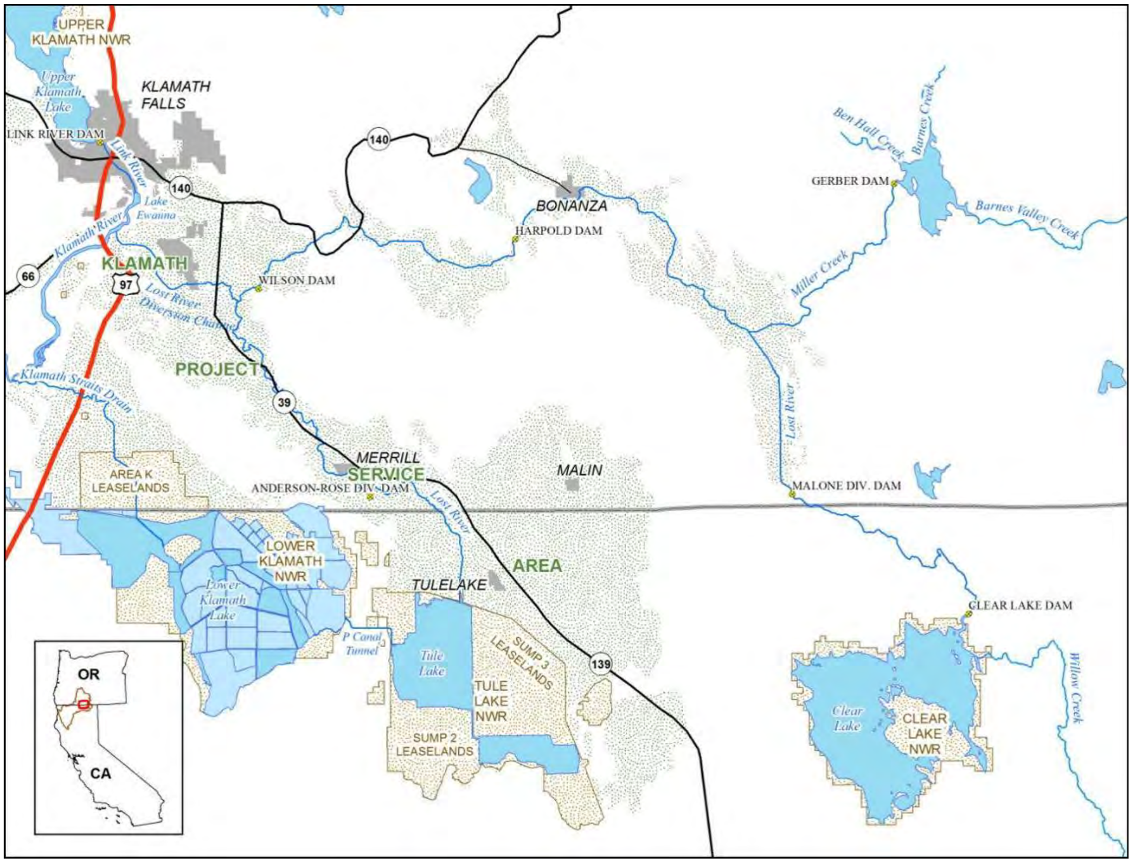


Figure 5-2. The Lost River drainage of northern California and southern Oregon and its connections to the Klamath River drainage. Project lands are shown as shaded. (Reclamation data)

5.1.7. Gerber Reservoir and Other Locations Species Current Condition

Data on other populations (i.e., Keno Impoundment, Klamath River Reservoirs, Tule Lake, Gerber Reservoir, and the Lost River proper) are extremely limited, but they suggest low numbers of individuals (Hodge and Buettner 2009, Desjardins and Markle 2000). Gerber Reservoir may be an exception to this.

Intermittent monitoring in Gerber Reservoir watershed since 1992 has documented a substantial SNS population with multiple size classes including many small individuals, which suggests regular recruitment occurs (Barry et al. 2007, Reclamation unpublished data 2018). SNS in Gerber Reservoir are similar to those in Clear Lake Reservoir in that the morphology of many individuals include characteristics associated with KLS (Markle et al. 2005, Barry et al. 2007). Despite the apparent hybridization, the USFWS considers the Gerber sucker population to be SNS until the status of these fish has been resolved (USFWS 2008a). SNSs in Gerber Reservoir have endured large fluctuations in habitat size (reservoir down to 4,796 feet in the early 90s and 4,797.9 feet in 2016) and geographical isolation from other sucker populations in the basin (Piaskowski and Buettner 2003, Reclamation unpublished data 2018). This has likely restricted genetic variation and population size in the region. LRS were not observed in Gerber Reservoir during early or recent fisheries investigations (Barry et al. 2007a, Leeseberg et al. 2007), and are likely not present in Gerber Reservoir.

Spawning at Gerber Reservoir occurs in its tributaries, predominantly in Barnes Valley Creek but also in Ben Hall (Barry et al. 2007), and possibly Barnes Creek. Shoreline spawning has not been observed at Gerber Reservoir (Leeseberg et al. 2007). Spawning surveys in 2006 detected approximately 1,700 SNSs of the nearly 2,400 that had been tagged the previous year (Barry et al. 2007a). Spawning migrations have not been regularly monitored by remote antennas. However, in 2006 suckers were present in tributaries from early March to mid-May (Barry et al. 2007). Some suckers in Gerber have demonstrated great mobility; moving among spawning tributaries at opposite ends of the reservoir within 24 hours (Barry et al. 2007). The most recent sampling effort in Gerber was conducted over 8 weeks in the spring of 2018 by Reclamation and over 1,200 individual suckers were captured (Reclamation unpublished data 2018). A few fish were re-captures, originally tagged in fall 2005 (Reclamation unpublished data 2018). Several cohorts were present, and individuals ranged in size from about 300 to 570 mm in fork length.

Current variability in population dynamics is largely unknown but given the relatively long-life expectancy of these species, populations are generally stable over the short-term. A long-life span and high fecundity enable these species to withstand unfavorable periods, and generally buffer against large fluctuations in abundance.

5.2. SONCC Coho Salmon Evolutionarily Significant Unit

SONCC coho salmon ESU were listed as threatened species by NMFS in 1997 (62 FR 24588; May 6, 1997). This ESU included populations spawning in coastal watersheds from Elk River, Oregon, to Mattole River, California (Figure 5-3). The threatened status was reaffirmed in 2005, including the addition of three hatchery stocks (70 FR 37160; June 28, 2005) and again in 2016 (NMFS 2016). The current boundary designations were recently confirmed by the genetic analysis of 18 polymorphic microsatellite DNA markers (Gilbert-Horvath et al. 2016). The four coho salmon populations in the upper portions of the drainage will experience the greatest magnitude and intensity of stressors, relative to the PA, on their viability based on their proximity to IGD. These four populations are the: Upper Klamath, Shasta, Scott, and the Middle Klamath River populations.

5.2.1. Description and Distribution

Adult coho salmon can measure more than 60cm in length and weigh up to 16 kilograms (kg), with an average weight of 3.6 kg. Coho salmon have dark, metallic-blue or green backs with silver sides and a light-colored abdomen. At maturity, they are often red along the side of the body. Within the marine environment, coho salmon display small black spots on their backs and the upper lobe of caudal fin. Coho salmon were historically distributed throughout the North Pacific Ocean from central California to Point Hope, Alaska, through the Aleutian Islands, and from the Anadyr River, Russia, south to Hokkaido, Japan. Given their wide distribution, it is likely that coho salmon historically inhabited most coastal streams in Washington, Oregon, and northern and central California.

5.2.2. Life History

Adult coho are anadromous and semelparous. However, the amount of time they spend rearing in the marine environment can vary (Quinn 2005), leading to different life history traits. Although these alternate life history traits that are important at the population level (Roni et al. 2012), a three-year life cycle is the most common. This life cycle is generally characterized by the first 14 to 18 months spent in freshwater, ocean residence for at least a full year, and a return to freshwater to spawn (Sandercock 1991, Quinn 2005).

5.2.2.1. Adult

In this document, adult life history will be classified into three stages: marine rearing, freshwater migration, and spawning.

5.2.2.1.1. Marine Rearing

Coho generally spend between 16 and 20 months rearing in the marine environment, though some early-maturing males may only rear for one year. Upon entering the ocean they feed on plankton in the nearshore environment, and as they grow, they move farther out, switching to a diet of larger prey such as herring and squid (Groot et al. 1995). Marine survival is influenced by a number of interacting factors including prey abundance, predator density, degree of intra-specific competition (including hatchery fish), and sport and commercial fisheries (NRC 1996).

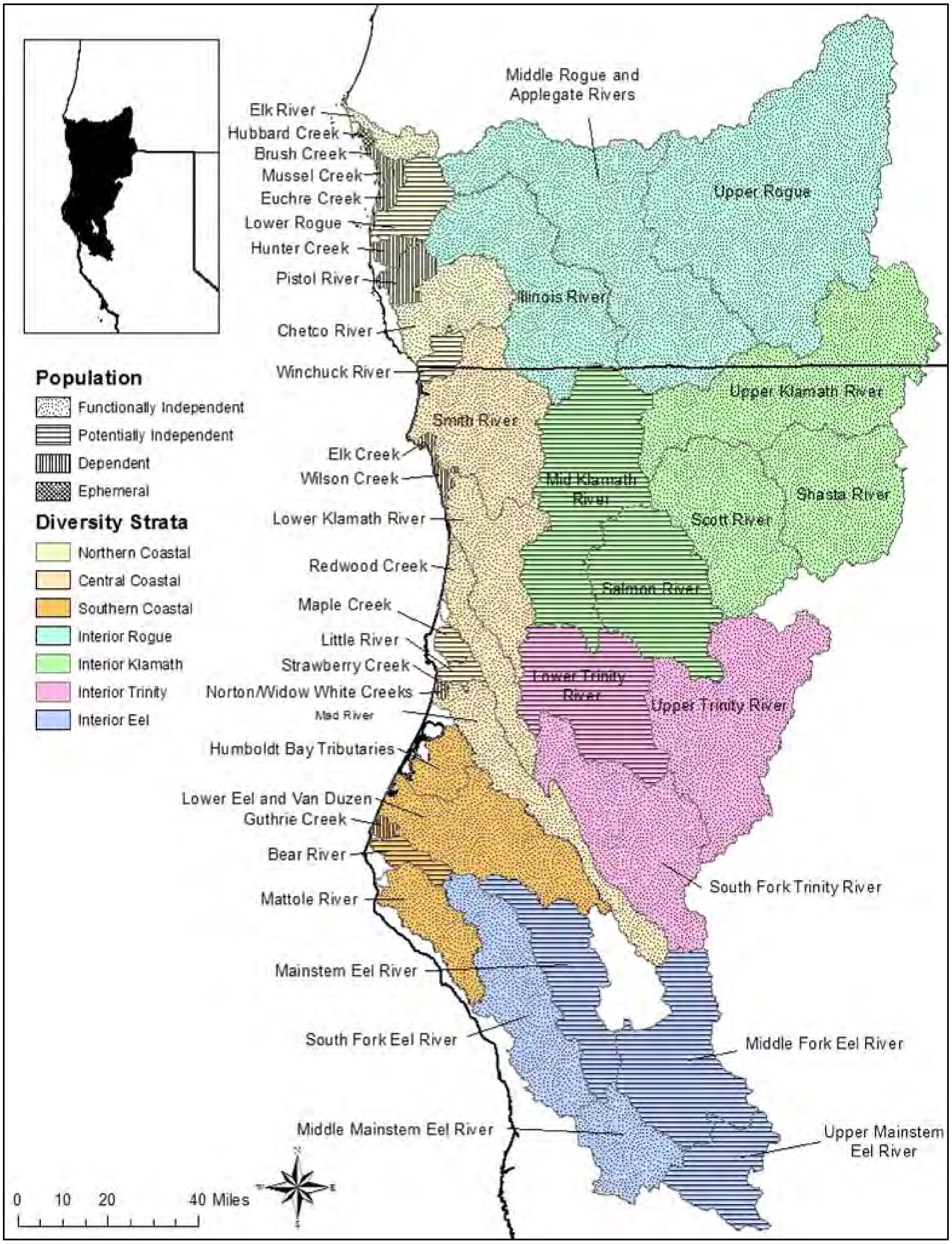


Figure 5-3. Historic population structure and seven diversity strata of the Southern Oregon/Northern California Coast coho salmon ESU.
Source: modified from Williams et al. 2006 in NMFS 2012b.

The relative importance of these factors is directly affected by ocean conditions (NRC 2004), particularly increasing water temperatures. Increases in water temperature influence survival in most life-stages of coho via heat stress, changes in growth and development rates, lowering resistance to disease (NMFS 2016), and by shifting feeding opportunities. Changes in feeding opportunities are particularly important as zooplankton communities shift to favor more warm-water-tolerant species that lack the lipid-rich tissue that colder-water species possess. For example, in 2016, the biomass of lipid-rich northern copepod species was the lowest ever observed, while in 2017, the lipid-deplete tropical and sub-tropical southern copepods had the highest biomass in recent records (Peterson et al. 2017). This finding coincided with an ocean-warming event in 2014, referred to as the “Warm Blob,” characterized by exceptionally high epipelagic ocean temperatures in the Northeast Pacific Ocean.

The Warm Blob initially formed in the Gulf of Alaska in 2013 and moved across the North Pacific in the spring of 2014 (Peterson et al. 2017), affecting the Baja, southern, and central coasts of California. Between November 2015 and January 2016, warm conditions were exacerbated as the Warm Blob was met by an unusually strong El Niño Southern Oscillation event in the Northeast Pacific Ocean. These conditions initiated a series of cascading trophic events creating conditions that no longer provided favorable growth opportunities for Pacific salmon. For example, Pacific salmon prey were dominantly larval rockfish and anchovies, indicators of poor feeding opportunities (Peterson et al. 2017). During this time, Columbia River coho salmon returns were some of the lowest ever recorded (Peterson et al. 2017).

Marine survival for populations south of Northern British Columbia, including the Klamath River, are typically below average in comparison to other northern states and provinces (Coronado and Hilborn 1998) and highly variable from year-to-year (Nickelson 2006). For example, marine survival of coho salmon smolts released from Fall Creek Hatchery (Alsea River, Oregon) ranged from near zero to 10 percent from 1970 to 1994 (Figure 5-4); low survival was attributed to ocean temperature and coastal upwelling (Emmett and Schiewe 1997). Moreover, Pearcy (1992) speculated that protected bays, inlets, and shallow littoral areas that favor survival are rare off California and Oregon and may contribute to these populations’ poor marine survival rates. In addition, oceanographic variability, resulting from inter-annual fluctuations in the intensity of upwelling or El Niño Southern Oscillation events, appears to be greater in the southern part of the species’ range (Lestelle 2007). In the Klamath River Basin, Nickelson (2006) found that the marine survival of hatchery-produced coho salmon was highly variable from year to year and presumed that wild coho salmon survival is similarly variable. It was estimated that the survival of Klamath River coho salmon originating from Iron Gate Hatchery (IGH) ranged from 0.12 percent to 5.7 percent from 1977 to 2001 (Nickelson 2006).

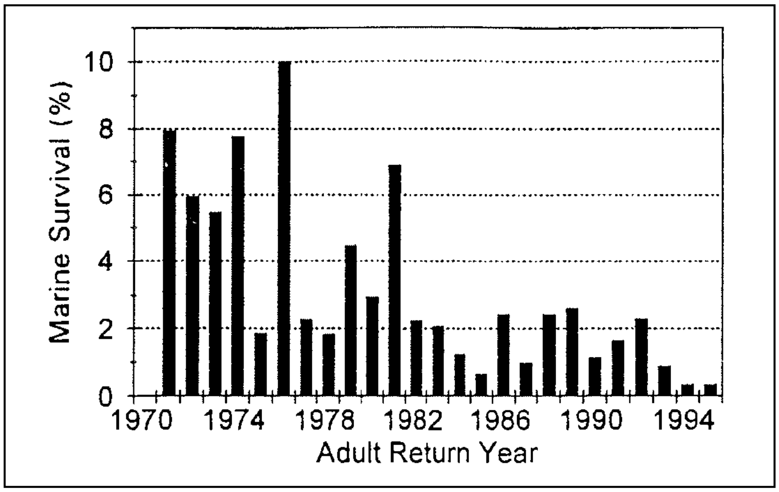


Figure 5-4. The influence of ocean temperature and coastal upwelling on marine survival of coho salmon released from Oregon hatcheries.
Source: Emmett and Schiewe 1997.

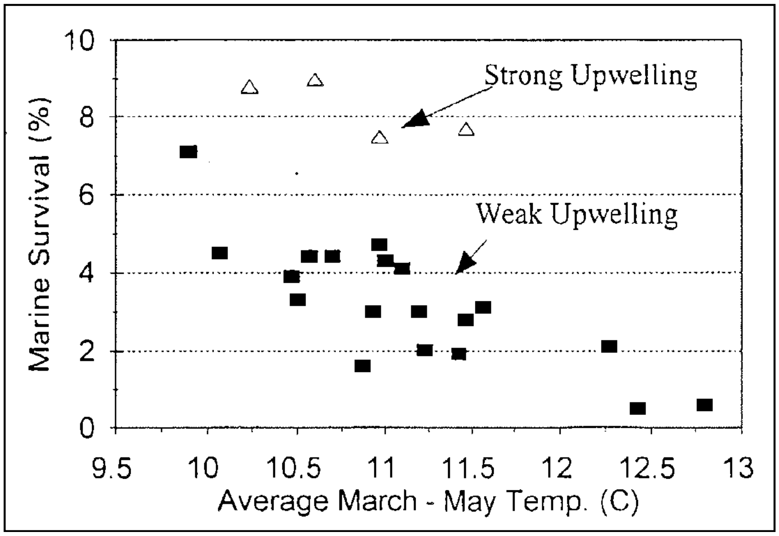


Figure 5-5. Marine survival of coho salmon smolts released from Fall Creek Hatchery (Alsea River Oregon), 1970 to 1994.
Source: Emmett and Schiewe 1997.

Smolt-to-adult return (SAR) rates provide insight into salmon ocean survival. For example, Lindley et al. (2009) suggested the poor performance of Sacramento River Fall Chinook salmon in the 2004 and 2005 brood years resulted from anomalous ocean conditions including weak upwelling, warm sea surface temperatures, and low prey densities. These findings were supported by near-normal smolt abundance estimates at the entrance to the estuary and typical freshwater rearing conditions for both brood years. In recent years, coho SAR rates in the Shasta and Scott Rivers have ranged from 0.5 to 16 percent (Chesney and Knechtle 2015, Magranet and Yokel 2017). Just south of the Klamath River Basin in Freshwater Creek, a tributary to Humboldt Bay, SAR rates have remained relatively low since 2007 ranging from 0.01 to 0.05 percent (Figure 5-6). Warm temperatures, strongly positive Pacific Decadal Oscillation (PDO) values, as well as lipid-depleted zooplankton populations continue to contribute significantly to the poor observed and predicted SAR values since 2014 (Peterson et al. 2017). Moreover, Peterson et al. (2017) estimated SAR in 2017 to be less than 2 percent for all Pacific Northwest coho salmon (Figure 5-7), consistent with observed declining trends.

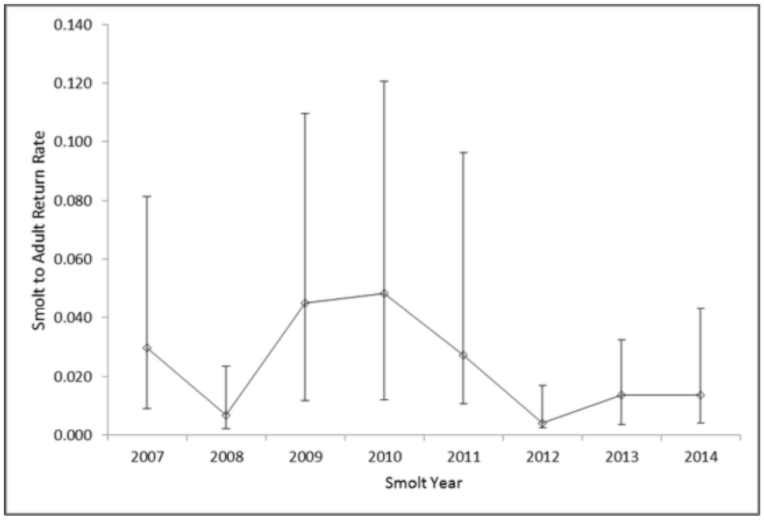


Figure 5-6. Smolt-to-adult return rates (95 percent confidence bounds) for Freshwater Creek coho salmon smolts by year of ocean entry, 2007 to 2014. Freshwater Creek is a tributary to Humboldt Bay in Northern California.
Source: Anderson & Ward 2016.

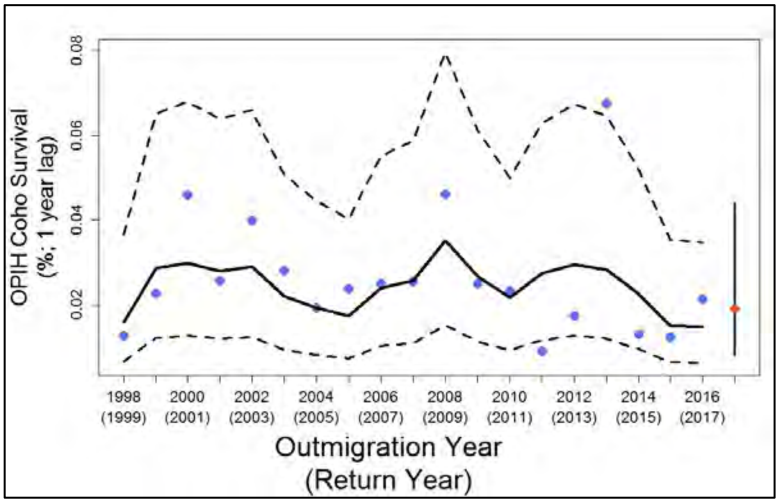


Figure 5-7. Time series of observed coho salmon smolt-to-adult returns rates (blue points) by outmigration year. The dark line represents dynamic linear model fit and dashed lines represent plus or minus 2 standard deviations from the mean model fit.
Source: Peterson et al. 2017.

5.2.2.1.2. Adult Freshwater Migration

Adult coho salmon migrate into the Klamath River in September, with peak migration in mid-October (Ackerman et al. 2006). Upon entry into the Klamath River estuary, adult coho salmon quickly migrate upstream, without extensive estuarine residence. Strange (2004) observed four adult coho salmon migrants averaged 17 hours in the estuary prior to upriver migration and a single individual holding for 24.5 days in the estuary. After estuary passage, adult coho salmon use the mainstem Klamath River as the primary migratory pathway to tributary spawning areas (Dunne et al. 2011).

Most spawning occurs in large tributaries such as the Scott, Shasta, and Trinity Rivers, as well as some higher order tributaries (Figure 5-8). Recent observations indicate that adult coho salmon return to the Scott and Shasta Rivers beginning in mid-October, when flows are sufficient to allow upstream migration (Chesney and Knechtle 2017, Magranet and Yokel 2017). Maintenance of adequate discharge in regulated tributaries is likely critical during the migratory period. For example, increased discharge in the highly-regulated Scott and Shasta Rivers seemed to elicit increased responsiveness in migratory behavior compared to Bogus Creek, an unregulated tributary (Manhard et al. 2018). Migratory timing models also suggest warming water temperatures are associated with increased migratory behaviors in the Scott and Shasta Rivers as well as Bogus Creek (Manhard et al. 2018), although the ecological significance of this finding remains unclear.

In addition to initiating migratory behavior, conditions in tributaries can determine availability of and access to important spawning habitat. For instance, low flow conditions in tributaries can be a significant barrier to reaching upstream spawning areas (Sutton et al. 2007). In 2013, California Department of Fish and Wildlife (CDFW) reported low flows associated with drought conditions and irrigation withdrawals in the Scott River impeded adult coho from reaching first and second order tributaries for spawning; adults were instead limited to spawning in the mainstem Scott River (CDFW 2016b).

The numbers of adult coho successfully reaching spawning areas in Klamath River tributaries has been variable over the POR but in recent years, appears to be declining (Figure 5-9). In the Shasta River for instance, only 46 coho salmon passed upstream of the weir in 2014, 45 in 2015, and 48 in 2016 (Chesney and Knechtle 2015, 2016, and 2017, respectively). Moreover, a substantial portion of the coho entering the Shasta River between 2008 and 2014 were identified as hatchery strays (Chesney and Knechtle 2017). Hatchery contributions were not estimated in 2015 or 2016 since no hatchery carcasses were recovered in either year. The Scott River adult returns were substantially higher than the Shasta in 2015 and 2016 (212 and 226, respectively); however, escapements to the Scott River have varied substantially over the POR (Figure 5-10), with a low of 63 in 2008 to over 2,500 in 2013 (Knechtle and Chesney 2017). Return trends for Scott and Shasta River coho populations were based on adult counts at video weirs (Figure 5-11; Knechtle 2015 in Williams et al. 2016). The trend for the Shasta River population did not differ significantly from zero, indicating that this population is virtually static or that annual variability is simply too influential to detect significant changes, and no trend statistics were presented for the Scott River population (Knechtle 2015 *in* Williams et al. 2016). Williams et al. (2016) also noted that low adult returns in the Shasta River in 2014 and 2015 paired with the increasing scarcity of other SONCC ESU coho populations is particularly concerning for the viability of the entire ESU.

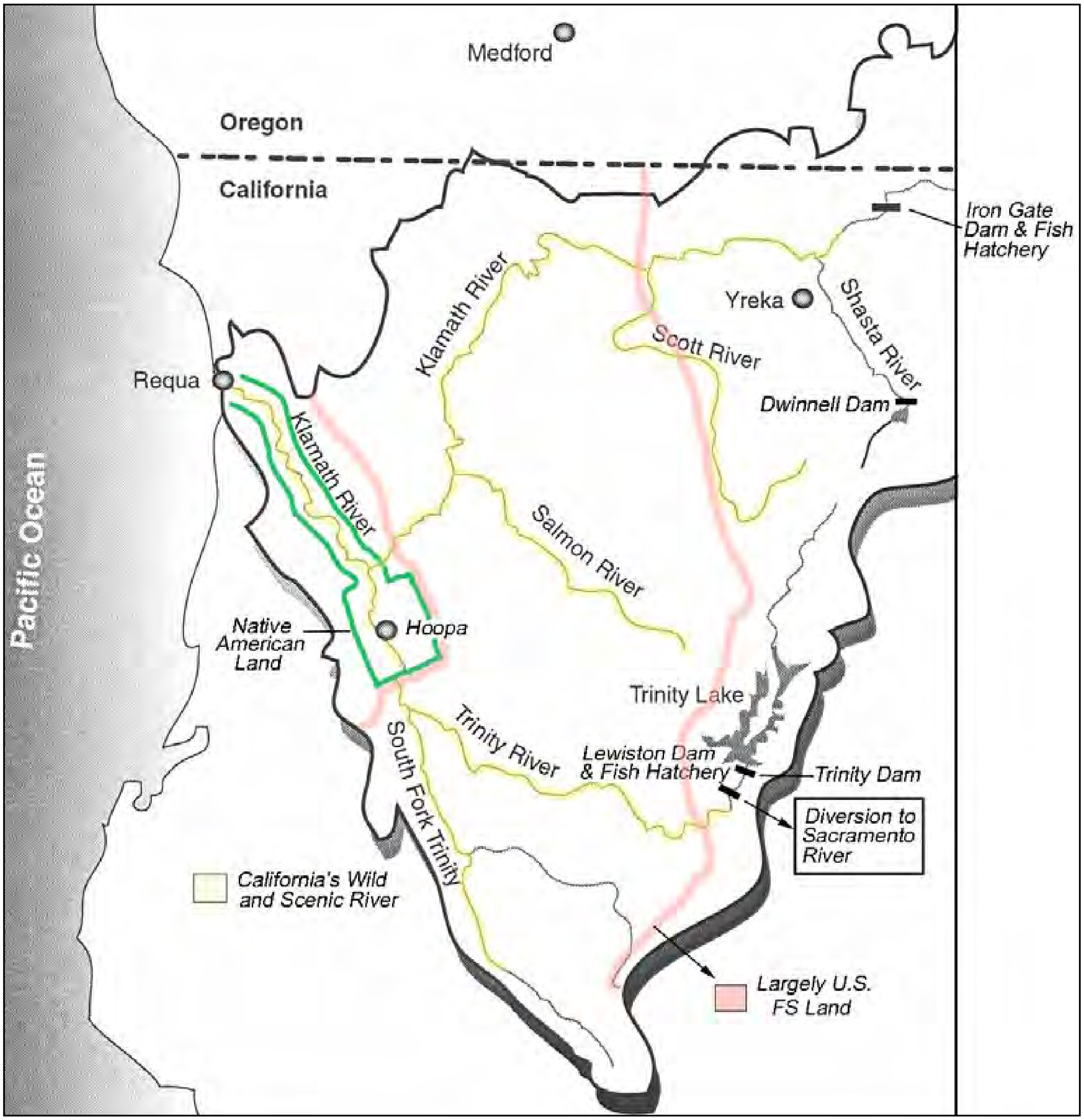


Figure 5-8. The Klamath River drainage downstream of the Iron Gate Dam. The Iron Gate Dam is currently an upstream barrier to anadromous salmonid migrations in the mainstem Klamath River. Green lines demonstrate the approximate boundaries of both the Yurok and Hoopa Valley tribal reservations. Pink lines demonstrate approximate boundaries of the watershed that are mostly federal lands (i.e., U.S. Forest Service). Yellow shaded rivers designate California Wild and Scenic River stretches.
Source: Reclamation 2012.

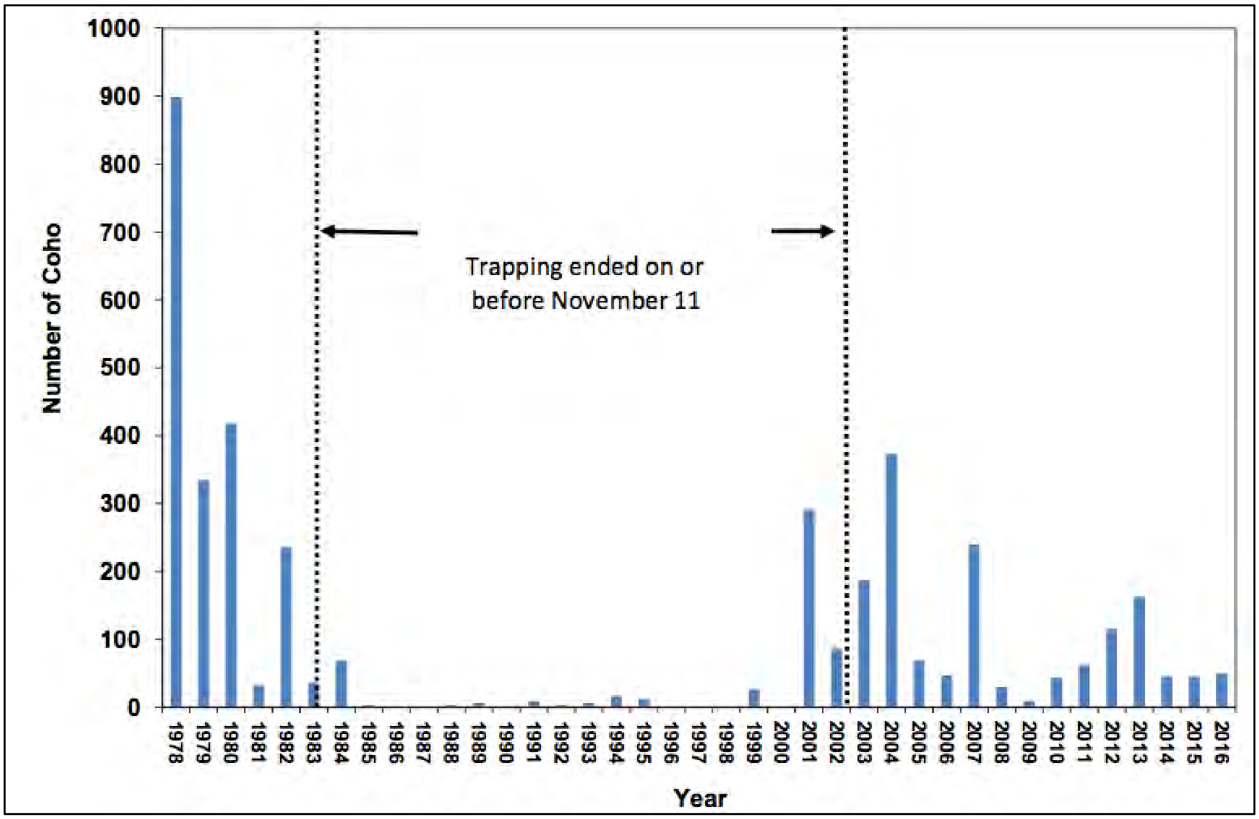


Figure 5-9. Returns of coho salmon to the Shasta River, California, 1978 to 2016. Dotted vertical lines indicate the period between 1984 and 2002 when the weir was removed (due to forecasted high flows) prior to November 11th, and the entirety of the coho return was not fully captured.
Source: Chesney and Knechtle 2017.

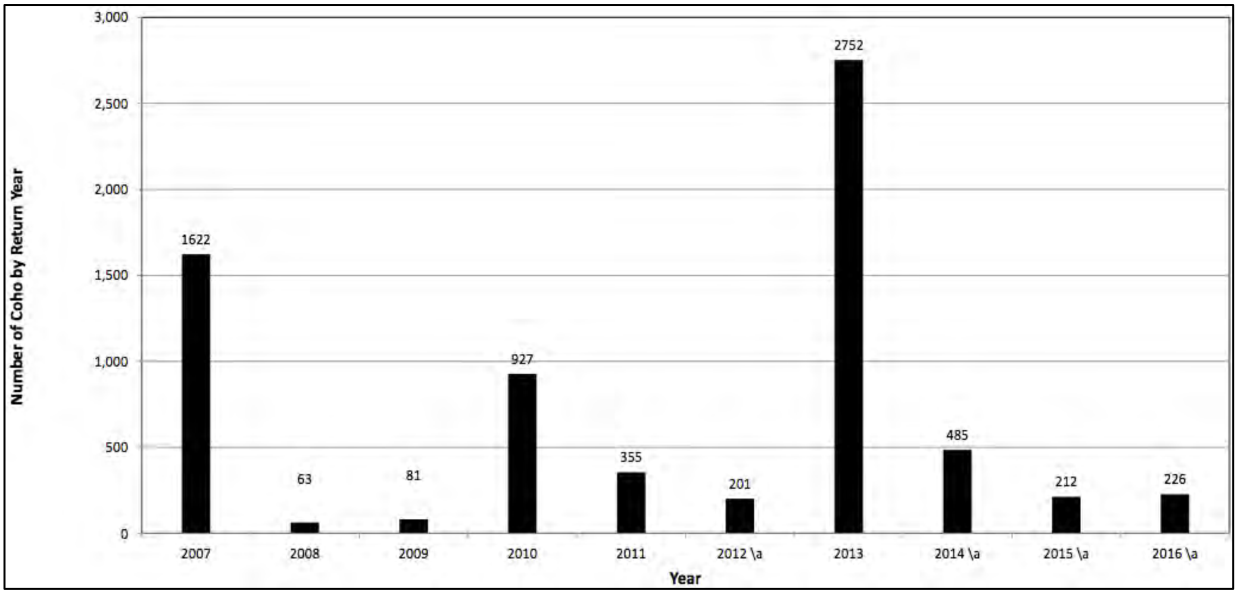


Figure 5-10. Estimated escapement by return year of adult and grilse coho salmon (age 2 and age 3) returning to the Scott River, 2007 to 2016. The symbol "\a" indicates a conservative estimate as weirs were removed prior to the end of the run (due to high forecasted river flows). Source: Chesney and Knechtle 2017.

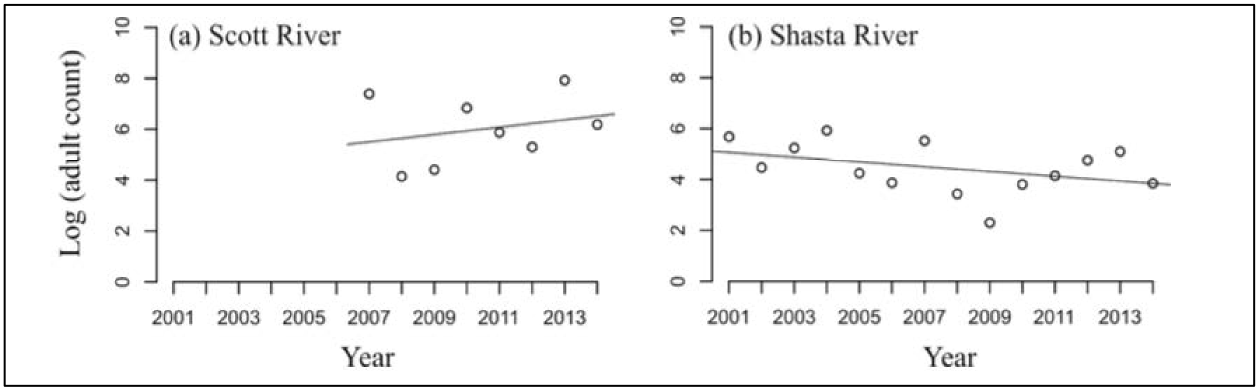


Figure 5-11. Population abundance trends for independent coho salmon populations in the Scott (a) and Shasta (b) Rivers from 2007 to 2014 and 2001 to 2014, respectively. Source: unpublished data from Knechtle (2015) presented in Williams et al. (2016).

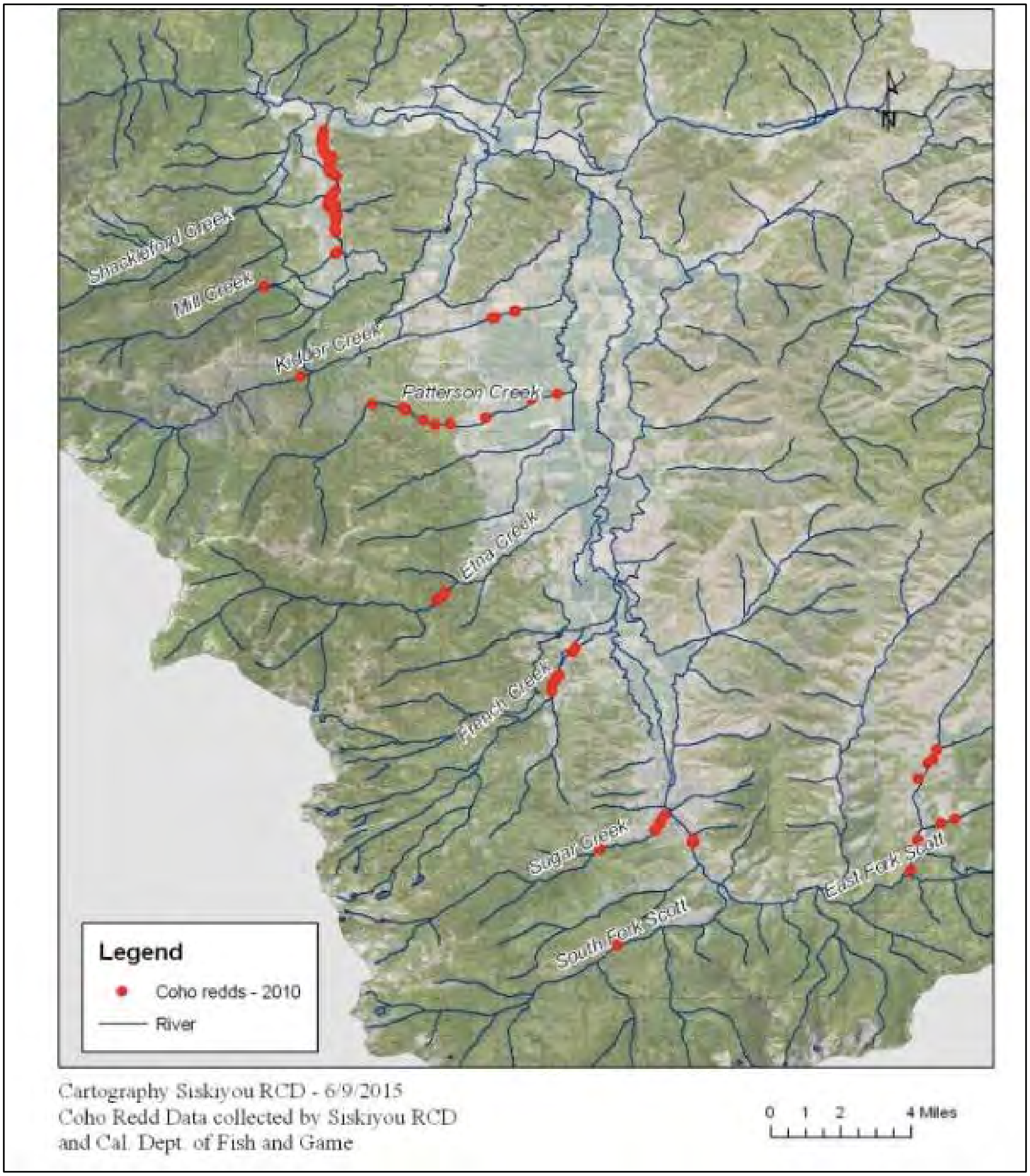
5.2.2.1.3. Spawning

Most coho salmon spawning occurs in the tributaries of the Klamath River from November through January. Salmon migration into natal tributary streams often occurs during higher fall flows (Koski 1966). During fall, ambient air and water temperatures generally decrease while rainfall events increase in frequency (NMFS 2010), encouraging adult migration into tributaries for spawning.

Both mainstem tributaries and higher-order tributaries support most spawning adult coho in the Klamath River Basin; however, distribution can be variable year to year. For instance, 2013 marked the largest return year of coho spawners since 2006 (Bull et al. 2015), yet spawner distribution into tributaries was extremely limited as a result of severe drought conditions from 2013 to 2014 (CDFW 2016a). Specifically, adult coho returning to the Scott River tributary in 2013 and 2014 were unable to access historical spawning tributaries and consequently were confined to the mainstem Scott River and portions of French Creek (Figure 5-12). Other historically important Scott River spawning tributaries such as Kidder, Patterson, Etna, and Sugar Creeks were inaccessible until mid-February of 2014 (Figure 5-13). Scott River spawning surveys conducted by the Siskiyou Resource Conservation District (SRCD) since 2014 indicate that French Creek has consistently supported coho salmon spawning in the Scott River (Table 5-1; Magranet and Yokel 2017), and likely provides vital spawning habitat.

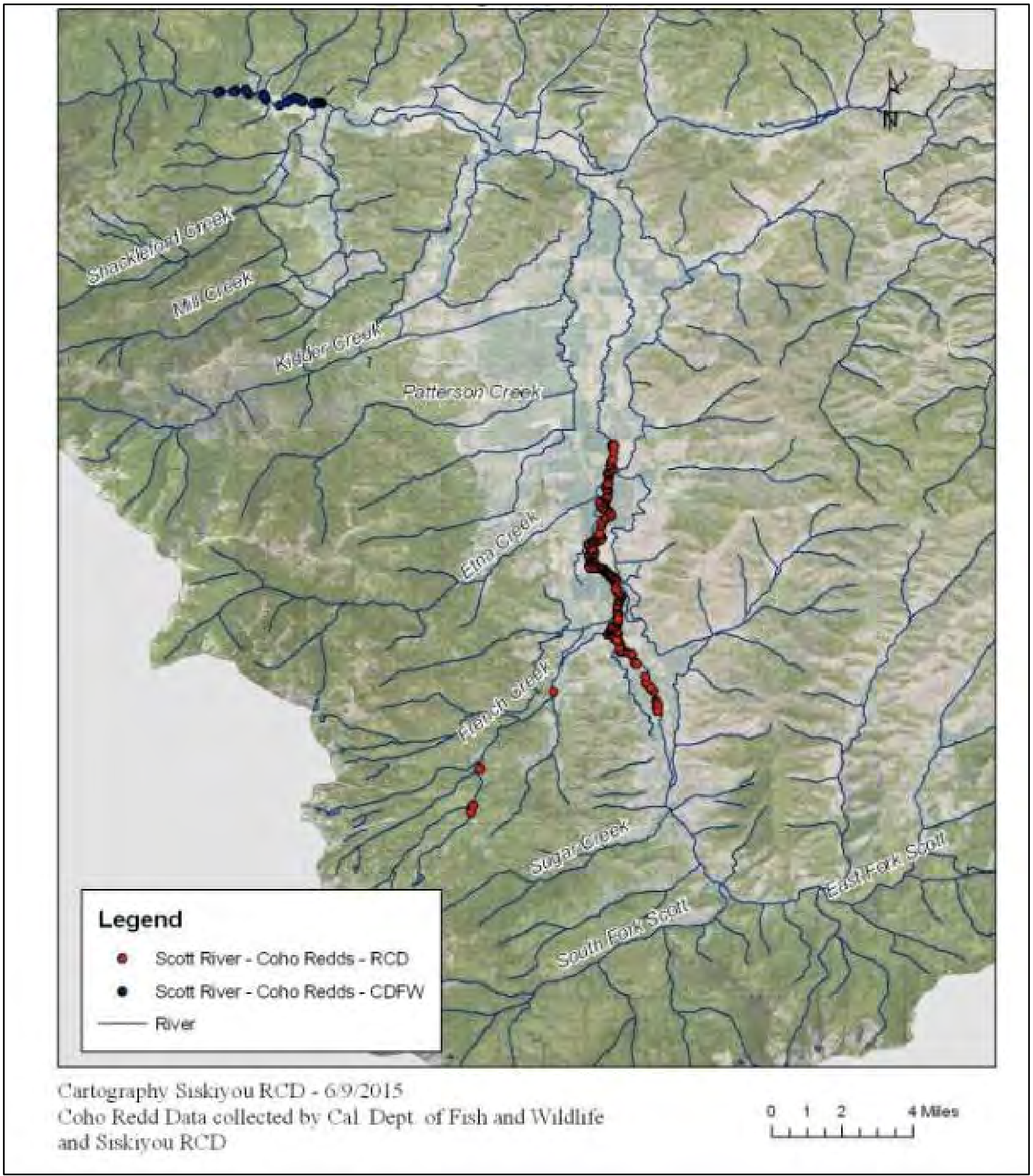
Coho populations spawning in tributaries within the Middle Klamath River (between Portuguese Creek and the Trinity River confluence) were estimated to be between 0 and 1,500 individuals depending on the strength of a particular year's run (Ackerman et al. 2006). Slate, Boise, Red Cap, Clear, Camp, and Indian Creeks support substantial returns of coho salmon, although total spawner abundance and overall population productivity is unknown. From 2013 to 2014, 64 coho salmon redds were observed in other Middle Klamath River tributaries: Aikens, Camp, China, East Fork Elk, Independence, Indian, Mill (tributary to Indian), South Fork Clear, and Titus creeks (Corum 2014). Recently, the Middle Klamath River population was determined to be at a moderate extinction risk (NMFS 2016).

As with most species of Pacific Salmon, coho salmon prefer spawning in tributaries, rather than mainstem rivers that do not have sufficient substrate, depth, and DO for egg development. Spawning in the mainstem Klamath River occurs to a much more limited extent than in tributaries (Soto et al. 2016), resulting in sparse mainstem spawner data. Between 2001 and 2004, Ackerman et al. (2006) estimated that less than four percent of all returning adult coho spawned in the mainstem Klamath River. From 2001 to 2005, Magneson and Gough (2006) documented a cumulative total of 38 coho salmon *redds* in approximately 83 miles of the mainstem Klamath River, between IGD (river mile [RM] 190.5) and the Indian Creek confluence (RM 107.4) between November 15 and December 18. Furthermore, roughly 68 percent of observed redds were within 12 RMs downstream of IGD; many of these fish likely originated from IGH (NMFS 2010). In 2008, Slezak (2009) counted 9 coho salmon redds in the mainstem Klamath; eight of which were located in side or split channels. The highest concentration of these redds (4) were found in a side channel near the confluence of Barkhouse Creek (RM 159.5). The number of redds observed in this survey were similar to counts between 2002 and 2005 but were considerably lower than counts in 2001. It should be noted that tributaries appear to play an important role in coho spawning activities in the mainstem Klamath River. Magneson and Gough (2006) found all mainstem redds were constructed within approximately 1 RM of a tributary mouth, highlighting the importance of tributary confluences in spawning site-selection. More recently, extensive surveys of coho spawning in the mainstem Klamath River have not occurred. However, coho redds have been observed opportunistically during fall Chinook spawning surveys in the mainstem Klamath providing limited counts of coho spawning activity.



Cartography Siskiyou RCD - 6/9/2015
Coho Redd Data collected by Siskiyou RCD
and Cal. Dept. of Fish and Game

Figure 5-12. Scott River coho redd distribution for sampled reaches during 2010 (some reaches of the Scott River and its tributaries were not sampled). Surveys conducted by California Department of Fish and Game.
Source: Bull et al. (2015).



Cartography Siskiyou RCD - 6/9/2015
Coho Redd Data collected by Cal. Dept. of Fish and Wildlife
and Siskiyou RCD

Figure 5-13. Scott River coho redd distribution for sampled reaches during 2013 (some reaches of the Scott River and its tributaries were not sampled). Surveys conducted by California Department of Fish and Game.
Source: Bull et al. (2015).

Table 5-1. Coho salmon redd density in the Scott River and tributaries for three cohorts. Table adapted from Magranet and Yokel (2017).

Stream	Reach	2014-2015 redds/mile	2015-2016 redds/mile	2016-2017 redds/mile
Shackleford Creek	Lower	6.7	0	1.8
Shackleford Creek	Middle	21.3	5.4	6.3
Mill Creek	Lower	22.9	31.4	20.6
Mill Creek	Upper	0	*not surveyed*	0
Kidder Creek	Upper	0	0	0
Patterson Creek	Middle	0	0	0.9
Patterson Creek	Upper	0	0	0
Patterson Creek	Lower	0	*not surveyed*	*not surveyed*
Etna Creek	Middle	0	0	0
French Creek	Lower	5.0	0	3.8
French Creek	Middle	8.0	2.7	11.7
French Creek	Upper	0	0	*not surveyed*
Miners Creek	Lower	*not surveyed*	2.2	15.8
Sugar Creek	Lower	0	10	7.8
Sugar Creek	Middle	1.7	0	9.4
Sugar Creek	Upper	0	0	0
Wildcat Creek	Middle	*not surveyed*	*not surveyed*	0
South Fork Scott R.	Middle	0	0	0
East Fork Scott R.	Middle	0	*not surveyed*	0.3
East Fork Scott R.	Upper	0	*not surveyed*	*not surveyed*
Mainstem Scott R.	Index Reach 12	0	*not surveyed*	0
Mainstem Scott R.	Index Reach 13	0	0	0
Mainstem Scott R.	Index Reach 14	1.9	*not surveyed*	0
Mainstem Scott R.	Index Reach 15	1.9	*not surveyed*	2.2
Mainstem Scott R.	Index Reach 16	1.9	*not surveyed*	4.8

5.2.2.2. *Egg Incubation and Fry Emergence*

Coho salmon embryos develop and hatch in 8 to 12 weeks, then remain in the gravel as alevins for another 4 to 10 weeks (Sandercock 1991) as they develop into the fry life stage. Fry emerge from the gravel as 30 to 50 mm fish and typically seek shallow stream margins for foraging and safety (NRC 2004). Within the Klamath River Basin, fry begin emerging in mid-February and continue through mid-May (Leidy and Leidy 1984).

5.2.2.3. *Fry*

After emergence from spawning gravels, coho salmon fry distribute themselves upstream and downstream, seeking favorable rearing habitat (Sandercock 1991). Coho fry prefer slower velocities, favoring velocities between 0.33 and 1.64 feet/s (0.1 and 0.5 meters per second [m/s]), but occupy habitats ranging from 0 to 3.51 feet/s (1.07 m/s; Hardy et al. 2006). They use habitat with water depths ranging from 0.2 to 2.89 feet (0.06 to 0.88m), favoring depths between 0.69 and 1.31 feet deep (0.21 and 0.40 m; Hardy et al. 2006). Coho fry prefer stream temperatures between 12 and 14°C; Moyle 2002), and coho are often associated with habitats containing large woody debris and other in-stream cover (Nielsen 1992, Hardy et al. 2006).

Although little is known about the drivers of coho fry movements immediately after emergence (Quinn 2005), early emigration is common. Dominant individuals will engage in agonistic and territorial behaviors as they begin exogenous feeding that can displace subordinates (Chapman 1962, Mason and Chapman 1965, Berejikian et al. 1999). Other, coho fry may migrate to estuarian habitats during summer and then into freshwater habitats for overwintering (Koski 2009) or remain in the in the estuary for the duration of their rearing (Hoehm Neher et al. 2013). Relocation of fry may also result from physical displacement or density-dependent behaviors; however, the fate of those individuals is not well documented. In the Klamath River Basin, movement of fry from higher order tributaries to mainstem tributaries or to the mainstem Klamath River during the summer, when water temperatures are high, may preclude survival unless fish find suitable thermal refugia (NRC 2004).

5.2.2.4. Juveniles

While there is no sharp physiological distinction between the fry and juvenile life-stages in coho, juveniles are characterized by increasing territoriality. Juvenile coho remain closely associated with slow velocity, low-gradient habitats (Lestelle 2007, Quinn 2005). They feed on insect drift, generally within an established territory, orienting upstream so they may dart out and grab food. Establishing feeding territories is a characteristic of most juvenile salmonids in streams and represents an important tradeoff between energy spent obtaining food and energy spent defending foraging territory. Moreover, juvenile coho will form a foraging hierarchy and exhibit three general behavioral patterns: dominants, subdominants, and floaters (Neilsen 1992).

Juvenile salmonids relocate to avoid adverse environmental conditions or to optimize foraging opportunities. The movement patterns and habitat-use of juvenile coho salmon can show considerable temporal variation. Non-natal streams often provide important rearing habitat for juvenile salmonids and are accessed through the mainstem Klamath River. Between May 2007 and May 2008, more than 2,700 juvenile coho salmon were successfully PIT-tagged and released to monitor movements throughout the Klamath Basin. Fish not only moved within small tributaries, they also used the mainstem Klamath River to travel between tributaries (Hillemeier et al. 2009). The longest distance traveled by an individual was 125 miles from Fort Goff Creek on September 18, 2007 and Salt Creek on May 10, 2008. The longest redistribution of a fish seeking overwinter habitat was 114 miles moving from China Creek on August 14, 2007 to Junior Pond Creek on January 2, 2008 (Hillemeier et al. 2009).

Monitoring coho populations in streams where spawning is rare, or doesn’t occur, can provide insights into the extent the Klamath mainstem is used as a redistribution corridor. Two streams routinely monitored for fish abundance during spring, summer, and fall are the Independence Creek floodplain channel (RM94) and Cade Creek (RM112). While some natal production of coho salmon has been observed in Independence Creek, extensive use by non-natal, YOY coho has been documented (Hillemeier et al. 2009). Similarly, Cade Creek supports juvenile coho salmon rearing but is rarely used for spawning. Hillemeier et al. (2009) found that when water temperature in the mainstem Klamath River exceeded stressful levels (approximately 19ºC), coho salmon utilized Cade Creek. Further, the authors observed increasing number of juvenile coho salmon moving into the stream as mainstem temperatures continued to rise. In addition to juveniles using the mainstream to access non-natal streams for refuge, others use the plumes at the confluence with the mainstem Klamath (e.g., Beaver Creek rkm 261) when temperatures are favorable (Sutton and Soto 2012).

Lestelle (2010) characterized seasonal habitat use and movement patterns by juvenile coho salmon in the Klamath Basin as four patterns: spring re-distribution (and rearing), summer rearing, fall re-distribution (and rearing), and winter rearing. Additionally, juvenile re-distribution during the summer rearing period has been documented throughout the basin (Sutton and Soto 2012, Soto et al. 2016, Manhard 2018).

Spring Re-Distribution/Rearing. The spring re-distribution/rearing pattern can include small-scale movements within a tributary to areas with deeper water or large-scale movements both upstream (Hay 2004, CDFW 2016b) and downstream (CDFW 2016b). Chesney et al. (2009) observed large-scale movements in the Shasta River as juvenile coho salmon migrated over four miles upstream to areas of cold, spring inflow after they experienced a rapid increase in maximum daily water temperatures. Irrigation diversions that reduce flows in early April (Figure 5-14, Figure 5-15) in the Scott and Shasta Rivers can substantially reduce rearing habitat (Gorman 2016) and can displace juvenile coho into the mainstem Klamath River (CDFG 2005 in Chesney et al. 2007, Chesney et al. 2004). Age-0 juveniles for brood years 2010 and 2012 to 2013 in the Shasta River were detected in summer rearing habitats further down in the basin (Adams 2013, CDFW 2016a).

Other coho fry disperse downstream after emergence, often facilitated by spring runoff (Soto et al 2016); some moving into the mainstem Klamath River, seeking low-velocity habitats to rear. Although limited, mainstem rearing habitat exists along the river shoreline and within backwater units (Beechie et al. 2005; Lestelle 2007).

Summer Re-Distribution/Rearing. Summertime movement patterns are largely driven by increases in water temperature. Few juveniles rear in the mainstem Klamath River during the summer as temperatures regularly exceed 24°C (NRC 2004), well above the thermal stress tolerance for juvenile coho rearing (review in Richter and Kolmes 2005). Sutton and Soto (2012) found that when water temperatures in the mainstem Klamath River approach approximately 19°C, juvenile coho begin to use thermal refugia. Furthermore, this study observed visual fish counts in these areas of refugia begin to decline as water temperatures exceeded 22 to 23°C, suggesting these areas became unsuitable habitats. In addition to temperature thresholds, juvenile coho can be limited by the availability of refugia areas in the mainstem Klamath River. Refugia are spatially and temporally variable with many factors impacting the size, shape, and function of the refugia habitat (Deas et al. 2006). In the mainstem Klamath River, changes in flow at IGD, meteorological conditions, and tributary contributions influence both the amount and extent of available refugia (Deas et al. 2006).

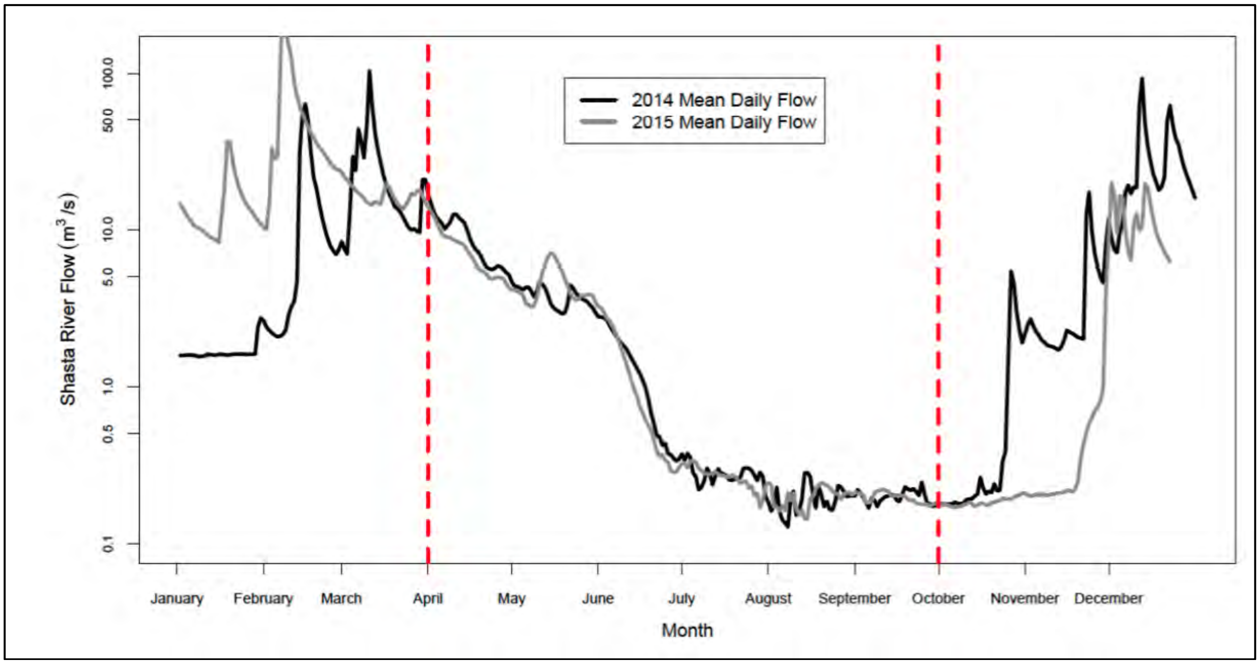


Figure 5-14. Mean daily flow in the Shasta River, measured at United States Geological Survey (USGS) stream gage 11517500. Red dotted lines indicate irrigation season (April 1st – September 30th)
Source: Gorman 2016.

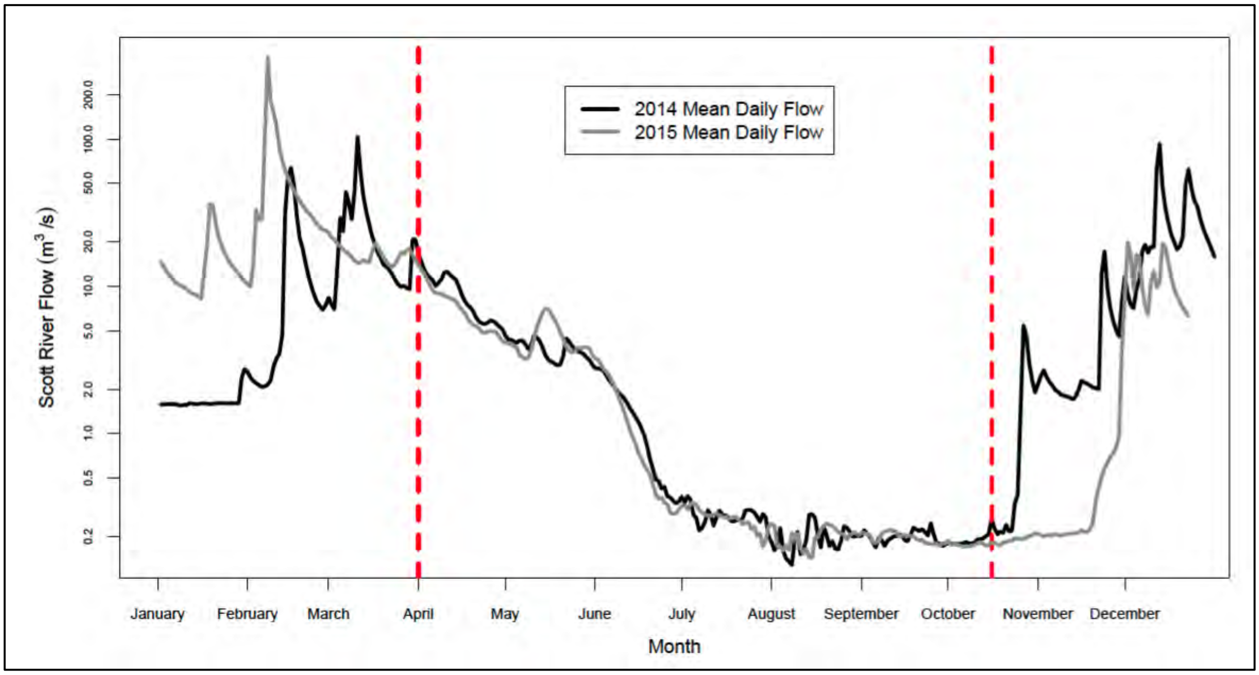


Figure 5-15. Mean daily flow in the Scott River as measured at United States Geological Survey (USGS) stream gage 11519500. Red dotted lines indicate irrigation season (April 1st – October 15th).
Source: Gorman 2016.

Although the mainstem offers only limited and patchy rearing habitats during the summer, it provides a corridor for redistribution to refugia in tributaries. Early-summer coho movements from natal tributaries to the mainstem Klamath corridor are well documented (Soto et al. 2016). Further, movement into and out of the Klamath mainstem is largely driven by increases in summer water temperatures (Manhard et al. 2018) as juvenile coho seek rearing habitat in cooler water (Soto et al. 2016). Most summer redistribution occurs downstream, which ultimately shortens the length of seaward migration for smolts. Manhard et al. (2018) suggested that shortening this migratory distance may enhance survival for juveniles contending with virulent parasites such as *Ceratonova shasta*, which can become especially problematic under warm water conditions (*see* Part 6.3.1.7).

During summer, most juvenile coho salmon rear in cooler tributaries (Figure 5-16); however, redistribution may also occur within major tributaries such as the Shasta and Scott Rivers. For example, coho in the Shasta River moved upstream when stream temperatures remained above 20°C for several days (CDFW 2016a). Other juvenile salmonids cope with high mainstem tributary temperatures by moving to pockets of thermal refugia such as off-channel habitats and beaver ponds. Concentrated numbers of juvenile coho have been observed in cold, spring-water refugia in the upper Shasta River, some having migrated over 6 km upstream (Chesney et al. 2009). However, during low summer flows upstream migration in mainstem tributaries may not be possible. For instance, juvenile coho in the Scott River were limited by dewatered sections of the streams during the 2013 drought year (CDFW 2016a).

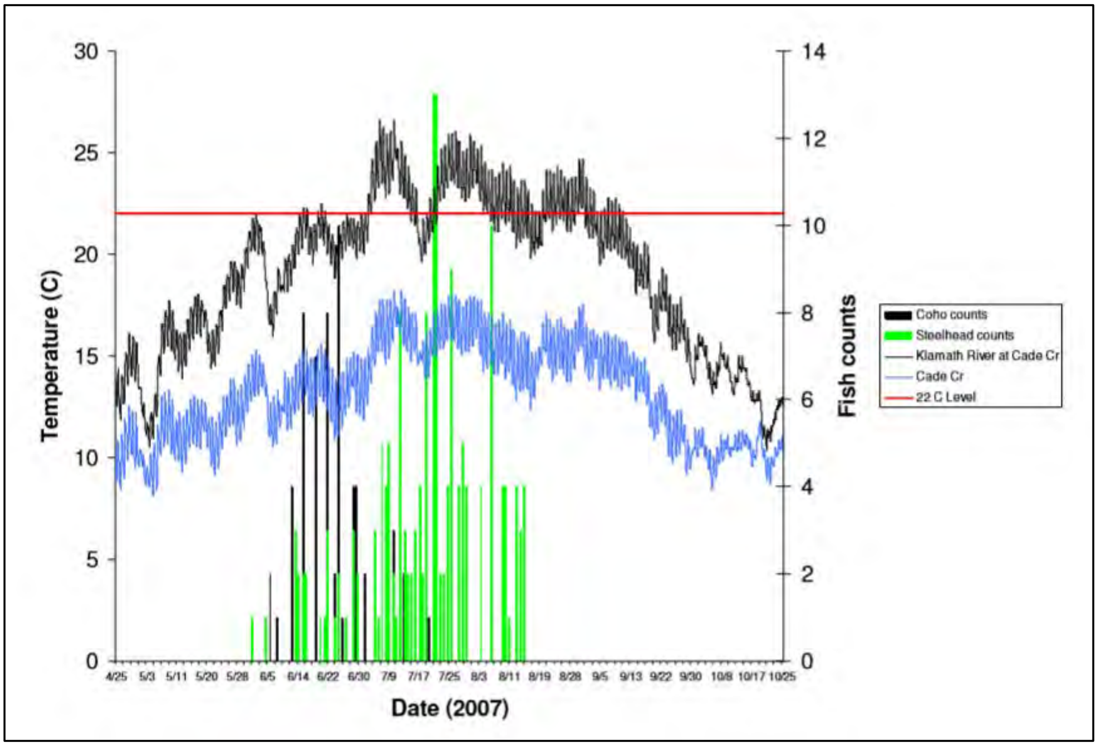


Figure 5-16 Timing of juvenile coho salmon movements into Cade Creek relative to mainstem Klamath and tributary temperatures during summer 2007. Black vertical bars are coho salmon catches. Fish numbers represent catches made by minnow traps in the lower reach of Cade Creek.
Source: Sutton & Soto (2010).

Fall Re-Distribution/Rearing. Fall conditions (beginning in September) in the Klamath River and its tributaries are characterized by declining water temperatures and increased flows and water velocities as storms become more frequent. Juvenile coho generally respond to fall conditions by moving to off-channel habitats such as ponds, floodplains, and higher-order tributaries (Peterson 1982, Swales and Levings 1989, Quinn 2005), which provide shelter from high velocity water. While there is some limited over-wintering habitat available in the mainstem Klamath, the most extensive fall re-distribution of juvenile coho in the Klamath basin occurs as individuals either move out of the mainstem or through the mainstem (from natal tributaries) seeking over-winter habitats in off-channel locations or higher-order tributaries (Soto et al. 2016). During this period, juvenile coho in the mainstem Klamath River almost exclusively moved upstream to find suitable overwintering habitat and this movement was strongly correlated to high flow events in the mainstem between November and December (Soto et al. 2016). Furthermore, juveniles in this study did not leave suitable overwintering habitat until they emigrated as smolts. In the Klamath River, some juvenile coho will also migrate downstream to off-channel ponds near the estuary and are thought to remain there before emigrating as smolts the following spring (Voight 2008); however, the frequency of this behavior is unclear.

Winter Rearing. The availability of overwintering habitat is one of the most important factors influencing the survival of juvenile coho salmon in streams (Moyle 2002). Coho seek low velocity habitats to overwinter (Bisson 1987), particularly off-channel habitats such as alcoves, backwaters, and off-channel ponds (Swales et al. 1986, 1988, Nickelson et al. 1992, Bell et al. 2001). These habitats can provide cover from predators as well as buffer fish from high discharge events that might otherwise lead to mortality or emigration (Erman et al. 1988, McMahon and Hartman 1989, Sandercock 1991).

Winter rearing patterns of juvenile coho salmon within the mainstem Klamath River corridor have been observed through a multi-year study initiated by the Karuk and Yurok Tribes to assess seasonal life history tactics. The movements of PIT-tagged juvenile coho captured in fyke and seine nets (Hillemeier et al. 2009) and monitored using stationary PIT tag detectors (Soto et al. 2016) at numerous sites in the mainstem corridor indicated significant re-distribution between initial tagging in summer and fall and subsequent detections during winter (Hillemeier et al. 2009, Soto et al. 2016). Moreover, re-distribution was less extensive for fish tagged in the mainstem Klamath River upstream of Happy Camp (RM 110); which the authors suggest may be related to smaller variation in mainstem and tributary flows above the Trinity River.

In the Shasta River, some parts of the river seem to provide adequate overwinter habitat while others do not (Adams 2013). Adams (2013) observed that in the winter juvenile coho in Big Springs Creek, a tributary to the Shasta River, moved from areas dominated by macrophyte cover when the aquatic vegetation “died-off” to areas in the Shasta River with woody structures that created deep pools with low velocities. The upper reaches of the Shasta River also provide important winter rearing habitat where multiple springs produce water temperatures optimal for rearing juveniles (Stenhouse et al. 2012).

5.2.2.5. Smolt Outmigration

Juvenile coho transform into smolts in preparation for moving into the saltwater environment. This transformation involves many complex processes including changes in morphology, physiology, and behavior (Hoar 1976, Wedemeyer et al. 1980, Folmar and Dickhoff 1980). The timing of smoltification is a response to fish-size, flow conditions, water temperature, DO, photoperiod, and food availability (Shapovalov and Taft 1954). During this process, smolts seek cover features (e.g., woody debris) that provide protection from high current velocities and predation. Shelter from higher velocities may be particularly important in preventing premature displacement (Hartman et al. 1982) since smolts exhibit reduced swimming abilities (Flagg and Smith 1981).

Smolts begin migrating downstream in the Klamath Basin between February and mid-June (NRC 2004). Long-term monitoring below IGD indicates Klamath River mainstem smolt outmigration occurs from mid-March through late-July (Gough et al. 2015, David et al. 2017a, David et al. 2017b). In tributaries, smolt outmigration varies depending on location within the basin. In the Scott and Shasta Rivers, migration can begin in February and extend through June, peaking from mid-April to mid-May (CDFW 2016a, 2016b). Outmigration in the Shasta River coincides with the drop in flows from irrigation withdrawal, typically in mid-April (CDFW 2016b). Smolts in the Trinity River begin outmigration in January and extend through June (Petros et al. 2017). Outmigration from Blue and McGarvey Creeks, lower Klamath River tributaries, occurs from March through early-June (Antonetti 2012, Antonetti and Partee 2013). Smolts usually leave the estuary by July (NRC 2004).

Survival rates of coho salmon smolts in the Klamath River are influenced by many factors. Survival rates, between the confluence of the Shasta River and IGD in 2009, had a positive correlation between survival and temperature, discharge, and fish weight, within the ranges studied (Beeman et al. 2012). However, Beeman et al. (2012) found the positive effects of increased discharge from IGD were small relative to seasonal increases in water temperature and concluded the greatest survival benefit of increased discharge would occur at lower water temperatures. In their study, Beeman et al. (2012) did not find any of these factors to affect survival rates downstream of the confluence with the Shasta River, but generally concluded that the survival of coho salmon smolts migrating seaward in the Klamath River were similar to, or greater than, survival rates in several other regulated river systems.

In the Klamath River Basin, smolt migration rates (km/day) tend to increase as fish move downstream, particularly for wild fish (Beeman et al. 2012). The pattern observed in this study was not clearly correlated with flow, fish length, release date, photoperiod or temperature predictor variables.

5.2.2.6. Mainstem Klamath River Usage

The Yurok and Karuk Tribes have studied the seasonal distribution and habitat use patterns of pre-smolt juvenile coho salmon within the mainstem of the Klamath River using PIT tagging technology in conjunction with extensive trapping and seining activities. These efforts have revealed extensive use of the mainstem Klamath as a corridor for re-distribution through monitoring the movements of individual fish. Their studies suggest the following movement patterns:

1. Fry dispersal from natal tributaries into the mainstem corridor during spring runoff (Soto et al. 2016).

2. Juveniles within mainstem corridor seek thermal refuge as water temperatures rise in early summer (Soto et al. 2016, Manhard et al. 2018).

3. Juveniles re-distribute in fall and early-winter in search of suitable overwintering habitats, typically during periods of increased flows. Patterns suggest that movement slows considerably once fish have either found suitable habitat or have emigrated (Soto et al.2016).

4. Smolt migration occurs in early spring (Gough et al. 2015, David et al. 2017a, David et al. 2017b).

5.2.3. Status and Trend

5.2.3.1. Population Abundance

The limited long-term data on coho salmon abundance indicate that spawner abundance has remained low for populations in this ESU in recent years. Data from the Shasta River are the longest existing time series (13 years) at the population unit scale and while returning adult numbers have been variable over the POR, counts have remained low since 2014 (Chesney and Knechtle 2017). Spawner abundance in the Scott River has been monitored since 2007 and is also highly variable, with an exceptional return year in 2013 (Knechtle and Chesney 2016).

Though population-level estimates of abundance for most independent populations are lacking, the available data indicate that none of the seven diversity strata (Figure 5-1) support a viable population (NMFS 2016). Nineteen independent populations in the ESU, including seven of the 10 populations in the Klamath River basin, are at high risk of extinction because they are below, or likely below, their depensation threshold (NMFS 2016). The Middle Klamath River, Scott River, and Upper Trinity River populations are classified at a “moderate” risk of extinction. Populations that are under depensation have increased likelihood of being extirpated. The extinction risk of an ESU depends upon the extinction risk of its constituent independent populations (Williams et al. 2008), and because the population abundance of most independent populations are below their depensation threshold, the SONCC coho salmon ESU is at high risk of extinction and is currently not viable.

5.2.3.2. Population Productivity

Available data indicates that many populations have declined, which reflects a declining productivity. In general, SONCC coho salmon have declined substantially from historic levels. Because productivity appears to be negative for most, if not all SONCC ESU coho salmon populations, this ESU is not currently viable.

5.2.3.3. Spatial Structure

When the BA was conducted by the Reclamation in 2012, data were inadequate to compare the spatial distribution of SONCC ESU coho salmon since the 2005 listing. However, Gilbert-Horvath et al. (2016) reaffirmed the SONCC coho salmon ESU boundaries through genetic analysis. Although, there is considerable year-to-year variation in estimated occupancy rates, it appears there has been no change in the percent of streams occupied by coho salmon from the late 1980s and early 1990s to 2000 (Good et al. 2005). However, the number of streams and rivers currently supporting coho salmon in this ESU has been greatly reduced from historical levels, and watershed-specific extirpations of coho salmon have been documented (Brown et al. 1994, Good et al. 2005, Moyle et al. 2008). Recent information for the SONCC ESU of coho salmon indicates that their distribution within the ESU has been reduced and fragmented, as evidenced by an increasing number of previously occupied streams from which they are now absent (NMFS 2001). However, extant populations can still be found in all major river basins within the ESU (70 FR 37160; June 28, 2005).

5.2.3.4. Diversity

The primary factors affecting the diversity of SONCC ESU coho salmon appear to be low population abundance and the influence of hatcheries and out-of-basin introductions. Although the operation of a hatchery tends to increase the abundance of returning adults (70 FR 37160; June 28, 2005), the reproductive success of hatchery-born salmonids spawning in the wild can be less than that of naturally produced fish (Araki et al. 2007). Because the main stocks in the SONCC coho salmon ESU (e.g., Rogue, Klamath, and Trinity Rivers) remain heavily influenced by hatcheries and have little natural production in mainstem rivers (Weitkamp et al. 1995, Good *et al*. 2005), many of these populations are at high risk of extinction relative to the genetic diversity parameter. In a review of salmon stocks in the Klamath River Basin, Quiñones et al. (2014) looked at returns of wild and hatchery spawning salmon and identified that hatchery releases may be "facilitating the extirpation of wild salmon populations in parts of the Klamath Basin." In their review, they acknowledge that hatcheries are one of many stressors on salmon populations in the Klamath River Basin. In the NMFS SONCC 5-year review, the Lower and Upper Klamath, Shasta, and Salmon River populations were estimated to be at a high extinction risk largely due to decreases in spawner densities (Table 5-2). Throughout the entire SONCC coho ESU, populations are largely identified as being at high extinction risk (NMFS 2016).

Table 5-2. Selected SONCC coho salmon ESU populations and their predicted current risk of extinction based on available information.
Source: NMFS (2016).

Stratum	Population	Estimated Extinction Risk	Extinction Risk Criteria Used
Central Coastal Basin	Smith River	High	Spawner Density
Central Coastal Basin	Lower Klamath River	High	Spawner Density
Central Coastal Basin	Redwood Creek	High	Spawner Density
Central Coastal Basin	Little River	Moderate	Spawner Density
Central Coastal Basin	Mad River	High	Spawner Density
Interior Klamath	Middle Klamath River	Moderate	Spawner Density
Interior Klamath	Upper Klamath River	High	Spawner Density
Interior Klamath	Shasta River	High	Spawner Density
Interior Klamath	Scott River	Moderate	Spawner Density
Interior Klamath	Salmon River	High	Spawner Density

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6. ENVIRONMENTAL BASELINE

The Environmental Baseline includes “the past and present impacts of all federal, state, or private actions and other human activities in the Action Area, the anticipated impacts of all proposed federal projects in the Action Area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process” (50 C.F.R. 402.02). The Environmental Baseline provides a reference condition to which the effects of operating the Project (Project) are added, as required by regulation (“effects of the action” definition in 50 C.F.R. 402.02).

Select elements of this section, Environmental Baseline, are discussed in this BA to provide a basis for the Effects Analysis contained in Parts 7, 8, and 9 of this document. A more thorough discussion can be found in prior ESA consultation documents (e.g., 2013 BiOp).

6.1. Climate Change

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). General climate trends identified in the Western U.S. suggest that historical 20th century warming is projected to continue with estimates varying from roughly 5 to 7 degrees Fahrenheit (°F) during the 21st century, depending on location (Reclamation 2011b).

Over the course of the 20th century, Klamath Basin average mean-annual temperature has increased by approximately 2°F in Jackson and Klamath Counties in south-central Oregon and Siskiyou County in north-central California (though large variations in annual temperature has been observed and the warming has not been steady; Reclamation 2011b). The warming rate of air temperatures for the Pacific Northwest over the next century is projected to be approximately 0.1 to 0.6°C per decade (0.18 to 1.08°F; ISAB 2007). Model results suggest that water temperatures in the Klamath River above Klamath, California, are projected to increase by approximately 5 to 6°F during the 21st century. Temperatures averaged over just the upper portion of the Basin (Klamath River above IGD) are projected to have a similar trend (Reclamation 2011b). Flint and Flint (2012) found indications that warming conditions have already occurred in many areas of the Klamath River Basin, and that the stream temperature projections for the 21st century may be an underestimate.

Projections suggest that some Western river basins may gradually become wetter (e.g., Columbia Basin) while others gradually become drier (e.g., San Joaquin and Truckee). The Klamath and Sacramento Basins have roughly equal chances of becoming wetter or drier (Reclamation 2011b); Klamath Basin annual precipitation has fluctuated considerably during the past century, varying between 20 to 45 inches (Reclamation 2011b).

Projection of climate change is geographically complex and varies considerably within the Klamath River Basin, particularly for precipitation. Precipitation conditions are generally wetter towards the coast and on the windward side of coastal mountain ranges, and precipitation tends to decrease towards the east and relatively arid conditions exist over the northern reaches of the Basin. Mean annual temperature in the lower Basin is warmer than the upper Basin, and the lower Basin experiences less variation in seasonal temperatures. Annual average temperatures are generally cooler in the interior plateau areas of the upper Basin, while warmer temperatures are observed in lower lying areas of the lower Basin and near the California coast (Reclamation 2011b). The overall precipitation change projection suggests a slight increase over the entire Basin during the early 21st century, transitioning to a northern increase and southern decrease by the 2070s (Reclamation 2011b).

Increased warming is expected to diminish the accumulation of snow during the cool season (i.e., late autumn through early spring), the availability of snowmelt to sustain runoff during the warm season (i.e., late spring through the summer), and reduce snow-water equivalents (NMFS 2010, Reclamation 2011b). Generally, snowpack decrease is projected to be more substantial over the portions of the Basin where cool season temperatures are generally closer to freezing thresholds (e.g., lower lying valley areas and lower altitude mountain ranges) and more sensitive to projected warming. In high altitude and high latitude areas, there is a chance that cool season snowpack actually could increase during the 21st century, because precipitation increases are projected and appear to offset the snow-reduction effects of warming in these locations (Reclamation 2011b). This conceptually leads to increases in December-March runoff and decreases in April-July runoff, though the degree to which these results occur in the Klamath River Basin appears to vary by subbasin (Reclamation 2011b).

For example, the Wood River and the Shasta River both have headwater areas at sufficiently high elevation and groundwater recharge areas to be more resilient than most stream reaches in the event of temperature increases and associated changes in precipitation (NRC 2004). In a study of the Klamath Basin, Mayer and Naman (2011) suggest that streamflow characteristics and response to climate vary with stream type between surface (rain basins and snowmelt basins) versus groundwater dominated basins. They posit that in the groundwater basins that sustain UKL inflows and mainstem river flows during the typically dry summers, the streamflow response to changes in snowpack are dampened and delayed and the effects are extended longer in the summer. Changes in snowpack, annual runoff, and runoff seasonality within the Klamath River Basin could change the availability of natural water supplies (NMFS 2010, Reclamation 2011b), increase the demand for water by humans (Döll 2002, Hayhoe et al. 2004), and decrease water availability for salmonids (Battin et al. 2007).

At present, most projected ecosystem impacts of climate change to fisheries are associated with decreased snowpack, reduced spring and summer discharge, and increases in air and water temperatures and include increased stress on fisheries that are sensitive to a warming aquatic habitat (Reclamation 2011b). For example, water temperature

1. Influences the time required for fish eggs to develop and the rate at which fry and juvenile fish grow;

2. Is likely to lead to shorter incubation periods and faster growth and maturation of young fish (Beckman et al., 1998);

3. Can increase metabolic costs and decrease growth during summer (Healy, 2006);

4. Causes earlier entry of juvenile salmon into the ocean; and

5. Increases exposure of fish to diseases and potentially alters the resistance of aquatic organisms to pathogens and parasites (Marcogliese, 2001; OCCRI, 2010).

Distributions of different types of cold-water refuge habitats in floodplain side channels and in-channel gravel bars (Hulse and Gregory, 2007; Burkeholder et al., 2008), and created by the exchange of stream waters and ground waters, could determine the future distribution and abundances of native cold-water fishes under warmer climate regimes (OCCRI, 2010). However, few studies have directly linked the use of cold-water habitats with the processes that create and maintain these essential refuges (OCCRI, 2010).

The ability to use storage resources to control future hydrologic variability and changes in runoff seasonality is an important consideration in assessing potential water management impacts due to climate-induced runoff changes. Increased winter runoff under climate change will not necessarily translate into increased storage of water leading into the spring season, as a result of limited storage capacity. When the future climate scenario is adjusted to reflect projected warming with precipitation increase (e.g., over the upper reaches tributaries to UKL), the conceptual effects on reservoir operations are less obvious, since changes in precipitation can offset some of the warming effects on spring–summer runoff.

While most of the predicted effects of climate change cannot be precisely forecast within the 10-year time frame of this consultation, the effects are expected to continue through the 2020s, such as increased mean seasonal runoff volume for December through March[6] (Reclamation 2011b, Table 3), and some studies suggest that the streamflows of the upper Klamath Basin may already be experiencing the effects of climate change (e.g., Mayer and Naman, 2011). It is important to acknowledge that the effects of climate change may be a factor in the operation of the Project in the future. However, the full magnitude and timing of the future effects is currently unknown.

6.2. Water Rights Enforcement

As discussed further in Part 1.3.2., in 1975 the State of Oregon began a basin-wide adjudication of all pre-1909 and federally-reserved water rights to water from the Klamath River and its tributaries in the State of Oregon. The Klamath Basin Adjudication includes hundreds of

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[6] Simulated changes in decade-mean hydroclimate suggest increases in flows of 22.3 percent in the Williamson River below Sprague River; 16.9 percent in the Klamath River near Seiad Valley; and 8.7 percent in the Klamath River near Klamath (Reclamation 2011b).

separate water right claims, including those made by the United States on behalf of the Klamath Project, Lower Klamath and Tule Lake NWRs, and the Klamath Tribes.

In 2013, the State of Oregon issued its Finding of Fact and Order of Determination, that has since been amended and corrected (i.e., the ACFFOD), which identifies, quantifies, and conditions valid water right claims. Under Oregon law, the water rights identified in the ACFFOD are enforceable unless judicially stayed.

Enforcement of water rights identified in the ACFFOD, particularly the instream flow water rights claimed on behalf of The Klamath Tribes, has significantly changed hydrology in the Upper Klamath Basin. These water rights vary by stream segment, but have a priority of "time immemorial", making them prior to (i.e., "senior" to all other water rights to water from those sources (*see* Part. 1.3.8., regarding The Klamath Tribes' water rights determined in the ACFFOD).

Through the BIA, calls have been made for OWRD to enforce The Klamath Tribes' instream flow water rights which has been done to varying degrees in every year since 2013. The level of necessary enforcement has varied over the course of the year and by stream segment, but frequently, the call on behalf of The Klamath Tribes has curtailed surface water diversions throughout much of the Upper Klamath Basin. In addition to surface water diversions, under certain circumstances, a water rights call can result in regulation of groundwater pumping. The State of Oregon, through OWRD, is responsible for and has a certain level of discretion in enforcing water rights based on a water users' call for regulation.

The ACFFOD is subject to ongoing judicial review before the Klamath County Circuit Court. Parties claiming water rights in the Klamath Basin Adjudication, including the United States, have filed various exceptions to the ACFFOD. The resolution of those exceptions is still ongoing, and the schedule for completing the adjudication is uncertain. The ACFFOD may be modified when this legal process is complete. Parties may also petition the court to judicially stay enforcement on all or portions of the ACFFOD while the exceptions are being resolved.

6.3. Lost River and Shortnose Suckers

6.3.1. Factors Affecting Suckers and their Habitat

6.3.1.1. Loss of Historical Populations and Range

The historical range of LRS and SNS has been severely reduced by drainage and management of Lower Klamath and Tule Lakes. Historically, both species occurred throughout the Upper Klamath Basin. Both species are present in UKL and tributaries, Clear Lake Reservoir and tributaries, Klamath River impoundments downstream to IGD, the Lost River, and the Tule Lake sumps (USFWS 2002a). A SNS population is present in Gerber Reservoir (USFWS 2002a). The loss of historic populations and range is a continued threat to both the LRS and SNS. Although the cause of decline for each lost population is not entirely understood, several populations of suckers are now extirpated (USFWS 2002a). Populations of suckers were historically noted in Lower Klamath Lake, including Sheepy Lake, and Lake of the Woods, though suckers in Lake of the Woods were likely bait bucket introductions by fishermen (Rose and Ford, 2004). Sucker populations in several small reservoirs on Willow Creek in the Clear Lake Reservoir subbasin appear to be ephemeral and related to hydrology. For example, these populations were extirpated in the 1990s after several consecutive drought years (USFWS 2002a) but have reestablished in several reservoirs and other locations in the tributaries (S. Burdick, personal communication, October 16, 2018). Suckers once spawned at Barkley Spring on the eastern shoreline of UKL and at several areas along the northwestern shoreline of UKL near Pelican Bay. Sucker spawning activity has not been observed since the early 1990s and is presumed to no longer occur at Barkley Spring or Pelican Bay (NRC 2004).

The range of LRS and SNS has not expanded nor contracted substantially since listing under the ESA in 1988. Since 1988, additional sucker populations have been identified in isolated sections of the Lost River drainage, within the historical range for both species that includes a population of SNSs in Gerber Reservoir and small populations of each species in Tule Lake (USFWS 2002a). Given the lack of connectivity between populations created by past and present water management and land use practices, suckers are not likely to repopulate disconnected bodies of water where they once resided.

6.3.1.2. Habitat Loss, Degradation, and Fragmentation

The diking and draining of wetlands throughout the Klamath Basin have been well documented in previous ESA section 7 consultations (Reclamation 2001a, USFWS 2002a). In the late 1800s, prior to most watershed development, approximately 223,000 to 330,000 acres (average = 276,000 acres) of shallow lake and associated wetland habitat existed. Presently, 76,000 to 122,000 acres (average = 99,000 acres) of shallow lake and wetland habitat exist in the Basin (Reclamation 2001). Overall, aquatic habitat available to suckers has decreased approximately 64 percent (or 177,000 acres) over the last century. No assessment of the amount of habitat needed to sustain a viable population is available. A concurrent, substantial decline in sucker populations over this time period was related in part to the large loss of lake and wetland habitat areas and blocked access to spawning and rearing areas and entrainment losses resulting from diversions (Reclamation 2002).

Review of U.S. Army Corps of Engineers section 7 ESA consultations indicates that some relatively minor wetland losses still occur in the Upper Klamath Basin, but effects of these actions on sucker populations are minimized during project planning and consultation (USFWS 2007a, 2007b). Dams and dikes throughout the Upper Klamath Basin converted hundreds of thousands of acres of sucker habitat for agricultural purposes (including Tule Lake), blocked sucker migration corridors, isolated population segments, and concentrated suckers into limited spawning areas, which potentially increased hybridization between species and inbreeding within species (Reclamation 2001a, inbreeding depression citation). The dams that are currently in place make it difficult (at times and locations impossible) for suckers to move throughout their historic range for resources, reproduction, or other needs. Dams throughout the Upper Klamath Basin have negatively impacted sucker habitat by altering the morphology of stream channels, water quality conditions, and habitat for exotic fish that may prey on suckers, compete with them for food and habitat, or introduce parasites or disease (Reclamation 2001a). There are seven major Project dams that fragment the habitats of listed suckers, including Clear Lake, Link River, Gerber, Malone, Miller Creek, Lost River Diversion (Wilson) and Anderson-Rose dams.

Only the LRD is equipped with a fish ladder designed specifically to allow sucker passage, which was installed and operational in spring 2005.

6.3.1.3. Habitat in Upper Klamath Lake Recovery Unit

A significant hydrological characteristic of UKL is its surface elevation, which fluctuates an average (± standard deviation) of 4.21 (± 0.94) feet annually, though UKL has fluctuated as little as 2.17 feet (1984) and as much as 6.25 feet (1995) between 1981 and 2016 (Table 6-1, USGS 11507001 (UKL) gage data). Before LRD was constructed in 1921, surface elevation of UKL was observed fluctuating between from 4,140 feet and 4,143.3 feet (Boyle 1976). Since 1921, water has been released from UKL for irrigation, wildlife refuge purposes, hydropower generation, flood control, and instream flows to support downstream fish needs (Buchanan et al. 2011). Seasonal precipitation, increased inflows, and reduced diversions have contributed to increases in UKL elevations from annual lows in the fall to peak elevations in the spring. The highest lake elevations have occurred in the spring and seasonally inundate the remaining lakeshore wetlands (Buchanan et al. 2011). Wetlands create rearing habitat for early life history stages of resident fishes, act as a sink for phosphorous, and have been an important source for tannic acids which counter the growth of cyanobacteria in lake waters (NRC 2004, Aquatic Scientific Resources [ASR] 2005). The elevation of UKL declines from approximately early-April to early-October due to agricultural diversions, decreases in tributary inflow, and releases to the Klamath River (Buchanan et al. 2011).

At present, spawning occurs in the Williamson and Sprague rivers and at a few shoreline spawning areas along the eastern shore of UKL (Hewitt et al. 2018; Figure 6-1. Spawning at shoreline areas is almost exclusively LRS (Hayes et al. 2002, Hewitt et al. 2018). Suckers currently have access to approximately 85 miles of riverine habitat for spawning and rearing in the Williamson and Sprague Rivers (Ellsworth et al. 2007). A small number of SNS may also spawn in the lower Wood River (USFWS 2008a).

Reduced lake elevations do not impact access or ability to spawn in the Williamson, Sprague, and Wood rivers. Of the eastern shoreline spawning areas, spawning has been observed in recent years at Sucker Springs, Silver Building Springs, Ouxy Springs, and Cinder Flat (Perkins et al. 2000a, Hayes et al. 2002, Janney et al. 2007, Hewitt et al. 2018). Few spawning suckers were trapped at Boulder Spring when it was monitored from 1999 to 2006; it is likely some fish still spawn at Boulder Spring, but it is no longer regularly sampled and has never been remotely monitored (B. Hayes, pers. comm., October 19, 2018). Shoreline spawning occurs from early March to early June with peaks in early April through mid-May (Janney et al. 2007, Buchanan et al. 2011); few adult LRS are detected arriving in late February at the shoreline spawning areas (D. Hewitt, USGS, personal communication, November 19, 2018). Spawning at shoreline springs begins when UKL temperatures are approximately 6°C (Hewitt et al. 2012). Shoreline spawning typically occurs in water depths ranging from 0.66 to 2 feet (0.2 to 0.6 m; Scoppettone et al. 1983, Sigler et al. 1985, Perkins et al. 200b, Reiser et al. 2001). Filling UKL in the fall/winter period allows suckers to have sufficient depth to access shoreline spawning areas and increases habitat available for larval, juvenile, and adult suckers through the summer (Buchanan et al. 2011).

Lake elevation plays an important role in the availability of the shoreline spawning habitats (Table 6-2, Reclamation 2001a, 2002.). Bathymetric surveys at shoreline spawning areas have identified Silver Building Springs, Ouxy Springs, and Cinder Flats at different elevations, indicating that these springs have different amounts of spawning habitat at various lake elevations (Table 6-2, Figure 6-2).

Table 6-1. Summary statistics for end of month elevations for Upper Klamath Lake from the Period of Record, water years 1981 to 2016 (USGS 11507001 (UKL) gage data). Number of years when lake elevations were less than or equal to the lower (4,141.40 feet) and higher (4,142.00 feet) end of month (EOM) lake elevations during the spawning season (EOM February to EOM May) identified by Burdick et al (2015) as minimums unlikely to limit the duration or number of individuals spawning at lakeshore spawning grounds. Frequency of end of month June elevations identified for developing embryo and larvae habitat availability.

Month	Average ± Standard Deviation (feet)	Minimum, Maximum (feet)	Number of years < 4,141.4 feet (percent of years	Number of years < 4,142.0 feet (percent of years)
Oct	4139.24 ± 1.06	4136.92, 4141.42	Not essential	Not essential
Nov	4139.70 ± 0.89	4137.81, 4141.30	Not essential	Not essential
Dec	4140.39 ± 0.84	4138.60, 4141.82	Not essential	Not essential
Jan	4141.06 ± 0.72	4139.32, 4142.04	Not essential	Not essential
Feb	4141.96 ± 0.62	4140.40, 4142.96	9 years (25 percent)	19 years (53 percent)
Mar	4142.50 ± 0.50	4140.49, 4143.22	1 years (3 percent)	5 years (14 percent)
Apr	4142.77 ± 0.47	4141.00, 4143.32	1 years (3 percent)	2 years (6 percent)
May	4142.65 ± 0.56	4140.72, 4143.24	2 years (6 percent)	4 years (11 percent)
June	4141.96 ± 0.79	4139.43, 4143.27	8 years (22 percent) Less essential	17 years (47 percent) Less essential
July	4140.81 ± 0.89	4138.78, 4142.62	Not essential	Not essential
Aug	4139.70 ± 1.02	4137.56, 4142.32	Not essential	Not essential
Sept	4139.19 ± 1.14	4136.84, 4142.04	Not essential	Not essential

Table 6-2. The percent of area with at least one-foot water depth at spawning sites along the eastern shoreline of Upper Klamath Lake is related to lake surface elevation and differs slightly between spawning locations. Source: U.S. Bureau of Reclamation 2001a, 2002.

Lake Surface Elevation (feet)	Sucker Springs	Silver Building Spring	Ouxy Spring	Cinder Flat	Composite of Shoreline Spawning
4,142.5	92				90.5
4,142.0	77	70	61	87	73.8
4,141.5	63				62.0
4,141.0	53	48	25	73	49.8
4,140.5			0+		36.7
4,140.0	33				30.2
4,139.5					17.6
4,139.0		0+			13.8
4,138.5	0+				7.3
4,138.0				0+	5.2

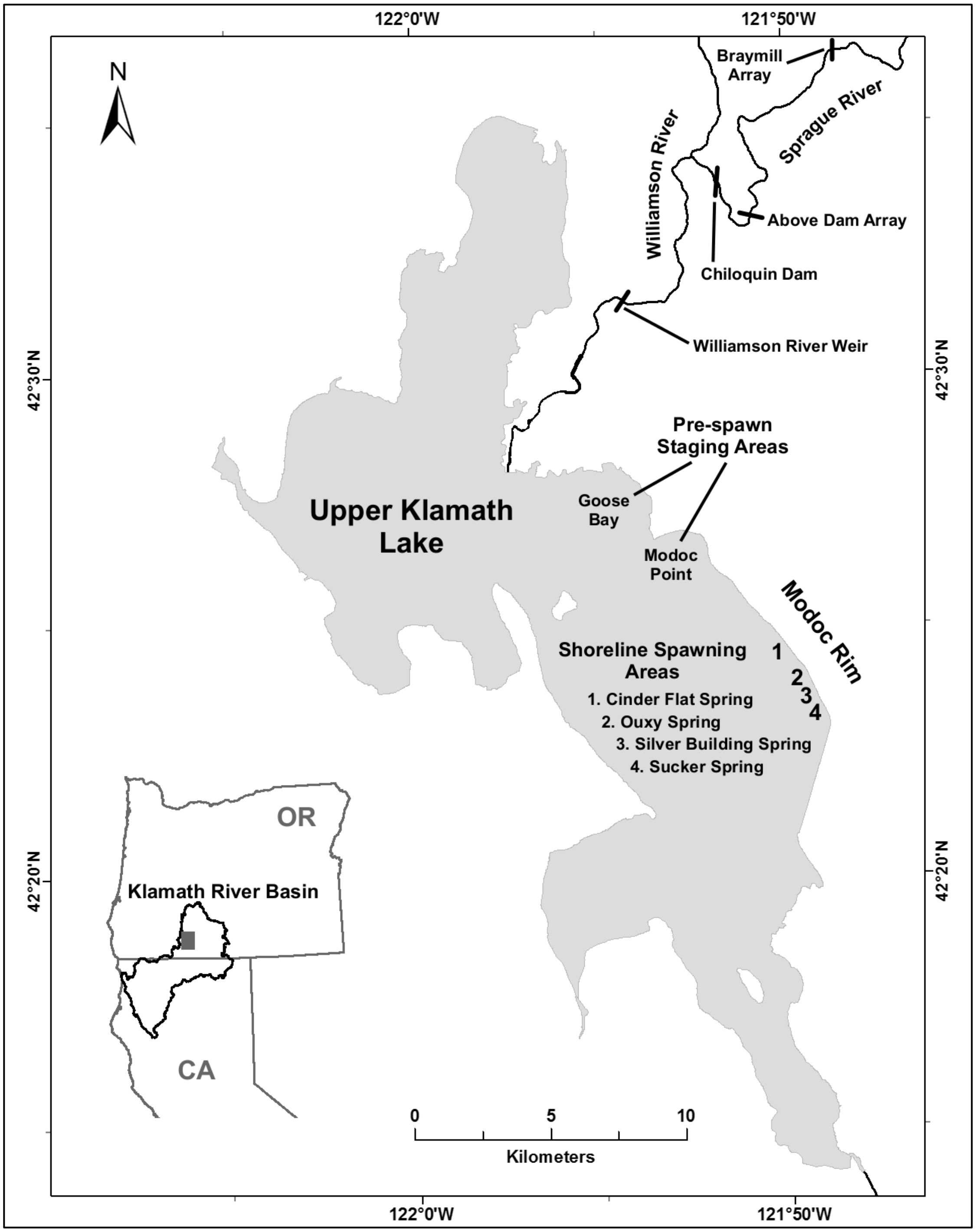

Figure 6-1. USGS sampling locations (pre-spawn staging areas, Williamson River Weir, and shoreline spawning areas) and remote detection antenna arrays for Lost River suckers and shortnose suckers in Upper Klamath Lake and its tributaries. Both species spawn in the Williamson and Sprague Rivers and a subpopulation of Lost River suckers spawn at several locations (numbered above) along the eastern shoreline of UKL during spring months each year. Inset shows Upper Klamath Lake relative to the Klamath River Basin.
Source: Hewitt et al. 2018.

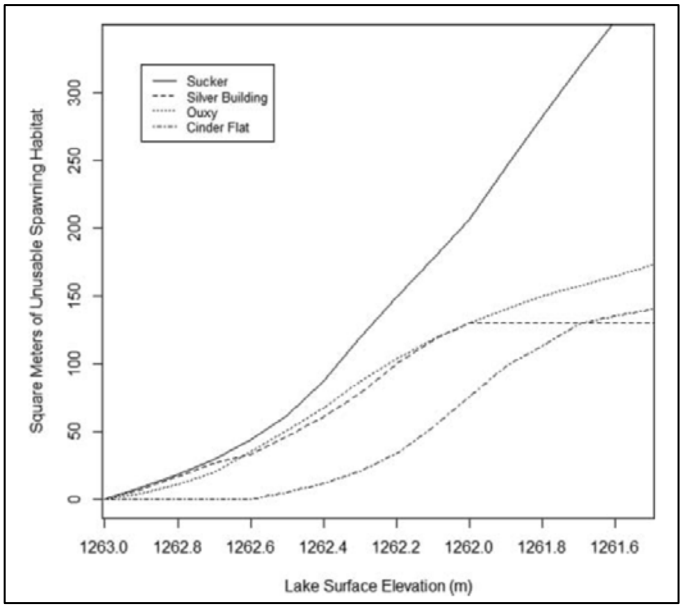

Figure 6-2. Square meters of unusable shoreline spawning habitat for Lost River suckers relative to elevation of Upper Klamath Lake. Figure from Burdick et al. 2015a. (Equivalent meters to feet for x axis are 1.0 m = 3.28 feet.)
Source: Burdick et al. 2015a.

Upper Klamath elevations necessary for shoreline spawning adults and overall egg production for LRS are above 4,141.40 to 4,142.06 feet (1,262.3 to 1,262.5 m) from February to May (Figure 6-2, Burdick et al. 2015a). Average percent inundation of spawning habitat to a depth of at least one foot at Cinder Flat, Ouxy, Silver Building, and Sucker Springs decreases from 100 percent at a full lake elevation of 4,143.3 feet to 73.8, 49.8, 30.2, and 13.8 percent at surface elevations of 4,142; 4,141; 4,140; and 4,139 feet, respectively (Reclamation 2002). At Sucker Springs, the lower extent of the spawning gravel is at an approximate elevation of 4,138.5 feet. At elevations 4,140; 4,141; 4,141.5; 4,142; and 4,142.5 feet; 33, 53, 63, 77, and 92 percent, respectively, of the spawning substrate is inundated to a depth of at least one foot (approximate minimum preferred depth for spawning).

The storage of water in UKL has generally resulted in increasing lake levels during the winter and spring with the target of filling the lake during April or May (Reclamation 2002). The result of filling UKL in the winter and spring for suckers is an increase in available spawning habitat for lakeshore spawners prior to or during the spawning season. The critical lake elevation for lakeshore spawners is 4,142 feet (Burdick et al. 2015a). When lake elevations do not reach 4,142 feet during the spawning season due to low inflows, winter irrigation deliveries, flood control releases, salmon disease mitigation flows, or drought conditions, shoreline spawning habitat is reduced impacting this subpopulation of LRS in two ways; fewer individuals participate in spawning aggregations and the amount of time adult suckers spend at spawning grounds is reduced. For example, in 2010, UKL surface elevation was low from March to June; lake elevation rose from 4,139.99 feet on March 1 to 4,141.25 feet on June 1 (USGS gage 11507001, Reclamation datum). In 2010, approximately 14 percent fewer females and 8 percent fewer males participated in shoreline spawning aggregations than in years when lake elevations were higher during spawning (Burdick et al. 2015a). Further, the median duration of time spent at shoreline spawning grounds decreased by 36 percent for females and 20 percent for males (Burdick et al. 2015a).

Lake elevations were less than 4,142 feet between end-of-month (EOM) February and EOM May in 1992 and 2010 from the POR. Average lake elevations in 1992 were slightly higher (0.61 feet) than 2010 during from EOM February to EOM May so it is likely (though not confirmed because populations were not remotely monitored) that the number of spawners and the duration of the spawn was reduced in 1992, though perhaps to a lesser degree. For the POR (WYs 1981 to 2016) lake elevations were greater than 4,142 feet in all spawning months (EOM February to EOM May) in 47 percent of years between 1981 and 2016. For most years, 1 or 2 EOM elevations (typically February, March, or May) were below 4,142 feet (Table 6-1). Within all 144 spawning-season months (4 months for 36 years) in the POR, lake elevations were greater than or equal to 4,142 feet in 79 percent of months. Lakeshore spawning suckers experienced elevations less than 4,142 feet in 19 of 36 (53 percent) at EOM February, 5 years (14 percent) at EOM March, 2 years (6 percent) at EOM April, and 4 years (11 percent) EOM May (Table 6-1). These elevations may have impacted the earliest spawners at the shoreline springs in up to 19 out of 36 years with lake elevations below 4,142 feet. However, Burdick et al. indicated the number of spawners is not impacted between 4,141.4 and 4,142 feet. Lakeshore spawning suckers had lake elevations less than 4,141.4 feet in 9 of 36 (25 percent) at EOM February, 1 years (3 percent) at EOM March, 1 years (3 percent) at EOM April, and 2 years (8 percent) EOM May (Table 6-1). During the POR, EOM February surface elevations were 4,141.4 feet or greater in 27 years out of 36 years. Thus, lakeshore spawning adult suckers have been impacted, especially in low WYs like 2010 when lake elevations were less than 4,141.3 feet from EOM February to EOM May. Within the POR, 2010 was the only year when lake elevations were less than 4,141.4 feet from EOM February to EOM May.

The effect that lake elevations less than 4,142 feet for 1 to 3 months has on the number of suckers spawning or the duration that suckers stay in the spawning area is not clear. It is possible that the impact is proportional to the elevation observed (how far below 4,142 feet) and the amount of time (how many months) elevations were less than 4,142 feet, though this has not been directly studied. The effect of insufficient lake elevations for 2 of 36 years, and 30 of 144 months is unclear because successful recruitment events are extremely rare for suckers.

The effects of reduced spawning area on gametes and larvae have not been directly studied due to challenges associated with collecting this type of data. However, it is likely that concentrated spawning at the shoreline areas have interfered with incubation of previously deposited eggs by either dislodging or smothering fertilized eggs (USFWS 2008a). Additionally, because widespread skipped spawning (entire population) has not been observed in UKL, little is known about impacts to populations or individual adult suckers. It is possible that there are both beneficial and negative impacts to an individual that skips spawning. One benefit may be an increase in body condition for females who absorb their eggs. Further, population level survival may be higher in years when spawning is skipped because fewer individuals are preyed on by avian predators. However, when some individuals skip spawning, fewer gametes are produced and there is less genetic variation in that age-class.

Habitat for egg incubation and embryo development is similar to adult spawning habitat at the shoreline areas. However, egg and embryo survival at the shoreline spawning areas may not require a minimum one-foot depth inundation of these habitats. To date, no investigations have been conducted on the depth of water required for embryo development; however, The Klamath Tribes observed over 95 percent of sucker embryos at Sucker Springs at depths greater than 1.0 foot (Reiser et al. 2001, p. 42). This observation is likely more supportive of adult sucker site selection for spawning than it is related to a minimum depth required for sucker egg incubation. Adverse effects to embyros and larval suckers are likely less when embryos have water depths similar to the depth females deposited eggs, typically 1 foot of water or more.

Spawning at the shoreline areas typically occurs from early March to late May with peak spawning in April. Maintaining inundation at lakeshore spawning habitat for several weeks will minimize desiccation of fertilized eggs and developing embryos. During the POR, lake elevations typically increased an average of 0.73 ± 0.36 feet in February, 0.72 ± 0.43 feet in March, and 0.27 ± 0.24 feet in April. However, there were three years (1982, 1986, 1999; 8 percent) when lake elevations decreased in March and four years (1992, 1994, 2003, 2015; 11 percent) when lake elevations decreased in April. Most of these reductions in lake elevation were minimal, the exceptions were March 1982 (-0.40 feet), March 1999 (-0.20 feet) and April 2015 (-0.35 feet). Despite large reductions in 1982 and 2015, lake elevations were greater than 4,142 feet after the decline and likely had no adverse effect on developing embryos. Despite the 0.2 feet reduction in March 1999, lake elevations stayed above 4141.7 feet. Thus, when the gametes deposited by lakeshore spawning adults in February, March, or early April are developing, there is no known adverse impact caused by very small elevation reductions in some years or larger reductions above 4,142 feet. Releases from UKL during the POR resulted in changes in lake elevations of an average ± standard deviation of -0.12 ± 0.34 feet in May and -0.69 ± 0.43 feet in June (EOM May to EOM June). Throughout May elevations decreased in 56 percent of years yet increased in 44 percent of years. Thus, embyros developing in May were not always impacted by changes in lake elevation. However, decreases in lake elevation greater than 0.5 foot occurred in four years in May during the POR (1992, 2007, 2012, and 2014). While lake elevations were greater than 4,142 feet during part of the spawning season in all of these years (except 1992), a reduction of 0.5 foot in May could have impacted the development of developing embryos.

The amount of emergent vegetation in Upper Klamath and Agency Lakes varies with lake elevation (Figure 6-3A). In the last century, wetlands around UKL were diked and drained for agriculture; however, in the last few decades, efforts have been taken to restore wetlands around UKL. Previously, the assessment of the percent of available wetland [sic:marsh] habitat at different lake elevations was presented in the 2012 BA (Reclamation 2012), however this analysis (Elseroad 2004) was conducted prior to the restoration of the Williamson River Delta, which created large amounts of wetland habitat. Elseroad (2004) used depth measurements collected at many locations in several wetlands and extrapolated (approximately proportionally) to the size of each wetland relative to other wetlands in UKL (Elseroad 2004). In an effort to include wetland habitat in the Williamson River Delta, Reclamation created a wetland layer of apparent emergent vegetation from satellite imagery taken in June 2018 (Figure 6-3B). Reclamation combined the wetland layer with topographic data collected by TNC prior to breaching the levees, Reclamation 2017 bathymetry data (Reclamation 2017), and 2010 LiDAR data (OLC, 2011), and derived the wetland area inundated with at least one foot of water using ArcGIS. As lake elevation decreases from spring into summer, the area of emergent vegetation available for larval sucker habitat also decreases (Table 6-3, Figure 6-3).

For the POR, the amount of wetland habitat increased substantially since The Nature Conservancy restored the Williamson River Delta. Prior to restoration, there were about 15 acres of emergent wetlands near the Williamson River mouth (Dunsmoor et al. 2000). Today, approximately 621 acres of wetland habitat is available at lake elevation 4,143 feet (Table 6-3). Since the levees were breached about a decade ago to restore the Williamson River Delta Preserve to some semblance of its natural condition, substantial changes have occurred on the landscape. The Nature Conservancy has engaged in active restoration of the Williamson River Delta including, but not limited to, reseeding upland grasses and planting shrubs, establishing riparian vegetation along the shorelines (sedges, roses, spireas, and willows), and transplanting nearly 400 wocus plants in open water areas (L. Nussbaum, The Nature Conservancy, personal communication, November 11, 2018). Inundation of the Williamson River Delta Preserve has resulted in the natural recolonization of an un-quantified amount of tule, cattail, and bulrush habitats as well (L. Nussbaum, The Nature Conservancy, personal communication, November 11, 2018). Larval suckers collected in the wetland areas were found to have fuller guts than larvae collected from refrence sites in the lake (Erdman et al. 2011), which typically results in better body condition, higher fitness, and higher survival. Providing wetland habitat for larval suckers in UKL may be important for increasing food resources, fitness, and survival.

The acreage and percentage of wetland habitat in Tulana and Goose Bay shown in Figure 6-3 and Table 6-3 were derived from pre-restoration topography data provided by The Nature Conservancy and a wetland layer created from satellite imagery taken June 2018 of apparent emergent vegetation. Reclamation 2017 bathymetry (Reclamation 2017) and LiDAR data (OLC, 2011) were used to derive percent inundation in other locations in Upper Klamath and Agency Lakes. The locations of areas considered wetlands in Upper Klamath and Agency Lakes are highlighted in green.

The wetland has been qualitatively monitored by The Nature Conservancy since 2007 but the amount of wetland habitat in the Williamson River Delta that has become available each year within the last decade is unknown. To quantify the amount of potential or emerging wetland habitat in the Williamson River Delta for larvae and juvenile suckers, Reclamation summarized EOM lake elevations from 2009 to 2016. The Baseline condition of available wetland habitat in (1) the Willimason River Delta and (2) throughout the entire lake is summarized for these 8 years. During the 2009 to 2016 POR, EOM lake elevations ranged from 4,140.44 to 4,142.17 feet (average ± standard deviation; 4,141.43 ± 0.51 feet) in June, 4,139.26 to 4,141.12 feet (4,140.21 ± 0.49 foot) in July, 4,138.60 to 4,139.92 feet (4,139.09 ± 0.40 foot) in August, and 4,137.84 to 4,139.16 feet (4,138.49 ± 0.44 foot) in September. On average, at these elevations approximately 81 percent of available wetland habitat (inundated to 1 foot or more) in the Williamson River Delta at EOM June, 77 percent at EOM July, 21 percent at EOM August and less than 10 percent (60 acres) at EOM September. Throughout the lake at these EOM elevations, an average of 95 percent of wetland habitat (inundated to 1 foot or more) was available in June, 64 percent at EOM July, 13 percent at EOM August and less than 9 percent at EOM September. It is likely that these lake elevations provided sufficient wetland habitats during June and July for larvae and juvenile suckers. The impact of decreasing amounts of wetland habitat throughout the remaining of the summer is unclear because juvenile suckers use wetland and open-water habitats (*see* Part 5.1).

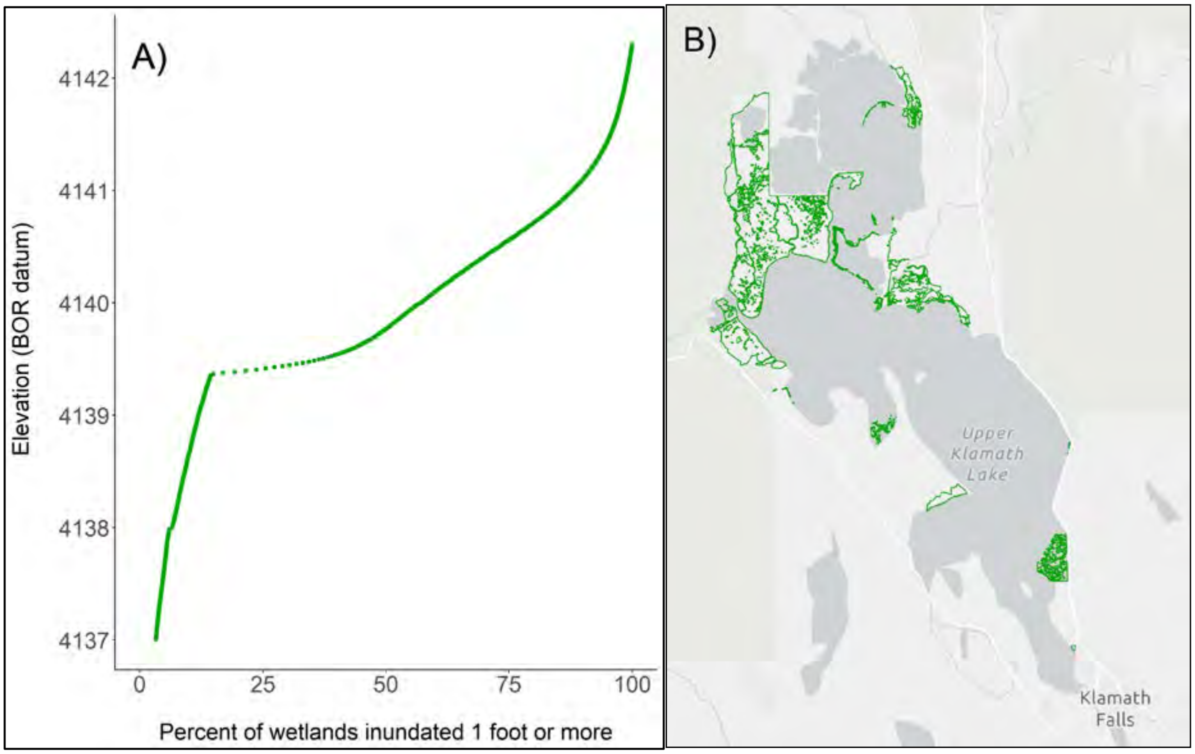

Figure 6-3. A) Availability of wetland edge habitat inundated to at least one-foot water depth available at different lake elevations (Reclamation datum) in Upper Klamath and Agency Lakes. Percentages derived from pre-restoration topography provided by The Nature Conservancy and a wetland layer created from satellite imagery taken June 2018 of apparent emergent vegetation. Reclamation 2017 bathymetry (Reclamation 2017) and 2010 LiDAR data (OLC, 2011) were used to derive percent inundation in other locations in Upper Klamath and Agency Lakes. B) Locations of areas considered wetlands likely to be considered sucker habitat in Upper Klamath and Agency Lakes are highlighted in green.

Table 6-3. Acres of emergent vegetation habitat at the Williamson River Delta under varying Upper Klamath Lake elevations.

Upper Klamath Lake Surface Elevation (feet)	Williamson River Delta Emergent Vegetation (acres)
4,143	621
4,142	566
4,141	481
4,140	365
4,139	132
4,138	61
4,137	34

During low DO events in UKL, adult suckers seek refuge areas from poor water quality, particularly Pelican Bay (Bienz and Ziller 1987, Buettner and Scoppettone 1990, Banish et al. 2007, 2009). Pelican Bay, Fish Banks, and Williamson River provide important refuge areas for juvenile and adult suckers in UKL when water quality conditions degrade during late summer. Although rare, some older juvenile suckers have been captured in the Williamson River Delta area during summer (Burdick 2012a, 2012b) and adult suckers are more commonly associated with the Pelican Bay and Fish Banks areas (Banish et al. 2009). In 2003, Banish et al. (2009) observed adult suckers congregating at Fish Banks and other areas outside Pelican Bay as water quality, particularly DO, declined in late July. In an apparent response to poor water quality, adult suckers entered Pelican Bay or congregated in the channel of Pelican Bay and were typically found in water 3.3 to 6.6 feet (1 to 2 meters) deep (Figure 6-4; Banish et al. 2009). Anderson (1991) found that water depths greater than 5 feet result in reduced predation by American white pelicans. Smaller adults (430 mm or less) and juvenile suckers, however, can be preyed on in water up to 33 feet deep by double-crested cormorants (Enstipp et al. 2006). While cormorants may not be limited by depths available in Pelican Bay, pelicans which are cooperative foragers, are better able to push suckers into shallow water at lower lake elevations (Anderson 1991). Thus, lower lake elevations when water quality conditions are poor, usually in July, August, and September, will likely increase avian predation on sucker survival. When lake elevation is 4,138.5 feet, minimum water depth from Fish Banks into Pelican Bay is 5 feet deep (Figure 6-4, Table 7-6). During the POR (1981 to 2016), lake elevations were never less than 4,138.5 feet in July. Lake elevations were less than 4,138.5 feet in the three driest years (8 percent; 1981, 1992, 1994) by EOM August, and in 9 years (25 percent) by EOM September. The risk of increased predation of adult suckers by pelicans may have been higher in years when less depth was available for access into Pelican Bay. Greater water depths in Pelican Bay and near the mouth of Pelican Bay provide suckers greater protection from avian predation. One uncertainty is the frequency of poor water quality events that cause suckers to seek refuge in Pelican Bay. Banish et al. (2009) found radio-tagged adult suckers in Pelican Bay in 2 of 3 years.

Adult suckers prefer deep water habitat in the northern portion of the lake in September, possibly to seek refuge from poor water quality such as high temperatures. Banish et al. (2009) found LRS and SNS in water with depths ranging from 13 to 20 feet (4 to 6 meters) deep in mid-September, whereas suckers were found in shallower habitat (6 to 13 feet; 2 to 4 meters deep) in July and August. The amount of habitat greater than 4 meters deep in September has varied among years (Tables 7-4 and 7-5). From 1981 to 2016, September lake elevations ranged from 4,136.9 to 4,142.1 feet. On average, lake elevations were 4,139.2 ± 1.1 feet and 903 to 957 acres (3.0 to 3.1 percent) of northern lake habitat deeper than 13 feet (4 m; Tables 7-4 and 7-5). At the lowest September EOM lake elevation in the POR, less than 900 acres of deep-water (greater than 13 feet) habitat in the northern portion of the lake was available for adult suckers. When adult suckers are concentrated into less habitat, food resources may become scarce, disease may become more prevalent, body condition may deteriorate, and mortality may increase. Adults may select depths of 13 to 20 feet deep to avoid avian predation, to obtain preferred food resources, or some other reason (Banish et al. 2009).

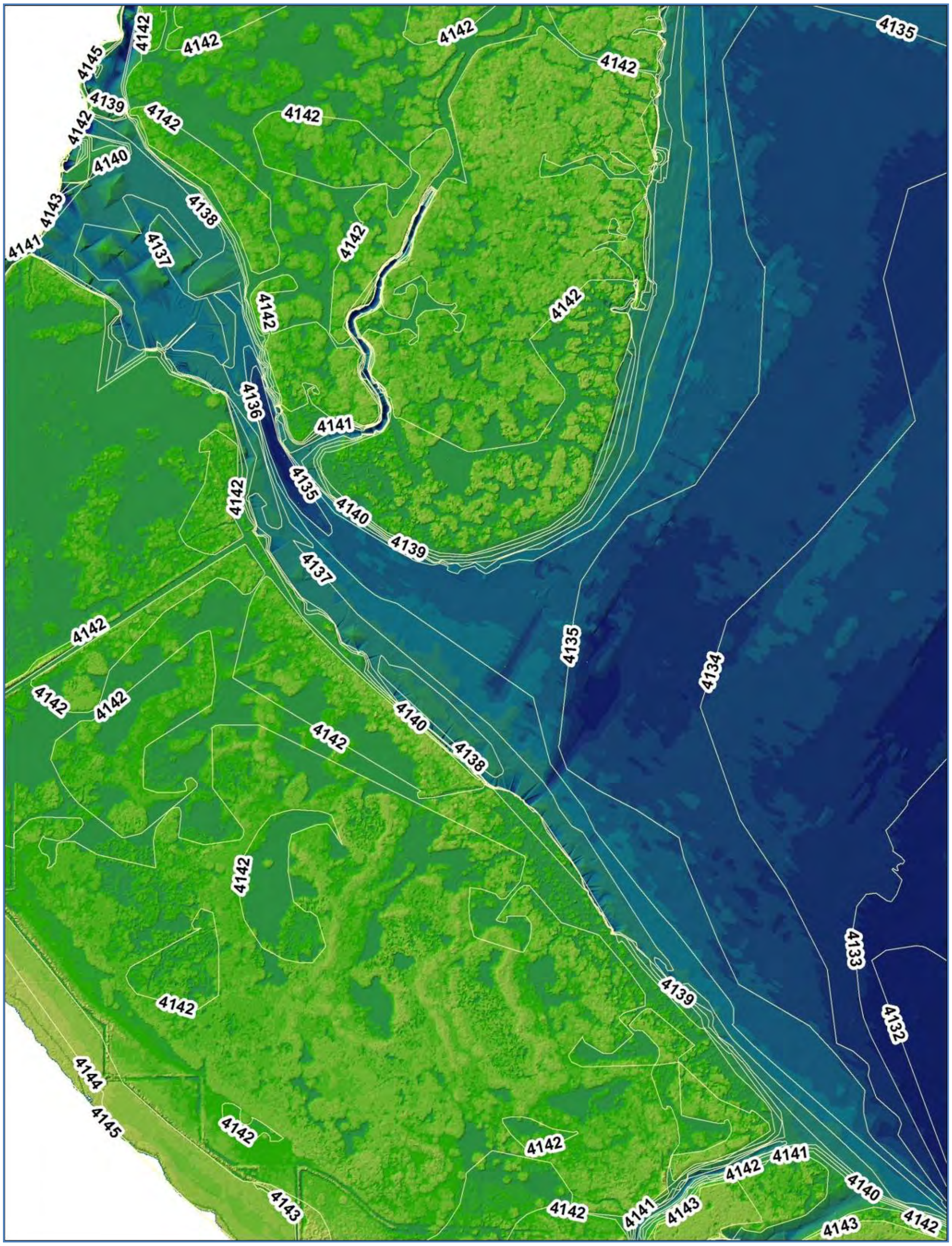

Figure 6-4. General lake bottom elevation of the access channel to Pelican Bay and the Fish Banks area to the east of Pelican Bay is about 4,135.53 feet (North American Vertical Datum 88; or about 4,133.5 feet in Reclamation datum). The terrain model was created in 2012 from multiple sources and contours were generalized and hand-edited to reduce data artifacts.

Both LRS and SNS reside downstream of UKL (NRC 2004). The 1.2-mile-long Link River is primarily used as a migration corridor for suckers moving between Keno Impoundment and UKL (Reclamation 1996, USFWS 2002). Juvenile suckers have been sampled in Link River throughout the year, suggesting that this area may provide some rearing habitat (Reclamation 1996, 2000). Below the Link River, larvae and age-0 suckers were most abundant in Keno Impoundment; juvenile and adult suckers were rare (Terwilliger et al. 2004, Reithal 2006). Small numbers of LRS and SNS were collected in both 2001 and 2002 (PacifiCorp 2004). Survey efforts in the 1990s captured only a few juvenile and adult LRS and SNS during limited sampling in the Keno Impoundment (Hummel 1993, ODFW 1996). From 2008 to 2012, Reclamation has captured and tagged a total of 1,136 SNS and 285 LRS during ongoing sampling for suckers in Lake Ewauna (Kyger and Wilkens 2011a, 2012a). From 2014 to 2017, 659 adult suckers were captured in Lake Ewauna and translocated to the Williamson River (Banet and Hewitt 2018).

Maximum water levels in the natural lake controlled by Keno Reef were similar to the currently managed Reservoir elevation (Weddell 2000). Historically, the Klamath River and Lower Klamath Lake above Keno Reef fluctuated in elevation more than they currently do (typically 1 to 1.5 feet). The historic annual fluctuation provided conditions that supported a large emergent wetland fringe to Lake Ewauna/Klamath River that is absent today (USFWS 2008a). An agreement between PacifiCorp and Reclamation specifies that the maximum water surface elevation of Keno Impoundment remains relatively constant most of the year, near 4,086.5 feet in elevation (PacifiCorp 2012). The result of constant elevations in this reach is the loss of vegetation diversity and a reduced amount of wetland habitat for suckers in the Keno Impoundment.

Sucker habitat requirements are less understood for endangered sucker populations in the Lost River Basin, such as Clear Lake and Gerber reservoirs, than in UKL, particularly at early life history stages. Habitats utilized by suckers in UKL, such as emergent vegetation, are generally scarce or absent along the shorelines of Clear Lake and Gerber reservoirs (Reclamation 2002). However, some vegetative cover may be available for larval suckers at Clear Lake and Gerber reservoirs when shoreline grasses and shrubs are flooded during high-WYs (USFWS 2002). The lower reaches of the primary spawning tributaries also provide some emergent and submerged shoreline vegetation during the spring and early summer when larvae may be present in the Lost River Basin reservoirs (USFWS 2002b). Furthermore, high turbidity of Gerber and Clear Lake reservoirs are suspected to provide additional cover for larvae where emergent vegetation is lacking (USFWS 2008a). Juvenile suckers occupy both shoreline and open-water habitats in these systems with and without vegetation (Scoppettone et al. 1995, Reclamation 2001a).

Clear Lake Reservoir. Low lake elevations and inflows associated with prolonged drought are the primary threat to LRS and SNS in Clear Lake Reservoir (USFWS 2007a, 2007b, 2008a). Clear Lake Reservoir is particularly vulnerable to drought because of the relatively small watershed, low average annual precipitation, diversions in the upper watershed, and substantial evaporation and seepage from its large surface area (USFWS 2007a, 2007b, 2008a). Additionally, Clear Lake Reservoir is more complicated than other systems due to the geomorphology of the lake; Clear Lake Reservoir is comprised of two lobes, east and west (Figure 6-5). The two lobes become hydrologically connected at a lake elevation of approximately 4,522 feet and Willow Creek (the primary spawning tributary) flows into the shallower east lobe. Most years the east lobe is connected to the deeper west lobe by a channel on the north side called the strait (Figures 6-5 and 6-6). The dam-channel gage and the west lobe gage read the same reservoir elevation at approximately 4,522.7 feet (Reclamation data).

In extreme-low WYs, the east lobe can become disconnected from the west lobe, and no longer provide adequate sucker habitat or access to Willow Creek (Figure 6-6). The dam on the northeast side of Clear Lake was constructed in 1910 to replace a berm dam (Figure 6-5). To access spawning grounds during low WYs, adult suckers in the west lobe must navigate through the strait, across the northern portion of the east lobe, into the dam channel, and up Willow Creek (lake surface elevation of 4,524 feet appears similar to Figure 6-6; Hewitt et al. forthcoming). In contrast, high lake elevations (e.g., 4,533.0 feet) provide suckers with substantial amounts of depth-cover and habitat during spawning migrations, and suckers are able to directly access Willow Creek from the east lobe (Figures 6-6; Hewitt et al. forthcoming).

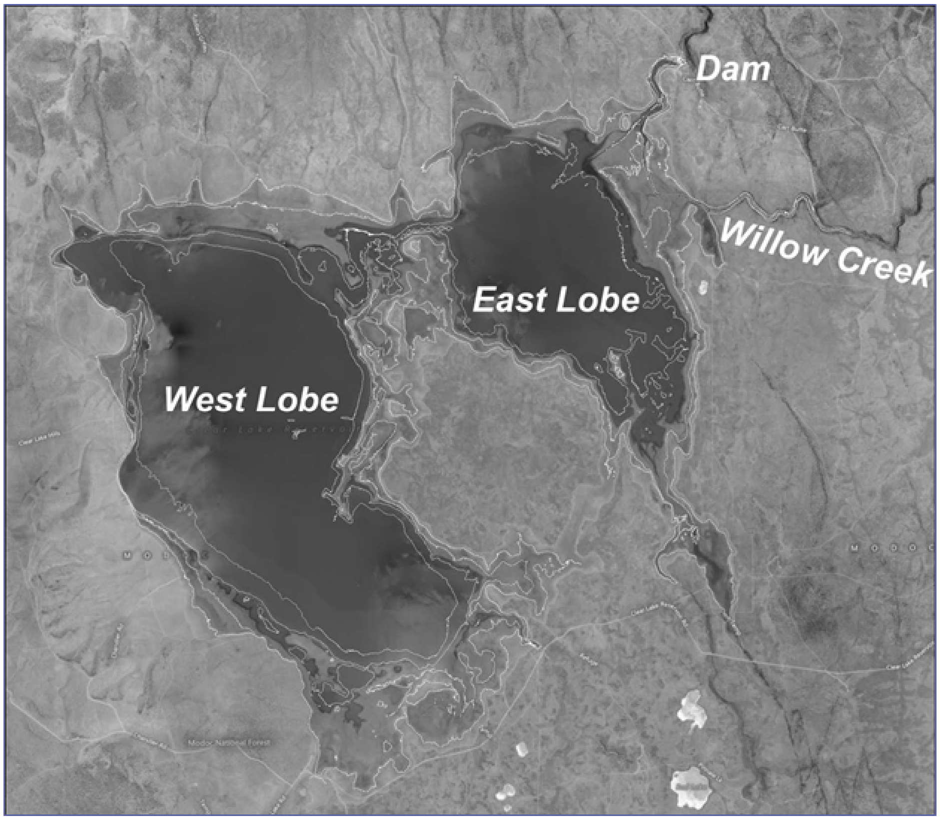

Figure 6-5. Aerial image of Clear Lake Reservoir showing the locations of Clear Lake Dam, Willow Creek, the two lobes of the Reservoir, and channels between the lobes and between the Reservoir and the Dam. Representative bathymetry of the lake is superposed on the image.

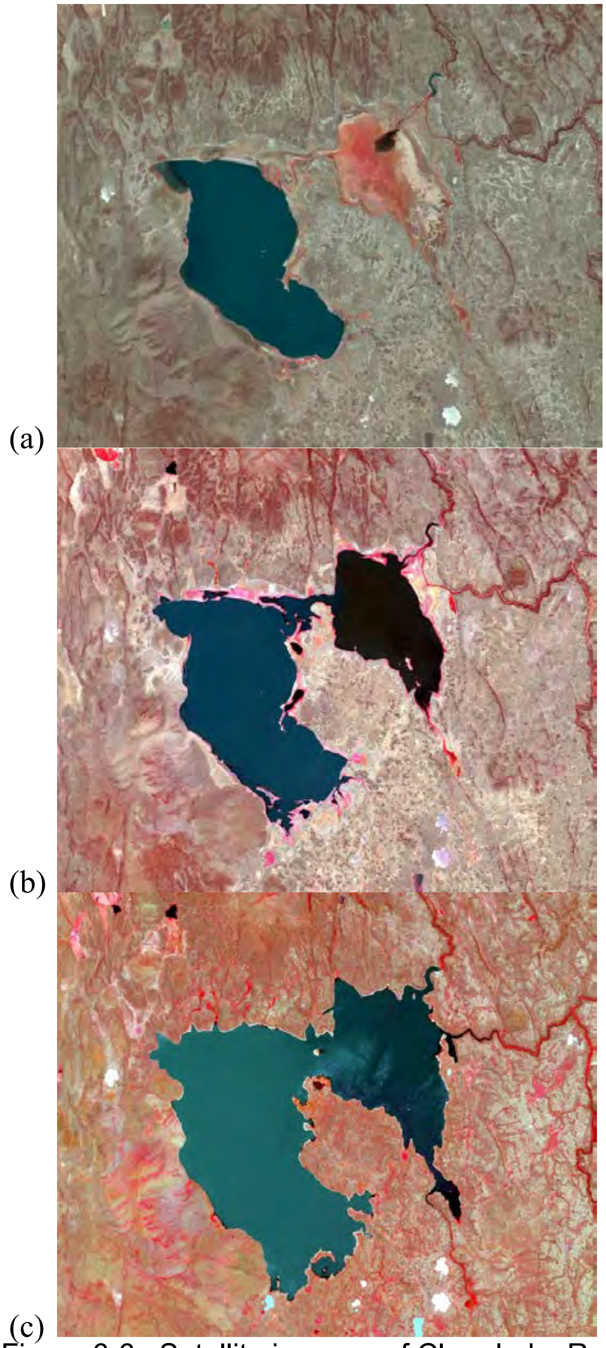

Figure 6-6. Satellite imagery of Clear Lake Reservoir at three different water surface elevations; (a) 4,518.6 feet on September 29, 2015, (b) 4,522.8 feet on August 23, 2016, and (c) 4,533.0 feet on June 19, 2017. The contrast between water and land is shown in false color imagery compiled from the near-infared, red, and green spectral bands using the geospatial software ArcGIS Pro. The first image was captured by satellite Landsat 8, the second and third images were collected by Sentinel 2A.

During a drought, lake surface elevation can decrease substantially, and elevations may be slow to recover, persisting for multiple years such as the events in the 1920s and 1930s (USFWS 2008a), and most recently 2012 to 2015 (Hewitt et al. 2019, forthcoming). Surface waters of the east lobe and the dam channel including the mouth to Willow Creek become hydrologically disconnected when Clear Lake drops below an elevation of about 4,522.0 feet (Figure 6-6; Sutton and Ferrari 2010). Typically, Willow Creek continues to contribute water to the dam forebay and later, the shallow east lobe. Access to Willow Creek is important because there are no other known sucker spawning areas in Clear Lake Reservoir. When suckers are unable to access Willow Creek in a given year, they do not spawn. As a result of tributary inflow and project-water deliveries, elevations in the dam channel are more dynamic than elevations in the west lobe (Figure 6-7). Further, even when the east lobe is filled to 4,522 feet, the west lobe may remain low, and the lobes may be fragmented for several months or years (e.g., 2013 to 2016; Figure 6-7). Several factors including seasonality, inflows from Willow Creek, deliveries from Clear Lake Reservoir for agriculture, evaporative and seepage losses, and surface water elevation in each lobe contribute to the rate the lobes equilibrate (Reclamation data, https://www.usbr.gov/pn/hydromet/klamath/arcread.html"https://www.usbr.gov/pn/hydromet/klamath/arcread.html).

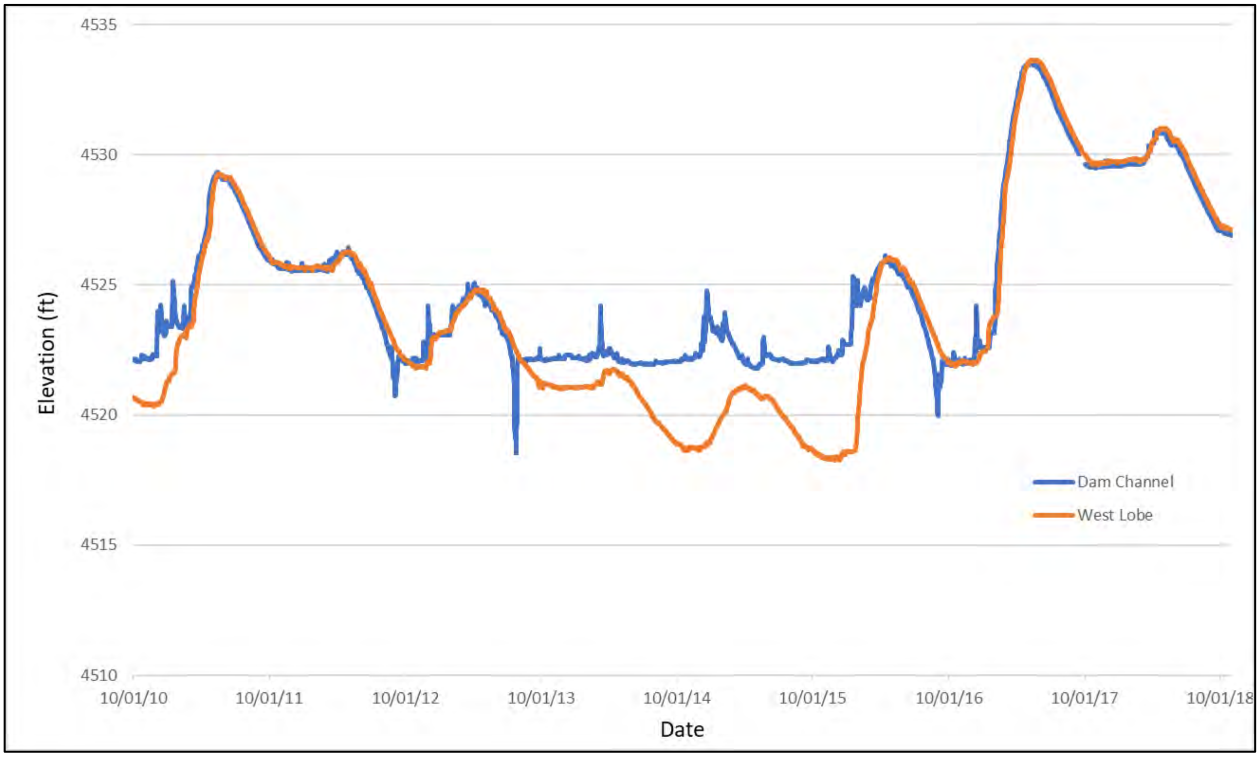

Figure 6-7. Surface elevations in Clear Lake Reservoir measured in the dam channel and the west lobe from October 1, 2010 to October 31, 2018 (Reclamation data available online). Surface elevations have been gaged in the west lobe since August 2010. The two lobes become hydrologically separated at approximately 4,522 feet.

Record low lake levels occurred in Clear Lake in the 1930s (4,515.2 feet) and again in 1992 (4,519.2 feet; USFWS 2008a). In the 1930s, low water levels persisted for eight years, reaching a minimum elevation of 4,514 feet, which is just one foot above the lowest elevation contour line shown on bathymetric maps (Reclamation 1994a). In 1992, Clear Lake Reservoir reached a low level of 4,519.4 feet after six years of drought, and the east lobe of the lake was dry, except for a small pool near the dam (USFWS 1994). Lake elevations in Clear Lake were also low 2013 to 2016 with all or portions of each year below 4,522 feet.

Low lake levels effect LRS and SNS by limiting access to spawning grounds in Willow Creek and by reducing survival through increased avian predation (USFWS 2002, 2008a, Evans et al. 2016, Hewitt and Hayes 2013, Hewitt et al. forthcoming). Annual survival ranges from 60 to 89 percent for adult LRS and 49 to 89 percent for SNS in Clear Lake Reservoir (Hewitt et al., forthcoming). Annual survival is lower in years when lake elevations are low (e.g., 2015) as suckers are more heavily preyed upon by avian predators as evidenced by PIT tags recovered from bird colonies (Evans et al. 2016, Hewitt et al. forthcoming).

When Clear Lake Reservoir elevation is 4,524.0 feet, the hydrologic control – the area between the lobes – is inundated with approximately 2.3 feet of water. This lake elevation, with flows (or pulses of flows) in Willow Creek of at least 42 to 45 cfs (discussed later) appears to be sufficient for suckers to move between lobes and access spawning grounds in Willow Creek, ascending over the historic dam (Reclamation 2003, USFWS 2008a, Hewitt and Hayes 2013; Hewitt et al. forthcoming; N. Banet, pers. comm., October 30, 2018). LRS and SNS will attempt to spawn as early as January or February in water as cool as 2to 3°C (Hewitt et al. 2019, forthcoming).

A radio telemetry study of LRS and SNS conducted in Clear Lake Reservoir and its watershed from 2015 to 2017 provides new information about how lake elevation affects the distribution of suckers before, during, and after spawning migrations (N. Banet, USGS, pers. comm., October 21, 2018). When lake elevations are low (less than 4,522 feet) both species will attempt (and sometimes succeed) to move into the east lobe, staging prior to a spawning attempt (Hewitt and Hayes 2013, Hewitt et al. forthcoming; N. Banet, pers. comm., October 30, 2018). However, when fish are unable to access the dam channel and Willow Creek they disperse to the west lobe, avoiding the shallower east lobe following the spawning season (N. Banet, USGS, pers. comm., October 30, 2018). In contrast, in moderate (2016) or high (2017) WYs LRS and SNS use both lobes approximately equally before and after spawning. During spawning migrations, LRS almost exclusively use the main stem of Willow Creek whereas SNS use smaller tributaries and migrate higher into the watershed including into Boles Creek and the Wildhorse drainage (N. Banet, USGS, pers. comm., October 21, 2018). The biological cost, however, for SNS migrating further into the watershed, is that they are less likely to return to Clear Lake Reservoir and more likely to be stranded above water-control structures in the upper watershed (N. Banet, USGS, pers. comm., October 21, 2018). Stranding is suspected to be the cause of mortality for at least some of these fish.

Annual changes in lake elevation in Clear Lake Reservoir vary dramatically among years. In wet years like 2017, lake elevations in Clear Lake Reservoir can increase by more than 11 feet (both lobes) between January and May (Figure 6-7). In contrast, lake elevations (especially in the west lobe) may increase by less than a foot between October and May in dry years (e.g., October 2011to May 2012 and October 2011 to May 2014). This is because, as mentioned earlier, low lake elevations fragment the habitat, and water in the east lobe does not spill to the west lobe until the east side is above 4,522 feet. As a result, elevations measured in the dam channel (east lobe) are more dynamic, fluctuating with changes in inflow and water deliveries.

Flows necessary for suckers to spawn in Willow Creek are not fully understood as flows have only been remotely gaged since 2013. In the POR since 2013, lake elevations were not high enough for suckers to spawn in 2014 and 2015. However, suckers did make spawning migrations in 2013 when flows were approximately 42.5 cfs and in 2016 when flows were 42 to 45 cfs (Hewitt et al. 2019 forthcoming). If flows of 42.5 cfs in Willow Creek are adequate for suckers to spawn, spawning could have occurred in 2014 (for a few days) and in 2015 (for several days) if lake elevations were greater than 4,524 feet (Hewitt et al. 2019 forthcoming). It remains unclear, however, how long flows greater than 42.5 cfs need to persist for suckers to ascend, spawn, and migrate back to Clear Lake without getting stranded.

The extent that water impoundments in the upper Clear Lake watershed are impacting flows in tributaries and lake elevations is not understood. A Memorandum of Understanding (MOU) between Reclamation and USFS (United States Forest Service) were written before suckers were listed as endangered. Briefly, the MOUs safeguard stream connectivity through most of the spawning season, until April 1 when head gates can be closed. However, telemetry studies (described above), have identified that suckers, especially SNS, become stranded behind head gates and the ultimate cause of mortality appears to be associated with stranding near impoundments. The amount of water impounded by these diversions is unclear, though USFS has documented over 30 small impoundments in the Clear Lake drainage (J. Jayo, USFS, pers. comm,, August 22, 2018). The extent that these diversions reduce tributary flows and lake elevations is unclear and has not been directly studied.

Project users have historically diverted approximately 35 TAF from Clear Lake Reservoir each year though more has been diverted in years when water is limited from other sources (e.g., UKL and the Klamath River). In Clear Lake Reservoir, one foot of lake elevation ranges from 13 TAF at low lake elevations (e.g., between surface elevations of 4,522 and 4,521 feet) to 22 TAF at high lake elevations (e.g., between surface elevations 4,533 and 4,532 feet (Ferrari, 2007). Thus, delivering the same quantity of water (e.g., 35 TAF) from Clear Lake Reservoir when the lake elevation is low results in a larger change in elevation (particularly on the east lobe) than making the same delivery when lake elevation is high.

The exceedances on hydrologic data from Clear Lake Reservoir for the period from 1911 to 2018 indicate that surface elevations are typically above 4,520.6 feet, the elevation identified as the end of September minimum elevation in the 2013 BiOp. Further review of the hydrologic data from Clear Lake Reservoir indicates that surface elevation was at or below 4,520.6 feet at the end of September during ten years, each of which occurred after construction of Clear Lake Dam in 1910 (Appendix 6A; 1931 to 1935, 1992, 2004, 2010, 2014 and 2015). Of those ten years, five were during the 1930s, a decade of historic drought in North America, and three were in the last decade (2010, 2014, and 2015). In three of the five remaining years when surface elevations were at or below 4,520.6 feet by the end of September, surface elevations rose to above 4,524.0 feet by the end of March in the following year (Appendix 6A; 1992, 2010, 2016). However, lake elevations were just above 4,520.6 feet at the end of September in 2013, surface elevations did not increase past 4,522 feet in the next year and instead remained below 4,522 feet for nearly 2.5 years in the west lobe (Figure 6-7).

For the POR (1911 to 2018), end of month (EOM) Clear Lake Reservoir elevations were 4,524 feet or higher at the 80 percent exceedance level for February, 85 percent for EOM March, and 90 percent for the EOM April, indicating that lake elevations were high enough for suckers to access spawning grounds in all but the driest years (Table 6-4). EOM lake elevations in the historical dataset (108 years), suckers in Clear Lake Reservoir were unable to access spawning grounds in 18 years (16.6 percent) during February, 12 years (11 percent) during March, and 11 years (10 percent) during April as lake elevations were less than 4,524 feet (Appendix 6A). The effect of elevations less than 4,524 feet during spawning season (February to April) for the POR, is that adult suckers were unable to access spawning grounds in years when tributary inflows were sufficient. Tributary inflows have been gaged since 2013. From 2013 to 2016, lake elevations were high enough for some suckers to spawn in mid-March in 2013, and substantially more suckers to spawn from early February to late April in 2016.

While Clear Lake Reservoir elevations were too low in 2014 and 2015 for suckers to access Willow Creek, Willow Creek had flows similar to flows that allowed suckers to access Willow Creek in 2013 (42 to 45 cfs) at least once in each year. During Baseline years 2006 to 2016 (for which we have sucker spawning information), suckers were able to access spawning grounds in 8 of 11 years. One of the 8 years (2010) was limited to a very short period (a few days in late April and early May), likely due to low lake elevations. Very few, or no suckers were able to access spawning grounds in Willow Creek in 2009, 2014, and 2015. Low lake elevations resulted in suckers unable to access spawning grounds in 27 percent of years from 2006 to 2016. The impact missed spawning had on the sucker populations may have been beneficial for individual adults yet adverse for juvenile and future adult populations. A possible benefit for individual adults was stranding of adult suckers above dams in the tributaries was reduced or not possible when suckers could not access Willow Creek at Clear Lake Reservoir. However, for juvenile populations and future adult populations, entire year classes were not produced, or so small they were unsubstantial.

Suckers concentrated in shallow water could experience increased incidences of disease, parasitism (especially lamprey), and bird predation (USFWS 2008a, Evans et al. 2016, Hewitt *et al*. forthcoming). It is also possible that high densities of fish could deplete the remaining food supply, causing additional stress and even mortality. In 1992, when Clear Lake elevation reached a minimum of 4,519.4 feet in October, suckers showed signs of stress by the following spring including low body weight, poor development of reproductive organs, reduced juvenile growth rates, and high incidence of external parasites and lamprey infestation (Reclamation 1994a). Overall fish body conditions were improved with increased body weight and fewer external parasites and lamprey wounds at higher lake levels in 1993 to 1995 (Scoppettone et al. 1995).

Periodic low inflows and combined high seepage and evaporative losses contribute to low surface elevations at Clear Lake Reservoir (Appendix 6A). Even without irrigation releases from the Reservoir (e.g., 2014 to 2015), lake elevations continue to decline as a result of evaporation and seepage when inflows are low, especially during multi-year droughts. Prolonged duration of low inflows and relatively high losses due to evaporation and seepage results in a significant reduction in lake surface area and depth, such as what was observed from 1931 through 1935, the early 1990s, and from 2013 to 2016. Flows in Willow Creek have been gaged since 2013 and this information has been critical for better understanding the hydrology of the Clear Lake watershed and managing consistent with BiOp required lake elevations.

Table 6-4. Exceedances of Clear Lake Reservoir surface elevations (feet above mean sea level; Reclamation datum) for the period of water years 1911 through 2018. The original Clear Lake Dam was constructed in 1910.

%	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
95%	4,518.94	4,518.95	4,519.27	4,519.89	4,521.21	4,522.05	4,522.33	4,521.66	4,520.73	4,519.98	4,519.47	4,518.69
90%	4,521.26	4,521.35	4,521.77	4,521.85	4,522.56	4,523.87	4,524.18	4,523.99	4,523.31	4,522.32	4,521.30	4,521.14
85%	4,521.83	4,522.00	4,522.38	4,523.22	4,523.61	4,525.70	4,525.64	4,525.29	4,524.40	4,523.08	4,521.91	4,521.79
80%	4,522.53	4,522.52	4,523.23	4,523.86	4,524.74	4,526.22	4,526.47	4,526.07	4,524.94	4,523.83	4,522.75	4,522.38
75%	4,523.80	4,523.80	4,524.40	4,524.74	4,525.64	4,527.00	4,527.52	4,527.35	4,526.65	4,525.43	4,524.35	4,523.68
70%	4,524.33	4,524.51	4,525.24	4,525.91	4,526.38	4,527.39	4,528.59	4,528.17	4,527.35	4,526.20	4,525.10	4,524.39
65%	4,525.56	4,525.84	4,526.24	4,526.69	4,527.12	4,528.47	4,529.02	4,529.08	4,528.54	4,527.32	4,526.58	4,525.78
60%	4,526.29	4,526.22	4,526.69	4,527.15	4,528.01	4,529.52	4,530.05	4,529.84	4,529.15	4,528.00	4,527.16	4,526.77
55%	4,526.97	4,527.04	4,527.77	4,528.25	4,529.10	4,530.57	4,531.25	4,530.67	4,530.01	4,529.03	4,527.94	4,527.23
50%	4,527.97	4,527.94	4,528.40	4,528.88	4,530.01	4,530.88	4,531.83	4,531.63	4,531.15	4,530.15	4,529.08	4,528.23
45%	4,529.22	4,529.18	4,529.63	4,529.94	4,530.77	4,531.62	4,532.51	4,532.40	4,531.69	4,530.99	4,530.17	4,529.50
40%	4,529.76	4,529.75	4,530.19	4,530.96	4,531.75	4,532.80	4,533.72	4,533.37	4,532.49	4,531.48	4,530.65	4,530.01
35%	4,530.49	4,530.63	4,530.80	4,531.37	4,532.46	4,533.63	4,534.23	4,533.74	4,533.23	4,532.34	4,531.46	4,530.80
30%	4,531.22	4,531.19	4,531.51	4,532.08	4,533.45	4,534.06	4,534.85	4,534.59	4,533.90	4,532.92	4,531.95	4,531.37
25%	4,531.83	4,531.71	4,532.05	4,533.32	4,533.87	4,535.11	4,535.54	4,535.13	4,534.55	4,533.53	4,532.76	4,531.87
20%	4,533.14	4,533.13	4,533.25	4,533.98	4,534.59	4,535.78	4,536.76	4,536.36	4,535.68	4,534.74	4,533.99	4,533.41
15%	4,533.48	4,533.57	4,533.78	4,534.45	4,535.62	4,536.90	4,537.79	4,537.52	4,536.62	4,535.65	4,534.63	4,533.77
10%	4,534.13	4,534.00	4,534.20	4,535.10	4,536.21	4,537.95	4,538.35	4,537.85	4,537.09	4,536.02	4,535.09	4,534.39
5%	4,534.99	4,534.92	4,535.55	4,536.12	4,537.24	4,538.80	4,539.22	4,539.04	4,538.47	4,537.47	4,536.20	4,535.53

Gerber Reservoir. LRS have not been identified as occurring in Gerber Reservoir. Use of the generic term "sucker" in Gerber Reservoir sections refers only to SNS. Shoreline spawning by SNS has not been observed in Gerber Reservoir. Adult spawning principally occurs in Barnes Valley and Ben Hall creeks. Access to these creeks requires a minimum surface elevation of approximately 4,805 feet from February through May (USFWS 2008a). Access to spawning grounds and available habitat vary with surface elevations and among years in Gerber Reservoir (Figure 6-8). Surface elevations at the end of February through May have been observed below the minimum elevation (4,805 feet) for suckers to access spawning grounds in only the driest years (95 percent exceedance) for the POR (1925 to 2017) at Gerber Reservoir including 1931, 1960, 1961, 1991, and 1992). For adult suckers in Gerber Reservoir, this results in skipped-spawning in 5 of 94 years (5 percent) due to low lake elevations. The impact low lake elevations have had on SNS populations in Gerber Reservoir is likely to be minimal. However, also necessary for SNS in Gerber Reservoir to spawn, are adequate flows in Barnes Valley and Ben Hall Creeks. During dry years both Barnes Valley and Ben Hall creeks typically have low spring flows that may not provide adequate upstream passage for spawning adults regardless of lake elevations (Reclamation 2001a). Low flows in spawning tributaries may reduce the frequency that suckers can spawn in Gerber. However, little spawning data is available for SNS in Gerber Reservior.

Surface elevations at the end of September have been observed below the proposed minimum elevation of 4,798.1 feet in 5 years from the POR (1925 to 2017) at Gerber Reservoir including 1931, 1960, 1961, 1991, and 1992), though Gerber was near minimums (4,798.18 feet) at the end of September in 2014 and end of September in 2015, and declined to below minimums before the end of October in 2015 (Appendix 6B). Lake surface elevations of at least 4,805.0 feet were reached the following spring by the end of March in every year except 1991 and 1992 (Table 6-5; Appendix 6B).

When summer surface elevations at Gerber Reservoir were less than 4,800.0 feet juvenile and adult sucker habitat were significantly reduced which likely resulted in increased competition for food, increased predation, and reduced fitness due to parasites and disease (Reclamation 2002, USFWS 2008a). Surface elevations below 4,800.0 feet are not common at Gerber Reservoir (Table 6-5) but have occurred in 14 WYs (15 percent) within the POR (1925 to 2017) including (WY (months below 4,800 feet)) 1924-25 (1 month), 1925-26 (1 month), 1926-27 (1 month), 1930-31 (2 months), 1931-32 (5 months), 1959-60 (1 month), 1960-61 (3 months), 1961-62 (4 months), and 1990-91 (3 months), 1991-92 (9 months), 1992-93 (4 months), 2013-14 (3 months), 2014-15 (5 months), and 2015-16 (3 months; also *see* Appendix 6B). When adult and juvenile suckers are concentrated into less habitat, resources may become limited, predation may be higher, and body condition may deteriorate as a result of increased disease, parasitism, or limited food resources. Some individuals may perish and mortality for the population as a whole may increase.

Surface elevations at the end of September have been observed below the proposed minimum elevation of 4,798.1 feet in 5 years from the POR (1925 to 2017) at Gerber Reservoir including 1931, 1960, 1961, 1991, and 1992), though Gerber Reservoir was near minimums (4,798.18 feet) at the end of September in 2014 and end of September in 2015, and declined to below minimums before the end of October in 2015 (Appendix 6B). Lake surface elevations of at least 4,805.0

feet were reached the following spring by the end of March in every year except 1991 and 1992 (Table 6-5; Appendix 6B).

At full pool (4,836 feet), the surface area of Gerber Reservoir is 4,000 acres, however, the surface area decreases to about 514 acres at 4,800.0 feet. Presuming suckers in Gerber Reservoir have depth preferences (6.6 feet or 2 meters or greater) similar to suckers in UKL, a surface elevation of 4,815.0 feet (not an uncommon elevation) provides adult suckers with about 1,280 acres of habitat (Peck 2000, Banish et al. 2009). In contrast, reservoir elevation of 4,800 feet provides suckers with less than 82 acres of habitat at preferred depth. However, depth preference for adult suckers at Gerber Reservoir (or Clear Lake Reservoir) has not been directly studied. During the period of 1986 through 2016, irrigation releases measured through Gerber Dam were approximately 34 to 35 TAF from April through October. An estimated 13 TAF is lost via evaporation and seepage in a high-WY (e.g., 2017; Reclamation, unpublished data).

Water quality at Gerber Reservoir is not monitored, and relatively little is known about water quality conditions in the reservoir. However, Gerber Reservoir could experience hypoxic conditions if ice (and especially deep snow on ice) covered the surface for several months. In October 1992, the water surface elevation of Gerber Reservoir reached a minimum of 4,796.5 feet before the onset of a prolonged and cold winter. No winter fish die-offs were observed (USFWS 2008a). Observations made of SNS during the summer of 1992 and following the winter of 1992 to 1993, showed signs of stress including low body weight, poor gonad development, and reduced juvenile growth rates, but there was no mass mortality (Buettner 2005, pers. comm. cited by USFWS 2008a). The impact of reduced body condition for suckers after a stressful winter was likely reduced gamete production (for adults), reduced growth, increased vulnerability to predation, disease, and or parasites; and lower survival for the population as a whole (though this was not quantified).

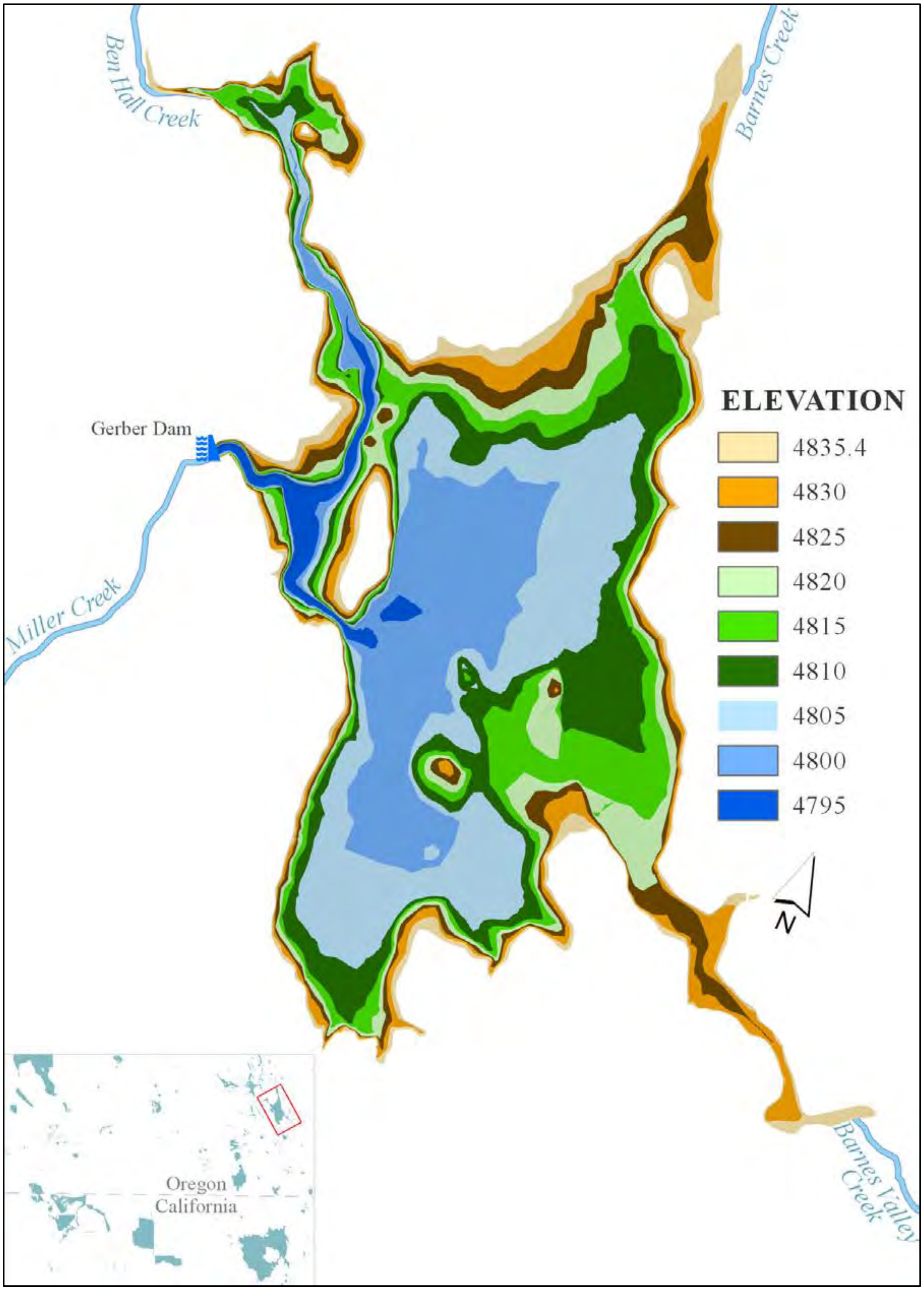

Figure 6-8. Wetted regions for Gerber Reservoir at different lake elevations. The upper elevations (greater than approximately 4,811 feet) were surveyed in 2001 by Reclamation. Source: Reclamation.

Tule Lake Sumps. Historically, Tule Lake was a 95,000-acre shallow lake with a small border of fringe wetlands and hosted one of the largest sucker populations (NRC). Now located within Tule Lake NWR, Tule Lake has been reduced to approximately 10,500 acres of open water and 2,500 acres of shallow wetlands (Hicks et al. 2000). The Lost River and return flows from the Project provide water to Sump 1A and Sump 1B, the deepest, separated remnants of the historic lake (Hicks et al. 2000, Reclamation 2007). Approximately 17,000 acres of farm land, acres that are part of the Tulelake NWR, surround Tule Lake (Hicks et al. 2000). This refuge was established by an executive order dated 1928. The refuge supports many fish and wildlife species and provides suitable habitat and resources for migratory birds of the Pacific Flyway. Sumps 1A and 1B are refuge facilities that are managed to meet flood control and wildlife needs, including the needs of endangered suckers. Reclamation, through a contract with TID, manages deliveries from the sumps and pumping from Pumping Plant D to aid Tule Lake NWR in maintaining the elevations necessary in the sumps to meet wildlife needs and requirements (Reclamation 2007).

Both LRS and SNS reside in Sump 1A, the larger sump of Tule Lake. The current number of suckers in Tule Lake sumps are relatively small, probably in the hundreds, possibly the low thousands of individuals, and is dominated by adults (Hodge and Buettner 2007, 2008, 2009). Surface elevations in Sump 1A have been maintained for a minimum elevation of 4,034.0 feet from October 1 through March 31 and a minimum elevation of 4,034.6 feet from April 1 through September 30 each year since the 1992 BiOp (USFWS 1992), including operations under the 2013 BiOp (NMFS and USFWS 2013).

Historically, populations of suckers in Tule Lake migrated up the Lost River to spawn at Big Springs near Bonanza, Oregon (RM 45), and probably other shallow riffle areas with appropriate spawning substrate (Coots 1965, ISRP 2005). Access to spawning areas in the Lost River is blocked by upstream diversion dams including the Lost River Diversion Dam (1912), Anderson-Rose Diversion Dam (1921), and Harpold Dam (1926). Currently, spawning migrations from Tule Lake are limited to a seven-mile portion of the lower Lost River below Anderson-Rose Diversion Dam (Hodge and Buettner 2008).

Reclamation and the USFWS have monitored endangered spawning runs from Tule Lake into the Lost River infrequently since 1991 (Reclamation 1998, Hodge and Buettner 2007, 2008, 2009). Spawning is restricted to one riffle area below Anderson-Rose Dam. Spawning runs have occurred in years that Anderson-Rose Dam spills or releases water. Releases were required as provisions of earlier BiOps (USFWS 1992, 2001, 2008a). For example, in 2006 and 2007, the Service entered into an agreement with TID to provide releases during the spawning season (USFWS 2008a). Successful egg incubation and survival of larvae to swim-up has been infrequent in recent years (Hodge and Buettner 2008, USFWS 2008a). Only two juvenile suckers were captured in Tule Lake in 2007 suggesting recruitment continues to be low (Hodge and Buettner 2008). Water levels in Tule Lake Sumps have been managed according to criteria set in previous BiOps (USFWS 2002). From April 1 to September 30, a minimum elevation of 4,034.6 feet was set in part to provide access to spawning areas below Anderson Rose Diversion Dam (USFWS 2008a).

Table 6-5. Exceedances for end of the month surface elevations (feet above mean sea level; Reclamation datum) at Gerber Reservoir 1925 through 2018.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
95%	4,797.95	4,797.94	4,800.23	4,800.12	4,804.94	4,809.13	4,809.03	4,807.95	4,804.31	4,801.93	4,799.68	4,798.15
90%	4,802.24	4,804.01	4,805.49	4,805.65	4,807.73	4,812.34	4,814.50	4,815.20	4,811.86	4,807.54	4,805.14	4,802.23
85%	4,804.18	4,804.94	4,807.04	4,808.27	4,809.13	4,814.90	4,818.65	4,817.53	4,815.29	4,811.36	4,807.19	4,803.99
80%	4,805.96	4,806.81	4,808.91	4,810.97	4,812.46	4,817.22	4,819.87	4,819.03	4,816.28	4,812.36	4,809.01	4,805.84
75%	4,806.99	4,807.46	4,809.26	4,812.22	4,814.47	4,818.67	4,821.41	4,820.16	4,817.04	4,813.49	4,809.86	4,806.96
70%	4,808.29	4,809.54	4,811.41	4,813.54	4,815.76	4,820.04	4,822.17	4,820.50	4,817.79	4,814.80	4,812.05	4,808.49
65%	4,810.51	4,810.89	4,812.86	4,814.64	4,816.83	4,821.32	4,823.27	4,821.92	4,819.11	4,815.44	4,812.95	4,810.68
60%	4,812.10	4,811.96	4,814.36	4,816.33	4,817.64	4,822.14	4,824.90	4,823.11	4,821.46	4,817.50	4,815.48	4,812.43
55%	4,813.69	4,814.14	4,815.42	4,816.79	4,818.06	4,823.81	4,826.43	4,825.00	4,822.53	4,819.63	4,816.47	4,814.01
50%	4,814.62	4,815.24	4,817.40	4,817.42	4,819.93	4,824.67	4,827.31	4,826.11	4,823.60	4,820.75	4,817.91	4,815.32
45%	4,816.83	4,816.71	4,818.68	4,817.93	4,820.82	4,825.39	4,828.69	4,827.00	4,824.52	4,821.65	4,819.16	4,817.36
40%	4,817.65	4,817.69	4,820.06	4,820.34	4,821.61	4,826.04	4,829.42	4,828.09	4,825.81	4,822.80	4,820.53	4,818.68
35%	4,819.52	4,819.78	4,820.63	4,820.75	4,822.96	4,826.77	4,830.18	4,829.80	4,828.05	4,825.29	4,822.12	4,819.91
30%	4,820.54	4,820.56	4,821.48	4,821.12	4,823.41	4,828.30	4,831.66	4,830.79	4,829.47	4,826.43	4,823.31	4,820.77
25%	4,821.02	4,821.46	4,822.45	4,823.13	4,824.75	4,830.64	4,832.23	4,831.98	4,829.72	4,826.78	4,823.58	4,821.24
20%	4,821.90	4,822.43	4,823.04	4,824.08	4,826.00	4,831.66	4,834.07	4,832.97	4,830.41	4,827.26	4,824.51	4,822.48
15%	4,822.75	4,822.91	4,823.86	4,825.59	4,828.50	4,832.58	4,834.93	4,833.58	4,831.01	4,827.99	4,825.13	4,823.41
10%	4,824.12	4,824.24	4,825.19	4,826.59	4,830.84	4,834.46	4,835.50	4,834.51	4,832.21	4,829.35	4,826.81	4,824.43
5%	4,825.57	4,825.76	4,827.54	4,829.68	4,833.20	4,835.69	4,835.81	4,834.86	4,833.16	4,830.79	4,828.06	4,825.78

Minimum flows below Anderson-Rose Dam were also previously required by the 2008 BiOp on Project operations. However, in 2009, the 2008 BiOp was amended, and those flows were no longer required as the USFWS stated in their letter dated January 6, 2009 (Reference # 8-10-09-F-070070), "…that habitat conditions in Tule Lake negatively influence recruitment far more than flows at Anderson-Rose Dam, and therefore, we determined that Term and Condition #2 [flows below Anderson-Rose Dam for spawning] is no longer necessary to minimize take of endangered suckers." Today, there are no minimum flows below Anderson-Rose Dam. Stranding of adult and juvenile suckers below Anderson-Rose Dam occurred in the spring of 2016 when flows below the dam receded quickly. Reclamation coordinated with TID in the summer of 2016 to install automatic gate controls at the dam that provides TID with much more control over spill situations at Anderson-Rose Dam; the gate sensors will reduce the likelihood of rapidly fluctuating flows and stranding risk to suckers immediately below the dam. The impact these actions have had on juvenile suckers is poor or no survival. The impact these actions have had on adults is less clear as adult suckers, while not well studied, appear to be surviving.

Water depths in Tule Lake Sumps 1A and 1B are shallow (less than five feet deep). However, lack of deep areas in the sumps and the gradual sedimentation that appears to be occurring (USFWS 2002) is detrimental to older juvenile and adult suckers that require water depths greater than three feet to avoid predation by piscivorous birds, particularly pelicans (USFWS 2008a). The USFWS has been investigating options to restore deep water habitat including small-scale dredging and flooding existing agricultural lease lands that have subsided (Mauser 2007, pers. comm. cited in USFWS 2008a). Low elevations in Tule Lake Sumps may lead to increased avian predation. PIT tags from adult suckers in Tule Lake have been found at bird nesting colonies and loafing areas (N. Banet, Fish Biologist, USGS Klamath Falls, personal communication, December 13, 2018).

During severe winters with thick ice cover, only small, isolated pockets of water with depths greater than three feet exist, increasing the risk of winter die-offs (USFWS 2008a). The April 1 to September 30 minimum elevation of 4,034.6 feet was set in part to provide rearing habitat in Tule Lake (USFWS 2008a) and the October 1 to March 31 minimum elevation of 4,034.0 feet was set to provide suckers with adequate winter water depths for cover and to reduce the likelihood of fish die-offs owing to low DO concentrations below ice cover (2008a). The impact harsh winters have on suckers is not well understood but harsh winters are likely to reduce body condition and fitness, meanwhile increasing stress and mortality associated with increased levels of parasites, disease, and predation.

Lost River. Most of the Lost River hydrologic Basin consists of old lakebeds and ancient lake terraces surrounded by basaltic mountains. The Lost River historically was a "semi-terminal" system that traveled 76 river miles starting in the uplands surrounding Clear Lake, north around Stukel Mountain, and terminated at Tule Lake. Today, the Lost River hydrology consists of a complex system of canals, pumps, and dams used to manage irrigation delivery and tail-water runoff. Much of the water flowing through the modern day lower Lost River channel comes from UKL via A Canal. This water is reused many times by different users, the primary users being agriculture and two wildlife refuges. Water flowing in the current Lost River channel empties into the Tule Lake NWR and can be pumped to the Lower Klamath Lake NWRs before flowing to the Klamath River via the KSD (Reclamation 2009).

The Lost River provides habitat for both LRS and SNS. The system was historically home to extensive sucker populations, but habitat within the Lost River is now largely fragmented and disconnected (Reclamation 2009). Sampling for suckers in the Lost River has not occurred recently, however past surveys have found suckers occurpying the Lost River (some SNS and few LRS; USFWS 2002). SNS were historically more common than LRS (Koch and Contreras 1973, Buettner and Scoppettone 1991, Shively *et al*. 2000b). The majority of suckers were caught above Harpold Dam though many were also captured in Wilson Reservoir[7] (i.e., impounded area behind the Lost River Diversion (Wilson) Dam; Shively et al. 2000b). Length-frequency distributions from Shively et al. (2000b) survey efforts indicate that several year classes were represented within the Lost River (Buettner and Scoppettone 1991, Shively *et al*. 2000b).

Juvenile and adult suckers are found throughout the Lost River, but the majority of catches were made near Harpold Dam and upstream to Miller Creek (Shively et al. 2000b). The riverine reach from Clear Lake Dam to Malone Reservoir is not expected to support large numbers of sucker populations due to its high gradient and lack of deep pool habitat (Buettner 2005 cited in USFWS 2008a). Early sucker life history stages have been identified in the impounded waters at Malone, Harpold, and Lost River Diversion (Wilson) dams (Shively et al. 2000b). Suckers were also identified in the reaches between these impoundments but in smaller numbers (Shively et al. 2000b).

Early sucker life history stages in the upper Lost River, from Wilson Reservoir up to Clear Lake Dam, are more numerous in the impounded areas, such as Lost River Diversion (Wilson) Dam and Malone Reservoir, and near natural inflow areas like Big Springs near Bonanza and Miller Creek, than other areas sampled (Shively et al. 2000b). Adequate flow and habitat conditions are likely to occur during the spring and summer with higher river flows augmented by releases from Clear Lake and Gerber Reservoirs (USFWS 2008a). Irrigation releases typically start in April, and augment groundwater and low-elevation runoff in this river reach. Flows in the upper Lost River are typically low during the fall and winter. However, they do increase downstream from tributary and spring accretions (USFWS 2008a).

Early sucker life history stages in the lower Lost River, below Lost River Diversion (Wilson) Dam, likely originated from UKL and possibly from the Lost River above Lost River Diversion (Wilson) Dam (USFWS 2008a). However, there is a lack of suitable rearing habitat in the Lost River below the Lost River Diversion (Wilson) Dam and suckers likely move downstream into Tule Lake or J Canal (USFWS 2008a). Modifications to the Lost River channel have fragmented fish habitats; however, based on fish survey results, early life history stages occupy the impoundments in modest numbers (Shively et al. 2000b), indicating that habitat is available for these life history stages at these locations.

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[7] Wilson Reservoir is impounded by Lost River Diversion Dam

Sucker populations upstream and downstream of dams in the Lost River (e.g., Malone, Miller Creek, Harpold, Lost River Diversion (Wilson) Dam, and Anderson-Rose) are physically isolated and, therefore, genetic exchange between populations is restricted to occasional downstream exchange (USFWS 2008a). Hybridization between sucker species trapped below dams may also occur at higher frequencies, because spawning fish are restricted to small and perhaps inadequate spawning areas. This may be happening below Anderson-Rose Dam in the lower Lost River (USFWS 2002). However, there is no evidence that loss of genetic variability has occurred (Dowling 2005). The dams also prevent passage to potential spawning, rearing and water quality refuge habitat, and the return of suckers that move downstream back to upstream habitat (USFWS 2008a).

Sucker spawning habitat in the Lost River is limited. Spawning has been documented below Anderson-Rose Dam, in Big Springs near Bonanza, Oregon, at the terminal end of the West Canal as it spills into the Lost River near Lorella, Oregon, lower Miller Creek, and above Malone Reservoir (Reclamation 1998, 2001, Sutton and Morris 2005, Hodge and Buettner 2007, 2008, 2009).

There is little potential spawning habitat in the lower Lost River upstream of Anderson-Rose Dam because construction of the Lost River Diversion (Wilson) Dam inundated historic spawning habitat near Olene, and because of loss and degradation of historic spawning habitat at Big Springs near Bonanza and other locations in the Lost River and its tributaries (USFWS 2008a). Suckers that reside in the lower Lost River, particularly in the lake habitat of Wilson Reservoir, may attempt to spawn at Big Springs near Bonanza, Oregon. Harpold Dam, including several other small diversion dams near Bonanza, Oregon, is seasonally removed October until April each year, allowing fish passage during the fall, winter, and early spring. A modified vertical slot fish ladder at the Island Park (Bonanza) Diversion Dam was installed in 2006 to provide suckers with an opportunity to move above this dam during summer months.

Above Bonanza, Oregon, there is more opportunity for sucker passage in the Lost River. SNS, presumably from the Lost River near Bonanza, spawn in the lower reaches of Miller Creek during April and May of some years (Reclamation 2001a, USFWS 2002). During a spill event in 1999 adult SNS were observed spawning in Miller Creek (USFWS 2008a). Spawning runs are infrequent during non-spill years and passage from the Lost River may be restricted by the shallow water depths at the mouth of Miller Creek (Reclamation 2001a, ISRP 2005).

Much of the fish habitat, including spawning habitats, in both the upper and lower Lost River is fragmented by the presence of dams and the irregular flows effecting adult sucker passage between habitats. Adult suckers have been observed attempting to spawn in the upper Lost River immediately upstream of Malone Reservoir (Sutton and Morris 2005). Adult suckers have also been observed spawning below Anderson-Rose Dam in the lower Lost River (Hodge and Buettner 2007, 2008, 2009).

6.3.2. Water Quality

In general, LRS and SNS are relatively tolerant of degraded water quality conditions. They tolerate higher pH, temperature, and un-ionized ammonia concentrations, and lower DO concentrations than many other fishes (Saiki et al. 1999, Meyer and Hansen 2002, NRC 2004).

Nonetheless, poor water quality events resulting in stressful and potentially lethal conditions for both LRS and SNS periodically occur at each body of water within the Upper Klamath Basin. This section describes past and present adverse water quality events at each body of water and the known and possible relationships between adverse water quality and other variables that have impacted suckers.

6.3.2.1. Water Quality: Upper Klamath Lake

While UKL was historically eutrophic (Sanville et al. 1974, Johnson 1985), large-scale watershed development from the late-1800s through the 1900s has likely contributed to the current hypereutrophic condition in UKL (Bortleson and Fretwell 1993). This legacy, combined with current nutrient loading from the watershed and lake sediment, facilitates extensive cyanobacteria blooms (Boyd et al. 2002) that typically result in large diel fluctuations in DO and pH, high concentrations of the hepatotoxin microcystin, and toxic levels of un-ionized ammonia during bloom decomposition (Boyd et al. 2002, Walker et al. 2012). Together, these conditions create a suboptimal environment for native aquatic biota and likely play a role in the decline of ESA-listed SNS and LRS (Perkins et al. 2000a). Indeed, in recent decades, UKL 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 (Buettner and Scoppettone 1990, Banish *et al*. 2007, Banish et al. 2009).

Phosphorus is the key driver of water quality issues in UKL (Boyd et al. 2002, Walker et al. 2012). Phosphorus occurs in relatively high levels in the local geology of the Upper Klamath Basin (Boyd et al. 2002, Walker et al. 2015), but has been, and continues to be, produced through past and current land use activities in the watershed (Walker et al. 2012, Walker et al. 2015). Specifically, average annual external phosphorus load to UKL is now approximately 40 percent higher than the natural background (Boyd et al. 2002, Walker et al. 2012). Additionally, the intact riparian areas and lake-fringe wetlands that historically filtered and retained phosphorus have been much diminished, further exacerbating the phosphorus loading issue. These factors, combined with internal loading as a result of current and historical external load (Boyd et al. 2002), result in summer water column phosphorus concentrations up to six times higher than the natural background (NRC 2004).

In 1998, Oregon Department of Environmental Quality (ODEQ) placed UKL and its tributaries on the 303(d) list of Oregon waters with impaired beneficial uses (ODEQ 1998). Subsequently, the UKL Drainage TMDL identified phosphorus as the key pollutant and recommended total phosphorus loading targets as the primary method to improve UKL water quality (Boyd et al. 2002). Specifically, the TMDL calls for a 40 percent reduction in external total phosphorus loading to limit the underlying causes of adverse water quality conditions (Boyd et al. 2002). 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 (Wherry and Wood 2018).

The focus on phosphorus loading and concentrations is critical to disrupt the processes directly linked to water quality issues in UKL, namely large cyanobacteria blooms during the growing season (Boyd et al. 2002). Of specific concern is the cyanobacteria species *Aphanizomenon flos-aquae* (AFA), which has only been present in UKL since the onset of large-scale watershed development in the late 1800s and early 1900s (Eilers et al. 2004, Bradbury et al. 2004). AFA, a nitrogen-fixing cyanobacteria, now dominates the UKL phytoplankton community during the growing season with bloom biomass reaching several orders of magnitude greater than that of other phytoplankton species (Nielsen et al. 2017). During bloom development and proliferation, AFA photosynthesis facilitates an increase in pH (Jassby and Kann 2010, Nielsen et al. 2017), often above levels thought to be stressful to SNS and LRS (Loftus 2001). At this same time, increasing water temperature and nighttime AFA respiration combine to reduce DO concentrations, which may pose additional challenges to listed suckers. Typically, by late July or early August, and often in tandem with hot and calm conditions, AFA blooms “crash” (Jassby and Kann 2010, Nielsen et al. 2017), resulting in increased organic biomass available for decomposition at the sediment-water interface. Increased decomposition subsequently results in reduced DO and possibly increased un-ionized ammonia concentrations, both of which may be stressful or lethal to listed suckers (Saiki et al. 1999, Loftus 2001), depending on the extent and duration of the suboptimal concentrations. In addition to changes in these water quality parameters, AFA bloom crashes increase the amount of available nitrogen for uptake by other phytoplankton, primarily the toxin-producing cyanobacteria *Microcystis aeruginosa* (Jassby and Kann 2010); UKL is often under an Oregon Health Authority recreational use health advisory for the algal toxin microcystin, produced by *Microcystis aeruginosa*, by early July. While there isn’t clear direct evidence that microcystin negatively affects listed suckers, it is another possible chronic stressor (Martin et al. 2015) and has been implicated in fish die-offs in other locations (Zanchett and Oliveira-Filho 2013). Regardless, adverse water quality events associated with AFA bloom dynamics may have lethal impacts to individual suckers (Perkins et al. 2000b) and may reduce the reproductive capacity of the populations by reducing the numbers of larger and more fecund females (Buchanan et al. 2011). Adverse water quality may also affect young suckers (Buchanan et al. 2011, Hereford et al. 2018), but the existing data has been unable to discern a clear relationship.

As mentioned above, past and current external phosphorus loading and internal loading (as a result of past external loading) are believed to be key drivers behind AFA bloom dynamics and subsequent water quality issues in UKL (Boyd et al. 2002, Walker et al. 2012). Additionally, there are specific meteorological conditions that further influence bloom dynamics. Both Wood et al. (1996) and Morace (2007) found a relationship between spring air temperature and the timing of the onset of the AFA bloom. The onset of the AFA bloom was delayed when spring air temperatures were cooler (Wood et al. 1996, Morace 2007). It has also been hypothesized that smoke or cloud cover can reduce the capacity of AFA to recover after a bloom crash (Morace 2007), which can result in depressed DO concentrations for extended periods. Conversely, a decrease in wind speed and an increase in air temperature and solar radiation in July and August can result in thermal stratification of UKL, which subsequently creates suboptimal conditions for AFA and typically leads to a bloom crash (Jassby and Kann 2010, Nielsen et al. 2017).

There is some support for the proposition that UKL surface elevation may also influence AFA bloom dynamics. For instance, Walker (2010) recommended a specific UKL elevation trajectory that targets higher lake elevations in the spring and early summer, but then “threads the needle” to avoid lake elevations (both high and low) that facilitate lower DO concentrations and higher un-ionized ammonia concentrations in the late summer and early fall. Specifically, Walker

(2010) suggests that higher UKL elevations reduce AFA biomass by reducing light intensity in the water column and increasing the ratio of sediment to water volume, thereby diluting the effects of internal phosphorus loading. Conversely, increasing UKL elevations above certain levels in the late summer increases the likelihood of thermal stratification, thereby exacerbating issues related to low DO and increasing un-ionized ammonia concentrations (Walker 2010). Previous work (Horn and Lieberman 2005) provides some support for the hypothesis that UKL depth may affect DO concentrations, however this work relied on prior UKL bathymetry, assumed a conservative diffusion coefficient (i.e., assumed slight reaeration due to wind and water surface contact with air), and suggested that the changes in probability of DO concentrations stressful or lethal to suckers changed little over the recent range of UKL elevations (i.e., those observed since implementation of the 2013 BiOp, a period which included three subsequent years of drought and correspondingly low UKL elevations).[8]

The most recent and best available science regarding water quality for the purposes of ESA section 7 consultations has not demonstrated a direct, consistent, and discernible relationship between UKL elevation and water quality (Wood et al. 1996, NRC 2002, Morace 2007, Jassby and Kann 2010, Nielsen et al. 2017, Wherry and Wood 2018; Evan Childress, pers. comm., November 20, 2018). Specifically, NRC (2002) did not find a relationship between UKL elevation and AFA density (represented by chlorophyll-*a* concentrations) and determined that the hypothesis that maintaining higher UKL elevations would effectively dilute internal phosphorus loading and reduce algal density was not supported. NRC (2002) also did not find a quantifiable relationship between UKL elevation and extremes of DO concentrations or pH. Similarly, Wood et al. (1996) concluded there was little evidence that UKL elevation affected any of the water quality parameters considered (chlorophyll-*a* concentrations, DO concentrations, pH, and total phosphorus concentrations) when examining the seasonal distribution of data and a seasonal summary statistic. Further, Wood et al. (1996) found that low DO concentrations, high pH, high phosphorus concentrations, and prolific AFA blooms were observed each year between 1990 and 1994, regardless of UKL elevation. It is important to note that Wood et al. (1996) did suggest that the very low UKL elevations in the summer of 1992 may have influenced DO concentrations, however it was not possible to fully determine the extent to which UKL elevation played a role in adverse water quality conditions in 1992. Additionally, UKL elevations in 1992 were some of the lowest elevations on record (Kann 2010) coinciding with one of the driest years on record in the Klamath Basin; UKL elevations at or near 1992 levels therefore would only be expected in severe drought conditions, which have occurred relatively infrequently since records began. Wood et al. (1996) also identified a possible relationship between June UKL elevation and chlorophyll-*a* concentrations but concluded that the effect was likely due to degree days and that it was not possible to disentangle the effects of UKL elevation and air temperature.

Regardless, Morace (2007) replicated the analysis of Wood et al. (1996) with additional years of data and was again unable to identify a discernible relationship between UKL elevation and water quality. Morace (2007) also did not support previous findings that suggested lower spring UKL elevations may coincide with an earlier onset of the AFA bloom (Wood et al. 1996).

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[8] Certain aspects and anomalies of the Reclamation 2017 bathymetry (Reclamation 2017) continue to be analyzed.

Conversely, Jassby and Kann (2010) did find preliminary evidence of a relationship between UKL elevation and May and June chlorophyll-*a* concentrations (a proxy measure for bloom onset), however the effect was largely driven by a few influential data points, as stated by the authors of the study. Additionally, Jassby and Kann (2010) did not indicate a clear subsequent effect on water quality during the bloom crash period, when water quality is most concerning for listed suckers. Nielsen et al. (2017) suggest a possible relationship between bloom onset timing and DO concentrations during the bloom crash period, however the preponderance of data available does not suggest a direct, consistent, and discernable relationship between UKL elevation and DO concentration during the bloom crash period. In conclusion, the best available science has not demonstrated a discernible and consistent relationship between UKL elevation and water quality. In other words, currently, the best available science does not indicate that changes in UKL elevation, within the range typically observed, result in water quality conditions that are harmful to listed suckers. This does not mean that UKL elevation or water depth does not have an effect on water quality, only that the best available science has not demonstrated a direct, consistent, and discernable relationship especially within the range of UKL elevations observed from 1990 to 2016.

Finally, there is some concern that winter water quality conditions under ice cover may also adversely impact suckers (Kann 2010). Ice cover can occur on UKL from November through March, though the extent and duration are dependent on winter air temperature, precipitation, and other meteorological conditions (USFWS 2008a). The available data, while limited, indicates that winter water quality parameters do not generally fall within levels considered stressful for suckers (Reclamation 2012b). It is also unclear how lake elevations through the POR may have contributed to poor under-ice water quality conditions as there have been no documented winter fish die-offs in UKL (Buettner 2007, pers. comm. cited in USFWS 2008a).

6.3.2.2. Water Quality: Keno Impoundment

The 20-mile section of the Klamath River between LRD and Keno Dam is characterized by morphology and hydraulic residence time typical of shallow lakes, with the exception of the 1.5-mile-long Link River at the head of this reach. UKL is considered the source of greatest nutrient and biochemical oxygen demand (BOD) loads to this reach of the Klamath River during the irrigation season via export of substantial AFA biomass from UKL (NRC 2004, ODEQ 2017, Schenk et al. 2018). As documented during AFA bloom crashes in UKL, decomposition of senescing AFA in the Keno Impoundment regularly leads to suboptimal DO concentrations and pH, which persist through the growing season (ODEQ 2017). Additionally, the shallow channel morphology facilitates water temperatures typically in excess of 25°C during the summer months (ODEQ 2017). While AFA blooms are often observed in the Keno Impoundment, these blooms are typically less intense and are spatially and temporally more variable than those observed in UKL (Reclamation 2007), again suggesting that the export of biomass from UKL largely drives water quality conditions in this reach.

During the irrigation season, very little water from the Project and Lost River watershed flows to the Klamath River. Generally, the Project has been characterized as a nutrient sink, rather than source (ODEQ 2017, Schenk et al. 2018), given that only 30 percent of the flow entering the Project is returned to the Klamath River (ODEQ 2017). However, there is evidence to suggest that discharge from the LRDC can have a substantial negative impact on DO concentrations at

Miller Island in the Keno Impoundment, though the magnitude and duration of the effect is less than that resulting from releases from UKL (ODEQ 2017) and is highly dependent on Project operations.

Outside of the irrigation season, water quality in the Keno Impoundment is greatly improved, owing to lower water temperatures, and an increase DO concentrations as a result of reduced biomass in (and therefore, exported from) UKL and increased oxygen saturation with reduced water temperatures (ODEQ 2017). During this period, the LRDC, which drains the Lost River watershed and the Project, flows towards the Klamath River and thereby contributes some nutrient and BOD load to the Klamath River (Schenk et al. 2018). However, this additional load tends to be relatively small compared to the total load from UKL (Schenk et al. 2018).
The Oregon portion of the Klamath River is listed as water quality impaired by Oregon under Section 303(d) of the Clean Water Act due to DO and chlorophyll-*a* concentrations, and pH and ammonia toxicity. ODEQ issued a revised Upper Klamath and Lost River Subbasins TMDL and Water Quality Management Plan in 2017 that called for reductions in nitrogen, phosphorus, and BOD loads, and reductions in human-caused temperature increases and hydraulic modification in the Klamath River (ODEQ 2017). The TMDL noted that meeting these objectives and/or meeting the water quality standards required reductions in nutrient and BOD loads from UKL and the Lost River, and possibly oxygenation or other DO augmentation in the Keno Impoundment and Lake Ewauna (ODEQ 2017).

6.3.2.3. Water Quality: Clear Lake Reservoir

At Clear Lake Reservoir, lower water levels may result in degraded water quality, particularly higher water temperatures and lower DO. However, water quality monitoring over a wide range of lake levels and years documented water temperatures and DO concentrations that are periodically stressful to suckers but were generally adequate for sucker survival (Reclamation 2012b). Finally, recent water quality sampling from November to May of 2016-17 and 2017-18 indicates that DO concentrations under ice cover remain above 8 mg/L (Reclamation unpubl.). There are few large-scale impacts outside of cattle grazing and road infrastructure in the Clear Lake Reservoir drainage that likely influence water quality.

6.3.2.4. Water Quality: Gerber Reservoir

About 75 percent of the land in the Gerber Reservoir watershed is publicly owned under the jurisdiction of the U.S. Forest Service, Fremont National Forest, and the U.S. Bureau of Land Management, Klamath Resource Area. The condition of the watershed upstream of Gerber Reservoir is relatively good (USFWS 2008a). Both U.S. Forest Service, Fremont National Forest, and the U.S. Bureau of Land Management, Klamath Resource Area have consulted with the Service under section 7 of the ESA on grazing management in the watershed and implemented management actions that protect sucker habitat (USFWS 2008a).

Water quality monitoring over a wide range of lake levels and years has documented water quality conditions that are periodically stressful to suckers but were generally adequate for sucker survival (Piaskowski and Buettner 2003, Phillips and Ross 2012). Generally, water quality is better in Gerber Reservoir than in other large reservoirs in the Upper Klamath Basin (Phillips and Ross 2012). Observed water quality conditions in Gerber Reservoir (i.e., temperature, pH, and DO concentrations) were adequate for suckers except low DO concentrations during portions of some winter months during ice cover conditions and portions of all summer months (Piaskowski and Buettner 2003). During summer and early fall, weak stratification of the water column develops occasionally in Gerber Reservoir particularly at sites near the outlet where depth is greatest (Piaskowski and Buettner 2003). When the reservoir is stratified, DO concentrations of less than four mg/L were observed at depths generally greater than four meters. This stratified condition, and associated hypoxia, typically persists for less than a month and over a small portion of the reservoir near the dam (Piaskowski and Buettner 2003). Winter stratification and the brief periods during summer months when DO concentration is low create stressful conditions for suckers. There have not been any observed fish die-offs reported from Gerber Reservoir.

6.3.2.5. Water Quality: Tule Lake

Tule Lake is classified as highly eutrophic because of high nutrient concentrations and resultant elevated biological productivity (ODEQ 2017). Tule Lake water quality is affected primarily by the import of UKL surface water through the LRDC and A Canal during the irrigation season, and secondarily by local runoff during winter and spring months from lands below Lost River Diversion Dam on the Lost River. Also, contributing to the eutrophic status of Tule Lake is its shallow bathymetry and internal nutrient cycling from lake sediment. Water quality can vary seasonally and diurnally, especially in summer. Water quality in the sumps is similar to UKL with large diurnal fluctuations in DO concentrations and pH (Buettner 2000, Hicks et al. 2000, Beckstrand et al. 2001), largely due to high levels of aquatic macrophyte and green algal biomass during the growing season.

Water quality conditions in Tule Lake during the winter tend to be optimal for suckers, except during prolonged periods of ice cover when DO concentrations decline (USFWS 2008a). A small adult sucker die-off occurred during the winter of 1992 to 1993 during an extended period of ice cover and low DO concentrations (Reclamation, unpublished data, cited in USFWS 2008a). A minimum elevation of 4,034.0 feet from October 1 to March 31 was set to provide adequate winter depths for cover and to reduce the likelihood of fish die-offs owing to low DO concentrations below ice cover (USFWS 2008a).

6.3.2.6. Water Quality: Lost River

Local geology suggests that the Lost River was historically eutrophic (ODEQ 2017). However, as with the basin above UKL, largescale changes in land use practices in the early 1900s and manipulations of the river channel and associated waterbodies throughout the 20th century have contributed to hypereutrophic conditions in the Lost River; as a result, Lost River water quality conditions are often suboptimal for listed suckers. Nutrient loading, greatest in the middle and lower portions of the Lost River watershed (Schenk et al. 2018), contribute to growth and subsequent senescense of which facilitates a cycle of high pH and suboptimal or lethal DO and toxic ammonia concentrations (ODEQ 2017).

DO concentrations are seasonally suboptimal for listed suckers in numerous reaches of the Lost River (ODEQ 2017). Extremely low DO concentrations have been measured in Wilson Reservoir, Harpold Reservoir, and at Anderson Rose Dam in the Lost River (Reclamation 2009). Periodic fish die-offs occurred in the Lost River during the 1990s and 2000s (Reclamation 2009). Whereas DO concentrations can periodically reach stressful conditions throughout the Lost River, median DO concentrations indicate that the middle reach of the Lost River may be the most water quality impaired (Reclamation 2012b). Eight stations registered DO concentrations of 1 mg/L or less, which is likely to be acutely lethal for suckers (Saiki *et al*. 1999). Finally, ODEQ (2017) notes that biological productivity in the Lost River appears to be limited primarily by available nitrogen, suggesting that a reduction in nitrogen loading may improve water quality.

The Oregon portion of the Lost River (including KSD) is listed as water quality impaired by Oregon under Section 303(d) of the Clean Water Act due to DO and chlorophyll-*a* concentrations, and pH and ammonia toxicity. ODEQ issued a revised Upper Klamath and Lost River Subbasins TMDL and Water Quality Management Plan in 2017 that called for reductions in inorganic nitrogen and carbonaceuous BOD (ODEQ 2017). The TMDL noted that oxygenation or other DO augmentation was likely necessary in three of the impounded reaches of the Lost River in order to meet the DO water quality standard for the Lost River (ODEQ 2017).

6.3.3. Pesticide and Herbicide Applications

Up to an estimated 60 percent of Project lands (120,000 acres), including private and public, are managed for agricultural production where pesticide use is common. A majority of Project irrigation drainage is received in the area that drains into the Tule Lake sumps within Tule Lake NWR. Thus, if pesticide residues are present in drain water from these lands, concentrations may be greatest in the Tule Lake sumps. Surveys regarding pesticide impacts to suckers have largely focused on the Tule Lake sumps as a likely place that agrochemicals may accumulate within the Project. Additionally, the highest concentration of intensively grown crops (e.g., potato, onion, garlic) reside in the Tule Lake area.

Pesticide residues may accumulate in drain waters and discharge into the Keno Impoundment from the Project. Additionally, this reach receives drainage from neighboring non-project areas such as Keno Irrigation District and private lands. However, the risk from chemical exposure for suckers in the Lost River and the Keno Impoundment is likely to be less than the risk for suckers in the Tule Lake sumps due to fewer intensively grown crops in these areas such as hay, or pasture land for cattle. The risk to the suckers posed by pesticide use is dependent on many factors, including chemical toxicity, mobility, persistence, amount applied, ground water-surface water interaction, application method, and proximity of application area relative to nearby water bodies.

Once in the sumps, they volatilize, degrade, settle to the bottom with sediment, or remain in the water column where they would be highly diluted (USFWS 2008a). Based on ecological fate analyses for pesticides used on the federal lease lands (USFWS 1995), it is anticipated that pesticide use does not likely pose a threat to LRS and SNS in Tule Lake sumps when label directions are followed and when appropriate buffers are in place (USFWS 2008a). For example, being consistent with the 1995, 1996, and 2008 BiOps on pesticide use.

There is little doubt that at least trace amounts of pesticides reach the Tule Lake sumps. Since the late 1980s, low levels of pesticides were detected in the sumps (Sorenson and Schwarzbach 1991, Dileanis et al. 1996, Cameron 2007b, Reclamation 2011, Reclamation unpublished data). Of the pesticides detected in waters and sediments around Tule Lake, the levels are below those known to be acutely toxic to aquatic life (Dileanis et al. 1996, Eagles-Smith and Johnson 2012), except for detections of bifenthrin and prodiamine during two sample dates in 2011

(Reclamation 2012 Unpublished Data). A nation-wide assessment by USGS from 1992 to 2001 found pesticides at low concentrations were nearly ubiquitous in the Nation's streams and rivers, even in undeveloped watersheds (Gilliom et al. 2006).

DaSilva (2016) monitored for 34 active ingredients at Tule Lake Basin sites to include sites near the TLNWR. While two herbicides were detected (2,4-D and dicamba) in multiple locations, neither exceeded the Aquatic Life Benchmarks values for fish (DaSilva 2016).

Between 1998 and 2000, several wildlife mortalities and fish die-offs were documented and investigated on Tule Lake NWR, but with the exception of one incident in which off-refuge use of acrolein caused a fish die-off, there was little supporting evidence that implicated pesticides as causative agents in any of the mortality events (Snyder-Conn and Hawkes 2004). However, the results of the study did reveal some evidence of trace wildlife exposure to the herbicides dicamba and 2,4-D and a few cases of limited acetylcholinesterase inhibition in birds, suggesting potential low-level exposure to organophosphate or carbamate insecticides (Snyder-Conn and Hawkes 2004, Eagles-Smith and Johnson 2012). However, some pesticides and herbicides in use within the Klamath Basin can be toxic at low concentrations (Eagles-Smith and Johnson 2012). While some products are listed as toxic, the actual risk of these products is a function of exposure or the amount released into the environment.

Based on limited existing data on pesticide impacts and distribution, pesticide use information, benchmark toxicity values, and habitat use of the threatened and endangered species, a 2007 BiOp (USFWS 2007d) evaluated impacts from direct exposure to the organisms, indirect effects through pesticide-induced reduction in prey populations, and pesticide-induced reductions in water quality. Although the assessment found that some level of pesticide exposure could occur to listed species, the evidence did not support a determination that the pesticide applications were likely to cause harm to the species considered (USFWS 2008a).

While most of the sampling to date in Tule Lake suggests pesticides may not be present in concentrations that would adversely affect suckers, a lack of detection of toxic pesticides does not necessarily mean they would not have adverse effects on LRS or SNS (USFWS 2008a, Eagles-Smith and Johnson 2012). Highly toxic pesticides, like metam-sodium (Vapam), can harm fish at low concentrations, indicating that some chemicals may be present at low but harmful concentrations and may escape detection during surveys. Further, many of the newer pesticides are difficult to monitor due to their rapid break down (USFWS 2008a). Although Reclamation (2011, Unpublished Data) indicates bimonthly water samples taken during the Vapam application period resulted in no detections at Tule Lake Sump 1A. Reclamation (2012) conducted an ecological risk assessment specific to soil fumigants (e.g., Vapam) used on federal lease lands within TLNWR analyzing the toxicity, environmental fate, transport, and exposure pathways. The assessment indicated there is "sufficient information that ecological risks to terrestrial, aquatic, and invertebrate species are negligible" for the majority of exposure scenarios.

In a review of existing pesticide data from the Upper Klamath Basin, Eagles-Smith and Johnson (2012) indicate that monitoring efforts to date have not been sufficient to detect low concentrations, or trace amounts, of pesticides that could have harmful impacts. In addition to possible adverse impacts from chemicals at concentrations below acute effects low concentrations or below detectable levels (Eagles-Smith and Johnson 2012), bifenthrin and prodiamine have recently been detected in Tule Lake and the bifenthrin detection was at a concentration that could adversely impact aquatic life (Reclamation 2011, Unpublished Data, Syngenta 2008, Australian Government 2010). Although the pesticide compounds bifenthrin and prodiamine were detected, these pesticide compounds currently are not approved for use on federal lease lands. This suggests that the origins of these compounds are coming from pesticide applications on lands not under Reclamation or USFWS jurisdiction. Current pesticide use on federal lease lands is consistent with and covered under the Lower *Klamath, Clear Lake, Tule Lake, Upper Klamath, and Bear Valley National Wildlife Refuges, Final Comprehensive Conservation Plan and Environmental Impact Statement*. Tule Lake and Sacramento, California: USFWS, Pacific Southwest Region (USFWS 2017), and pesticide use on Project facilities and rights-of-way is consistent with and covered under previous BiOps.

6.3.4. Fish Health - Disease, Pathogens, and Parasites

Degraded water quality conditions may compromise fish health and increase their susceptibility to disease and parasites (Holt 1997, Perkins et al. 2000b, ISRP 2005). Several parasites are common in the Upper Klamath Basin and when combined with other environmental stressors, can have synergistic effects on the health and survival of suckers. The extent that pathogens affect suckers is not fully understood but some parasites likely contribute to sucker mortality.

Lernaea sp., a parasitic copepod or “anchor worm,” which feeds on fish tissues by puncturing the skin of its host (Briggs 1971), is a common parasite on suckers in the Upper Klamath Basin. *Lernaea* infestation was apparently absent prior to 1995. Low-level *Lernaea* infestation was first seen on YOY LRS and SNS in 1995 but prevalence (percent infested) increased substantially in the mid-to late-1990s and peaked for both species in about 2003 and 2004 (Simon et al. 2012).

Lernaea sp. are commonly found on juvenile suckers (both species) in UKL and Clear Lake during summer months, though infections appear to me more common in LRS with up to 9 attachment sites on some individuals (Burdick et al. 2017). Attachment typically occurs in the dermis, along the dorsal fin or body, but attachment can also occur in the nares (Burdick et al. 2017). Attachment sites can open a pathway for other pathogens or disease whereby causing secondary infections. Severe inflammation and necrosis (dead tissue) in the skin and muscle occur far and deep beyond the attachment site (Janik et al. 2018). The *Lernaea* that appear to affect suckers in UKL were identified by Janik et al. to be *Lernaea cyprinacae*. Prevelence of *Lernea* sp. infections appears to vary among years (Burdick et al. 2017)

The trematode metacercariae, *Bolbophorus* sp. (Janik et al. 2018), commonly called “black spot,” is a flat worm that infects the skeletal muscle tissue of LRS and SNS in UKL. Of the two species, prevalence of infection appears to be higher in SNS (Burdick et al. 2017, Janik et al. 2018). Number of metacercariae infections in suckers is typically higher for SNS than LRS; as many as 11 raised cysts have been observed on a single young of the year sucker (Burdick et al. 2017, Janik et al. 2018). Host response includes melanization of the skeletal muscle tissue that surrounds the encysted digenean metacercariae, however the surrounding tissue is typically unaffected (Burdick et al. 2015b, 2017).

A number of pathogens have been identified from moribund (dying) suckers, including Gram-negative bacterial infections of apparent *Flavobacterium columnare* which can damage gills, produce body lesions, which leads to respiratory problems, an imbalance of internal salt concentrations, and provides an entry route for lethal systemic pathogens (ISRP 2005, Foott 1997, 2004, Holt 1997). Apparent columnaris infections were found in some moribund juvenile suckers in mesocosms (Hereford *et al*. 2016, 2018). While columnaris infections are suspected to impact suckers in most cases, Morris et al. (2006) found that LRS exposed to *Flavobacterium columnare* and exposed to high concentrations of un-ionized ammonia in laboratory trials, had higher survival than those that were exposed to lower concentrations of un-ionized ammonia, or control fish. Morris et al. (2006) suggested that the the columnaris bacterial infection was killed or compromised by the highest un-ionized ammonia concentration, or that suckers exposed to *Flavobacterium columnare* had elevated immune response that allowed them to survive elevated un-ionized ammonia concentrations. These findings suggest that interactions among parasites and water quality conditions may be complex. A total of 304 bacterial genera were detected in skin mucous of YOY juvenile suckers from UKL, several of which are potentially pathogenic (Burdick et al. 2009). Further research is necessary to determine which bacteria pose a serious health risk to suckers (Burdick and Hewitt 2012).

One parasite that severely impacts young of the year SNS is the nematode larvae *Contracaecum* sp. (Janik et al. 2018). This parasite, which is approximately 17 mm in length, has been found in some (19 percent) SNS hearts, and in one (of 75) unidentified sucker heart (Janik et al. 2018). When present, the nematode enlarged and thinned the atrium, and prevented normal heart function (Janik *et al*. 2018). While not terribly common, *Contracaecum* sp. is expected to cause cardiovascular failure and inhibit swimming performance (Janik *et al*. 2018). Affected suckers are not suspected to survive (Janik et al. 2018).

While its prevalence in wild suckers is not known (Banner and Stocking 2007, Burdick et al. 2017), *Ichthyobodo* sp. (formerly *Costia* sp.) is a parasite that attaches to the gills or skin (Callahan et al. 2002). This obligate ectoparasite can cause or contribute to mortality of wild juvenile suckers by impairing normal body functions (Hereford et al. 2016, 2018). For example, *Ichthyobodo* sp. infestations in fish can cause anorexia, surface cell-death, reduced oxygen uptake, reduced ion regulation, and impaired circulation (Lom and Dyková, 1992). Interestingly, fish rarely show distress or have changes in behavior prior to mortality (Callahan et al. 2002). This parasite is commonly associated with mortality of juvenile suckers in mesocosms in UKL (Hereford et al. 2016, 2018). Trichodinid protozoan parasites have been observed on juvenile suckers from both UKL and Clear Lake (Burdick *et al*. 2015b, Janik et al. 2018)

Parasites were not identified as a threat at the time of listing, but recent information indicates they could be a threat to the suckers (Buchanan et al. 2011). Parasites can lead to direct mortality, provide a route for pathogens to enter fish through wounds, and can make fish more susceptible to predation (Robinson et al. 1998). While many parasites are common, especially in UKL, the role Project operations have on their occurrence is unknown.

Typically, there is a direct relationship between prevalence of stress and prevalence of parasites and disease. Many factors may contribute to stress (and therefore prevalence of disease and parasites) including but not limited to fish density, water quality, habitat availability, preferred-food resource availability, predation, seasonality, or some combination of these factors. For juvenile suckers in UKL, parasites or other signs of stress are relatively common though not prevalent throughout July, August, and September, and no specific disease or parasite has been found to be widespread (Burdick et al. 2017). The lack of information regarding disease, parasites, and stress affecting juvenile suckers is likely due to the inherit hardiness of the species and the difficulty for researchers to capture compromised and affected suckers using passive gear. Several studies (Saiki et al 1999, Meyer and Hansen 2002; Lease et al. 2003, Hereford et al. 2018) have found suckers show little to no sign of distress until immediately before death, despite high parasite loads, compromised water quality conditions, or other factors, which may explain why understanding causes of mortality for juvenile suckers is so difficult. Further, suckers with compromised health may be heavily predated upon.

6.3.5. Entrainment Losses

Entrainment of listed suckers can occur from the downstream movement of fish into diversions or spillways by drift, dispersion, and volitional migration (PacifiCorp 2012). Effects to fish associated with entrainment may include harassment, injury, and mortality as fish pass through or over spillways, into canals, or into pumps. Spillway mortality of entrained fish can occur from strikes or impacts with solid objects (e.g., baffles, rocks, or walls in the plunge zone), rapid pressure changes, abrasion with the rough side of the spillway, and the shearing effects of turbulent water (Clay 1995). Entrainment at and lack of passage through Klamath River dams and other irrigation structures were added to the list of threats to the endangered suckers after the original listing (USFWS 1992, NRC 2004). Entrainment into irrigation and power-diversion channels is now recognized as being responsible for losses of “millions of larvae, tens of thousands of juveniles, and hundreds to thousands of adult suckers each year” (NRC 2004). Changes in the physical structure at the southern end of UKL, such as channel cuts in natural reefs, and changes in lake hydrology likely contribute to entrainment of suckers from UKL (USFWS 2008a).

Entrainment also occurs at other diversion dams in the Project including at Clear Lake, Gerber, Miller Creek, Malone, Lost River Diversion and Anderson-Rose dams (Reclamation 2002). Clear Lake Dam was screened in 2003 to prevent entrainment of juvenile and adult suckers but not larvae. The effectiveness of the screen in excluding juvenile and adult suckers was verified in 2003 when fish salvage operations conducted below Clear Lake Dam at the end of the irrigation season captured only three suckers (Bennetts et al. 2004) compared to several hundred suckers captured before the screen was installed (Piaskowski 2002). Numerous additional points of diversions or delivery exist in the Project area including: A Canal (UKL); J Canal, Q Canal, Pumping Plant D and R Canal (Tule Lake sump); and the LRDC and its associated lateral canals (Reclamation 1992, 2001). *See* Reclamation (2001b) for more comprehensive list of diversion locations and estimated diversion quantities within the Project. Much of the effort to estimate and understand entrainment of suckers has focused on fish that move downstream from UKL. Although entrainment has not been measured at all diversions, entrainment of suckers likely occurs at other locations within the Project, particularly at unscreened diversions or diversions nearest to known populations of suckers.

Reclamation completed construction of a fish screen at the entrance to the A Canal in March 2003 to reduce fish entrainment known to occur at this diversion (Reclamation 2007). UKL has been suggested as a better suited environment for suckers than the Keno Impoundment due to the food rich environment in UKL and the frequency and duration of poor water quality events in the Klamath River (Reithal 2006, Markle et al. 2009), and access to spawning (USFWS 2008a). LRS and SNS were particularly vulnerable to entrainment at A Canal before the screen was installed. Entrainment studies at the south end of UKL from 1997 to 1999 (Gutermuth et al. 2000a, 2000b) have been utilized to estimate and understand entrainment from UKL at the Link River, A Canal, and both the East Side and West Side power developments at the Link River (USFWS 2007c, 2008, 2009, Tyler 2012a, 2012b).

Entrainment of young fish is a potentially important contributor to recruitment failure, given that the entrained larvae that are passed through through the A Canal fish screen and YOY juveniles that are entrained at LRD likely originate from known spawning aggregations in the tributaries or shoreline areas, and individuals exiting UKL to the south may be permanently lost from the population (NRC 2004).

Entrainment estimates from UKL are typically based on extrapolation of observations from Gutermuth et al. (2000a, 2000b) with A Canal fish screen assumptions and annual updates for inter-annual sucker production and water conveyance (USFWS 2008a, Tyler 2012a, 2012b, NMFS and USFWS 2013). Annual estimates for suckers exiting UKL via the Link River are variable and range between 100,000 and 6,000,000 for larvae, between about 10,000 and 140,000 for juveniles, and usually fewer than 230 adult suckers (USFWS 2008a, Korson et al. 2011, Korson and Kyger 2012, Tyler 2012a, 2012b). Not all sucker entrainment at the southern end of UKL is lethal (PacifiCorp 2012), as some adults return to UKL using the LRD fish ladder (Kyger and Wilkens 2011a, 2012a).

Of the number of YOY juvenile suckers entrained each year from UKL, some individuals may survive in the Keno Impoundment (Reithal 2006, Terwilliger et al. 2004, Phillips et al. 2011, Tyler and Kyger 2012). While this reach does not provide ideal conditions, some of these suckers may survive to older juvenile and adult life history stages and attempt returns to UKL via the LRD fish ladder. However, the number of individuals that do survive in the Keno Impoundment is likely small. Of an estimated 6 million larvae, 100,000 juveniles, and 100 older juvenile/adult suckers that disperse annually into the Keno Impoundment from UKL, an estimated 80 percent of these fish perish (i.e., about 5 million larvae, 80,000 juveniles, and 80 older juvenile/adult suckers annually) due to the impaired water quality conditions below the Link River (USFWS 2007c).

Population impacts due to the loss of larval, juvenile, and adult suckers are uncertain (USFWS 2008a, PacifiCorp 2012). Numbers of larval suckers that are estimated to be lost through entrainment represent a small proportion of the potential fecundity of the breeding population. Each female shortnose and LRS can produce up to 72,000 and 236,000 eggs per year, respectively (Perkins *et al*. 2000a). There are thousands of reproductively active female suckers in UKL each year (Janney et al. 2008, 2009, Hewitt et al. 2011), suggesting a high reproductive potential in any given year.

Whereas, there are no reliable estimates for larval and YOY juvenile suckers (USFWS 2007a, 2007b), there are extrapolations of data from surveys that inform us on the magnitude of early life history stage entrainment from UKL. Data from The Klamath Tribes (1996) estimated the total annual production for larval suckers at about 73 million. The entrainment of an estimated 6 million larval suckers represents approximately 8.2 percent of the total annual sucker production at that life history stage (USFWS 2007c). More recently, Simon et al. (2012) estimated the number of larval suckers in UKL between 19 and 29 million based on an extrapolation of early June fish surveys in 2011. Estimated entrainment at the southern end of UKL was 2.4 million larval suckers in 2011 based on amount of water exiting UKL and the magnitude of larval sucker production (Tyler 2012b). These numbers suggest that larval entrainment could represent 8 to 13 percent of estimated numbers of larval suckers available in UKL during a given year. Although using a combination of work by Simon et al. (2012) and Tyler (2012b) represents a higher percent of total annual production than using earlier estimates of larval production, data suggests that sucker larvae in 2011 were mostly retained in UKL by the central gyre rather than by shoreline retention (Simon et al. 2012). How the number of larval suckers produced and entrained affects recruitment to the adult populations in UKL is still uncertain (PacifiCorp 2012).

Entrainment of YOY juvenile suckers is also variable among years and can represent a substantial percent of the annual sucker production. Low cast net catches of YOY suckers in Lake Ewauna and higher catches in northern and middle UKL in 2011 suggest that retention of juvenile suckers was relatively high in 2011 with about 850,000 YOY juvenile suckers of both species present in early August of that year (Simon et al. 2012). Estimated entrainment at the southern end of UKL was about 7,000 YOY juvenile suckers (Tyler 2012b); however, monitoring at the fish bypass at A Canal estimated that about 140,000 YOY juvenile suckers were bypassed back to UKL (Korson and Kyger 2012). An entrainment estimate of 7,000 juvenile suckers represents less than 1 percent of 2011 YOY juvenile sucker abundance (i.e., 850,000), but using 140,000 bypassed YOY juveniles as an entrainment number represents greater than 16 percent of the 2011 YOY juvenile sucker abundance.

Long-lived LRS and SNS typically exhibit relatively low mortality. However, adult suckers in UKL are nearing their maximum life expectancy and mortality appears to be increasing rapidly (Hewitt et al. 2017, E. Janney, USGS, pers. comm., May 11, 2018); likewise, mortality for juvenile suckers continues to be widespread each year as substantial recruitment events into the adult population have not been observed (Hewitt *et al*. 2017, Burdick et al. 2018). Given the current status of suckers in UKL, it is likely that entrainment losses through A Canal bypass and LRD adversely impact sucker populations through a reduction of in the number of suckers available to recruit to the adult populations.

The number of suckers entrained at facilities decreases progressively downstream from the LRD (PacifiCorp 2012). This corresponds to the relative distribution of the suckers in reservoirs downstream of the LRD (PacifiCorp 2012). Each of these reservoirs, including the Keno Impoundment, is likely seeded by larval and juvenile suckers emigrating from UKL (Desjardins and Markle 2000). Based on entrainment studies at LRD and fish distribution studies in reservoirs, substantial numbers of larval and juvenile suckers disperse downstream from UKL to reside in the downstream reservoirs (USFWS 2007c). There is no evidence that self-sustaining populations exist in any of the reservoirs, but it is possible that some larval and juvenile suckers in the Keno Impoundment are from spawning in the Link River (Smith and Tinniswood 2007).

However, it is more likely that most of the suckers in the Keno Impoundment arrived from UKL (Markle *et al*. 2009). SNS spawning and larval production occurs in Copco No. 1 Reservoir; however, there is little recruitment into the adult population (USFWS 2007c).

Annual entrainment losses from the Keno Impoundment via the spillway at Keno Dam are nearly 570,000 larvae, nearly 15,000 juveniles, and 15 adult suckers (PacifiCorp 2012). Of these entrainment estimates, approximately 12,000 larvae and nearly 300 juveniles are thought to expire as a result of trauma while passing the spillway at Keno Dam (PacifiCorp 2012). Entrainment losses from the Keno Impoundment are also likely through the LRDC and other unscreened diversions (North Canal, Ady Canal, and other diversions). Sampling in the LRDC between Reeder Road and Tingley Lane captured eight juvenile suckers in 64 trap nets fished on 16 sample dates (Foster and Bennetts 2005). Sampling was conducted weekly from late May through late September and represents 1,200+ hours (Foster and Bennetts 2005). During the same effort, a screw trap was fished on seven dates between mid-July and early September at Station 48 on the LRDC capturing two suckers (one juvenile and one dead adult; Foster and Bennetts 2005). Fish entrainment monitoring at Miller Hill Pumping Station which feeds parts of C Canal from the LRDC in July and August 2008 did not capture suckers but did capture other fish species (Korson 2010). Fish sampling near Ady and North canals indicated the juvenile suckers are present near both locations during the summer (Phillips et al. 2011). These efforts indicate the presence of suckers in relatively low abundance in the LRDC and near other diversions that are susceptible to entrainment.

Miller Creek is located at the outlet of Gerber Reservoir and extends about nine miles downstream until it enters the upper Lost River (Reclamation 2001a). Water is released at Gerber Dam into Miller Creek for irrigation during April through September. About midway between the Dam and the Creek's confluence with the Lost River, flows are diverted into North Canal during the irrigation season. After irrigation season, remaining flows in upper Miller Creek come from groundwater influences and a small amount of flow from valves on Gerber Dam left open to prevent winter freezing of the gate controls. However, during wet years when Gerber Reservoir spills, winter and spring flows in Miller Creek can reach several hundred cfs. SNS, presumably from the Lost River near Bonanza, spawn in the lower reaches of Miller Creek during April and May of some years (Reclamation 2001a, USFWS 2002). During a spill event in 1999, adult SNS were observed spawning in Miller Creek (USFWS 2008a). Spawning runs are infrequent during non-spill years and passage from the Lost River may be restricted by the shallow water depths at the mouth of Miller Creek (Reclamation 2001a, ISRP 2005). Gerber Dam is not screened against the entrainment of fish from the Reservoir. The infrequency of spawning in Miller Creek and the absence of a fish screen at Gerber Dam suggests that most of suckers encountered in Miller Creek are likely a result of entrainment from Gerber Reservoir.

Past survey efforts of Miller Creek indicate that up to several hundred suckers are likely entrained into Miller Creek from Gerber Reservoir annually. In 1992 and 1993, 229 and 34 SNS, respectively, were salvaged immediately below Gerber Dam (Reclamation 1994b). Most fish in both years were juveniles (Reclamation 1994b). Since 1993, no salvage has occurred below Gerber Dam due to safety considerations (Bennetts and Piaskowski 2004). In 2003, Reclamation captured 72 juvenile suckers (YOY and older juveniles) in Miller Creek below Gerber Dam during 1,078.9 hours of screw trap sampling from June 12 through October 1

(Hamilton et al. 2004). Sucker catch per unit effort is approximately 0.067 suckers per hour. Assuming a static catch per unit effort for suckers, the estimated number of individuals that would have been captured in screw trap sampling of Miller Creek throughout the 2003 irrigation season is approximately 217 juvenile suckers (e.g., 135 days*24 hours*0.067 suckers per hour).

Reclamation also operated a screw trap in North Canal (of Miller Creek drainage) in 2003 and captured 49 juvenile suckers during 1,193.9 hours of screw trap sampling from June 4 through October 1 (Hamilton et al. 2004). The sucker catch per unit effort is approximately 0.041 suckers per hour and indicates an estimated 133 juvenile suckers were entrained into North Canal during 2003 (e.g., 135 days*24 hours*0.041 suckers per hour).

Based on fish salvage and screw trapping data from Miller Creek, up to 250 suckers are annually entrained from Gerber Reservoir. Some entrained suckers may survive in pools of Miller Creek between annual irrigation seasons; however, most of these fish likely die as a result of dewatering Miller Creek at the end of the irrigation season.

A fish screen designed for fish greater than 30 mm total length was installed at Clear Lake Reservoir in 2002, however, suckers are free-swimming at sizes less than 15 mm total length. While not fully understood, losses to entrainment at Clear Lake Reservoir were sampled below the fish screen in 2013, a year when adult suckers successfully spawned in Willow Creek and lake elevations were relatively low (approximately 4,522 to 4,524.8 feet; (Sutphin and Tyler, 2016). An estimated 270,000 larval suckers and 3,700 juvenile suckers were lost to entrainment in 2013 (Sutphin and Tyler, 2016). As mentioned previously, spawning success varies with lake elevation and flows in Willow Creek (Hewitt and Hayes, 2013; Hewitt et al. forthcoming). In low WYs like 2013, Willow Creek flowed through the dam forebay prior to flowing into Clear Lake Reservoir's East lobe or out into the Lost River for agriculture deliveries (*see* Figure 6-6(b)). Entrainment may be lower in years when lake elevation is high enough for larvae to egress directly into Clear Lake Reservoir (*see* Figure 6-6(c)).

Unquantified sucker entrainment also occurs within the Lost River, Tule Lake Sumps, and at other unscreened diversions throughout Project (Reclamation 2001b).

6.3.6. Bird Predation

Bird predation on endangered suckers has been studied at Clear Lake Reservoir and UKL. American White pelicans (*Pelecanus erythrorhynchos*) and double-crested cormorants (*Phalacrocorax auritus*) are the most abundant avian predators and both species have nesting colonies at Clear Lake Reservoir and UKL (Evans et al. 2016). Pelicans are more common at nesting colonies at Clear Lake Reservoir while cormorants are more common at nesting colonies at UKL. With their larger beak, pelicans are able to consume larger fish (up to 730 mm, Evans et al. 2016) than cormorants (up to 450 mm, Hatch and Weseloh 1999). Individual pelicans are able to forage on suckers up to 4 feet (1.25 m) deep (Anderson 1991). However, as cooperative foragers, pelicans often drive fish into shallow water (Anderson 1991). In contrast, cormorants can forage for fish in water up to 33 feet (10 m) deep but are more limited in the size of fish they can consume (Enstipp et al. 2017). Other avian predators of suckers in the Upper Klamath Basin including gulls (*Larus* sp.), herons (*Ardea* sp.), and Caspian terns (*Hydroprogne caspia*), nest among pelicans and cormorants, and likely contribute to the sucker mortality (Evans *et al*. 2016).

Bird predation varies by sucker age-class and species, bird colony location, nesting success, and year (Evans et al. 2016). Relative to their availability, avian predators often select smaller suckers including juveniles and SNS, though exceptions to this were observed in some years. Deposition rates for avian predators have not been specifically studied for pelicans or cormorants in the Upper Klamath Basin, thus specific estimates relative to bird species are not available. Additionally, from the data available, Evans et al. (2016) were able to estimate minimum (not actual) bird predation on both species of suckers at each lake by scanning bird nesting colonies for sucker PIT tags. Again, actual estimates require deposition rates for each avian predator in each Lake. Avian predators in Clear Lake had the highest predation rates on suckers in Clear Lake; minimum avian predation rates for Clear Lake nesting birds are estimated to be 4.6 percent for LRS and 4.2 percent for SNS (Evans et al. 2016). Avian predation at UKL accounts for a minimum of 0.6 percent LRS and 1.8 percent SNS mortality. Recovered PIT tags from Clear Lake Reservoir included tags that were implanted in suckers that were released at other locations, principally UKL demonstrating that piscivorous water birds nesting on islands in Clear Lake Reservoir traveled to other Lakes and streams to consume PIT-tagged suckers (Roby et al. 2011, Evans et al. 2016). Interestingly, pelicans nesting at Clear Lake were more likely to prey upon adult suckers spawning at the springs on the east side of UKL, whereas UKL pelicans were more likely to prey upon suckers spawning in tributaries (Evans et al. 2016).

Additional information regarding factors that may influence predation on suckers by fish-eating birds is not currently understood; however, fish age, fish behavior (including that caused by disease or parasites, poor water quality, or loss of deep water habitat (lake elevation), or changes in habitat), fish proximity to bird nesting areas, bird colony size and success rate, and the availability of other prey items were suggested as possibly influencing PIT tag recovery inferences (Roby *et al*. 2011, Evans et al. 2016). Bird predation may also vary seasonally, though this has not been directly studied.

6.4. Coho Salmon

6.4.1. Factors Affecting Coho Salmon and their Habitat

The following is a discussion on select factors effecting coho salmon. Only those factors most relevant to implementing the PA are discussed.

6.4.1.1. Riverine Conditions - Hydrology

Stream flow patterns and conditions regulate numerous processes in the freshwater life cycle of salmonids. This includes growth rates, migratory patterns, reproductive success, and disease susceptibility. Changes to the hydrology of a watershed can disrupt these processes and affect the survival of salmonids during their freshwater residency. The Klamath Basin, like most major rivers in the western U.S., has undergone significant hydrologic changes during the past century. Most notably, the surface-water hydrology of the upper Klamath Basin has been extensively modified by drainage of lakes and wetlands for agriculture and the diversion and routing of water for irrigation (Wagner and Gannett 2014), resulting in dramatically altered streamflow dynamics in the Klamath River.

Prior to the first major construction developments by Reclamation in the early 20th century, the Klamath River hydrograph had flows that increased through fall and winter, peaked in April, and gradually declined during summer (Figure 6-9; NRC 2004). Construction began on the Project in 1906 with the A Canal. This was followed by the construction of the Clear Lake Dam in 1910, the Lost River Diversion (Wilson) Dam and many of the distribution structures in 1912, the Anderson-Rose Diversion Dam (formally Lower Lost River Diversion Dam) in 1921, the Malone Diversion Dam was constructed on the Lost River in 1923 to divert water to Langell Valley, and numerous other off-Project irrigation developments. As of the early 21st century, Reclamation's Project consists of an extensive system of canals, pumps, diversion structures, and dams capable of routing water to approximately 230,000 acres of irrigated land in the upper Klamath River Basin (Figure 6-10; Braunworth et al. 2001, Lewis 2002, Reclamation 2011).

Also, in the upper basin are six mainstem dams (non-Reclamation owned or operated), all of which alter flows on the mainstem Klamath River, and are listed by name and year completed in descending order:

1. Link Dam (1921);
2. Keno Dam (1965);
3. JC Boyle Dam (1958);
4. Copco 1 Dam (1918);
5. Copco 2 Dam (1925); and
6. IGD (1962).

The LRD, is near the outlet of UKL, is used in regulating the level of UKL for water-management purposes and hydropower. Irrigation water is withdrawn seasonally through the A Canal, which is just above the LRD. Below the LRD, the additional five dams are operated by PacifiCorp and produce hydropower, except Keno Dam. IGD, the terminal dam on the mainstem, is also used for reregulation of flow to the Klamath River mainstem. The dams block access of coho salmon to large portions of their historical range and can directly or indirectly affect coho. These dams also control the ramping of flow (change in discharge over short periods), which is consistent with optimal operation of hydropower production facilities. Ramping flows can be detrimental to coho fry, which can become stranded at the river margin when flow decreases rapidly (NRC 2004).

Below IGD, increases in discharge occurs through four large tributaries — the Shasta, Scott, Salmon, and Trinity Rivers, all of which have water limitations via dams and irrigation withdrawals during the irrigation season — and through numerous small tributaries. The hydrographs of the larger tributaries show severe depletions of flow; consequently, the small tributaries now provide some of the best habitat for coho salmon (NRC 2004). The Trinity River Dams (Trinity Dam and Lewiston Dam constructed in 1962 and 1963, respectively) have had a substantial influence on Trinity River flows and Klamath River flows below its confluence with the Trinity. Similarly, the development of Reclamation's Rogue River Basin Project from the mid-1950s to the mid-1960s further increased water withdrawals, impacting flows in the Klamath River from diversions that reduce flows in Jenny Creek, a tributary to the Klamath River upstream of IGD.

Following the development of the Project and subsequent irrigation projects, as well as other mainstem water developments, peak Klamath River flows shifted from a mean maximum in April to a mean maximum in March (Figure 6-9; NRC 2004). The NRC (2004) speculated that the earlier peak in annual runoff was associated with increased flows from the Lost River diversions into the Klamath River and the loss of seasonal hydrologic buffering from overflow that was historically stored in Lower Klamath Lake and Tule Lake. This change in timing (earlier peak flows) can also be attributed to UKL storage to maximize Project water combined with Project irrigation deliveries beginning in April, which would reduce later season flows. Mean minimum flows also occur earlier and are more prolonged than historical estimates (Figure 6-9); this shift is attributed to water management practices, particularly irrigation demands in the upper Klamath basin (NRC 2004).

Changes in seasonal or annual flow regimes have been the result of dam operation, ongoing land use changes, increased irrigation withdrawals, and reductions in base flows in the upper Klamath Basin over the past 50 years (NRC 2004). For example, Van Kirk and Naman (2008) determined that more than half of the reduction in base-flow in the Scott River was attributed to irrigation related water withdrawal. Moreover, off-Project agricultural diversions in both the Shasta and Scott Rivers, especially during dry WYs, have dewatered sections of these rivers, impacting the mainstem Klamath River downstream of IGD (Klamath River Basin Fisheries Task Force 1991 in NMFS 2013).

The effect of shifting peak and base-flows, as well as lower overall flows during the spring and summer months, has direct consequences on the survival of all freshwater life stages of coho salmon in the Klamath River basin. Adult coho spawners respond to freshets during the fall as a cue for upstream migration to natal streams. If flows are below subsistence levels, spawners may not be prompted to immigrate and have been documented aggregating near the mouth of rivers (Sandercock 1991), including the Klamath River (Guillen 2003). Sufficient flows are also necessary for successful redd construction, egg development, and survival from alevins to smolts to returning adults. Conversely, excessive high flows can result in redd scouring and direct egg mortality (Erickson 2007, Quinn 2005). For coho fry and juveniles rearing in the Klamath River, habitats are maximized at flows between 1,302 and 5,507 cfs (1,302 – 4,607 cfs and 1,384 – 5,507 cfs; respectively based on revised calculations), and habitat becomes less suitable for fry below 1,500 cfs (Hardy et al. 2006). In some years, such as 2002, discharges fell well below 1,500 cfs throughout the mainstem Klamath River (Table 6-6) and were some of the lowest on record (Guillen 2003). While 2002 was considered a “dry” year in the Klamath Basin (Guillen 2003), Hardy and Addley (2001) estimated that discharge for a dry-year scenario at IGD would be significantly higher if unimpaired by water diversions to the Project (Table 6-6). Adequate flow is also critical for smolt emigration. In the Klamath River, smolt survival was high when flows exceeded 5,500 cfs (Beeman et al. 2012) and low when flows fell below 1,500 cfs (David et al. 2017a). A summary of the effects of some IGD flow ranges on coho is summarized in Table 6-7.

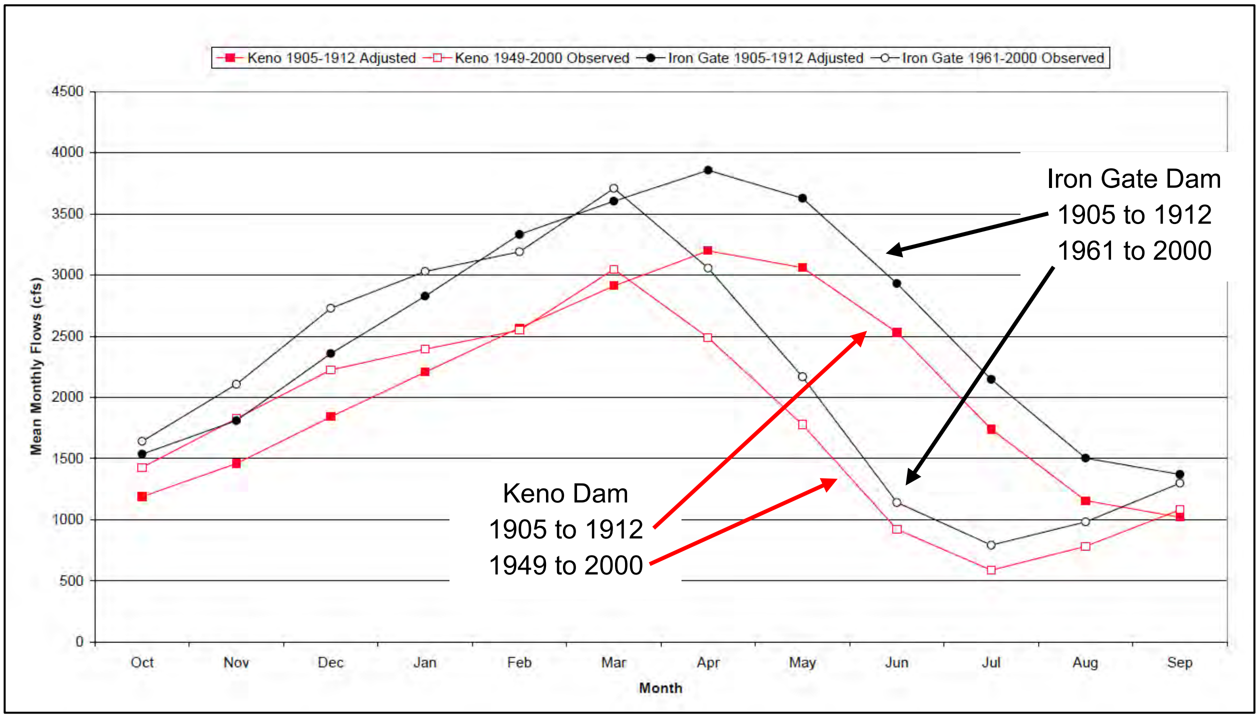

Figure 6-9. Estimated historical adjusted mean monthly flows from 1905 to 1912 at Keno and Iron Gate Dams (Balance Hydrologics 1996 *in* Hardy et al. 2006) compared to the mean monthly flows observed at the Keno Gage for the 1949 to 2000 Period of Record and at Iron Gate for the 1961 to 2000 period or record (*modified from* Hardy et al. 2006).

6.4.1.2. Riverine Conditions - Water Quality

Klamath River water quality is primarily influenced by Upper Klamath Basin water quality conditions (*see* Part 6.2.2), land use practices (past and present), variations in hydrologic conditions (including tributaries to the Klamath River), PacifiCorp reservoirs, and Project operations. Reductions in some water quality parameters such as nutrient concentration, dissolved oxygen (DO), temperature, pH, and periphyton and macrophytes can directly impact coho salmon at every life stage. The interaction of these parameters (e.g., confounding effects) are not well documented in the lower Klamath Basin as to their effects on coho salmon. The Klamath River is somewhat unique in that it originates in shallow, naturally eutrophic UKL which delivers substantial biomass, nutrient, and thermal load to the Klamath River (NCRWQCB 2010; *see* Part 6.2.2 for details). As the river nears the Pacific Ocean, it becomes generally less eutrophic due to increased stream gradient and inputs of cooler, less eutrophic water from tributaries (NCRWQCB 2010). Note that water quality in the Klamath River watershed upstream of the California/Oregon border is discussed in detail in Part 6.2.2. As such, the following narrative will primarily focus on water quality in the Klamath River within PacifiCorp reservoirs and below IGD.

Portions of the Klamath River are listed as impaired under section 303(d) of the Clean Water Act due to microcystin, elevated nutrients, organic enrichment/low dissolved oxygen (DO), sedimentation/siltation, and/or elevated water temperature (NCRWQCB 2010). Given the water quality dynamics in the Upper Klamath Basin above the California/Oregon state line (described in Part 6.2.2), the two states have coordinated Klamath River and UKL Drainage TMDLs to ensure they are complimentary (NCRWQCB 2010). The water quality parameters (or pollutants) of concern in the Klamath River in California include water temperature, DO, carbonaceous biological oxygen demand, total phosphorus, total nitrogen, and microcystin (NCRWQCB 2010). And finally, the “sources” of these pollutants have been generally categorized as water quality originating in Oregon (termed “stateline”), within PacifiCorp facilities, entering the Klamath River from Iron Gate Hatchery, and entering the Klamath River from tributaries (NCRWQCB 2010).

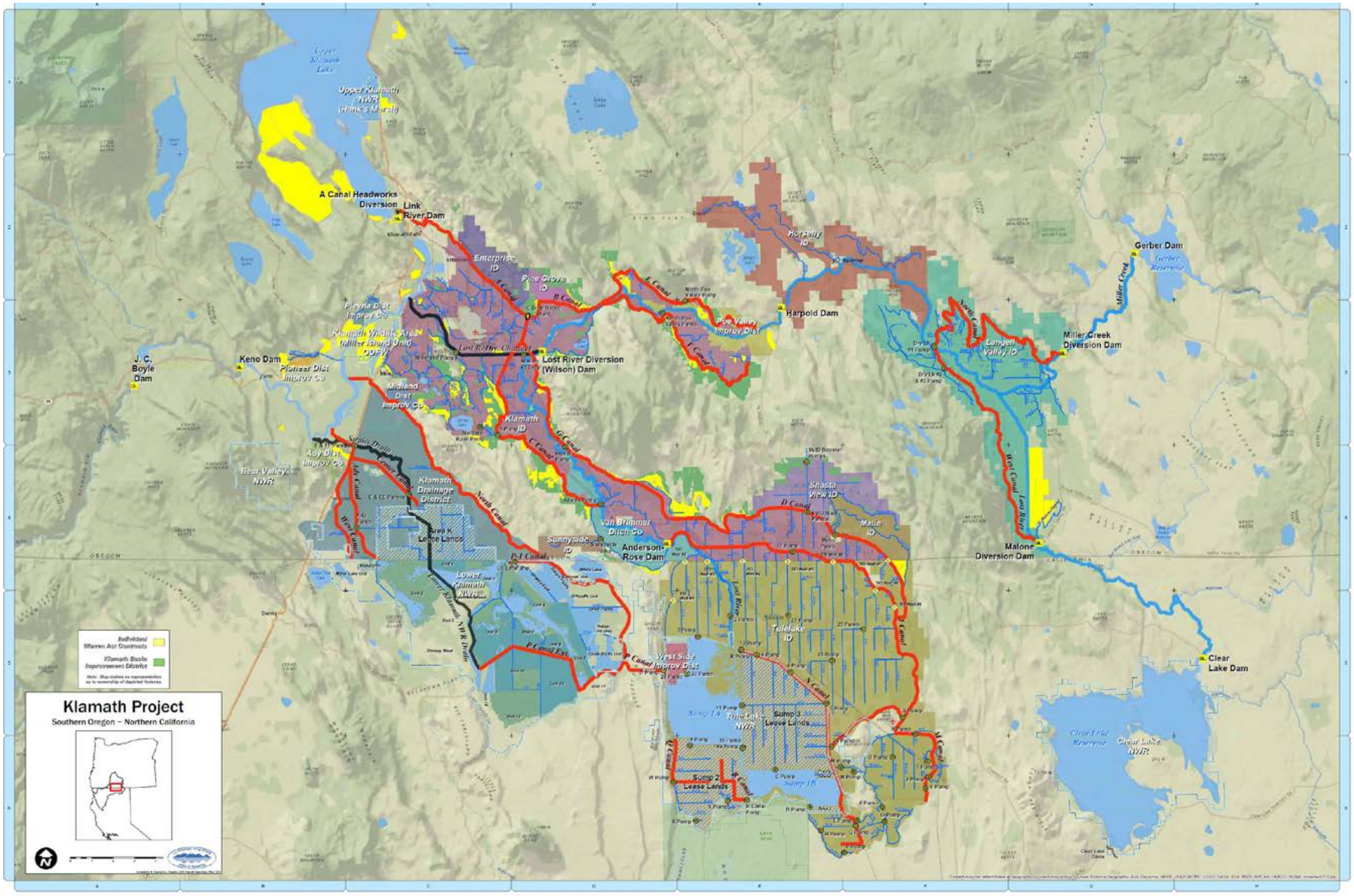

Figure 6-10. Map of the Klamath Basin with Klamath Project structures and diversions.

Table 6-6. Comparison of discharge regimes (in cfs) at various gage sites for the period of record for each gage during August and September for the mainstem Klamath River (IGD and Orleans), Trinity River (Lewiston), and Salmon, Scott, and Shasta Rivers. This table was adapted from Guillen (2003).

Category	**IGD (Aug)**	**IGD (Sep)**	**Orleans (Aug)**	**Orleans (Sep)**	**Lewiston (Aug)**	**Lewiston (Sep)**	**Salmon (Aug)**	**Salmon (Sep)**	**Scott (Aug)**	**Scott (Sep)**	**Shasta (Aug)**	**Shasta (Sep)**
Mean	976	1281	2045	2191	261	234	260	200	63	53	38	74
Median	1030	1330	1968	2142	189	197	237	192	60	49	33	73
Minimum	398	538	549	790	41	41	82	80	6	4	8	27
Maximum	1208	2052	3666	3807	628	556	839	528	629	228	111	182
2002 flow[1]	666	813	1263	1305	471	454	171	125	15	12	24	32
2002 percentile	7.3	7.3	9.4	7	85.5	90	18	12	13.3	10	32	6.1
Years of Record	42	42	75	75	91	91	79	79	61	61	66	66
2002 rank (high=1 to low)	39	39	68	70	14	10	65	70	52	55	45	62
3 Lowest flow years & rank	1991(40) 1994(41) 1992(42)	1991(40) 1994(41) 1992(42)	1994(73) 1992(74) 1931(75)	1991(73) 1992(75) 1931(75)	1920(89) 1931(90) 1924(91)	1929(89) 1931(90) 1924(91)	1977(77) 2000(78) 1931(79)	1992(77) 1931(78) 2001(79)	1981(59) 1994(60) 2001(61)	1981(59) 1994(60) 2001(61)	1955(64) 1981(65) 1939(66)	1977(64) 2001(65) 1981(66)
Estimated unimpaired flow*	1141	1174										

[1] Removing the additional pulse flow on September 27, 2002 from IGD, reduces September IGD flows to 760 cfs; Orleans flows to 1,287 cfs; and Klamath flows to 1,987 cfs.

Source: Hardy and Addley (2001).

Table 6-7. Summary of selected Iron Gate Dam discharge effects on coho salmon at different life stages.

Lifestage	Flow Range (cfs)	Effect/Behavior	Source
Egg	>5,163	Redd scour occurs resulting in high egg mortality downstream of IGD	Ericksen et al. 2007
Fry	3,000	Maximum fry habitat achieved in the R. Ranch study site downstream of IGD	Hardy et al. 2006
Fry	2,800	Maximum fry habitat availability achieved in the Tree of Heaven study site downstream of the Shasta River confluence	Hardy et al. 2006
Fry	1,500-2,100	Maximum fry habitat availability achieved in the Seiad study site downstream of the Scott River confluence	Hardy et al. 2006
Juvenile Rearing	1,500-5,500	Maximum rearing habitat availability achieved in the R. Ranch study site downstream of IGD	Hardy et al. 2006
Juvenile Rearing	6,000-7,000	Maximum rearing habitat availability achieved in the Tree of Heaven study site downstream of the Shasta River confluence	Hardy et al. 2006
Juvenile Rearing	>10,000	Maximum rearing habitat availability achieved in the Seiad study site downstream of the Scott River confluence	Hardy et al. 2006
Smolt	1,300-1,400	Highest proportion of smolts observed migrating downstream of IGD	David et al. 2017a & 2017b
Smolt	1,020-10,300	IGD discharge had a positive effect on yearling coho salmon survival upstream of the Shasta River, but the effects were smaller than those of water temperature. Estimated 0.67 percent increase in survival for every 100 cfs increase in flow released from IGD.	Beeman et al. 2012
Adult Migration and Spawning	882-1650	Active spawning observed. Main stem Klamath River coho salmon built redds where water velocity was near or above the upper end of the preferred range.	Magneson & Gough 2006

6.4.1.2.1. Nutrient Loading

Nutrient dynamics are key drivers of primary productivity in aquatic systems. Elevated levels of primary productivity can adversely affect aquatic organisms such as coho indirectly as a result of suboptimal pH and DO concentrations associated with photosynthesis and respiration, respectively, and potentially harmful concentrations of cyanotoxins.

Nutrient dynamics above Keno Dam are largely driven by the export of algal biomass from UKL, which is described in detail in Part 6.2.2 and will not be discussed further here.

Generally, nutrient concentrations are highest at Keno Dam and decrease longitudinally with increasing distance downstream (Asarian *et al*. 2010). For total nitrogen, Asarian *et al*. (2010) demonstrated a general upward trend in concentrations from June – October at sites below IGD.

Conversely, total nitrogen concentrations below Keno Dam and above Copco Reservoir and total inorganic nitrogen concentrations throughout the Klamath River were highly variable and likely closely correlated with biological activity (Asarian *et al*. 2010). Annual maximum total nitrogen concentrations from 2005 – 2008 were observed in August or September below Keno Dam and ranged from approximately 3,000 ug/L to between 4,000 and 4,500 ug/L (Asarian et al. 2010). At Klamath River sites below IGD, annual maximum total nitrogen was typically less than 1,500 ug/L with very low concentrations (i.e., approaching detection limits) near the mouth of the river (Asarian *et al*. 2010).

Total phosphorus and soluble reactive phosphorus (the form most readily available for biological uptake) generally increased from June – October at sites below IGD, with variable patterns below Keno (for both total phosphorus and soluble reactive phosphorus) and above Copco (for soluble reactive phosphorus) that were likely closely correlated with biological activity (Asarian et al. 2010). Annual maximum total phosphorus concentrations from 2005 – 2008 were observed in August or September below Keno Dam or in Copco Reservoir and ranged from approximately 250 ug/L to 500 ug/L (Asarian *et al*. 2010). At Klamath River sites below IGD, annual maximum total phosphorus was typically less than 200 ug/L (Asarian et al. 2010).

Due to tributary dilution and nutrient retention (nutrient sequestration via biological uptake and denitrification) in the river and reservoirs, the Klamath River is considered a nutrient sink from June – October; specifically, Asarian and Kann (2010) found that phosphorus and nitrogen concentrations and loads decreased substantially between Keno Dam and Turwar (near the mouth of the river) annually during this period. It should be noted that these findings do not suggest permanent (i.e., interannual) nutrient sequestration, but rather highlight dynamics within the growing season. Of the two mechanisms responsible for nutrient sequestration, tributary dilution had a greater effect on nutrient concentrations relative to nutrient retention, however nutrient retention was particularly important when considering inorganic nitrogen (the form of nitrogen most readily available for biological uptake; Asarian and Kann 2010). Relative to nutrient sources, Asarian and Kann (2010) also found that the primary source of nutrient load to individual mainstem reaches was the mainstem reach immediately upstream (65 – 85 percent of inflow load on average), while tributaries contributed relatively little nutrient load (5 – 20 percent and 5 – 10 percent for gaged and ungagged tributaries on average, respectively).

Finally, note that the Klamath River TMDL calls for specific nutrient targets and allocations at stateline, PacifiCorp reservoir tailraces, the IGH discharge point, and below the confluence with the Salmon River (NCRWQCB 2010; *see* Table 5.1 therein for details). Generally, the Klamath River TMDL acknowledges a need to reduce the nutrient load entering the Klamath River in California from upstream areas in Oregon (*see* Part 6.2.2 for details regarding sources and their relative contributions to nutrient load origination in Oregon).

6.4.1.2.2. Dissolved Oxygen

Adequate concentrations of DO in freshwater streams and rivers are essential for the survival, growth, and development of salmonids. Reduced concentrations of DO can affect fitness and survival by shifting embryo incubation periods, reducing the size of fry, and decreasing feeding activity, and extremely low DO concentrations can be lethal to salmonids. To ensure sufficient DO concentrations for coldwater fishes, the Klamath River TMDL calls for specific DO concentrations at stateline, PacifiCorp reservoir tailraces, the IGH discharge point, and below the confluence with the Salmon River (NCRWQCB 2010; *see* Table 5.1 therein for details).

The lowest DO concentrations in the Klamath Basin are observed in summer and early fall in the reaches above Copco Reservoir (Reclamation 2012, PacifiCorp 2018). These conditions are largely influenced by algal blooms in UKL that provide an influx of organic matter (PacifiCorp 2018; UKL algal dynamics are described in Part 6.2.2.1.) and the effect of UKL algal dynamics appears to attenuate further downstream. DO concentrations and water temperatures in the LRD to Keno Impoundment reach similarly affect water quality within the PacifiCorp reservoirs (*see* Part 6.2.2.2.). DO conditions in Copco and Iron Gate reservoirs vary seasonally due to thermal stratification, seasonal temperature variation of inflowing waters, and seasonal nutrient loading and organic matter inputs from upstream sources (PacifiCorp 2018).

Generally, DO concentrations in the Klamath River below IGD exceed minimum DO requirements for salmonids and other coldwater species (Asarian and Kann 2013, PacifiCorp 2018). However, annual minimum DO concentrations from 2001 – 2011 were as low as 3.5 mg/L at IGD, with a general upward trend from 2001 – 2011 (Asarian and Kann 2013). Asarian and Kann (2013) indicated that the lowest DO concentrations (daily minimum DO, averaged over 2001 – 2011) occur from mid-July through late August, with Klamath River minima (7.3 to 7.0 mg O_2/L [milligrams of oxygen per liter] when averaged over 2001 to 2011) occurring between IGD and rivermile 100 (approximately the location of Happy Camp, CA). Similarly, PacifiCorp (2018) indicated that seasonal minima (approaching 5 mg/L) occurred in August and mid-September downstream of IGD; DO concentrations at all other monitored Klamath River sites were above 8 mg/L during calendar year 2017 (PacifiCorp 2018).

6.4.1.2.3. pH

Generally, pH in the Klamath River below IGD is substantially lower than that observed in UKL, the Keno Impoundment, and PacifiCorp reservoirs. Highest annual maximum pH from 2001 to 2011 was between 9.0 and 9.5 at IGD, which tends to have the highest pH in the mainstem Klamath River (Asarian and Kann 2013). More generally, the highest pH concentrations (daily maximum pH, averaged over 2001 to 2011) occurs from mid-July to mid-September, with Klamath River maxima (8.6 to 9.0 when averaged over 2001 to 2011) occurring between IGD and rivermile 90 (approximately 10 miles downstream of Happy Camp, CA) (Asarian and Kann 2013).

In addition to daily maximum pH regularly approaching 9.0 below IGD, the Klamath River downstream of IGD remains in a weakly buffered state and pH levels throughout the river thereby fluctuate widely as a result of the diurnal changes in primary production in the summer months. Photosynthesis and associated uptake of carbon dioxide by aquatic plants and algae increases pH during the day, whereas plant/algae and fish respiration at night decreases pH to more neutral conditions (NMFS 2010). Ammonia toxicity can also be a concern in aquatic environments, like the Klamath River, where high nutrient concentrations coincide with elevated pH and water temperature.

6.4.1.2.4. Algal and Macrophyte Dynamics

Photosynthesis and respiration by periphyton and macrophytes are the primary drivers of the daily cycles of DO and pH and are related to temperature in the Klamath River. Periphyton (algae attached to the substrate or macrophytes) and macrophytes (rooted aquatic plants) have seasonal growth patterns in the Klamath River, with low biomass during high winter and spring flows and maximum biomass reached during the low-flow warm period in mid/late summer (Asarian et al. 2015). Factors affecting this seasonal cycle include water velocity, substrate, light, water temperature, and nutrient availability (Asarian et al. 2015, Gillett et al. 2016). High flows appear to limit periphyton and macrophyte biomass due to increasing water velocities dislodging/disrupting aquatic vegetation (Asarian and Kann 2013, Asarian *et al*. 2015).

The effect of periphyton and macrophytes on DO concentrations is influenced by biomass and water depth. Periphyton and macrophytes are attached to the riverbed, therefore, as water depth increases these organisms have less effect on water column DO concentrations because their oxygen production (photosynthesis) and consumption (respiration) is “diluted” by the increased water volume. Conversely, when water depth is low or temperatures high, the ratio between the bed surface area and the water volume is higher, and periphyton effects on DO concentrations are greater.

In addition to periphyton and macrophytes in the mainstem Klamath River, the cyanobacteria species *Microcystis aeruginosa* and AFA also influence water quality in the Klamath system, particularly in the PacifiCorp reservoirs and immediately downstream of IGD (Asarian and Kann 2011, Asarian and Kann 2013, PacifiCorp 2018). Furthermore, *Microcystis aeruginosa* produces the hepatotoxin microcystin, which can sometimes reach substantial concentrations in the reservoirs and the Klamath River, though it is unclear what effect toxin concentrations may have on listed coho. Biomass of both cyanobacteria species is substantially higher below the reservoirs than in the Klamath River above, suggesting that the reservoirs themselves are the source of these species and associated cyanotoxin to the Klamath River below IGD (Asarian and Kann 2011). The conditions that facilitate large cyanobacteria blooms are primarily driven by external nutrient loading (i.e., export of nutrients from upstream reaches) and lacustrine conditions in the reservoirs (Asarian and Kann 2011; *see* Parts 6.2.2.1 and 6.2.2.2 for details regarding upstream water quality and nutrient loading).

The Klamath River TMDL calls for specific targets and allocations associated with cyanobacteria populations in the PacifiCorp reservoirs (NCRWQCB 2010; *see* Table 5.1 therein for details).

6.4.1.2.5. Water Temperature

Summer water temperatures in the Klamath River regularly exceed those considered optimal for salmonids. Daily mean temperature (averaged over 2001 to 2011) exceeded 21°C from early July to late August in most of the Klamath River below IGD (Asarian and Kann 2013). Additionally, daily maximum temperature (averaged over 2001 to 2011) exceeded 23°C from mid-July through late August between rivermiles 160 (the confluence with Beaver Creek) and 40 (the confluence with Tully Creek; Asarian and Kann 2013). Highest annual maximum daily water temperature between 2001 and 2011 was between 28 and 29°C at Happy Camp, CA (Asarian and Kann 2013). Generally, water temperatures immediately downstream of IGD are lowest, with a steep upward trend downstream to Seiad Valley and Happy Camp, and then a gradual decreasing trend downstream to the mouth (Asarian and Kann 2013). While air temperature generally drives seasonal and longitudinal trends in water temperature in the Klamath River, the large thermal mass of storage reservoirs (including UKL) causes changes to seasonal water temperature as well. In particular, it is estimated that warming temperatures in the spring and cooling temperatures in the fall are delayed by 2 to 4 weeks as a result of PacifiCorp's Klamath Hydroelectic Project (NMFS 2012b). These effects result in IGD release temperatures that are below equilibrium in late spring to mid-summer and above equilibrium throughout the fall (PacifiCorp 2012).

The Project and PacifiCorp's Klamath Hydroelectric Project can affect mainstem Klamath River water temperatures through changes to hydrology and water storage. The magnitude of these effects depends on three principal factors: 1) the temperature of the water as it is released from the impoundments; 2) the volume of the release; and 3) the meteorological conditions (e.g., ambient air temperature). The large thermal mass of storage reservoirs (including UKL) causes changes to seasonal water temperature, and water releases at IGD can influence diurnal temperature patterns. These changes can have both positive and negative effects on Klamath Basin coho salmon populations.

Impacts of IGD releases during the summer are difficult to assess due to confounded relationships with mean, minimum, and maximum temperatures (NRC 2004). Under moderate flow conditions in mid-August (e.g., 1,000 cfs release from IGD, the low flow scenario) with typical accretions from tributaries, maximum daily temperatures increase rapidly downstream of IGD to a peak of 26ºC within 15 miles. Daily minimum temperatures caused by nocturnal cooling reach a minimum of 20ºC within about the same distance. By the time this water reaches Seiad Valley (RM 129), maximums are greater than 26ºC, and minimums are 22ºC; the average gain from IGD to Seiad Valley was 2ºC (NRC 2004). Also, at low IGD releases, temperatures in the mainstem Klamath River are affected substantially by the Scott River and minimally by the Shasta River (NRC 2004). At high flows, the increases in minimum temperatures may adversely affect fish (NRC 2004), while the reduction in maximum temperatures would be expected to reduce stress for fish during juvenile rearing (Table 6-8). A summary of known temperature effects, within the range of temperature conditions experienced by Klamath coho, is shown in Table 6-8.

Table 6-8. Summary of water temperature effects on Klamath coho salmon.

Coho Lifestage	Temperature in Celsius	Coho Effect/Behavior	Source
Egg	2.5 to 6.5	Maximum egg survival	Richter and Kolmes 2005
Fry	12.0 to 14.0	Optimum growth	Moyle 2002
Juvenile Rearing	< 1.7	Lower lethal temperature	Stenhouse 2012
	< 4.4	Mortality increases, growth rates are no longer positive, feeding ceases	Stenhouse 2012
	10.0 to 15.5	Optimal range for normal physiological responses and behavior	Stenhouse 2012
	19.0	Begin using thermal refugia	Sutton and Soto 2012
	15.5 to 20.3	Metabolism and respiration increase dramatically, pathogen virulence and disease susceptibility begin to increase, infected fish may experience increased mortality	Stenhouse 2012
	> 20.3	Decreased or eliminated feeding behavior	Stenhouse 2012
	21.3	Juveniles with adequate energy input showed positive growth, normal plasma protein levels and complement activities, and no stress response	Foote et al. 2014
	> 22.0 – 23.0	Visual counts decline suggesting an upper threshold for survival	Sutton and Soto 2012
	> 24.0	Limited residence in the mainstem during summer by moving into pockets of thermal refugia	NRC2004
	28.2	Temperature stressors begin to negatively affect behavior and can lead to mortality if exceeded	Stenhouse 2012
Smolt	11.0 to 12.0	Range within which salmonids were observed migrating	Richter and Kolmes 2005
	12.0 to 12.5	Suggested threshold for limits of smoltification	Richter and Kolmes 2005
	8.03 to 22.92	Increases in water temperature had a positive effect on smolt survival throughout the range observed. A 1-degree increase in water temperature increased survival by approximately 2.3 times the survival benefit estimated for a 100 cfs flow increase, and the effect of temperature was most pronounced at low flows (1,400 cfs)	Beeman et al. 2012
Adult Migration and Spawning	7.2 to 15.5	Suggested optimal temperatures for adult migration	Richter and Kolmes 2005
	20.0	Adult coho have reduced quality and rapid deterioration	Richter and Kolmes 2005
	4.4 to 15.6	Spawning occurs	Richter and Kolmes 2005
	16.0 – 26.0	Survival predicted to decline from 95 to 1 percent between 16 and 26 degrees	Ericksen et al. 2007

6.4.1.3. Riverine Conditions - Fine Sediment and Gravel Recruitment

High levels of sediment transport can reduce habitat and water quality for salmonids. Fine sediment accumulation can impact spawning gravels and alter invertebrate composition and densities (Shea et al. 2016). For example, excess fine sediments can limit available spawning habitat by reducing inter-gravel flows necessary for egg-to-fry survival (Greig et al. 2005). Fine sediment deposits are also of concern because high densities of *M. speciosa* (freshwater polychaete worms) have been observed in these habitats (Som and Hetrick 2017, Hillemeier *et al*. 2017). In the Klamath Basin, declines in coho populations have been attributed in part to habitat loss associated with altered sediment supplies from timber harvest and mining practices between 1940 and 1960 (Weitkamp *et al*. 1995 in NMFS 2014).

Currently, natural and anthropogenic processes in the Upper Klamath Basin limit the transportation of fine sediment to the Klamath River. Most sediment delivered from tributaries of UKL are trapped due to its large surface area, except under high runoff conditions when some fines are transported through the lake (Reclamation 2012). The hydroelectric section below UKL (Keno Dam to IGD) is considered to interrupt the supply of fines delivered to the Klamath River from this reach, with only 3.4 percent of the total sediment smaller than 0.063 mm (Stillwater Sciences 2010). The majority of Klamath River fines are transported from the Scott River and other major tributaries downstream (NMFS 2013).

Coarse sediment transport is also impeded by hydroelectric dams on the Klamath River, which is evident in the low estimate of total sediments ≥ 0.063 mm delivered to the Klamath River from above IGD (1.4 percent; Stillwater Sciences 2010). Alterations of the natural hydrograph due to the dams on the Klamath River have also impacted the mobility of coarse sediments, leading to immobile or stable beds and armoring of substrate (Shea et al. 2016). Disruption of streambed mobilization can lead to the interstitial spaces of the bed to fill with fines (Shea et al. 2016, Som and Hetrick 2016), and reduce spawning habitats. For the Upper Klamath River coho population, a reduction in course sediment could limit quality of substrate for spawning adults downstream of IGD (Coho Recovery Plan 2014).

Natural flows, or flow management in regulated systems, are critical to maintaining natural channel functions, such as sediment transport, floodplain/riparian health, and streambed conditions. Managing flows below dams to mimic natural hydrographs is critical to produce a balanced sediment regime (Wohl et al. 2015, Schmidt and Wilcock 2008). Reclamation (2011) defined natural flows for the 1.5-, 2-, and 10-year return period for the Klamath River below IGD to be 4,389, 6,030, and 15,610 cfs, respectively (Shea et al. 2016). Surface flushing flows, deep flushing flows and geomorphically effective flood flows were recommended to maintain channel functions and reduce disease prevalence in the Klamath River (Hillemeier *et al*. 2017, Reclamation 2018).

To maintain channel form, restore the river's natural channel function and reduce disease prevalence, Hillemeier et al. (2017) recommended surface flushing, deep flushing and geomorphically effective flows for the Klamath River below IGD, which was also supported in Reclamation (2018). As per the Guidance Memo, annual surface flushing flows of at least 6,030 cfs at IGD for a 72-hour period were recommended (Hillemeier et al. 2017) to mimic a 2-year return period interval (Shea et al. 2016). The range of surface flushing flows was estimated as 5,000 to 8,700 cfs (Shea et al. 2016). Hillemeier *et al* (2017) recommended that deep flushing flows should occur at least every other year unless precluded by drought and be at least 11,250 cfs as measured in a 24-hour period at IGD (range of deep flushing flows: 8,700 to 12,500 cfs) (Hillemeier *et al*. 2017). This discharge would be similar to a 5-year return period event (Shea et al. 2016).

Floods, or geomorphically effective flows, are also important mechanisms for maintaining channel form on rivers, including long-term maintenance of the riparian corridor and floodplain, and are classified as discharges greater than 15,000 cfs below IGD (Shea et al. 2016). Flows approximating the 10-year return period magnitude (or geomorphically effective flows) can rework gravels on riffles, erode channel banks, re-widening the channel, and remove substantial amounts of aquatic vegetation in the reaches of the Klamath River blow IGD to Shasta River (Ayres Associates 1999). Geomorphically effective flood flows were defined to be greater than 11,250 cfs with no specific flow magnitude or duration being described in the Guidance Memo (Hillemeier et al. 2017).

6.4.1.4. Climate Change

Climate change affects anadromous salmonid populations in both marine and freshwater phases of their lifecycle. Changes in precipitation and air temperature impact freshwater habitat through altered streamflows, decreased snowpack, and reduced water quality (Battin et al. 2007). Short- and long-term fluctuations in ocean conditions are believed to play an important role in regulating salmonid productivity and survival (Johnson 1988, Mantua et al. 1997). The global effects of climate change on river systems and salmon are often superimposed upon the local effects within river systems of logging, water utilization, harvesting, hatchery interactions, and development (NMFS 2010). Changes in peak streamflow timing and snowpack will negatively impact salmonid populations due to habitat loss associated with lower water flows, higher stream temperatures, and increased human demand for water resources (NMFS 2010).

In the Pacific Northwest, changes in climate have altered precipitation patterns. River basins with prominent snowmelt inputs, such as the Klamath Basin (NRC 2004), are particularly susceptible as increased rains result in earlier and elevated winter peak flows, decreased snowpack, and reduced baseflows (Stewart et al. 2005, Battin et al. 2007). These shifts in the winter hydrograph have the potential to negatively impact mainstem Klamath River coho during the egg and emergence (alevin) life-stages. For example, when flows exceed 5,163 cfs at IGD, redds can be destroyed by streambed scour (Erickson et al. 2007). While the mainstem Klamath River flows are influenced by the hydroelectric dams between IGD and Keno Dam, hydrographs below IGD still show a dominant effect of snowmelt (NRC 2004) and peak flows have exceeded the 5,163 cfs threshold in most years since the dam was built (Hardy et al. 2006). Taken together, this suggests that hydroelectric flow management will not be able to fully mitigate the effects of climate change on mainstem Klamath hydrographs. In addition to altered winter flows, changes in snowpack have resulted in reduced baseflow, which in turn has contributed to higher temperatures during summer and fall and reduced spawning habitat in many watersheds throughout the Pacific Northwest (Mote et al. 2003 *in* Battin et al. 2007). The effects of climate change on reduced baseflows will likely be amplified in the Klamath Basin as irrigation related withdrawals have increased in tributaries (Van Kirk and Naman 2008).

Long-term and interannual variations in water temperature have been attributed to changes in air temperatures (Isaak et al. 2012). In the Pacific Northwest, stream temperatures have generally decreased in the spring and increased in the summer, fall, and winter due to climate change (Isaak et al. 2012). This pattern of increasing stream temperatures has also been observed within the Klamath Basin. Since the early 1960's, stream temperatures have increased 0.58°C per decade, the number of days with temperatures that exceed 15°C has increased by 9 days per decade, and the length of mainstem channel with temperatures lower than 15°C has declined 8.2 km per decade (Bartholow 2005). These elevated temperatures pose a threat to Klamath

Basin salmonids through increased stress and risk of disease (Strange et al. 2012). Bartholow (2005) suggested that sub-yearling salmonids may require out-migration or refugia to avoid lethal thermal conditions in the mainstem Klamath River. Furthermore, Beeman et al. (2012) found that temperature was the strongest predictor of coho smolt mortality between the Scott River confluence and IGD. Increased temperatures were also identified as a potential factor contributing to the large salmon and steelhead disease outbreak in September 2002 (Lynch and Risley 2003). Warming trends are expected to continue, as recent modeling predicts an increase in Klamath Basin water temperatures of 1 to 2°C over the next 50 years (Perry et al. 2011).

Fluctuations in ocean conditions present addition threats to anadromous salmonids. Dunne et al. (2011) found that climate change affects anadromous fish species by its influence on the productivity of the ocean and marine phase growth and survival of the adult fish. Evidence suggests that marine survival among salmonids fluctuates in response to long-term cycles of climatic conditions and ocean productivity (Hare et al. 1999, Mantua and Hare 2002) related to the Pacific Decadal Oscillation. Short-term climatic regime shifts, such as the El Niño condition, have also appeared to reduce survival and productivity levels in coho populations on the Oregon Coast (Johnson 1988). Since the Oregon and California coast lack extensive bays, straits, and estuaries that buffer adverse oceanographic effects, poor ocean productivity can be especially detrimental to coho salmon in these regions (Bottom et al. 1986 *in* NMFS 2014). Dunne et al. (2011) concluded that natural changes in the freshwater and marine environments will play a major role in salmonid abundance, and that climate shifts will undoubtedly influence productivity and abundance of coho salmon returning to the Klamath Basin.

6.4.1.5. Fish Hatcheries

Two fish hatcheries operate within the Klamath River Basin, Trinity River Hatchery near the town of Lewiston and IGH on the mainstem Klamath River near Hornbrook, California. Both hatcheries mitigate for anadromous fish habitat lost as a result of the construction of dams on the mainstem Klamath and Trinity Rivers, and production focuses on Chinook and coho salmon and steelhead.

Fish hatcheries have known impacts on naturally-produced fish. A scientific panel was convened at the request of NMFS to summarize the biological relationship between hatchery and wild Pacific salmon populations (Hey et al. 2005). The panel included scientists from a range of specialties that pertain to the questions, including population biology, evolutionary genetics, and especially salmon and fisheries biology. The panel's report titled, *Considering Life History, Behavioral and Ecological Complexity in Defining Conservation Units for Pacific Salmon* was released in June 2005 (Hey et al. 2005). In their review of available research, the panel found that salmon reared in hatcheries differ from natural-origin salmon in morphology and life-history traits (Kostow 2004) and behavior (Fleming *et al*. 1997, Olla et al. 1998). The panel concluded that "there are biological differences between hatchery and wild fish that arise because of the differences between artificial and natural environments" (Hey *et al*. 2005).

There are few evaluations of hatchery salmon impacts on ESA-listed coho salmon in the Klamath Basin, especially at the population-scale. However, mechanisms of potential impacts include myriad of genetic (Araki *et al*. 2007) and ecological effects (Oosterhout et al. 2005, Harnish et al. 2014), and some level of risk associated with hatchery fish impacts is typically assumed. Only a few research projects have demonstrated that hatchery fish reduce natural-origin fish survival or production at a population scale (Pearsons et al. 2008). Moreover, studies that directly quantified population-scale impacts of hatchery-origin anadromous salmonids have shown variable results, including cases where effects were negative (e.g., Buhle et al. 2009), positive (e.g., Sharma et al. 2006), or not quantifiable (e.g., Lister 2014).

Kostow (2009) found the following factors contribute to the ecological risk on releasing hatchery-origin salmon into waters with a natural-origin population: large releases of hatchery fish; hatchery fish increase density-dependent mortality; hatchery fish do not out-migrate after release; and, hatchery fish have some physical advantage over natural-origin fish. These factors are discussed below.

The relative numbers of hatchery-origin fish. The relative numbers of hatchery-origin compared to natural-origin fish is an important consideration when assessing the risk of hatchery releases to natural-origin fish. Nickelson et al. (1986) demonstrated that when large numbers of hatchery coho salmon juveniles were stocked in Oregon coastal streams, the total density of coho salmon juveniles increased by 41 percent but the density of natural-origin coho salmon juveniles significantly decreased by 44 percent, suggesting that hatchery-origin fish were replacing natural-origin fish.

There are many examples of mixed-stock fisheries' impacts due to hatchery-origin fish being supplemented at much higher densities than the natural populations. These populations of mixed hatchery/natural fish where the targeted stocks are hatchery fish can impact natural fisheries (Noakes et al. 2000), especially where natural-origin fish are intermingled among the hatchery fish and are fished at unsustainable rates (Larkin 1977). For example, Flagg et al. (1995) noted that the large releases of hatchery coho salmon on the lower Columbia River lead to harvest rates of up to 90 percent while the natural-origin populations declined to near extinction. Levin et al. (2001) tested the hypothesis that massive numbers of hatchery-raised Chinook salmon reduce the marine survival of wild Snake River spring Chinook salmon, an ESA-listed species. Based on a unique 25-year time-series, Levin et al. (2001) demonstrated a strong, negative relationship between the survival of natural-origin Chinook salmon and the number of hatchery fish released, particularly during years of poor ocean conditions. Levin *et al*. (2001) suggested that hatchery programs that produce increasingly higher numbers of fish may hinder the recovery of depleted wild populations.

Predation. Another ecological mechanism that causes decreased survival is increased predation by piscivorous fish, birds, and mammals. Predators are attracted to the exceptionally high concentrations of fish that can result when hatchery fish are released. Natural-origin fish typically are intermingled among the hatchery fish, and therefore they are also consumed at higher than natural rates when the hatchery fish are present and attracting predators (Collis et al. 1995, Nickelson 2003).

Hatchery Fish Increase Density-Dependent Mortality. Hatchery programs can significantly increase fish densities and interfere with the density-dependent mechanisms that regulate natural-origin populations. Hatchery fish can occupy habitat and consume resources that would otherwise be available to natural-origin fish. When hatchery fish are present, the dynamics of a natural-origin population can become independent of its own abundance and instead respond to much higher total fish abundance (Kostow 2009). High fish densities in fresh water have been associated with decreased growth, increased or premature emigration, increased competition for food, decreased feeding territory sizes, and increased mortalities (Gee et al. 1978, Hume and Parkinson 1987, Nielsen 1994, Keeley 2000, 2001, Bohlin et al. 2002, Zaporozhets and Zaporozhets 2004).

Hatchery Fish Do Not Out-Migrate After Release. The ecological effects of hatchery programs are most severe when natural-origin and hatchery fish share a limited environment for a substantial period of time. In particular, early life stage hatchery-origin juveniles need to use rearing habitats in fresh water before they are ready to smolt and out-migrate to the ocean (Kostow 2009). Hatchery fish that are released as putative smolts are probably less ready to out-migrate than managers expect based on size criteria (Kostow 2009).

Besides delaying their out-migration, Kostow (2009) found that sometimes the hatchery fish never move into the ocean at all. Instead, they become residual fish, remaining to grow in fresh water until they die or return to spawning areas as resident adults. In the Pacific Northwest, residual hatchery fish are most commonly documented in steelhead (Evenson and Ewing 1992, Viola and Schuck 1995, McMichael et al. 1997) and in Chinook salmon (Gebhards 1960, Mullan et al. 1992). Residual hatchery fish probably have ecological effects similar to those of other hatchery fish: they occupy rearing habitats and compete for food and space that would otherwise be available to natural-origin fish. However, residual fish do so over a relatively longer time frame, which would increase the severity of the effects. Also, as the residual hatchery fish grow, they may become piscivorous on smaller natural-origin fish (Kostow 2009).

Hatchery Fish Have Physical Advantages Over Natural-Origin Fish. Research has demonstrated that the developmental and evolutionary forces in hatcheries and natural streams are different enough that substantial biological differences occur between hatchery and natural-origin fish (Gross 1998). The traits that have been associated with ecological risk of hatchery fish include larger sized juveniles (Berejikian *et al*. 1996, Rhodes and Quinn 1998, 1999, McMichael et al. 1999, Peery and Bjornn 2004) and more aggressive or dominant juveniles (Berejikian et al. 1999, Einum and Fleming 2001). These characteristics can give hatchery fish a short-term competitive edge and can increase the disruption of natural-origin fish, even if they eventually lead to poorer survival or lower reproductive success in the hatchery fish themselves (Nickelson et al. 1986, Berejikian et al. 1996, Deverill et al. 1999, Enium and Fleming 2001, Kostow et al. 2003).

The ecological effect of larger hatchery juveniles is that larger fish tend to win more competitions, placing natural-origin juveniles at a disadvantage (Kostow 2009). For example, Rhodes and Quinn (1999) studied hatchery and natural-origin coho salmon interactions following the planting of coho salmon in two Washington streams. They observed juvenile hatchery coho salmon were larger and heavier than natural-origin coho salmon at planting, but also the hatchery coho salmon had a higher growth rate in the streams and continued their size advantage through the summer growing season, implying they remained superior competitors (Rhodes and Quinn 1999).

Excessive aggressive behavior by hatchery juveniles would generally give them a competitive advantage over natural-origin fish, similar to the advantage of larger size (Kostow 2009). Large and aggressive hatchery juveniles may display more often and win more dominance challenges after they are released into natural streams. Thus, they may successfully disrupt natural-origin juveniles from their feeding territories, forcing them into marginal or more exposed habitats (Nielsen 1994, Peery and Bjornn 2004), or to undergo premature emigration (Chapman 1962). Natural-origin fish may experience poorer growth as a consequence of dominance and competition interactions, which could impair their long-term survival (Nielsen 1994, Rhodes and Quinn 1999).

Rhodes and Quinn (1998) found coho salmon reared in a hatchery dominated size-matched fish from the same parental population reared in a stream. Hatchery-reared salmon also dominated naturally spawned salmon, even when the wild salmon were prior residents. Thus, the combined effects of greater size and rearing experience of hatchery-produced salmon were sufficient to overcome a wild salmon’s advantage of prior residence. Fenderson et al. (1968) found that when hatchery-reared and wild landlocked Atlantic salmon (*Salmo salar*) juveniles of the same age and size were permitted to compete for social dominance and for food in aquaria, twice as many hatchery salmon attained dominance as wild salmon.

The impacts of hatchery releases may also vary by season. Although Peery and Bjornn (2004) studied Chinook salmon, their finds are likely applicable to coho salmon. Peery and Bjornn (2004) found that behavioral interactions between natural and hatchery Chinook salmon could affect aggressiveness of, and habitat use by, natural Chinook salmon. The outcome of the hatchery–wild behavioral interactions appeared related to a combination of an increase in localized fish density as occurs during supplementation stocking programs, the relative sizes of the hatchery and natural Chinook salmon, and the aggressiveness of the hatchery fish. Peery and Bjornn (2004) found these behavioral interactions between natural and hatchery Chinook salmon were different based on the season. During spring and summer, the natural Chinook salmon appeared dominated by the larger and more aggressive hatchery fish. During fall, however, some natural fish exhibited aggressive and habitat-selection behaviors that would increase their energy demands and exposure to predators when similar sized hatchery fish were present (Peery and Bjornn 2004). In addition, residual hatchery-origin Chinook salmon and steelhead also likely occupy coho salmon rearing habitats, competing for limited resources.

IGH coho salmon production focuses on the conservation of the Upper Klamath Population Unit, which is currently below the high-risk abundance level established by NMFS (CDFW 2014). To conserve the remaining genetic and phenotypic traits of the Upper Klamath Population Unit, the IGH coho program is operated as an “integrated type,” where natural and hatchery origin fish are used as broodstock.

When a program is well integrated, the proportion of natural origin fish used in hatchery broodstock (pNOB) is greater than the proportion of hatchery fish on spawning grounds (pHOS) (CDFW 2014). At IGH, the target minimum of 20 percent pNOB has been meet each year since goals were updated in 2009 (28 percent average), except in 2012 (Table 6-9). While pHOS data are limited for many Upper Klamath tributaries, a weir on Bogus Creek, the largest tributary in the Population Unit, controls the number of hatchery fish allowed into spawning grounds.

Available data indicate average pHOS of 46 percent in Bogus Creek (Table 6-9), which is close to the pNOB/pHOS levels. These are considered acceptable levels under the 2014 Hatchery and Genetic Management Plan since there is no limit on pHOS when fewer than 310 natural origin spawners return. However, because pHOS typically exceeds pNOB, it is likely that the hatchery environment is driving population genetics and natural genetic traits are not being conserved (CDFW 2014).

Hatchery fish also pose ecological threats, such as increased risk of predation and competition, to rearing natural origin salmonids (Collis et al. 1995, Nickelson 2003). Though these effects have not been quantified in the Klamath Basin, average annual releases of 5,766,512 Chinook salmon, 80,651 coho salmon, and 82,528 steelhead from IGH (based upon data available since 2001; CDFW 2013, CDFW 2014, CDFW 2016) are assumed to have impacts on SONCC coho.

These spring-released hatchery-origin Chinook salmon that may pause during their migration to the marine environment will be in direct competition with rearing natural-origin coho salmon, while fall releases may remain within freshwater for an extended period and be in competition with rearing natural-origin salmon during that period. This may also be true of the juvenile steelhead released between March 15 and May 1. In an effort to reduce the effects of this competition on natural-origin fish, IGH coho salmon are released at a size similar to natural origin yearlings (CDFW 2014). Additionally, IGH coho and Chinook salmon are volitionally released, which is believed to reduce impacts on natural origin fish (Nickelson 2003).

The IGH may also have effects on adult anadromous fish in the ocean and during spawning. To estimate the marine harvest of SONCC coho salmon, projected exploitation rates on Rogue River and Klamath River hatchery coho salmon stocks are calculated during the preseason planning process using the coho salmon Fishery Regulation Assessment Model (FRAM, Kope 2005). Harvest options are then crafted that satisfy the 13 percent maximum ocean exploitation rate on Rogue River and Klamath River hatchery coho salmon (NMFS 2010). However, in mixed stock fisheries, the catch is composed of salmon from a variety of natural-origin and hatchery stocks and the various stocks are frequently subjected to differential harvest rates (Noakes 2000). The difference in the rate of harvest of hatchery-origin versus natural-origin Klamath River coho salmon is not known (Dunne et al. 2011), although assumed to be similar.

Hatchery salmon production that leads to introgression with the natural-origin spawning salmon stocks can affect natural-origin salmon by altering their genetic composition and associated phenotypic traits that influence fitness of individuals. Araki et al. (2008) found evidence that indicates hatchery salmon have lower fitness in natural environments than natural-origin fish. Thus, hatchery strays can reduce the fitness of natural-origin fish. This decline in fitness can occur rapidly, sometimes within one or two generations (Dunne et al. 2011). Additionally, the presence of hatchery salmon can confound interpretation of the status of natural-origin salmon (Dunne et al. 2011).

There is evidence that IGH fish are straying to streams where they are likely to interbreed with natural-origin fish in the watershed. For example, hatchery coho salmon adult straying into the Shasta River Basin has been estimated at 2, 73, 20, and 25 percent, for the years 2007, 2008, 2009, and 2010, respectively (Chesney and Knechtle 2010); with low adult return numbers contributing to this wide variation. Ackerman and Cramer (2006) estimated that hatchery origin adult coho salmon comprise 16 percent of adult carcasses recovered in the Shasta River Basin. These data suggest that hatchery effects may be considerable for the coho salmon population within the Shasta River.

Table 6-9. Proportion of natural origin coho used in broodstock (pNOB) at IGH, total natural and hatchery origin coho returns at Bogus Creek, and the proportion of hatchery fish on the spawning grounds (pHOS) of Bogus Creek (CDFW 2016, CDFW 2016b, Manhard et al. 2018).

Year	IGH pNOB (%)	Bogus Creek Total Returns	Bogus Creek pHOS (%)
2009	30	7	0
2010	26	154	28
2011	23	142	75
2012	9	198	---
2013	23	386	---
2014	31	131	82
2015	52	26	---
Average	28	170	46

6.4.1.6. *Fish Disease*

Klamath River salmonids are exposed to various pathogens that cause infection and mortality. Prevalent pathogens include, but are not limited to, *Flavobacter columnare* (columnaris), *Ichthyopthirius multifilis* (ich), *Nanophyetes salmincola*, and the myxozoan parasites *Parvicapsula minibicornis* and *Ceratonova shasta* (Foott 2002). Infection and disease proliferation are primarily dependent on water temperature and fish density (Warren 1991; Stocking and Bartholomew 2007). However, stream flow can be a contributing factor, especially as it relates to habitat suitability (Hillemeier et al. 2017, Shea et al. 2016, Som et al. 2016b) and dilution effects (Hillemeier et al. 2017, Som and Hetrick 2016) for *P. minibicornis* and *C. shasta*. More specifically, low, stable flows are thought to increase disease virulence (Som et al. 2016b). However, there remains considerable debate about the nature of the relationship between flow management and disease conditions (Reclamation 2018). Some evidence alludes to a possible link between flow management and disease proliferation (Shea et al. 2016, Som et al. 2016b). Still, other studies conclude no apparent association between flow and other factors, such as polychaete density, that influence disease conditions (e.g., Malakauskas et al. 2013).

6.4.1.6.1. Ceratonova shasta

The life-cycle of *Ceratonova shasta* (*C. shasta*) involves two hosts: salmonids and the polychaete worm, *Manayunkia speciosa* (*M. speciosa*) (Bartholomew et al. 1997) (Figure 6-11). Briefly, each host releases *C. shasta* spores (Hallett and Bartholomew 2011). Actinospore stages are released from infected *M. speciosa* into the water column as temperatures warm, typically in late March or early April (Som et al. 2016b). These neutrally buoyant actinospores released from *M. speciosa* infect fish through the gills (Bjork and Bartholomew 2010), traveling through the bloodstream to the intestine, where myxospore replication and maturation of *C. shasta* occurs. The parasite replicates in the fish, causing tissue damage and eventually maturing to the myxospore stage (the diseased state resulting from this process was previously termed ceratomyxosis [Hallet and Bartholomew 2011]). Upon maturation, the higher density myxospores are released from infected adult or juvenile carcasses and are available for uptake (via suspension feeding, *see* below) by *M. speciosa*.

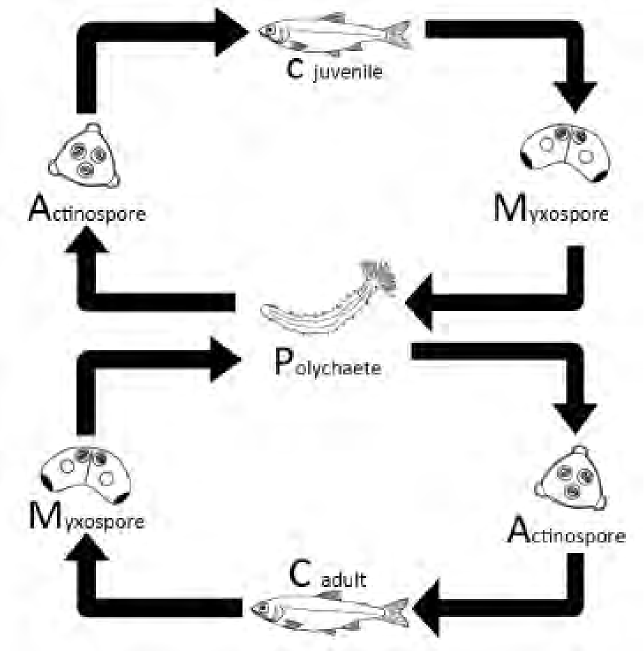

Figure 6-11. The life cycle of *Ceratonova shasta*. Actinospores released into fresh water from infected *Manayunkia speciosa* polychates develop into myxospores in the intestine of salmonids. Both juvenile and adult salmonids may become infected with actinospores and contribute myxospores to the system.
Source: Foott et al. 2011.

Given the critical role of *M. speciosa* in the lifecycle of *C. shasta*, it is important to understand the lifecycle and habitat requirements of *M. speciosa* itself. *M. speciosa* prefers depositional areas with low water velocity such as lake and reservoir in- and outflows, pools, eddies, riffles, and runs (Som et al. 2016a); runs and eddy-pools tend to have the highest relative *M. speciosa* densities and frequency of occurrence (Stocking and Bartholomew 2007). M. *speciosa* construct flexible tubes which allow them to suspension-feed (Som et al. 2016a). M. *speciosa* reproduction typically peaks in the spring to early summer as temperatures increase (Stocking and Bartholomew 2007), and the reproductive cycle includes a stage in which non-feeding larva are brooded in the maternal tube until they reach suitable size for release (as cited in Som et al. 2016a).

M. speciosa are thought to be infected with *C. shasta* myxospores through suspension feeding (Hallett and Bartholomew 2011), though infection in adult *M. speciosa* is relatively rare (i.e., less than 6 percent prevalence of infection in the Klamath River from 2013 – 2017) (Bartholomew et al. 2018). Neither horizontal (between *M. speciosa* individuals) nor vertical (adult to egg or larvae) *C. shasta* infection has been observed in *M. speciosa* (Hallett and Bartholomew 2011).

Prevalence of infection is directly correlated with the number of adult salmon returning to spawn, but is also influenced by other factors contributing to myxospore production, survival, and availability (Som et al. 2018a). Som et al. (2018a) indicated that infected *M. speciosa* may occur in areas exhibiting a smaller range in water depth and velocity at peak flows, relative to areas with uninfected *M. speciosa* populations. Similarly, Som et al. (2018a) noted that the highest *M. speciosa* prevalence of infection was observed during drought years with relatively homogenous Klamath River flow regimes. Finally, it appears that *M. speciosa* infection may be more likely if maturing *M. speciosa* leave maternal tubes during periods when myxospores are present in the water column and available for uptake (Julie Alexander, pers. comm., July 12, 2018).

Once myxospores have infected *M. speciosa*, the myxospores develop into actinospores (Hallett and Bartholomew 2011), a process that takes approximately 700 degree-days (Julie Alexander, pers. comm., July 12, 2018), or 7 weeks at 17°C (as cited in Hallett and Bartholomew 2011). Several hundred actinospores can be released each day from a single infected *M. speciosa* individual (Hallett and Bartholomew 2011). Actinospore concentrations (and presumably the rate at which actinospores are released from *M. speciosa* individuals) increase to measurable concentrations when water temperatures reach approximately 10°C, increase with increasing water temperatures up to 17°C, and then decrease with increasing temperatures beyond this (Foott et al. 2011). Actinospores are viable for up to 13 days at 11°C, but only 3 to 7 days at 18°C (Hallet and Bartholomew 2011). In the Klamath River system, actinospore concentrations typically peak in the late spring or early summer (Bartholomew et al. 2018), depending on water temperatures and degree-days within a given year. Annual maximum actinospore concentrations vary substantially between years (Bartholomew et al. 2018) due to a number of factors related to salmonid and *M. speciosa* life history stage timing and densities, and hydrologic and meteorological conditions (as described here and in Shea et al. 2016, Som et al. 2018a and b, and Som and Hetrick 2016). Similarly, actinospore concentrations tend to vary intra-annually between sampling sites, though the highest spore concentrations typically occur near the confluence of Beaver Creek (Bartholomew et al. 2018).

Actinospores attach to salmonid gills, migrate to the gill blood vessels where they replicate, and then migrate via the circulatory system to the intestine and other internal organs (as cited in Hallett and Bartholomew 2011). Once in the intestines, actinospores develop into myxospores, a process that typically takes 2 weeks at 18°C (as cited in Hallett and Bartholomew 2011). The progression of myxospore development is often fatal to the salmonid host; clinical signs of the disease state (previously termed ceratomyxosis) include necrosis of intestinal tissues, often accompanied by a severe inflammatory reaction (Hallett and Bartholomew 2011). Myxospores are released when the salmonid host dies (Hallett and Bartholomew 2011). As such, years with greater adult salmon returns, and areas with concentrated spawning and associated mortality may contribute substantially to the Klamath River myxospore load (Som and Hetrick 2016). Finally, neither horizontal (fish to fish) nor vertical (adult to egg) *C. shasta* infection has been observed in salmonids (Som et al. 2016b).

The timing and severity of *C. shasta* infection and related mortality in salmonids is affected by a variety of factors including dose (a mechanism of velocity and spore concentration), exposure duration, water temperature, and the inherent resistance of the fish strain (Hallett et al. 2012).

Additionally, concentrations of specific *C. shasta* spore genotypes may influence infection rate and severity and associated mortality in specific salmonid species (Atkinson and Bartholomew 2010). Atkinson and Bartholomew (2010) identified *C. shasta* genotypes O, I, II, and III. Of particular interest in this BA is genotype II, which infects coho (Atkinson and Bartholomew 2010). Finally, it is important to note that *C. shasta* infection does not always result in mortality. Indeed, infection at low doses does not necessarily lead to a diseased state and subsequent mortality unless the fish is overwhelmed by spores (Hallett et al. 2012).

Hallett et al. (2012) found that both spore concentration and water temperature affected infection severity and mortality. Specifically, 5 genotype II actinospores per liter led to ≥ 40 percent mortality in tested coho at water temperatures greater than 15°C (Hallet et al. 2012). Similarly, Hallett et al. (2012) found that water temperature and spore concentration affected the disease duration (i.e., time from exposure to mortality), though water temperature explained a substantial part of the variation in disease duration. Ray et al. (2012) also found that water temperature was negatively correlated with “mean days to death” after exposure to *C. shasta* in Chinook and coho.

Migrating juvenile salmon, including young of year juveniles re-distributing, in April through July are particularly susceptible and at risk to infections by *C. shasta* during emigration (NMFS 2012a). As such, there is extensive monitoring of *C. shasta* prevalence of infection (POI) and associated mortality during this time period each year. Between 2009 and 2018, *C. shasta* maximum observed POI at the Kinsman trap on the Klamath River (prior to the date at which 80 percent of outmigrating salmon juveniles passed the trap) ranged from zero percent (2010 and 2013) to 100 percent (2015) (True et al. 2017). Note that annual maximum POI occurred after the 80 percent outmigration date in some years (i.e., 2010, 2013, 2014, and 2016) (True et al. 2017); POI occurring after the 80 percent outmigration date is not representative of conditions that the majority of outmigrating salmon would’ve experienced.

Since 2007, Oregon State University scientists have monitored mortality related to *C. shasta* exposure and infection through “sentinel studies” in which Klamath River (Iron Gate Hatchery and/or Trinity River Hatchery) Chinook and coho are held in live cages in the river (and thereby exposed to *C. shasta*) at various sites in April, May, June, and September (*see* Bartholomew et al. 2018 for additional details regarding methods). From 2009 to 2017, April mortality was generally less than 15 percent for Chinook and close to 0 percent for coho (Bartholomew et al. 2018). For May during the same timeperiod, Chinook mortality ranged from 90 (2015, Seiad Valley) to zero percent, with the highest observered percent mortality in 2014 and 2015 (Bartholomew et al. 2018). For June during the same timeperiod, Chinook mortality ranged from 80 percent (2016, Orleans) to zero percent, with the highest percent mortality in 2009, 2014, 2015, and 2016 (Bartholomew et al. 2018). Similarly, for coho in June of 2009 through 2017, mortality ranged from approximately 70 (2014, Seiad Valley) to zero percent, with the highest percent mortality in 2009, 2011, and 2014 (Bartholomew et al. 2018). Note that, as for POI above, there should be some consideration regarding outmigration timing and the relative impact of high percent mortality to the entire juvenile population if it’s occurring after the 80 percent outmigration date.

Given the multi-stage and multi-host lifecyle of *C. shasta*, there are opportunities to disrupt *C. shasta* dynamics in the Klamath River through specific management actions. There is particular interest in increased flow to facilitate disruption of preferred *M. speciosa* habitat and physical disturbance of occupied habitat, dilute pathogen concentrations, and decrease in-stream temperatures. These actions support the assertion that for an infectious zone to exist, there must be adequate *M. speciosa* habitat, stable flow, proximity to spawning areas (salmonid release of myxospores), and temperatures above 15°C (Som et al. 2016b).

Sediment maintenance flows, or flushing flows, are naturally occurring environmental occurrences that mobilize the fine sediment surface layer (i.e., sand, silt, and clay smaller than 2mm in diameter; Kondolf and Wilcock 1996). Sediment mobilization can cause dislodgement and redistribution or reduction of benthos (e.g., Giller et al. 1991, Mosisch and Bunn 1997). Indeed, monitoring of *M. speciosa* densities in 2017, a high flow year, revealed low densities relative to previous years (Bartholomew 2018). However, the behavioral plasticity of *M. speciosa* allows the species to tolerate a wide range of velocities and can persist, disperse, and redistribute to more suitable habitat following dislodgment (Malakauskas *et al*. 2013, Alexander et al. 2014). In particular, microhabitat associated with *Cladophora* buffers against sediment disturbances from high flow events, and *M. speciosa* densities have been shown to be unaffected within those microhabitats in flow events greater than 5,000 cfs (Stocking and Bartholomew 2007).

It is also possible that increased discharge can dilute spore concentrations (Hallet et al. 2012). Flow conditions may also influence spore concentrations, as observed in 2005 when flows declined from 6,000 cfs spore DNA increased (Figure 6-12). Accordingly, Hillemeier et al. (2017) recommended implementation of spring dilution flows when spore concentrations exceed 5 spores per liter or POI exceeds 20 percent. These thresholds were based on mortality observations by Hallett et al. (2012) described above, though do not account for the effect of water temperature also demonstrated in Hallett et al. (2012). Indeed, although spore concentrations decreased following high flows in 2005, POI remained steady at approximately 40 percent (Figure 6-12, Hillemeier et al, 2017), emphasizing the importance of other factors such as temperature that influence *C. shasta* infection in Chinook, as described above.

Results from a study of coho salmon smolt survival align reasonably well with information about disease conditions (Beeman et al. 2012; Figure 6-13). IGD discharge had a positive effect on survival of yearling coho salmon, but the effects were smaller than those of water temperature (Beeman et al. 2012; Figure 6-13). Lowest survival also occurred in study reaches within the disease infectious zone downstream of IGD.

In 2018, Reclamation implemented two flows intended to disrupt *C. shasta* dynamics largely based on the Klamath River Disease Guidance Document (Hillemeier et al. 2017). A surface flushing flow (6,030 cfs for 72 hours) was released from IGD in late April to scour preferred *M. speciosa* fine sediment habitat. Additionally, a dilution flow (3,000 cfs until 50,000 AF is expended) was implemented in late May with the intention of diluting *C. shasta* actinospore and myxospore concentrations within the water column (and to reduce salmon prevalence of infection). *M. speciosa* density was substantially reduced after the surface flushing flow in April 2018, relative to what was observed earlier in the spring (Julie Alexander, pers. comm., July 12, 2018). However, *M. speciosa* density rebounded by the time the dilution flow was implemented in May 2018 (Julie Alexander, pers. comm., July 12, 2018). This information suggests that a surface flushing flow prior to February would likely allow for rebound of *M. speciosa* populations during the outmigration period (Julie Alexander, pers. comm., July 12, 2018), which would likely have implications for disease dynamics. Relative to the effectiveness of the dilution flow, Oregon State University scientists are currently analyzing monitoring data collected before, during, and after the 2018 dilution flow and are planning to release a report in the near future detailing the effectiveness of this flow in diluting spore concentrations and reducing POI.

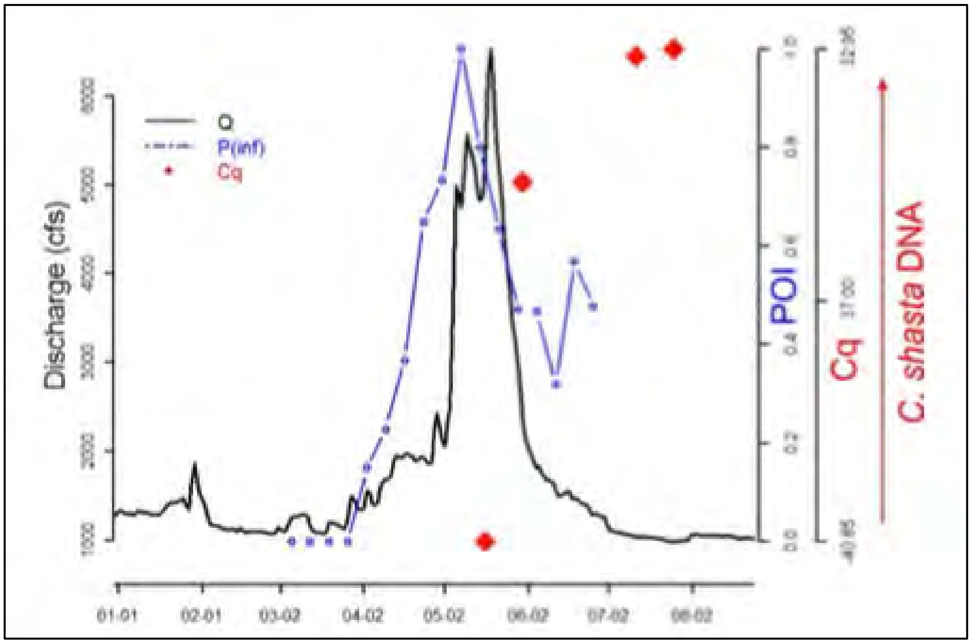

Figure 6-12. Daily river discharge (solid black line), weekly-stratified prevalence of *C. shasta* infection among sampled Chinook salmon (open blue circles connected by blue lines), and Cq scores for water monitoring samples (solid red diamonds), all estimated for an area of the mainstem Klamath River between the Shasta and Scott confluences. The inset right axis represents the range of prevalence of infection values in fish, and the outset right axis represents Cq values that reflect quantities of *C. shasta* DNA; these are scaled so that increasing values correspond to increases in spore concentrations.
Source: Hillemeier et al. 2017.

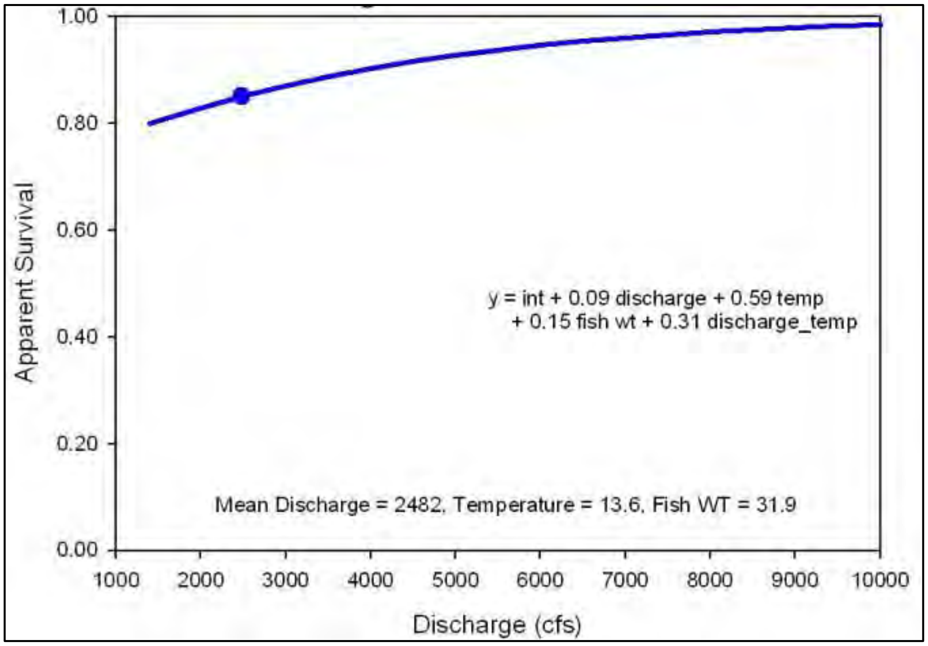

Figure 6-13. Predicted relationship between discharge and coho salmon smolt survival between Iron Gate Dam and the Shasta River confluence.
Source: adapted from Beeman et al. 2012.

6.4.1.6.2. Other Fish Parasites/Disease

F. columnare and *I. multifilis*: One notable fish disease incidence in the Klamath Basin was the large fish die-off that occurred in the lowermost 36 miles of the Klamath River mainstem in 2002. Pathology reports confirmed that the primary cause of death for approximately 34,000 salmonids (97 percent adult Chinook; Belchik et al. 2004) was ich and columnaris infection (USFWS 2002, CDFG 2004). Only relatively small numbers of coho salmon were found (estimated at 0.5 percent of total) in the fish die-off. Coho salmon migration occurs later than the Chinook salmon fall migration, which probably explains why few coho salmon were affected (NRC 2004).

Impaired upstream fish passage because of atypical low flow (lowest 10th percentile since 1951), and above average fish return in 2002, is thought to have led to effective disease transmission conditions. However, NRC (2004) speculated that it was more likely a sequence of events involving daily water temperatures that caused the mortality rather than blockage of fish passage due to low flow; NRC (2004) found that temperatures in the Klamath River reached or approached the inhibitory migration levels. A comparative analysis with historical Klamath River flow records could not conclusively demonstrate that water depth impeded upstream migration (CDFG 2004b). However, NMFS (2010) suggested that anecdotal field observations and gage height data supported the hypothesis that some fish migration may have been impeded. Because salmon are more vulnerable to infectious diseases at higher temperatures (McCullough 1999), crowding also encouraged the disease outbreak that resulted in the die-off (NRC 2004). Warm temperatures (18 to 23°C) further promoted pathogen proliferation, making fish susceptible to disease (Udey et al. 1975, Zinn et al. 1977). These pathogens are widespread (i.e., *F. columnare* and *I. multifilis*) and typically become lethal to fish when under a high degree of stress (NRC 2004), which would occur with high temperatures, overcrowding, and limited migratory abilities.

N. salmincola: This parasite may be the most common trematode endemic to the U.S. and is prevalent on the Pacific Northwest coast (Harrell and Deardorff 1990). The life cycle of the *N. salmincola* requires three hosts, one of which is salmonid fishes, and both fresh and ocean water fish can be parasitic vectors (Eastburn et al. 1987, Bennington and Pratt 1960). *N. salmincola* is commonly known for its association with "salmon poisoning disease," which can be fatal to dogs (Millemann and Knapp 1970, Eastburn et al. 1987). Overall, the parasite is relatively harmless to coho salmon and is not thought to be influenced by Reclamation's PA.

P. minibicornis: The lifecycle of *P. minibicornis* is very similar to that of *C. shasta* (Figure 6-14). Similar to diseases and parasites previously described, *P. minibicornis* parasite abundance and salmonid infection incidence also occur in the Klamath River mainstem from IGD to the estuary (Foott et al. 2009) and within tributaries (Bartholomew et al. 2009; Foott et al. 2009). For example, Bartholomew and Foott (2010) reported *P. minibicornis* infection in 90 percent of Chinook salmon and 50 percent of coho migrants. Migrating juvenile salmon, including YOY juveniles re-distributing, in April – July are susceptible and at risk to infections by *P. minibicornis*. Given that many juveniles rear in tributaries (Lestelle 2007) the greatest impacts to SONCC coho salmon through disease are due to juveniles re-distributing in the mainstem and smolts during emigration (NMFS 2012a).

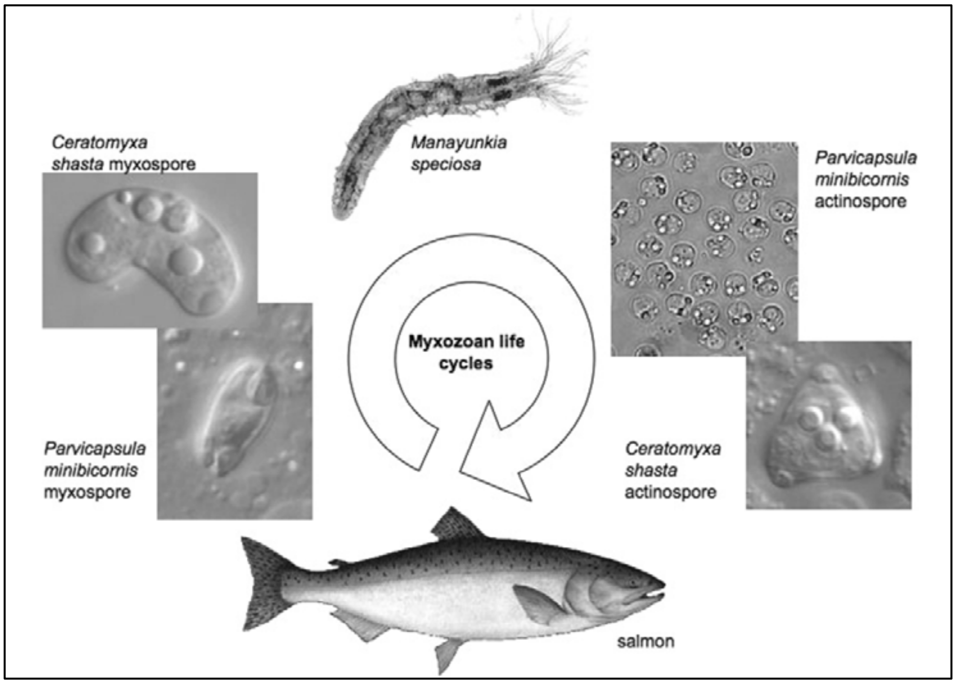

Figure 6-14. The life cycle of *Ceratonova shasta* and *Parvicapsula minibicornis* (graphic developed by J. Bartholomew, Oregon State University). *Manayunkia speciosa* is a small freshwater polychaete worm (3 to 5 mm in length) and intermediate host of both parasites. Source: Som et al. 2016.

6.4.2. SONCC Coho Salmon ESU Critical Habitat

Critical habitat (formally designated on May 5, 1999 – 64 FR 24049) for the SONCC coho salmon ESU includes all accessible waterways, substrate, and adjacent riparian zones between Cape Blanco, Oregon, and Punta Gorda, California (64 FR 24049; May 5, 1999). Exclusions to the critical habitat are:

1. Areas above specific dams identified in the FR notice (The FR includes IGD, and therefore the Klamath River upstream of the dam is not listed in the SONCC coho salmon ESU and it is not critical habitat);

2. Areas above longstanding, natural barriers to fish passage (i.e., natural waterfalls); and

3. Tribal lands.

The essential habitat types of SONCC coho salmon ESU designated as critical habitat are:

1. Juvenile summer and winter rearing areas;
2. Juvenile migration corridors;
3. Adult migration corridors;
4. Spawning areas; and
5. Areas for growth and development to adulthood.[9]

Within the five essential habitat types, essential features (also known as primary constituent elements) of critical habitat include adequate quantity and/or quality of: (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) provision of safe passage conditions. In addition, designated freshwater and estuarine critical habitat includes riparian areas that provide the following functions: shade, sediment, nutrient or chemical regulation, streambank stability, and input of large woody debris or organic matter (64 FR 24049, May 5, 1999). Of these essential features, water quantity/quality, water velocity, water temperature, substrate, and overall habitat quantity are most impacted by implementing the PA.

6.4.2.1. Juvenile Summer and Winter Rearing Areas

Summer and winter juvenile rearing areas should contain adequate substrate, water quality, water quantity, water temperature, water velocity, cover/shelter, food, riparian vegetation, and space. These essential features are necessary to provide sufficient growth and reasonable likelihood of survival to smoltification. Although some streams in the SONCC coho salmon ESU remain intact relative to their historic conditions, most waterways in the ESU fail to provide sufficient summer and winter rearing areas for juveniles. Specifically, summer rearing areas are reduced by low flow conditions, high water temperatures, insufficient DO concentrations, excessive nutrient loads, invasive species, habitat loss, disease, pH fluctuations, sedimentation, removal or

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[9] Areas for growth and development to adulthood are restricted to the marine environment for coho salmon, (NMFS 2010), and not impacted by the implementation of the PA.

non-recruitment of large woody debris, summer embeddedness, stream habitat simplification, and loss of riparian vegetation. Winter rearing areas are limited by high water velocities from excessive surface runoff during storm events, increased suspended sediment, removal or non-recruitment of large woody debris, and stream habitat simplification. In addition to impacts on specific rearing areas, pervasive changes to streambeds and substrate (e.g., lack of gravel recruitment, sedimentation, embeddedness, etc.), as well as removal of riparian vegetation in many waterways in this ESU, has limited the amount of invertebrate production in streams, an important food resource for rearing juveniles.

6.4.2.2. Juvenile Migration Corridors

Juvenile migration corridors must have sufficient water quality, water quantity, water temperature, water velocity, and safe passage conditions to allow coho salmon juveniles and smolts to emigrate to estuaries and ocean or to migrate into non-natal rearing zones and tributaries. In the ESU, juvenile migration corridors are constrained by low flow conditions, disease effects, high water temperatures, low water velocities, and a lack of habitat complexity; these conditions can slow or impede emigration or upstream and downstream redistribution. Additionally, low DO levels, excessive nutrient loads, insufficient pH levels, and other water quality factors negatively influence juvenile migration corridors in the ESU.

6.4.2.3. Adult Migration Corridors

Adult migration corridors should provide satisfactory water quality, water quantity, water temperature, water velocity, cover/shelter, and safe passage conditions for adults to reach spawning areas. Adults generally migrate in the fall or winter months to spawning areas. While adult migration corridors are a necessary step in the lifecycle for the species, the condition of this essential habitat type in the ESU is probably not as limiting for the recovery of the species, as other essential habitat types, such as juvenile summer and winter rearing areas (NMFS 2013).

6.4.2.4. Spawning Areas

Coho salmon primarily spawn in tributary streams from November through January in the ESU. Spawning areas for SONCC coho salmon must include adequate substrate, water quality, water quantity, water temperature, and water velocity to ensure successful redd construction, egg deposition, and egg-to-fry survival. Sedimentation is a widespread problem throughout the ESU as it leads to the embedding of spawning gravels, impeding redd construction, as well as reducing egg-to-fry survival. Redd scouring from excessive storm runoff is also problematic in the ESU as it can lead to direct egg mortality, especially if the discharges exceed 5,163 cfs at IGD gage (Erickson et al. 2007). Lastly, low-recruitment or non-recruitment of spawning gravels is common throughout the ESU, limiting the amount of spawning habitat and exacerbating substrate embeddedness.

6.4.2.5. SONCC Coho Salmon Critical Habitat Summary

The current function of critical habitat for SONCC coho salmon has been degraded relative to its unimpaired state. Most of streams and rivers in the ESU reflect some degree of habitat degradation that is limiting one or more life-stages of coho salmon. Additionally, critical habitat in the ESU often lacks the ability to establish essential features due to ongoing human activities and the lack of fluvial processes. Most notably, water diversions that reduce summer base flows are common in systems throughout the ESU and result in reduced water quality and quantity below levels critical to juvenile coho salmon survival.

6.4.2.6. Restoration Activities – Klamath Basin Coho Restoration Grant Program.

There are several restoration and recovery actions underway in the Klamath Basin aimed at improving habitat and water quality conditions for anadromous salmonids, some of which are supported by Reclamation (NMFS 2013). Reclamation has provided $500,000 per year since 2013 (approximately $3 million) for the Klamath Coho Habitat Restoration Program administered by National Fish and Wildlife Foundation (NFWF). The grant program funds restoration activities to improve habitat, water quality, water quantity, and fish passage, as well as research projects for coho salmon recovery (*see* Part 8 - Effects of Implementing the PA on Coho Salmon for detailed descriptions and effects analyses). Restoration activities can occur on the mainstem Klamath River and its tributaries, with most restoration being conducted in the Shasta, Scott, and Salmon River Basins. Restoration projects are typically implemented by state, tribal, local, or private non-governmental organizations.

Reclamation has supported three grant cycles (2016, 2017, and 2018) via funding through NFWF for restoration and research/monitoring projects, whereas a total of 21 projects have been selected for full or partial funding (Table 8-15). Of these projects, seven have started implementing their projects for the grant years of 2016 and 2017; however, no grant contracts have been completed for the 2018 grant year. Of those seven projects, three have begun implemented restoration activities:

1. Parks Creek Fish Passage Design and Planning: Cardoza Ranch with design plans developed;

2. Lower French Creek Off-Channel Habitat Development with in-stream habitat structures installed and several off-channel ponds restored;

3. Bogus Creek Fish Passage with passage barriers removed, providing additional habitat for coho salmon.

The grant program is still in its infancy and therefore has not had sufficient time to implement many of its funded restoration projects. Overtime, it is anticipated that the program will implement more on-the-ground restoration projects that may benefit coho populations. Dunne et al. (2011) found that restoration efforts are currently improving habitat in tributaries downstream of IGD, but the extent of changes and their effect on populations or even use of the habitat are undocumented. NMFS (2010) stated benefits from restoration activities should continue through at least 2018, and possibly increasing as more projects are implemented. Consequently, if restoration efforts are to improve coho populations, then more projects will need to address the limiting factors by implementing on-the-ground solutions.

7. EFFECTS OF IMPLEMENTING THE PROPOSED ACTION ON LOST RIVER AND SHORTNOSE SUCKERS

Part 7 of the BA evaluates if implementing the PA may affect individuals and populations of both LRS and SNS and their designated critical habitat. When the discussion addresses effects to individuals and populations of both species, the generic expression "*suckers*" is used. When the discussion requires species differentiation, the text names the species of interest. This part is organized by hydrologic watersheds of the Klamath River Basin and the Lost River Basin, closely emulating Recovery Units and management units within the Revised Recovery Plan for the LRS and SNS (herein referred to as the Recovery Plan; USFWS 2012).

The PA is the continued operation of the Project including storage and delivery of irrigation water from bodies of water in the Upper Klamath Basin and O&M of canals, dams, and pumps consistent with water storage and delivery (*see* Part 4.3, Proposed Action). To evaluate storage and delivery of surface water from UKL, hydrologic information during the past 36 water-years (October 1, 1980 to September 30, 2016) was modeled using WRIMS to simulate management decisions of the PA (*see* Part 3.1., Analytical Approach). Resulting surface elevations for UKL from WRIMS were evaluated based on model output and percent exceedance of the modeled output. The modeled output informs resource managers on the expected outcomes to surface water (i.e., lake surface elevations and in-stream flows) that result from the PA. The Effects Analysis of the PA on suckers in UKL is conducted by reviewing information on lake surface elevation, impacts of lake surface elevation to sucker habitats at each life history stage, and direct impacts to individual suckers based on outputs from the model. Modeled UKL elevations for the PA based on the 36-year POR are shown in the exceedance tables for lake surface elevations (Table 7-3). Review of model exceedance tables provides the necessary context for understanding expected frequency of occurrence for specific surface elevations at specific times of the year. Model output was also reviewed for each model year, particularly for extreme dry conditions, to analyze the lowest range of likely lake surface elevations.

The PA includes the continued storage and delivery of irrigation water from Clear Lake Reservoir, Gerber Reservoir, Tule Lake, and Keno Impoundment consistent with recent management including maintenance of surface elevations at or above minimum levels for each body of water. The PA contains a minimum September 30 surface elevation for both Gerber and Clear Lake reservoirs. At Gerber and Clear Lake reservoirs, inflow forecasts, evaporative and seepage estimates, and outflow measurements are monitored during in-season management to provide for elevations at or above the respective September 30 minimum surface elevations. In order to analyze the extent of impacts to endangered suckers at both locations resulting from the PA, a review of surface elevations, in conjunction with biological information at Gerber and Clear Lake reservoirs is used to evaluate the frequency of lake elevations that are likely to occur.

The PA is to continue to operate Keno Impoundment with a consistent surface elevation of 4,086.5 feet and to operate the Tule Lake Sumps with a spring/summer surface elevation at or above 4,034.6 feet and a fall/winter surface elevation at or above 4034.0 feet. At Tule Lake Sump 1A, minimum surface elevations are maintained April through September to facilitate irrigation deliveries and protect endangered suckers. Minimum surface elevations are maintained October through March to protect endangered suckers and for flood control purposes (USFWS 1992). Surface elevations in the Keno Impoundment are maintained to facilitate irrigation and water operation infrastructure maintenance.

7.1. Potential Effects in the Upper Klamath Lake Recovery Unit

7.1.1. Effects to Upper Klamath Lake Individuals and Populations (Shoreline and Tributary Habitat)

The PA influences the amount of habitat available for each sucker life history stage, including larvae, YOY juveniles, older juveniles, and adults, in UKL. Each sucker life history stage (Figure 7-1) has different habitat needs. This analysis evaluates the effect of lake surface elevations resulting from the PA on the habitat associated with each life history stage in UKL and a discussion of other aspects of the PA, like incidental entrainment of fish and maintenance activities of water infrastructure, that may impact suckers. In comparison to historical operations, modeled UKL surface elevations do not fluctuate as widely (i.e., the difference between the highest and lowest elevation) in most years, and the end of season (end of September) lake elevations are generally higher than those that occurred within the POR (Figure 7-2).

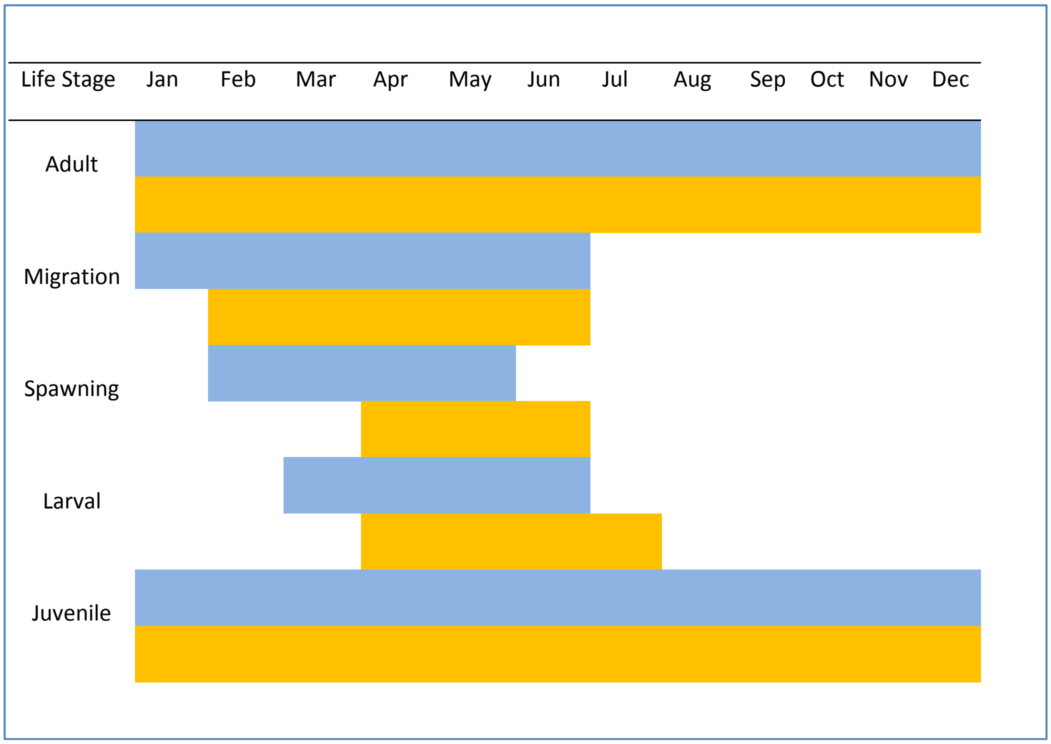

Figure 7-1. Each stage in the life history of suckers, such as spawning by adults, has a seasonal component of importance. Lost River suckers are represented by blue and shortnose suckers are represented by yellow.
Source: USFWS, forthcoming.

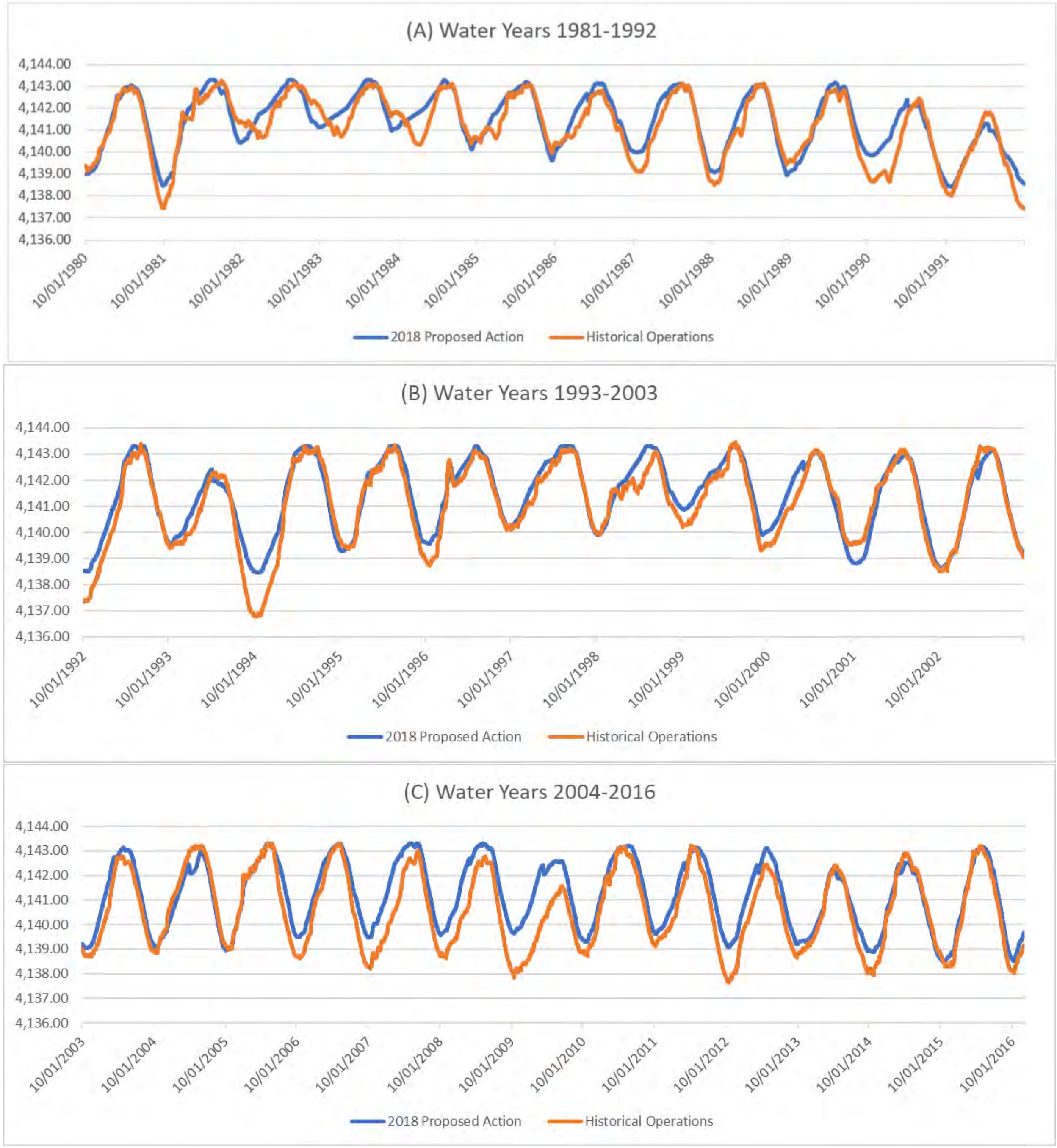

Figure 7-2. Surface elevations simulated by the 2018 Proposed Action using the central tendency control logic (blue line) in comparison with historical lake elevations (orange line). Figure (A) includes water years 1981 to 1992, (B) includes water years 1993 to 2003, and (C) includes 2004 to 2016.

7.1.1.1. Effects to Upper Klamath Lake Spawning Success

The modeled output from the POR indicates that the PA should provide lakeshore-spawning suckers with UKL elevations sufficient to inundate 74 percent or more of spawning habitat with 1 foot or more of water (a UKL elevation of at least 4,142 feet) in all months from the end of

February to the end of June in 25 of 36 years (69 percent). More specifically, lake elevations are predicted to be greater than or equal to 4,142 feet 83 percent of years at EOM February, 97 percent of years at EOM March, 92 percent of years at EOM April, 92 percent of EOM May, and 75 percent of EOM June (Table 7-1). The PA will reduce the amount of available spawning habitat for the earliest spawners at the shoreline springs in 6 out of 36 years with lake elevations below 4,142 feet. However, lake elevations are typically increasing between EOM February and EOM March so the amount of spawning habitat inundated will typically increase during March and April. Additionally, Burdick et al. (2015) indicated the number of spawners and the duration for which they spawn is unlikely to be reduced *between* 4,141.4 and 4,142 feet. The PA meets a surface elevation EOM February 4,141.4 feet in 35 out of 36 years. Thus, the PA will still impact early spawning some years but that impact is only in 3 percent of years based on an elevation of 4,141.4 feet (Table 7-1).

Table 7-1. Summary statistics for end of month elevations for Upper Klamath Lake from 36 hydrological scenarios using the central tendency control logic derived from the Proposed Action viewer, inclusive of water year scenarios 1981 to 2016. Number of years when lake elevations are projected to be less than or equal to the lower (4,141.4 feet) and higher (4,142.0 feet) end-of-month (EOM) lake elevations during the spawning season (EOM February to EOM May) identified by Burdick et al (2015) as minimums unlikely to limit the duration or number of individuals spawning at lakeshore spawning grounds.

Month	Average ± Standard Deviation (feet)	(Minimum, Maximum)	Number of years < 4141.4 feet (percent of years)	Number of years < 4142.0 feet (percent of years)
Oct	4,139.7 ± 0.8	(4,138.5, 4,141.4)	Not essential	Not essential
Nov	4,140.1 ± 0.8	(4,138.9, 4,141.6)	Not essential	Not essential
Dec	4,140.9 ± 0.6	(4,139.7, 4,141.8)	Not essential	Not essential
Jan	4,141.7 ± 0.5	(4,140.4, 4,142.3)	Not essential	Not essential
Feb	4,142.3 ± 0.4	(4,140.9, 4,142.7)	1 years (3 percent)	6 years (17 percent)
Mar	4,142.7 ± 0.3	(4,141.3, 4,143.1)	1 years (3 percent)	1 years (3 percent)
Apr	4,142.9 ± 0.5	(4,141, 4,143.3)	1 years (3 percent)	3 years (8 percent)
May	4,142.8 ± 0.6	(4,140.1, 4,143.3)	1 years (3 percent)	3 years (8 percent)
June	4,142.2 ± 0.7	(4,139.8, 4,143.1)	5 years (14 percent) Less essential	9 years (25 percent) Less essential
July	4,141.1 ± 0.6	(4,139.5, 4,142.2)	Not essential	Not essential
Aug	4,140 ± 0.6	(4,138.9, 4,141.4)	Not essential	Not essential
Sept	4,139.5 ± 0.7	(4,138.5, 4,141.2)	Not essential	Not essential

Typically, maximum lake surface elevation will be attained each year in April or May (Tables 7-1 and 7-2). Lakeshore-spawning LRS begin spawning when temperatures are approximately 6°C and large numbers of suckers are typically detected at the lakeshore springs by the middle of March. Hence, both end of February and end of March lake elevations are assessed in this effects analysis. Burdick et al. (2015) observed fewer sucker detections at the lakeshore spawning areas in 2010, when lake surface elevation was lower than 4,141.3 feet throughout the spawning season. These results suggest that lake surface elevation at or above 4,142.0 feet by the beginning of March (or earlier) is important for lakeshore spawning access and activity. When lake surface elevations are 4,142.0 feet, approximately 74 percent of shoreline spawning habitat is inundated to a depth of at least 1.0 foot (Table 6-2).

Lake surface elevations by the end of February are at or above 4,142 feet in more than 80 percent of years as identified in end of month exceedances from the PA modeled output (Table 7-3). In the 36-year POR analyzed, there were six years (model years 1991, 1992, 1993, 1994, 2005, and 2014) where the surface elevation of UKL did not reach at least 4,142 feet by the end of February (Table 7-1 and Table 7-2). However, lake surface elevations by the end of March are at or above 4,142 feet in 95 percent of years as identified in end of month exceedances from the modeled output (Table 7-3). The PA results in one year from the 36-year POR analyzed (1992) in which the surface elevation of UKL failed to reach at least 4,142 feet by the end of March, and in fact the hydrologic conditions of a year like 1992 never allow the lake to increase above 4,142 feet (Table 7-2). However, there are a number of years in which the surface flushing flow results in a drop below 4,142 ft for one or two days in March or April. The effects of implementing a surface flushing flow (namely reductions in UKL surface elevations) on lakeshore spawning suckers have not been directly studied, however, implementing surface flushing flows may result in negative effects to lakeshore spawners, eggs, or both, and may potentially discourage some lakeshore spawners.

The modeled output for the PA (Table 7-1, Table 7-2) indicates that the frequency at which reduced habitat may concentrate spawning or compel suckers to skip spawning at the shoreline areas is relatively low. The extent that slightly lower than 4,142-foot lake elevations at the end of February in 6 of 36 years affects lakeshore spawners is unclear but is likely to be small, especially since lake elevations in those 6 years were near 4,142 feet. LRS and SNS have high reproductive output (Perkins et al. 2000a) that would offset occasional low reproduction years when conditions are poor with substantial gains in years when spawning habitat conditions are good if juveniles survive.

The PA will occasionally result in UKL surface elevations that may affect adult suckers spawning at the shoreline areas through a reduction of available spawning habitat. The impact is a reduction in the numbers of individual LRS that spawn at the shoreline spawning area and a reduction in the amount of time they spend at spawning grounds. The reduction in the number of spawners, or the amount of time spent at spawning grounds, is likely to affect, and likely to adversely affect lakeshore spawners.

Table 7-2. Modeled end of month UKL surface elevations (feet above mean sea level, Reclamation datum) for the Period of Record (water year 1981 – through water year 2016) from the Proposed Action.

Model Year	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1982	4,139.15	4,139.55	4,140.56	4,141.48	4,142.61	4,142.81	4,143.03	4,142.88	4,141.97	4,140.60	4,139.31	4,138.47
1982	4,138.87	4,139.89	4,141.26	4,141.99	4,142.69	4,142.79	4,143.23	4,143.26	4,142.67	4,142.16	4,140.91	4,140.47
1983	4,140.76	4,141.32	4,141.78	4,141.99	4,142.39	4,142.79	4,143.12	4,143.26	4,142.82	4,142.10	4,14,1.39	4,141.16
1984	4,141.32	4,141.59	4,141.79	4,141.99	4,142.39	4,142.79	4,143.24	4,143.25	4,142.92	4,14,1.90	4,140.96	4,141.13
1985	4,141.40	4,141.59	4,141.79	4,141.99	4,142.39	4,142.71	4,143.28	4,142.98	4,142.40	4,141.01	4,140.32	4,140.53
1986	4,140.82	4,141.35	4,141.79	4,142.28	4,142.73	4,142.80	4,143.01	4,143.17	4,142.42	4,141.21	4,140.03	4,139.92
1987	4,140.37	4,140.93	4,141.75	4,142.28	4,142.67	4,142.98	4,143.09	4,142.69	4,142.05	4,141.39	4,140.51	4,140.05
1988	4,140.01	4,140.39	4,141.32	4,142.28	4,142.69	4,143.01	4,143.11	4,142.89	4,142.55	4,141.18	4,139.85	4,139.15
1989	4,139.17	4,139.96	4,140.80	4,141.70	4,142.39	4,142.79	4,142.98	4,143.00	4,142.18	4,140.66	4,139.48	4,139.10
1990	4,139.41	4,139.83	4,140.48	4,141.47	4,142.34	4,142.94	4,143.14	4,142.89	4,142.48	4,141.25	4,140.33	4,139.91
1991	4,139.90	4,140.20	4,140.53	4,141.23	4,141.91	4,142.40	4,142.13	4,142.03	4,141.14	4,140.16	4,139.20	4,138.59
1992	4,138.49	4,139.08	4,139.73	4,140.36	4,140.86	4,141.30	4,140.96	4,140.56	4,139.84	4,139.55	4,138.86	4,138.54
1993	4,138.61	4,139.18	4,139.98	4,140.85	4,141.54	4,142.79	4,143.28	4,143.07	4,142.91	4,141.48	4,140.44	4,139.60
1994	4,139.82	4,139.98	4,140.62	4,141.29	4,141.80	4,142.40	4,141.87	4,141.69	4,141.05	4,139.96	4,139.00	4,138.51
1995	4,138.52	4,139.15	4,139.84	4,140.80	4,142.21	4,143.09	4,143.28	4,143.21	4,142.90	4,141.83	4,140.29	4,139.34
1996	4,139.42	4,139.67	4,140.99	4,142.27	4,142.40	4,142.79	4,143.28	4,143.29	4,142.60	4,141.37	4,140.16	4,139.62
1997	4,139.79	4,140.43	4,141.63	4,141.99	4,142.39	4,142.77	4,143.28	4,142.97	4,142.46	4,141.42	4,140.50	4,140.26
1998	4,140.48	4,141.15	4,141.79	4,142.28	4,142.69	4,142.80	4,143.27	4,143.30	4,143.10	4,142.01	4,140.67	4,139.93
1999	4,140.17	4,141.00	4,141.69	4,141.99	4,142.39	4,142.79	4,143.28	4,143.24	4,142.87	4,141.78	4,141.28	4,140.90
2000	4,141.01	4,141.41	4,141.79	4,142.28	4,142.40	4,142.79	4,143.28	4,143.18	4,142.46	4,141.30	4,140.01	4,140.05
2001	4,140.34	4,140.89	4,141.64	4,142.28	4,142.69	4,142.82	4,143.09	4,142.57	4,141.50	4,140.52	4,139.45	4,138.85
2002	4,138.88	4,139.50	4,140.68	4,141.92	4,142.39	4,142.94	4,142.89	4,142.81	4,141.89	4,140.57	4,139.33	4,138.68
2003	4,138.77	4,139.20	4,139.98	4,141.26	4,142.29	4,142.58	4,143.04	4,143.01	4,142.06	4,140.74	4,139.71	4,139.22

Table 7-2. Modeled end of month UKL surface elevations (feet above mean sea level, Reclamation datum) for the Period of Record (water year 1981 – through water year 2016) from the Proposed Action.

Model Year	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
2004	4,139.07	4,139.38	4,140.35	4,141.30	4,142.40	4,142.77	4,143.12	4,142.99	4,142.15	4,141.05	4,139.79	4,139.19
2005	4,139.30	4,139.68	4,140.42	4,141.13	4,141.78	4,142.35	4,142.24	4,142.96	4,142.43	4,141.13	4,139.81	4,139.00
2006	4,139.11	4,140.06	4,141.32	4,141.99	4,142.39	4,142.79	4,143.28	4,143.11	4,142.50	4,141.54	4,140.27	4,139.51
2007	4,139.65	4,140.35	4,141.24	4,142.06	4,142.69	4,143.09	4,143.29	4,142.91	4,142.06	4,141.04	4,140.08	4,139.48
2008	4,140.01	4,140.45	4,141.13	4,142.05	4,142.69	4,143.09	4,143.29	4,143.25	4,142.88	4,141.56	4,140.38	4,139.62
2009	4,139.78	4,140.38	4,141.00	4,142.07	4,142.69	4,143.06	4,143.24	4,143.13	4,142.85	4,141.54	4,140.51	4,139.74
2010	4,139.84	4,140.16	4,140.62	4,141.54	4,142.30	4,142.20	4,142.51	4,142.54	4,142.28	4,141.11	4,139.90	4,139.39
2011	4,139.51	4,140.08	4,141.13	4,142.00	4,142.64	4,143.09	4,143.12	4,143.18	4,142.66	4,141.73	4,140.51	4,139.69
2012	4,139.83	4,140.23	4,140.73	4,141.69	4,142.51	4,142.84	4,143.08	4,142.87	4,142.25	4,141.10	4,139.92	4,139.23
2013	4,139.25	4,139.66	4,140.78	4,141.55	4,142.28	4,142.57	4,143.09	4,142.64	4,141.77	4,140.67	4,139.78	4,139.19
2014	4,139.35	4,139.43	4,139.86	4,140.47	4,14,1.58	4,142.30	4,141.88	4,141.60	4,140.80	4,139.95	4,139.37	4,138.97
2015	4,139.01	4,139.41	4,140.59	4,141.41	4,142.44	4,142.47	4,142.40	4,142.03	4,141.19	4,140.16	4,139.19	4,138.63
2016	4,138.61	4,138.89	4,140.07	4,141.17	4,142.11	4,143.01	4,143.12	4,142.90	4,142.07	4,140.77	4,139.34	4,138.59

Table 7-3. Modeled percent exceedances for UKL end of month surface elevations (feet above mean sea level, Reclamation datum) for the Period of Record (water year 1981 through water year 2016) from the Proposed Action.

%	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
5%	4,141.3	4,141.6	4,141.8	4,142.3	4,142.7	4,143.1	4,143.3	4,143.3	4,142.9	4,142.1	4,141.3	4,141.1
10%	4,140.9	4,141.4	4,141.8	4,142.3	4,142.7	4,143.1	4,143.3	4,143.3	4,142.9	4,141.9	4,140.9	4,140.6
15%	4,140.6	4,141.2	4,141.8	4,142.3	4,142.7	4,143.0	4,143.3	4,143.2	4,142.9	4,141.8	4,140.6	4,140.4
20%	4,140.4	4,141.0	4,141.7	4,142.2	4,142.7	4,143.0	4,143.3	4,143.2	4,142.8	4,141.7	4,140.5	4,140.0
25%	4,140.1	4,140.8	4,141.6	4,142.1	4,142.7	4,142.9	4,143.3	4,143.2	4,142.7	4,141.5	4,140.5	4,139.9
30%	4,140.0	4,140.4	4,141.3	4,142.0	4,142.6	4,142.8	4,143.3	4,143.2	4,142.6	4,141.5	4,140.4	4,139.9
35%	4,139.8	4,140.4	4,141.3	4,142.0	4,142.4	4,142.8	4,143.2	4,143.1	4,142.5	4,141.4	4,140.3	4,139.7
40%	4,139.8	4,140.3	4,141.2	4,142.0	4,142.4	4,142.8	4,143.2	4,143.0	4,142.5	4,141.3	4,140.3	4,139.6
45%	4,139.8	4,140.2	4,141.0	4,142.0	4,142.4	4,142.8	4,143.1	4,143.0	4,142.4	4,141.2	4,140.1	4,139.5
50%	4,139.6	4,140.1	4,140.9	4,142.0	4,142.4	4,142.8	4,143.1	4,143.0	4,142.4	4,141.2	4,140.0	4,139.4
55%	4,139.4	4,140.0	4,140.8	4,141.7	4,142.4	4,142.8	4,143.1	4,142.9	4,142.3	4,141.1	4,139.9	4,139.3
60%	4,139.3	4,139.9	4,140.7	4,141.5	4,142.4	4,142.8	4,143.1	4,142.9	4,142.2	4,141.0	4,139.8	4,139.2
65%	4,139.2	4,139.7	4,140.6	4,141.5	4,142.4	4,142.8	4,143.1	4,142.9	4,142.1	4,141.0	4,139.8	4,139.2
70%	4,139.2	4,139.7	4,140.6	4,141.4	4,142.3	4,142.8	4,143.0	4,142.9	4,142.1	4,140.7	4,139.7	4,139.1
75%	4,139.1	4,139.5	4,140.5	4,141.3	4,142.3	4,142.6	4,143.0	4,142.7	4,142.0	4,140.7	4,139.5	4,139.0
80%	4,138.9	4,139.4	4,140.4	4,141.2	4,142.2	4,142.5	4,142.7	4,142.6	4,141.8	4,140.6	4,139.4	4,138.8
85%	4,138.8	4,139.3	4,140.0	4,141.1	4,141.9	4,142.4	4,142.3	4,142.3	4,141.4	4,140.4	4,139.3	4,138.6
90%	4,138.6	4,139.2	4,139.9	4,140.8	4,141.7	4,142.3	4,142.1	4,141.9	4,141.1	4,140.1	4,139.2	4,138.6
95%	4,138.5	4,139.1	4,139.8	4,140.5	4,141.4	4,142.1	4,141.7	4,141.4	4,140.7	4,139.9	4,139.0	4,138.5

7.1.1.2. Effects to Upper Klamath Lake Embryo Habitat

The PA results in increasing lake elevations during late winter and spring, with a maximum annual lake elevation occurring in April or May of each year. Although a water depth requirement for successful embryo development is not known, the PA may impact embryo development through desiccation of spawning sites when surface elevations decline precipitously in May and early June, whereby embryos are exposed. Embryo survival is most likely to be impacted by changes in lake elevations at the shallowest spawning sites, such as Ouxy and Silver Building Springs (Table 6-1, Figure 6-2). Desiccation of spawning sites will adversely impact individual embryos and may adversely impact populations if a relatively high number of spawning sites become dewatered during embryo development. Reductions in spring UKL elevation may also increase susceptibility of embryos to avian predators, although the magnitude of impacts are not well understood. The PA may also result in reduced lake surface elevations while embryos are developing as a result of implementation of a surface flushing flow to reduce disease risks to coho salmon. Implementation of surface flushing flow results in a range of impacts to UKL, from minor impacts to up to a 0.47-foot decline in a relatively short amount of time. An unknown associated with the PA for lakeshore embryo development is the impact of an approximately half a foot decrease in lake elevation in a short (9 days) amount of time (Appendix 4). Surface flushing flows will be implemented during downstream tributary accretion events to reduce the amount of water released from the UKL and to minimize the impact of declining lake elevations on embryo development (Appendix 4). Whereas, rapid declines in lake elevation during embryo development may have adverse affects to embryo development and survival, lake elevation declines associated with implementation of surface flushing flow in the PA are generally small enough that the impacts could be relatively small to embryos at the shoreline spawning areas. If disease mitigating flows other than surface flushing flows are implemented, Reclamation anticipates the declining lake elevations to be more gradual than those for the surface flushing flow, occurring over a longer duration late in the spring months and likely reducing impacts to embryos. Reclamation anticipates improvements that offset some adverse impacts from the PA to suckers from actions taken through funding the conservation measures.

7.1.1.3. Effects to Upper Klamath Lake Larval Sucker Habitat

Shallow, near-shore areas, particularly with emergent vegetation, provide habitat for larval suckers (especially SNS; USFWS 2008a). This type of vegetation affords larval suckers with some protection from predators (Markle and Dunsmoor 2007), more diverse food resources (Cooperman and Markle 2004), and protection from turbulence during storm events (Klamath Tribes 1996). Larval suckers begin to appear in UKL in March, with peak abundance occurring in mid-May to mid-June. Larvae transform to juveniles by mid- to late-July (Buchanan et al. 2011).

Although emergent wetland habitat exists at locations around UKL, wetlands at the Williamson River Delta are particularly important (USFWS 2008a). Wetlands at the Delta are adjacent to the major source of larvae emigrating from spawning areas in the Williamson and Sprague Rivers (Dunsmoor et al. 2000), and this area consistently has the highest densities of larvae in UKL during late spring surveys (Terwilliger et al. 2004).

The PA is anticipated to provide lake surface elevations at or above 4,142 feet by the end of June in 70 percent of years, and at or above 4,140.65 feet in 95 percent of years. At 4,142 feet, approximately 98.8 percent of emergent wetland-edge habitat is inundated to at least 1.0-foot water depth; at 4,140.65 feet, approximately 78 percent of the emergent vegetation habitat in UKL is inundated to at least 1.0-foot water depth (Figure 6-3). Lake elevations will be at or above 4,140 feet by the end of July in 90 percent of years, resulting in 57 percent of wetland habitat inundated to 1 foot or more (Figure 6-3, Table 7-3). The amount of wetland habitat inundated to 1 foot or more declines from 93.3 percent to 14 percent between lake elevations 4,141.3 and 4,139.3 feet (Figure 6-3). Even during dry conditions, such as when lake elevations are at the 95 percent exceedance level, it is anticipated that greater than 53 percent of emergent vegetation will be inundated by at least 1.0 foot of water through the end of July. Modeling of the PA resulted in three years from the 36-year POR when the end of July lake surface elevation is below 4,140.0 feet (model years 1992, 1994, and 2014; Table 7-1, Table 7-2). For surface elevations below 4,140.0 feet, less than 57 percent of emergent vegetation is inundated to at least 1 foot. Even during the driest year in the POR (1992), the PA provides portions of emergent vegetation (76, 51, and 37 percent of habitat) as larval sucker habitat with surface elevations of 4,140.6, 4,139.8, and 4,139.5 feet at the end of May, June, and July, respectively (Figure 6-3, Table 7-2).

The PA maintains at least 82 percent of inundated emergent vegetation habitat for larval suckers in UKL through the end of June in all years except during model year 1992. During extended dry conditions, as in model years from the early 1990s, the PA maintains lake elevations such that one third or more emergent vegetation is inundated with at least 1.0-foot of water through the end of July. As the Williamson River Delta continues to return to some semblance of its natural condition, the amount of wetland habitat available to suckers is expected to increase. The amount of emergent wetland-edge habitat in the Williamson River Delta ranges from 34 acres at 4,137 feet to 621 acres at 4,143 feet surface elevation (Table 6-3).

The PA provides substantial (50 percent or more) amounts of emergent vegetation inundated to at least a 1.0-foot depth through the end of July in all years except model year 1992 (Figure 6-3, Table 7-2). It is unclear if larval production for tributary spawners declines during low inflow events or during extended droughts. However, the PA maintains lake surface elevations that allow for some wetlands to be available for larval development even during extremely low inflow years through the end of June and into July. Because the amount of emergent wetland habitat will decrease before larvae develop into juveniles and move to open-water habitat on their own volition, the PA will adversely impact larval sucker habitat in UKL.

7.1.1.4. Effects to Upper Klamath Lake Young-of-the-Year Juvenile Habitat

When UKL elevations decline below 4,139 feet, approximately 88 percent of vegetated habitats preferred by larval suckers and, perhaps to lesser extent YOY juveniles, are not available and suckers must move to other habitats. Below a surface elevation of 4,138.0 feet little to no rocky substrate is available for juveniles as near-shore habitat transitions to fine sediments (Simon et al. 1995, Bradbury et al. 2004, Eilers and Eilers 2005). Given that the PA will likely not result in UKL elevations below 4,138.0, some rocky substrate will be available for YOY suckers. During late summer and early autumn, near-shore vegetated habitat is typically not available for juveniles, available habitat is inaccessible for sampling, or both; thus, juvenile suckers appear to leave near-shore areas as lake surface elevation is nearing annual lows (Terwilliger 2006). It is not understood whether this observed seasonal movement by YOY suckers is due to loss of near-shore habitats that are an artifact of decreases in lake surface elevation (USFWS 2002), or if juveniles prefer open-water habitat later in the summer (Reclamation 2007).

Any decrease in lake elevation during summer months results in decreases in available habitat for YOY juvenile suckers. Because seasonal declines in lake elevation (and thus the availability of wetland habitat) have occurred every year in the last century, it is difficult to compare among years and better understand the affect of habitat availability on YOY suckers. Lake surface elevations under the PA remain at or above 4,138.8 feet by the end of August and above 4,138.4 feet by the end of September (Table 7-2; the lowest elevations simulated from the POR). At these elevations, 10 percent and 8 percent of wetland habitat is inundated to 1-foot or more at the end of August and end of September, respectively. The PA provides an end of September elevation greater than 4,138 feet in all years. However, on average modeled lake elevations are anticipated to be much higher (Tables 7-1 and 7-2). By the end of August, lake elevations will be greater than 4,140.0 feet in more than half of years, and greater than 4,139.4 feet at the end of September in more than half of years (Table 7-2). The PA provides an end of September elevation greater than 4,138 feet in all years. Surface elevations above 4,138 feet are assumed to provide some diversity in nearshore substrates as habitats for YOY juvenile suckers based on nearshore substrate surveys (Simon et al. 1995, Bradbury et al. 2004, Eilers and Eilers 2005). Available wetland habitat inundated to 1.0-foot or more will be reduced to about 23 percent in 50 percent of years. Under the PA, seasonal declines in lake surface elevations and wetland habitat from May through September, may adversely impact juvenile YOY sucker. The anticipated impacts of this PA are not greater the impacts described in the Environmental Baseline and are not anticipated to result in greater adverse impacts.

7.1.1.5. Effects to Upper Klamath Lake Older Juveniles and Adult Habitat

While little is known about habitat needs for adult LRS and SNS, Reiser et al (2001) found adult suckers congregate in the northern portion of UKL during summer months. This area, specifically Pelican Bay, has been identified as particularly important for older juveniles and adults to seek refuge from poor water quality (Banish et al. 2009). During summer months, adult suckers occupy water at least 6.6 feet (2 m) deep until mid-September when they select deeper water, 13 to 20 feet deep (4 to 6 meters; Banish *et al*. 2009). Deep water may provide refuge from poor water quality such as warm temperatures, protection from avian predators, and access to preferred food resources (Banish et al. 2009). Adequate depth is necessary for suckers to safely access water quality refuge areas in Pelican Bay and preferred habitat in mid-September.

Assessing the amount of preferred habitat at the 50 percent exceedance level (Table 7-3) may provide some insight for the conditions likely to occur under the PA. At the 50 percent exceedance level, the PA maintains UKL surface elevations above 4,141.1, 4,140.0, and 4,139.4 feet by the end of July, August, and September, respectively (Table 7-3). At these surface elevations, about 22,600 acres (76 percent) of habitat greater than 6.6 feet (2 m) will be available for adult suckers in the northern portion of Upper Klamath Lake throughout July (Table 7-4 and Table 7-5). At the end of August, the amount of preferred habitat (deeper than

6.6 feet or 2 m in the northern section of the lake) is reduced to about 19,100 acres (64 percent of available habitat). In September when adult suckers prefer habitat 13 to 20 feet (4 to 6 m) deep, the amount of habitat available in 50 percent exceedance years is expected to be reduced to about 1,200 acres (18 to 19 percent of available; Table 7-2, Table 7-4 and Table 7-5).

During dry conditions at the 95 percent exceedance levels, the PA maintains UKL surface elevations above 4,139.8, 4,138.9, and 4,138.5 feet by the end of each July, August, and September, respectively (Table 7-3). At these surface elevations, about 17,300 acres (58 percent) of habitat greater than 6.6 feet (2 m) are available for adult suckers in the northern portion of UKL throughout July (Table 7-2) and 15,300 acres (51 percent) available at the end of August (Table 7-4 and Table 7-5). In September when adult suckers prefer habitat 13 to 20 feet (4 to 6 m) deep, the amount of habitat available in 95 percent exceedance years is expected to be reduced to about 1,000 acres (16 to 17 percent; Tables 7-3, Table 7-4 and Table 7-5).

It is difficult to assess the effect the PA will have on adult sucker populations in UKL. It is possible that the reductions in preferred habitat may be contributing to the continued decline of sucker populations. Alternatively, there may only be slight impacts resulting from less habitat as the population has experienced substantial reductions in the last two decades such that a smaller population may already occupy and require less habitat. The reductions of preferred habitat during the driest drought years (1 in 20) may have consequences for the already reduced adult sucker populations (*see* sucker status in Part 5.1). Suckers concentrated and confined in small areas could experience increased incidences of disease, parasitism (especially lamprey), and bird predation (USFWS 2008a), all factors that have been observed to be prevalent in UKL. High densities of fish could also deplete preferred food items, causing additional stress and possible mortality (USFWS 2008a). However, the effects of low surface elevations, and possible concentration of suckers into reduced habitats, on population size, age-class distribution, recruitment, or decreased individual condition are not fully understood. The relationship between lake elevation and adult survival is not understood because there was very little variation in adult survival estimates from 1999 to 2014 (despite varying spring and summer lake elevations). While the forthcoming survival estimates for 2017 and 2018 are expected to be substantially reduced, the cause is suspected to be associated with senescence and reaching their average and maximum life expectancies (Hewitt et al. 2017).

Surface elevations at the end of September may impact older juvenile and adult suckers by reducing the amount of open water habitat available. However, habitat information about older juveniles is poor because few older juveniles survive and even fewer are captured (Burdick and VanderKooi 2010, Burdick 2012a, 2012b). The PA is not anticipated to create surface elevations below 4,138.4 feet, approximately 0.7 feet higher than the minimum end of September elevation within the 2013 BiOp. Thus, the PA is anticipated to improve late summer habitat availability for older juvenile and adult suckers, relative to the 2013 BiOp.

It is anticipated that UKL surface elevations are less critical to adult suckers from November through March because suckers redistribute throughout the lake after water quality in the lake improves and lake levels increase through the winter (Banish et al. 2007, 2009, USFWS 2008a). A concern during the winter is water quality conditions under ice cover may also adversely impact suckers (Kann 2010). Ice cover can occur on UKL from November through March, though the extent and duration are dependent on winter air temperature, precipitation, and other meteorological conditions (USFWS 2008a). The available data, while limited, indicates that winter water quality parameters do not generally fall within levels considered stressful for suckers (Reclamation 2012b). It is also unclear how lake elevations through the POR may have contributed to poor under-ice water quality conditions as there have been no documented winter fish die-offs in UKL (Buettner 2007, pers. comm. cited in USFWS 2008a). Winter conditions as a result of the PA may affect but are not likely to adversely affect suckers. Winter die-offs have never been documented and survival for adult suckers has been consistently high despite different winter conditions (more vs. less ice cover). The potential over-winter impacts to suckers due to the PA are likely minimal.

Additionally, the PA results in minimum lake elevations being greater than 4,141 feet in some modeled years (e.g.1983, 1984) at the end of September, which would provide all suckers substantially more habitat than during low WYs. The PA will have adverse impacts to juvenile and adult sucker habitat. Reclamation anticipates that the adverse impacts will be partly offset through implementation of the conservation measures (see Section 4).

Table 7-4. Acres in northern Upper Klamath Lake available by depth (meters) for a range of lake surface elevations and probability of exceedance (POE) for August and September. Data includes Reclamation 2017 bathymetry (Neuman 2017) and field surveys. Elevations are in Reclamation datum (feet above mean sea level).

Lake surface elevation in Reclamation datum (feet)	Acres of Lake at depths between 0 and 1 meter	Acres of Lake at depths between 1 and 2 meters	Acres of Lake at depths between 2 and 3 meters	Acres of Lake at depths between 3 and 4 meters	Acres of Lake at depths > 4 meters	POE for Aug	POE for Sept
4,143.3	6,314.2	4,833.2	10,754.9	12,642.3	6,531.3		
4,143.0	7,824.5	3,888.9	10,189.0	14,102.6	5,071.0		
4,142.5	9,319.0	3,490.9	10,684.3	13,509.9	3,846.1		
4,142.0	9,366.6	4,651.9	11,214.0	12,461.1	2,874.0		
4,141.5	9,409.3	5,562.5	11,953.6	10,751.1	2,320.3		
4,141.0	8,118.2	7,693.8	12,248.3	8,506.1	1,927.4	5-10	5
4,140.5	6,013.7	9,499.9	12,391.5	6,682.7	1,613.7	20-25	10-15
4,140.0	4,833.2	10,754.9	12,642.3	5,153.7	1,377.6	50	20
4,139.5	3,888.9	12,006.6	12,284.9	3,811.8	1,259.3	75	45
4,139.0	3,490.9	12,705.2	11,489.0	2,678.8	1,167.3	95	75
4,138.5	4,651.9	13,477.8	10,197.3	1,789.6	1,084.4		95
4,138.0	5,562.5	14,591.5	8,113.2	1,304.6	1,015.7		
4,137.5	7,693.8	14,385.5	6,368.9	970.6	956.8		
4,137.0	9,499.9	14,156.6	4,917.6	711.0	902.7		

7.1.1.5.1. Effects to Adult Sucker Access to Upper Klamath Lake Areas of Refuge from Poor Water Quality

During dry conditions, such as those at the 95 percent exceedance level, the PA maintains lake surface elevations above 4,139.8 feet, 4,138.9 feet, and 4,138.5 feet by the end of July, August, and September respectively (Table 7-4). These surface elevations provide at least 6.5 feet (EOM July), 5.5 feet (EOM August), and 5.0 feet (EOM September) water depth in Fish Banks and the channel to Pelican Bay (Tables 7-4 and 7-5). Water depths greater than 4 feet allow suckers more protection from avian predators when entering and utilizing Pelican Bay as refuge habitat during poor water quality events in UKL. While American white pelicans are cooperative foragers, working in groups to herd fish into shallow areas, individuals can typically only capture prey at water depths of 4 feet of less (Anderson 1991). Thus, the end of month lake elevations in the PA may provide adult suckers sufficient depth to reduce the risk of avian predation. Success rates of cooperative foragers for adult suckers is unknown. It is likely the PA will provide adult suckers sufficient depth to access Pelican Bay without substantial risk of predation in most years.

Table 7-5. Percent of acres in northern Upper Klamath Lake available by depth (meters) for a range of lake surface elevations and probability of exceedance (POE) for August and September. Data includes Reclamation 2017 bathymetry (Neuman 2017) and field surveys. Elevations are in Reclamation datum (feet above mean sea level).

Lake elevation (feet)	Percent of Lake at depths between 0 and 1 meter	Percent of Lake at depths between 1 and 2 meters	Percent of Lake at depths between 2 and 3 meters	Percent of Lake at depths between 3 and 4 meters	Percent of Lake at depths > 4 meters	POE for Aug	POE for Sept
4,143.3	15.4	11.8	26.2	30.8	15.9		
4,143.0	19.0	9.5	24.8	34.3	12.3		
4,142.5	22.8	8.5	26.2	33.1	9.4		
4,142.0	23.1	11.5	27.6	30.7	7.1		
4,141.5	23.5	13.9	29.9	26.9	5.8		
4,141.0	21.1	20.0	31.8	22.1	5.0	5-10	5
4,140.5	16.6	26.2	34.2	18.5	4.5	20-25	10-15
4,140.0	13.9	30.9	36.4	14.8	4.0	50	20
4,139.5	11.7	36.1	36.9	11.5	3.8	75	45
4,139.0	11.1	40.3	36.4	8.5	3.7	95	75
4,138.5	14.9	43.2	32.7	5.7	3.5		95
4,138.0	18.2	47.7	26.5	4.3	3.3		
4,137.5	25.3	47.4	21.0	3.2	3.1		
4,137.0	31.5	46.9	16.3	2.4	3.0		

Table 7-6. Water depth at various lake elevations at Fish Banks and Pelican Bay derived from Reclamation 2017 bathymetry (Neuman 2017). These areas provide water quality refuge to suckers during summer months in Upper Klamath Lake.

Lake Surface Elevation (feet)	Water Depth (feet) for Areas where Lake Bottom is 4,133.5 feet
4,143.0	9.5
4,142.5	9.0
4,142.0	8.5
4,141.5	8.0
4,141.0	7.5
4,140.5	7.0
4,140.0	6.5
4,139.5	6.0
4,139.0	5.5
4,138.5	5.0
4,138.0	4.5
4,137.5	4.0
4,137.0	3.5

7.1.1.6. Effects to Water Quality

While there has been some concern that Project operations may affect UKL water quality through management of UKL elevation, the best available science does not demonstrate a direct, consistent, and discernable relationship between UKL elevation and water quality. This does not mean that UKL elevation or water depth does not have an effect on water quality, only that the best available science has not demonstrated a clear, consistent, and discernable relationship especially within the range of UKL elevations observed from 1990-2016, nor over the range of UKL elevations analyzed in the KBPM output for the POR.

Adverse water quality and fish disease likely impact suckers in UKL at both the individual and the population levels (Perkins et al. 2000b). The PA is not anticipated to influence water quality or fish disease in UKL aside from the possibility of periodic, but infrequent, concentrating of fish in limited habitat during late summer months when disease could be more-readily spread among individuals (*see* Part 6.2.5. Fish Health - Disease, Pathogens, and Parasites). Furthermore, there have been no known large winter fish die-offs documented in UKL (Buettner 2007, pers. comm. cited in USFWS 2008a). As such, the PA is not anticipated to impact water quality conditions for suckers during the spring/summer irrigation period and under ice cover conditions.

7.1.1.7. Entrainment Losses from Upper Klamath Lake

The PA will adversely impact larvae, YOY juvenile, and both older juvenile and adult suckers through entrainment in diverted water through numerous diversion points, principally at A Canal and LRD. The numbers of suckers at each life history stage will vary annually dependent on the amount of water transported and the numbers of suckers exposed to entrainment at each life history stage, a function of annual sucker production at earliest life history stages, and perhaps other factors such as wind speed and direction and water quality. Relatively low numbers of older juvenile and adult suckers entrained from UKL are anticipated due to the screening of the A canal (Gutermuth *et al*. 2000a, 2000b, USFWS 2007c, 2008, Tyler 2012a, 2012b).

Sucker entrainment losses at LRD and A Canal resulting from the PA can be estimated. Based on estimates for sucker entrainment by life history stages (Gutermuth et al. 2000a, 2000b) and applying assumptions to account for changes since the Gutermuth et al. efforts (e.g., construction of A Canal fish screen and bypass, reduced sucker populations in UKL etc), entrainment estimates can be calculated from modeled output. Applying seasonal occurrences of sucker life history stages, based on Gutermuth et al. (2000a, 2000b), to the volume of water that Reclamation anticipates delivering through the Link River and A Canal and a sucker population reduction of approximately 80 percent (USFWS 2013), the PA could result in about 3.1 million larval suckers, 136,000 juvenile suckers, and 113 adult suckers encountering or passing infrastructure at either LRD or A Canal fish screen and trash rack (Table 7-6). Reclamation is not distinguishing between harass and harm for the incidental take of suckers as a result of entrainment. Entrainment has adverse impacts to all life stages of both species of suckers. Sucker entrainment at LRD and A Canal will continue under the PA. Construction and continued operation of the A Canal fish screen reduces the negative impact of entrainment by preventing juvenile and adult suckers from entering the Project canal system.

Table 7-7. Estimated sucker entrainment at Link River and A Canal for the Proposed Action from the period of record based on seasonal periodicity of life history stages and previous estimates of Gutermuth et al. (2000a, 2000b) with assumption of an 80 percent reduction in Upper Klamath Lake sucker populations since Gutermuth et al. estimated entrainment. Estimates assume encounters at the A Canal fish screen and trash rack result in entrainment.

Year	**Larvae at Link River**	**Larvae at A Canal**	**Juveniles at Link River**	**Juveniles at A Canal**	**Adults at Link River**	**Adults at A Canal**
1981	916571.2	441508.5	63876.0	37525.2	2.1	78.6
1982	1851414.6	568920.1	67217.1	55128.5	3.4	108.3
1983	2440786.2	561055.7	69661.6	56012.7	4.2	108.5
1984	2269242.9	608859.9	69900.3	51841.6	4.0	108.5
1985	1562017.4	646723.9	61577.6	43618.2	2.9	103.3
1986	1345004.5	615227.6	63621.8	46881.8	2.7	103.9
1987	960730.1	546864.3	56985.4	39742.0	2.1	90.3
1988	901325.4	426817.2	66748.2	38237.4	2.2	78.0
1989	1863933.7	583800.5	56967.9	50034.0	3.3	104.3
1990	837714.7	425991.5	58811.0	37334.0	2.0	77.0
1991	1049892.4	295994.5	58950.6	26988.3	2.2	54.6
1992	889516.0	16305.8	56056.2	913.0	2.0	2.4
1993	2212868.3	482041.7	66695.7	49124.4	3.9	94.3
1994	1001444.1	170168.3	64415.3	10326.2	2.3	26.0
1995	1588510.6	466226.1	67466.9	51450.2	3.1	95.3
1996	1613298.3	504873.2	75862.9	46635.1	3.2	93.7
1997	1256518.6	540497.4	62508.0	40071.7	2.6	90.1
1998	2156663.5	441993.7	73019.8	60121.2	3.9	102.2
1999	2220280.6	578472.1	64639.2	48410.4	3.8	102.2
2000	1515391.7	564738.7	58400.9	41706.1	2.8	94.0
2001	867087.7	433782.9	55457.7	36150.7	2.0	76.5
2002	1105152.0	525384.8	60242.3	39602.9	2.3	88.2
2003	1075748.6	476579.4	58201.6	42465.2	2.3	86.9
2004	867788.5	507609.3	63246.7	42082.1	2.1	89.2
2005	1074233.9	371623.5	60330.3	43333.6	2.3	78.4
2006	2238053.7	597872.6	70739.6	51399.5	4.0	107.0
2007	1147803.9	528976.3	52389.9	39006.2	2.3	87.9
2008	1456633.1	490520.5	66866.2	45911.5	2.9	91.7
2009	1085887.5	450532.5	67535.4	42333.1	2.4	84.4

Year	Larvae at Link River	Larvae at A Canal	Juveniles at Link River	Juveniles at A Canal	Adults at Link River	Adults at A Canal
2010	809398.2	410092.1	66028.2	38763.0	2.0	77.1
2011	1891044.8	508134.2	71994.9	49991.7	3.5	97.5
2012	1363343.8	477278.5	66237.4	43134.4	2.8	87.6
2013	818880.3	451740.3	66105.9	35760.4	2.1	77.7
2014	1000709.1	214765.7	62677.9	16151.9	2.2	36.0
2015	823698.0	323721.1	62552.8	29187.1	2.0	59.4
2016	1018467.9	501862.5	70039.6	41006.9	2.4	87.6
Minimum	809398.2	16305.8	52389.9	913.0	2.0	2.4
Average	1363807.1	465487.7	64000.8	40788.4	2.7	84.1
Maximum	2440786.2	646723.9	75862.9	60121.2	4.2	108.5

7.1.2. Keno Impoundment and Below Keno Dam Individuals and Populations

Reclamation's responsibility below Keno is the release of UKL surface water at the LRD for downstream needs discussed elsewhere in this document. The flows are anticipated to provide adequate habitat to individual suckers that reside in reservoirs below Keno Dam. Impacts of potential take of listed suckers below Keno Dam resulting from degradation and loss of habitat due to low instream flows on the overall population is likely minimal (PacifiCorp 2013). This is consistent with USFWS' conclusions contained in the 2013 BiOp (USFWS 2013) that indicated that while PacifiCorp's current operation and associated minimum instream flow requirements below Keno, J.C. Boyle, and Copco No. 2 dams may affect individual suckers in this area, these effects are minimal within the context of the overall population size and geographic range of the LRS and SNS. These reaches are not part of the original habitat complex of the listed suckers and are inherently unsuitable for completion of life cycles of these suckers given the dams prevent movement (USFWS 2013). The focus of this section will be on the LRD and the Keno Impoundment where the Project has the greatest influence, through water operations, on the two endangered sucker species.

7.1.2.1. Effects to Keno and Downriver Spawning Access and Fish Passage

No known sucker spawning habitat exists in the Klamath River downstream of the Link River mouth to the Keno Dam (Buchanan *et al*. 2011). Spawning activity in the lower Link River, upstream of the West Side hydropower facility, was observed during May 2007 (Smith and Tinniswood 2007). The PA includes the release of surface water from UKL through the LRD (*see* Part 4.3.2). The PA includes releases from the LRD during spring months that are likely adequate for suckers spawning and moving in the Link River. Less than 100 LRS and SNS are detected on the antenna array in the Link River each year (B. Hayes, USGS, pers. Comm., October 19, 2018). However, the frequency of brief but high flows and velocities resulting from the PA may periodically hinder passage for small suckers in the Link River.

7.1.2.2. Effects to Keno and Downriver Young-of-the-Year Juvenile Habitat

All life stages of listed suckers have been found in the Link River in recent years, based on monitoring below UKL and the LRD. This habitat is primarily a migration corridor for large numbers of larval and juvenile suckers dispersing downstream from UKL (Gutermuth et al. 2000b, Foster and Bennetts 2006). Young suckers often migrate to the Keno Impoundment, however, it is unclear if this is a destination that meets their needs, or if their pre-settlement life history was such that they migrated to other lake habitats, such as the historic Lower Klamath and Tule lakes.

The Keno Impoundment is relatively shallow (average depth of 7.5 feet) and long (22.5 miles) and receives most of its water from UKL via the Link River (PacifiCorp 2012). Substantial quantities of water are also diverted from, and discharged to, the Keno Impoundment through and from facilities managed by Reclamation and several private permit holders (USFWS 2007c). Due to overall reductions in irrigation deliveries under the PA, Reclamation anticipates that Project return flows in the Keno Impoundment may be reduced.

YOY juvenile suckers in the Keno Impoundment likely use near-shore habitats of emergent vegetation or the transition zones between vegetation and open water. More YOY juvenile suckers were captured in trap nets fished close to the shoreline near emergent vegetation than in open water areas in Lake Ewauna of the Keno Impoundment (Tyler and Kyger 2012). Furthermore, sampling in a reconnected wetland bordered by North and Ady canals captured more YOY juvenile suckers in transition zones near emergent vegetation than in open water or in vegetation (Phillips et al. 2011).

The PA is consistent with PacifiCorp's current operations at Keno Dam, which provide for a surface elevation in this reach of 4,085.5 feet. This operation is consistent with past operations of surface elevations in the Keno Impoundment. The ongoing management to operate for stable surface elevations in the Keno Impoundment impacts development of additional wetland habitats and degrades the quality of existing wetlands through controlled water depth (USFWS 2007c). However, stable surface elevations do provide sucker access to the established wetland habitats for rearing during sucker early life history stages. The PA will have adverse impacts on YOY juvenile habitat in the Keno Impoundment. The adverse impacts from this PA are a continuation of the impacts described in the Environmental Baseline and are not anticipated to be result in greater impacts than those that have occurred previously.

7.1.2.3. Effects to Keno and Downriver Older Juveniles and Adults Habitat

Little is known about habitat use in the Keno Impoundment by older juvenile and adult suckers. Limited available information suggests adult suckers still migrate into the Link River during the spring and summer (Piaskowski 2003, Kyger and Wilkens 2011), and juveniles apparently reside in the Link River, Lake Ewauna, and/or the Keno Impoundment below the LRD throughout most of the year (USFWS 2002, Phillips et al. 2011). Some efforts to evaluate sucker passage at the Link River fish ladder has observed congregations of adult suckers in Lake Ewauna near the Link River during late winter and spring months (Kyger and Wilkens 2011, 2012a). However, this effort did not survey elsewhere in the Keno Impoundment for adult suckers at that time of year or attempt to define adult sucker habitat in Lake Ewauna. The relatively low number of tagged adult suckers detected at the Link River fish ladder and the relatively high recapture of tagged suckers in the Keno Impoundment, in relationship to the numbers of adult suckers that were tagged in 2008 through 2010 (Kyger and Wilkens 2011) suggests adult suckers do not exit the Keno Impoundment in high numbers or with much frequency. It is likely that older juvenile and adult suckers in the Keno Impoundment occupy similar habitats as suckers in UKL, such as areas that provide depth and access to water quality refuge. The lower Link River is an important water quality refuge area for juvenile and adult suckers during periods of low DO in the Keno Impoundment (USFWS 2007c). It is assumed that older juveniles and adult suckers in the Keno Impoundment utilize water depth as they do in UKL.

The PA will not impact offshore, deeper habitats available to older juvenile and adult suckers. The PA is not anticipated to appreciably impact flows in the Link River during summer months when suckers use the lower Link River as water quality refuge.

7.1.2.4. Effects to Keno and Downriver Water Quality

Despite the relatively high tolerance for poor water quality by LRS and SNS, suckers are likely affected by impaired summer water quality in the Keno Impoundment (NRC 2004, Saiki et al. 1999). The PA includes continued surface water releases from UKL to this reach for Project irrigators and other downstream needs and thus will likely influence water quality in the Keno Impoundment. However, due to reductions in deliveries under the PA, Reclamation suspects that return flows to the Keno Impoundment may be reduced, which may alleviate some concerns about the quality (specifically nutrient load) of water returning from the Project.

Two sources of nutrients into the Keno Impoundment from the Project include the LRDC and the KSD (*see* Part 6.2.3.2 for additional details). Water returning to the Klamath River from these facilities contains nutrients, organics, and sediment. The use of agrichemicals on Project lands, particularly fertilizers, may increase nutrient concentrations of flows returning to the Klamath River via the LRDC and the KSD. However, the quality of water entering, within, and leaving the Keno Impoundment is largely due to the export of algal biomass from UKL, and subsequent decomposition within this reach (ODEQ 2017). Adverse water quality events in the Keno Impoundment impact suckers that reside there. Quantifying the role of return flows in creating adverse water quality events is difficult to ascertain, because the eutrophic outflow from UKL confounds the ability to separate water quality effects of the Project from other factors. However, there is evidence to suggest that discharge from the LRDC can have a substantial negative impact on DO concentrations at Miller Island in the Keno Impoundment, though the magnitude and duration of the effect is less than that resulting from releases from UKL (ODEQ 2017) and is highly dependent on Project operations.

Improvements in Project infrastructure that allow recirculation of return flows within the Project may reduce the volume of return flow reaching the Klamath River. Similarly, the PA does not count re-diversion of return flows against Project Supply in the spring/summer (meaning that Project irrigators are likely to redivert this water), which will also likely result in reduced return flow to the Klamath River. Finally, the Project may reduce overall nutrient loads to the Klamath River given that only about 30 percent of UKL/Klamath River water diverted onto the Project returns to the Klamath River (ODEQ 2017).

In conclusion, the PA has some impact to water quality in the Keno Impoundment reach of the Klamath River, but this impact is minimal relative to the large contribution of nutrient and organic matter arriving from UKL. As such, Reclamation concludes that the PA is likely to have little affect on nutrient loading to the Link to Keno Reservoir reach of the Klamath River.

7.1.2.5. Entrainment Losses Keno and Downriver

Unscreened diversions from the Keno Impoundment of the Klamath River have an adverse impact to individual suckers at each life history stage. The impacts due to the loss of larval, juvenile, and adult suckers are uncertain (PacifiCorp 2012) but the magnitude of impacts is likely related to the amount of water diverted and both the seasonal and diurnal timing of diversions.

7.2. Lost River Basin Recovery Unit

The Lost River Basin Recovery Unit is comprised of the following management units: Clear Lake Reservoir and tributaries, Tule Lake, Gerber Reservoir and tributaries, and Lost River proper (USFWS 2011b). While robust information about the timing, triggers, and basic needs for spawning migrations, as well as meaningful annual survival estimates for both species have been available from UKL for past consultations, this information has not been available about suckers in Clear Lake until the current consultation. Even still, few LRS are tagged in Clear Lake, limiting researcher's ability to estimate annual survival with meaningful confidence intervals (Hewitt et al. forthcoming). information on early sucker life history ecology and habitat use within the Lost River watershed, particularly Tule Lake, Lost River, and both Clear Lake and Gerber Reservoirs, is sparse though juvenile monitoring has occurred in Clear Lake since 2015 (Burdick et al. 2018). Given a lack of direct observations, larval sucker ecology in the Lost River watershed is assumed to be similar to UKL, except for the use of emergent vegetation by larval and juvenile suckers. Permanent emergent vegetation is generally scarce or absent along the shorelines of Clear Lake and Gerber Reservoirs (Reclamation 2002). It is possible that high turbidity at both of these locations provides cover to early sucker life history stages (USFWS 2008a).

7.2.1. Clear Lake Reservoir Individuals and Populations

Management of Clear Lake Reservoir under the PA will continue the on-going operation to provide for a minimum surface elevation of no less than 4,520.6 feet on September 30 each year. Dam releases become impaired at a surface elevation below 4,522 feet due to a sediment deposit between the east lobe and Clear Lake dam (Sutton and Farrari 2010). Similar to processes described in past consultations (USFWS 2002, 2003, NMFS and USFWS 2013), about April 1 of each year, the current April through September inflow forecast, current Reservoir elevation, estimated leakage and evaporative losses, and an end of September minimum elevation of 4,520.6 feet are used to determine available irrigation water from Clear Lake Reservoir. The amount of irrigation water available is periodically updated with new inflow forecasts and surface elevations as the irrigation season progresses. In-season updates inform the decisions to curtail or terminate irrigation deliveries to avoid going below the minimum surface elevation.

Lake elevation and high tributary inflows are necessary for adult suckers to make annual spawning migrations between the two lobes in Clear Lake Reservoir and access spawning grounds in Willow Creek (Hewitt et al. forthcoming). Suckers in Clear Lake will spawn at temperatures as cool as 6°C and will stage to spawn (move from the west lobe to the east lobe) as early as January (Hewitt et al. forthcoming). Suckers in Clear Lake opportunistically spawn when lake elevations are 4,524 feet or higher, and inflows are approximately 42 to 45 cfs or higher in Willow Creek; typically, early March through the end of May (Hewitt et al. forthcoming). Several age classes are represented in population surveys for both species, indicating successful recruitment occurs some years (Hewitt et al. forthcoming). However, meaningful additions to the population are most apparent after large spawning events, which do not occur every year (Hewitt et al. forthcoming). Annual survival of LRS is 60 to 89 percent and 42 to 89 percent for SNS in Clear Lake (Hewitt *et al*. forthcoming); substantially lower than survival of suckers in UKL (typically 90 percent, Hewitt *et al*. 2017). Unlike UKL, the LRS population in Clear Lake is smaller than the SNS population. Abundance estimates are not yet available for suckers in Clear Lake. Entrainment at Clear Lake was estimated to be 270,000 larval suckers and 3,700 juvenile suckers in 2013 (Sutphin and Tyler 2016). It is unclear how entrainment varies among years, spawning timing and conditions in tributaries, and lake elevations, though the estimate derived in 2013 is suspected to be high (*see* Sutphin and Tyler 2016 for more information). However, available information indicates that the Clear Lake sucker populations have persisted under recent management of the lake (USFWS 2008a).

7.2.1.1. Effects to Clear Lake Adult Spawning and Migration

Low lake levels can adversely affect LRS and SNS by limiting access to Willow Creek (USFWS 2002, 2008a, Hewitt et al., forthcoming). The PA to store and divert surface water from Clear Lake Reservoir while maintaining an end of September minimum surface elevation of 4,520.6 feet each year will adversely impact adult suckers in years when lake elevations are at this minimum followed by a year (or years) when lake elevations do not increase by 3.4 feet to 4,524 feet or greater prior to the end of February or March. Suckers in Clear Lake are opportunistic spawners; moving into tributaries as early as March during large inflow events when temperatures are 6°C. It is likely that suckers in Clear Lake will be unable to spawn any year following a 4,520.6 feet EOM September lake level year. The exception to this, is when tributary inflows are large in January, February, and March such that lake elevation reaches 4,524 feet and flows remain high in Willow Creek. While not an annual occurrence, these events do occur; for example, lake levels increased by more than 5 feet by the end of February in WYs 2016 and 2017.

While the 4,520.6 feet September EOM minimum is established, this minimum has not occurred with great frequency; only in 90 to 95 percent exceedance years. For the POR (WY1911 to 2018), end of September elevations were at or below 4,520.6 feet in only ten years (9.26 percent). In one of these years (WY 2016), lake elevations increased by 3.4 feet or more such that lake level was at least 4,524 feet by the end of February, allowing suckers to spawn. In five of these years (50 percent), lake elevations increased by 3.4 feet or more such that lake levels were at least 4,524 feet by the end of March, presumably allowing suckers to spawn in April and May if flows were sufficient in Willow Creek. Spawning migrations in Willow Creek have been remotely monitored since 2006 and flows in Willow Creek have been remotely monitored since 2013. However, lake levels were too low in 2014 and 2015 for suckers to access Willow Creek. Thus, little is known about annual frequency, seasonal timing, and flows (e.g., cfs) necessary for suckers to make a spawning migration (*see* Part 6.2.1).

Lake levels in Clear Lake do not end below the elevation necessary for suckers to access spawning grounds in most years. End of September lake levels for the POR were less than 4,524 feet in 26.85 percent (29/108) of years. Thus, only in the 30 percent driest years (70 percent exceedance), are lake elevations expected to be less than 4,524 feet.

Seasonal increases of lake elevation in Clear Lake typically increase from EOM December to EOM April. The largest increases occur most often in March but lake elevations also increase substantially throughout February and April. Average ± standard deviation increases in lake level are 0.05 ± 0.26 foot in November, 0.41 ± 0.74 foot in December, 0.59 ± 0.89 foot in January, 0.90 ± 1.32 foot in February, 1.21 ± 1.68 foot in March, 0.72 ± 1.23 foot in April for the POR (WY 1911 to 2018). Understanding the seasonality of accretions provides a tool for managers to predict when lake elevations may be sufficient for suckers to access spawning tributaries and to understand the timing of discharge events in Willow Creek. Flows necessary for suckers to spawn in Willow Creek, as well as their frequency of occurrence, is expected to be better understood in the coming years.

Changes in lake elevation from EOM October to EOM April among years reflect differences in hydrologic conditions. Changes in lake elevation from EOM October to EOM April vary substantially among years, including decreasing 0.62 foot (WY 1977) during dry years and increasing 14.31 feet (WY 1956) during wet years. For the POR (WY 1911 to 2018), lake elevations in Clear Lake Reservoir typically change an average ± standard deviation (min-max) of 0.89 ± 1.60 foot (-1.51 to 7.63 feet) from EOM October to EOM January, 1.79 ± 2.25 feet (-0.91 to 9.75 feet) from EOM October to EOM February, 2.99 ± 2.81 feet (-0.98 to 12.23 feet) from EOM October to EOM March, and 3.69 ± 3.43 feet (-1.47 to 14.11 feet) from EOM October to EOM April. Thus, if lake elevations end near 4,520.6 feet, on average, lake elevations will not be high enough for suckers to access Willow Creek until the EOM April.

The PA is likely to impact the frequency in which adult suckers can make spawning migrations in the driest years. However, as future operations are intended to be similar to historic operations, it is likely that the adult suckers will be able to access spawning grounds in Willow Creek 80 percent of years (presuming inflows are also sufficient in Willow Creek to support a spawning migration). The PA at Clear Lake Resevoir is consistent with the historic operations at the reservoir, therefore the impacts are not anticipated to be greater than those described in the Environmental Baseline.

7.2.1.2. Effects to Clear Lake Habitat for Larvae and Young-of-the-Year Juveniles

At Clear Lake Reservoir, larval and YOY juvenile suckers likely utilize habitat similar to older juveniles and adults including depth, surface area, and areas near-shore. Earlier life history stages may show more association with the shoreline at Clear Lake Reservoir than later stages; however, shoreline and lake surface area both decrease with reduced surface elevations. Thus, the description of lake surface area and depth as habitat for adult suckers is applicable to larvae and both YOY and older juveniles (*see* Part 7.2.1.3., Effects to Clear Lake Habitat for Older Juvenile and Adult Suckers).

7.2.1.3. Effects to Clear Lake Habitat for Older Juveniles and Adults

The PA of a minimum surface elevation of 4,520.6 feet at the end of September preserves a lake surface area of 10,680 acres of habitat, of which 7,940 acres is at least 3 feet deep. At this surface elevation, the east lobe has a water depth of 7 inches, except for the pool nearest the dam into which Willow Creek flows. At 4,520.6 feet, the east lobe is not likely to provide adequate habitat as any fish in the east lobe at this elevation has a high probability of being stranded or preyed upon by avian predators. The east lobe is dry at 4,520 feet.

At the minimum surface elevation of 4,520.6 feet, the west lobe averages approximately 5.5 feet of water depth. Of the 10,680 acres of habitat available at 4,520.6 feet elevation, 7,940 acres are at least 3 feet deep, 7,540 acres are 4 feet deep, and 7,100 acres are 5 feet deep. Despite 4,520.6 feet as the minimum, lake elevations have occasionally been below 4,520.6, especially during dry years due to additional losses from evaporation and seepage. Lake elevations were less than 4,520.6 feet in one month or more in at least ten years between 1911 and 2017. The amount of available habitat 3 feet deep or more doubles to 19,660 acres at about 4,530 feet. The total amount of all wetted habitat at 4,530 feet is about 21,200 acres.

Avian predation, including but not limited to double-crested cormorants and American white pelicans, is higher when lake elevations are low. This has been detected in lower survival estimates of adult suckers during low WYs, and in greater proportions of available PIT tags found at nesting colonies and loafing areas (Evans et al. 2016; *see* Part 6.2.1.).

During the majority of months and years, surface elevations are anticipated to be above surface elevations that substantially impact older juveniles and adult suckers through reduced habitat (Table 6-4). However, the PA is anticipated to adversely affect larvae, juveniles, older juveniles, and adult suckers by reducing habitat availability, particularly lake surface area and depth, during infrequent periods of prolonged drought. During consecutive years of low inflow, individual suckers may also experience reduced body condition, which can lead to mortality, and populations may contract in size if substantial numbers of adults are lost to mortality or individual reproductive health is compromised to the point that there is a reduction in recruitment. The adverse impacts from this PA at Clear Lake are a continuation of the impacts described in the Environmental Baseline and are not anticipated to be result in greater impacts than those that have occurred previously.

7.2.1.4. Effects to Clear Lake Water Quality as Habitat

At Clear Lake Reservoir, lower water levels may result in degraded water quality, particularly higher water temperatures and lower DO. However, water quality monitoring over a wide range of lake levels and years documented water quality conditions that were adequate for sucker survival (Reclamation 1994a, 2000, 2001, 2007).

Low lake levels in Clear Lake Reservoir pose an unquantified risk to listed suckers from adverse water quality (USFWS 2008a). In October 1992, the water surface elevation of Clear Lake was as low as 4,519.4 feet before the onset of a hard winter, and no fish die-offs were observed, although suckers showed poor condition factors in the following spring (Reclamation 1994a). It is uncertain if water quality conditions or crowding and competition for resources were responsible for impacts to suckers following the winter 1992 to 1993.

The proposed minimum lake level for Clear Lake at the start of the winter period from October to February is 4,520.6 feet. This elevation is anticipated to provide adequate water depths for protection against winter-kill of suckers (USFWS 2008a). Implementation of the PA is not anticipated to substantially impact water quality as sucker habitat in Clear Lake Reservoir.

7.2.1.5. Effects of Entrainment Losses at Clear Lake

The outlet at Clear Lake Dam is screened against fish entrainment. The screen was designed for a fish approach velocity not to exceed 0.75 feet per second, and with a mesh size no larger than 1/4 inch. The required total area of the fish screens was determined based on a flow of 200 cfs and the above screening criteria. With full screen submergence and a discharge of 200 cfs, the screen approach velocity is approximately 0.53 feet/s. Reclamation assumes no downstream losses of all fish greater than about 35 mm TL. It is assumed that YOY juvenile suckers attain this size in Clear Lake Reservoir by about July of each year based on larval and juvenile emigration sampling in Willow Creek (Scoppettone et al. 1995). Based on sampling in 2013, entrainment of larval and juvenile suckers is occurring at the Clear Lake Dam (Sutphin and Tyler, 2016). Older juveniles and adult suckers may become impinged on the fish screen; however, the screen was designed with a maximum approach velocity intended to prevent impingement.

Periodically, fish stranding of all sucker life history stages has occurred in Clear Lake Reservoir when the pool nearest the dam disconnects from the east lobe of Clear Lake Reservoir at a surface elevation of about 4,522.0 feet (Reclamation 2012). This disconnect in 2009 resulted in the capture and relocation of 48 juvenile suckers and the observation of three adult sucker mortalities (Reclamation 2012). The pool nearest the dam is the only area identified at Clear Lake Reservoir that poses a stranding risk.

In 2013, a one-year effort to measure entrainment at Clear Lake Dam estimated that millions of larval fish and thousands of juvenile fish are being entrained through the fish screen at Clear Lake Dam (Sutphin and Tyler 2016). Among this estimate are thousands of larval and juvenile suckers. Adult suckers were detected in Willow Creek during 2013 although lake elevation remained relatively low throughout the spring months (Hewitt et al. forthcoming). The proximity of Willow Creek to Clear Lake Dam and the overlap between the seasonal timing of larval sucker emigration from the creek and irrigation deliveries suggest that larval and small YOY juvenile sucker are susceptible to entrainment at Clear Lake Dam (Reclamation 2012). This was verified in the 2013 effort when sucker entrainment estimates were developed from fish sampling behind the fish screen (Sutphin and Tyler 2016). Entrainment losses of larval and small juvenile suckers are an adverse impact of the PA on individuals.

In 2013, Reclamation estimated that about 270,000 larval suckers and about 3,700 juvenile suckers passed through or around the fish screen into the Lost River at Clear Lake Dam (Sutphin and Tyler 2016). An estimate of the total larval and juvenile suckers was not able to be developed from the effort to measure larval sucker drift in nearby Willow Creek in 2013. Therefore, it is difficult to relate the losses from entrainment at the dam to a population level for suckers in Clear Lake. Although unknown, entrainment is likely variable between years and may be influenced by annual larval and juvenile production, timing of larval outmigration from Willow Creek, juvenile sucker distribution within the East and West lobes, and the timing and magnitude of irrigation releases. If the numbers of entrained individuals are a substantial proportion of the number available in any year, then there is likely an adverse impact to sucker populations at Clear Lake Reservoir resulting from entrainment losses that result from the PA. The PA at Clear Lake is consistent with the historic operations at the reservoir, therefore the potential entrainment impacts are not anticipated to be greater than those described in the Environmental Baseline.

7.2.2. Effects to Gerber Reservoir Individuals and Populations

The PA for Gerber Reservoir is to operate the reservoir volume so that the surface elevation is at or above 4,798.1 feet annually on September 30. Reclamation determines the available irrigation supply, around April 1 of each year, by evaluating the annual April through September inflow forecast, current Reservoir elevation, estimated leakage and evaporative losses, and an end of September minimum elevation of 4,798.1. The amount of irrigation water available is updated with new inflow forecasts and surface elevations as the irrigation season progresses. In-season updates inform the decisions to curtail or terminate irrigation deliveries to avoid going below the minimum surface elevation.

7.2.2.1. Effects to Gerber Reservoir Adult Spawning and Migration

Access to Gerber Reservoir tributaries, where SNS spawning occurs, requires a minimum surface elevation of about 4,805.0 feet during February through May (USFWS 2008a). During very dry years both Barnes Valley and Ben Hall creeks typically have low spring flows that may not provide adequate upstream passage for spawning adults regardless of lake elevations (Reclamation 2001a). Although surface elevations at the end of September have been observed below the proposed minimum elevation of 4,798.1 feet in 5 years from the POR (1925 to 2018) at Gerber Reservoir (1931, 1960, 1961, 1991, and 1992), surface elevations of at least 4,805.0 feet were reached the following spring by the end of March (Table 6-5; Appendix 6B). Based on review of surface elevations from the POR for Gerber Reservoir, the PA, which maintains the current lake management of a minimum surface elevation at or above 4,798.1 feet at the end of September, will not impact SNS access to spawning habitat during the succeeding spring months based on the hydrology of Gerber Reservoir. The PA at Gerber Reservoir is consistent with the historic operations and therefore the impacts to adult spawning and migration are not anticipated to be greater than those described in the Environmental Baseline.

7.2.2.2. Effects to Gerber Reservoir Habitat for Larvae and Young-of-the-Year Juveniles

Sucker habitat requirements are less understood for endangered sucker populations in the Lost River Basin. Assumptions regarding sucker habitat use at each life history stage are based on observations from UKL and are described in Clear Lake Reservoir sections above. The description of lake surface area and depth as habitat for older juvenile and adult suckers at Gerber Reservoir is applicable to larvae and both YOY and older juveniles (*see* Part 7.2.2.3., Effects to Gerber Reservoir Habitat for Older Juvenile and Adult Suckers).

7.2.2.3. Effects to Gerber Reservoir Habitat for Older Juvenile and Adult Suckers

The effects of low water elevations at Gerber Reservoir on the resident SNS population in terms of population size, age-class distribution, recruitment, or decreased body condition are not fully understood. However, available information (Barry et al. 2007a, Leeseberg et al. 2007) indicates that the Gerber Reservoir sucker population has remained viable under the current management regime (USFWS 2008a). Additionally, an effort to renew adult sucker sampling at Gerber Reservoir in spring 2018 encountered a small number of suckers that were previously captured in 2005 and 2006 indicating persistence of individuals through consecutive years of low lake elevations in 2014 to 2015 and the resulting reduction of available habitat in those years (Reclamation, unpublished data).

The PA may adversely impact individual suckers through infrequent reductions of habitat availability, particularly decreased shoreline, surface area, and water depth. During infrequent events of prolonged drought, individual suckers will likely experience reduced condition, which can lead to mortality, and populations may contract in size if substantial numbers are lost to mortality or individual reproductive health is compromised that leads to a reduction in recruitment. The PA at Gerber Reservoir is consistent with the historic operations and therefore the impacts to juvenile habitat reduction are not anticipated to be greater than those described in the Environmental Baseline.

The minimum proposed elevation for the end of September is 4,798.1 feet and will likely provide adequate water depths for protection against winter-kill of the SNS (USFWS 2008a).

7.2.2.4. Effects to Gerber Reservoir Water Quality as Habitat

Water quality monitoring over a wide range of lake levels and years has documented water quality conditions that are periodically stressful to suckers but were generally adequate for sucker survival (Reclamation 2001a, 2007, Piaskowski and Buettner 2003, Phillips and Ross 2012). Periodic stratification during summer and fall in the deepest portion of Gerber Reservoir can result in DO concentrations that are stressful to suckers (Piaskowski and Buettner 2003). Stratification at Gerber Reservoir has been observed persisting for less than a month, over a small portion of the Reservoir near the dam (Piaskowski and Buettner 2003) and is likely more the result of meteorological conditions than lake surface elevations.

The PA results in periodic low surface elevations at Gerber Reservoir during late summer and fall (Table 6-5). In Gerber Reservoir, low lake levels may result in degraded water quality including higher pH values and lower DO concentration. The PA may infrequently impact SNS in Gerber Reservoir by contributing to degraded water quality conditions through low surface elevations. The adverse impacts can be to both individuals and populations through loss of individual body condition or loss of individuals through mortality. The PA at Gerber Reservoir is consistent with the historic operations and therefore the impacts related to reduced surface elevations and poor water quality are not anticipated to be greater than those described in the Environmental Baseline.

7.2.2.5. Effects of Entrainment Losses at Gerber Reservoir

Larval sucker entrainment losses at Gerber Reservoir remain unquantified but could be substantial as the outlet of Gerber Dam does not have a fish screen. Whereas, efforts to measure larval sucker losses from Gerber Reservoir through entrainment have been attempted, those efforts have not produced reliable catches that could be used to develop entrainment estimates for this life stage. The unquantified larval entrainment at Gerber Reservoir is likely proportional to the amount of deliveries made from Gerber Reservoir and annual sucker production in any given year; however, entrainment through the loss of individuals from a population likely results in an adverse impact to SNS populations in Gerber Reservoir.

Past efforts to quantify entrainment or salvage stranded suckers in Miller Creek downstream of Gerber Reservoir suggest approximately 200 to 250 YOY and older juvenile suckers are annually entrained (*see* Part 6). Based on quantities of water delivered in the past decade and the PA, it is assumed up to 250 YOY and older juvenile suckers will be entrained under the PA. This is an adverse impact to suckers entrained due to the ephemeral nature of Miller Creek during fall and winter, or when irrigation deliveries are curtailed (which has been as early as July). The opening of Gerber Dam frost valves at the end of the irrigation season allows for a Miller Creek flow of approximately 2 cfs, in addition to accretions from seep and storm run-off. This amount of flow may not allow for stream pool connectivity but is believed to prevent mortalities among fish stranded in stream pools at the end of the irrigation season. It is unknown if the number of entrained individuals adversely impacts SNS populations in Gerber Reservoir as a result of the PA; however, available information (Barry et al. 2007a, Leeseberg et al. 2007) indicates that the Gerber Reservoir sucker population has remained viable under the current management regime (USFWS 2008a). The PA at Gerber Reservoir is consistent with the historic operations and therefore the potential entrainment impacts are not anticipated to be greater than those described in the Environmental Baseline.

7.2.3. Effects to Tule Lake Individuals

7.2.3.1. Effects to Tule Lake Adult Spawning and Migration

From April 1 to September 30, a minimum surface elevation of 4,034.6 feet was determined for Tule Lake Sump 1A in part to provide access to spawning areas below Anderson Rose Diversion Dam (USFWS 2002, 2008a) and in part to provide for delivery of irrigation water to lands east and south of Sump 1A. The PA, which continues to manage Tule Lake Sump 1A for a surface elevation of 4,034.6 feet from April through September, will not impact sucker access to the lower Lost River due to lake elevation when conditions, such as flows, encourage spawning in the Lost River. The PA at Gerber Reservoir is consistent with the historic operations and therefore the impacts to adult spawning and migration are not anticipated to be greater than those described in the Environmental Baseline.

7.2.3.2. Effects to Tule Lake Habitat for Larvae and Young-of-the-Year Juveniles

The wetland area of Tule Lake Sump 1A near the Lost River mouth likely provides sufficient habitat for larvae and young juveniles assuming that larval and YOY juvenile suckers in Tule Lake utilize near-shore and vegetated habitats similar to suckers in UKL. Larval suckers in UKL appear to depend on shallow, near-shore areas (Simon et al. 2000, 2009), particularly those areas vegetated with emergent wetland plants in UKL (Buettner and Scoppettone 1990, The Klamath Tribes 1995, Simon et al. 1995, 1996, Markle and Simon 1993, 1994, Cooperman and Markle 2000, Dunsmoor et al. 2000, Reiser et al. 2001, Cooperman 2002, Markle and Dunsmoor 2007). Water levels in Tule Lake sumps have been managed according to criteria set in previous BiOps (USFWS 2002). From April 1 to September 30, a minimum elevation of 4,034.6 feet was set in part to provide for dispersal of larvae and to provide rearing habitat in Tule Lake (USFWS 2008a). These water level operations appear to provide adequate habitat for larval and juvenile sucker life stages (USFWS 2008a). The PA is not anticipated to impact the amount or quality of larval sucker habitat in Tule Lake Sump 1A.

7.2.3.3. Effects to Tule Lake Habitat for Older Juveniles and Adults

Water depth as cover for older juvenile and adult suckers is limited due to the shallow bathymetry of the Tule Lake sumps. Surface elevations in Tule Lake Sump 1A of 4,034.6 feet from April through September and 4,034.0 feet from October through March appear to provide adequate habitat with areas of water depth greater than 3 feet to older juveniles and adults; however, there is continued concern about the shallow bathymetry of the sumps and the possibility of continued sedimentation (USFWS 2008a). The PA may adversely impact older juvenile and adult suckers in Tule Lake Sump 1A due to limiting habitat, largely water depth. The PA at Tule Lake is consistent with the historic operations and therefore the impacts related to reduced surface elevation and habitat are not anticipated to be greater than those described in the Environmental Baseline.

7.2.3.4. Effects to Tule Lake Water Quality as Habitat

Because of the shallow depths in Tule Lake sumps and relatively small change in water levels, the impact of water level management on water quality is probably small (USFWS 2008a). Poor water quality in Tule Lake can reduce the body condition and survivorship of individual suckers.

The impact of the PA on water quality within Sump 1A is difficult to assess due the naturally nutrient-rich inflows from surface water to Tule Lake. The PA likely contributes to the adverse impact to the water quality in the sumps in combination with the nutrient concentrations of inflows and internal nutrient cycling within the sumps. The PA adversely impacts suckers in Tule Lake through contributing to adverse water quality conditions. The PA at Tule Lake is consistent with the historic operations and therefore the impacts related to poor water quality are not anticipated to be greater than those described in the Environmental Baseline.

7.2.3.5. Effects of Entrainment Losses at Tule Lake

There are five federally-owned, unscreened diversion points from Tule Lake sumps (R Pump, R Canal, Q Canal, D Pumping Plant, and N-12 Lateral Canal; Loyd and Bolduc 2004). These diversions are an unquantified risk to suckers in Tule Lake through entrainment. Although unquantified, the risk to suckers is likely low due to the low numbers of early life history stages present (Hodge and Buettner 2008, 2009), and due to the assumptions that adult suckers tend to avoid diverted flows and are better able to avoid diverted flows than earlier life history stages. However, entrainment losses are an adverse impact of the PA PA, as described in the Environmental Baseline.

7.2.3.6. Effects of Possible Sucker Relocation from Tule Lake Sumps

During dry conditions with significant reductions in available surface water, elevations in the Tule Lake sumps may recede to levels that may adversely impact suckers in the sumps. If Reclamation and the USFWS, through discussions deem it necessary to relocate suckers from Tule Lake, Reclamation, USFWS, and the Refuges will coordinate on a proposal to relocate suckers from the Tule Lake sumps before seasonally stressful water conditions develop. In the rare instance that dry winter conditions would precipitate sucker relocation from Tule Lake sumps, it is anticipated that approximately 500 adult suckers could be captured and relocated in a two-week effort (Courter et al. 2010). With advance planning and additional effort, it is estimated that up to 1,000 adult suckers could be captured and relocated. The observed short-term (i.e., within 48 hours after release) mortality from capture, transport, and release of adult suckers was less than five percent (Courter et al. 2010). If the mortality associated with the capture and relocation of 1,000 adult suckers from Tule Lake is double the previous short-term observation, then it is anticipated that 100 adult suckers will die as a result of stresses from capture and relocation.

In the unlikely event that a relocation effort is needed at the Tule Lake sumps, this action will result in an adverse impact to suckers through the stress of up to 1,000 individuals and the mortality of up to 100 individuals from the action of capture, transport, and release.

7.2.4. Effects to Lost River Proper Individuals

7.2.4.1. Effects to Lost River Proper Adult Spawning and Migration

Much of the fish habitat, including spawning habitats, in both the upper and lower Lost River is fragmented by the presence of dams and the irregular flows effecting adult sucker passage between habitats. The PA which seasonally controls flows in the Lost River will result in adverse impacts by limiting adult sucker access to spawning habitat in the Lost River and its tributaries, which reduces sucker reproduction in the Lost River. These impacts are the same as those described in the Environmental Baseline.

7.2.4.2. Effects to Lost River Proper Habitat for Larvae and Young-of-the-Year Juveniles

As a result of the PA to operate the Lost River for water delivery during the irrigation season and flood control during fall and winter, individual YOY juveniles are adversely impacted through a reduction of habitat availability. During irrigation season, habitats in the Lost River are suitable for early sucker life history stages. Fall and winter habitats become fragmented by October at the end of irrigation season as flows in the Lost River recede. However, periodic weather and low elevation runoff events increase Lost River flows during fall and winter, temporarily allowing connectivity between impounded areas and deep pools. The reduction of flows in both the upper and lower Lost River may lead to stress from crowding, lack of food and cover, increased predation and disease, and increased risk of poor water quality (Reclamation 2007). Past and current operations of Lost River facilities provide adequate habitat to maintain small groups of SNS in the Lost River; however, flow diversions in the Lost River have negative impacts to individual suckers in the Lost River when flows are significantly reduced after the irrigation season (USFWS 2008a). These impacts are consistent with what was described in the Environmental Baseline.

7.2.4.3. Effects to Lost River Proper Habitat for Older Juveniles and Adults

Based on Shively et al. (2000b), older juvenile and adult endangered suckers reside in impounded areas or deep pools in the Lost River except during the spring spawning period when they migrate (Reclamation 2001a, USFWS 2002, Sutton and Morris 2005). Most of the adult sucker observations in the Lost River are from the upper Lost River above Bonanza, Oregon (Shively et al. 2000b). There are few older juvenile or adult suckers residing in the lower Lost River, below Lost River Diversion (Wilson) Dam (Reclamation 2001a, USFWS 2002).

Adult sucker habitat is fragmented within the Lost River similar to habitat for earlier life history stages in the Lost River. As with earlier life history stages, seasonal flow diversions under the PA, particularly flow reduction at the end of irrigation season in the Lost River, have negative impacts to individual suckers in the Lost River. Increased crowding of adult suckers into remaining available habitat at either the impoundments or deep pools, following reduced flows at the end of the irrigation season adversely impact individual adult suckers in the Lost River. Inflows from groundwater and low elevation runoff during weather events in the fall and winter periodically lessen the impacts of reduced habitat during the fall and winter months by reconnecting isolated areas of habitat (i.e., reservoirs and deep pools).

7.2.4.4. Effects to Lost River Proper Water Quality as Habitat

Run-off and drain water likely contain nutrients, organics, and sediment, which have adverse effects to LRS and SNS habitat by deteriorating water quality (USFWS 2008a). The effects would most likely be due to low DO concentration from decay of algae and macrophytes, and from organics that decompose and consume oxygen (USFWS 2008a). Adverse effects to LRS and SNS from Project runoff and drainage are most likely to occur in the middle and lower Lost River system because these habitats are downstream from large agricultural areas (USFWS 2008a). It is difficult to partition and assess water quality impacts related to nutrients between those carried on return flows and those carried on waters from Clear Lake Reservoir, Gerber Reservoir, and accretions in the Lost River. However, periods of adverse water quality, regardless of the source in the Lost River, adversely impact individual suckers that are present. The PA will adversely impact water quality in the Lost River through an incremental contribution of nutrients transported on return flows, consistent with what has been described in the Environmental Baseline.

7.2.4.5. Effects of Entrainment Losses at Lost River Proper

Unscreened diversions in the Lost River pose an unquantified adverse impact to individual suckers at each life history stage. Both lethal and non-lethal impacts related to entrainment are anticipated as a result of the PA within the Lost River, consistent with what has been described in the Environmental Baseline.

7.3. Effects of Operation and Maintenance Activities Associated with Klamath Project Operations

Gates at Gerber Dam, Clear Lake Dam, LRD and fish ladder, Lost River Diversion (Wilson) Dam, the LRDC, and A Canal are exercised twice each year before and after irrigation season, March through November. The exercising of irrigation gates will likely have short-term, temporary impacts to larval, juvenile, and adult suckers in the immediate vicinity of the dam during exercise operations. It is anticipated that most individuals will move away from the exercised gate due to the sudden change in the surrounding environment; however, an unknown quantity of individuals may be entrained through the gates during exercises. The component of the PA that includes O&M of Project facilities related to dam and diversion gates is anticipated to possibly have adverse impacts to suckers largely through harassment and entrainment. Sucker captive rearing and funding of sucker-related habitat restoration projects are anticipated to offset some adverse impacts due to operation and maintenance of Project facilities.

7.3.1. Effects of Clear Lake Dam Maintenance

Typically, once each year before the start of irrigation season in March or April, gates at Clear Lake Dam are opened to flush sediment that accumulates in front of the dam gates. This activity creates a maximum release of 200 cfs and lasts for approximately 30 minutes. Periodically, the fish screens at Clear Lake Dam need to be manually cleaned during the irrigation season dependent on lake elevations and sediment. During the cleaning, one of the two fish screen sets is always in place to prevent entrainment of juvenile and adult fishes.

Sudden opening of the Clear Lake Dam gate may entrain individual larval, juvenile, and adult suckers, but it is anticipated that a number of fish will move away from the disturbance created by the open gate. However, it is likely that a small number of suckers at each life history stage could be entrained through the dam during a 30-minute flushing release. The downstream transport of sediment into the Lost River during gate openings is short-term and temporary in nature with most of the sediment settling in pools in the upper Lost River between Clear Lake Reservoir and Malone Reservoir. Manual cleaning of the fish screens at Clear Lake Dam are anticipated to have insignificant impacts to suckers.

7.3.2. Effects of A Canal Headworks Maintenance

Gates at A Canal are only operated and exercised with the fish screens in place. Should an occasion occur where the fish screens become inoperable during irrigation season, it is likely that all flows will need to be truncated in order to replace or repair the fish screen. These activities at

A Canal are not anticipated to impact suckers. At the end of irrigation season, the A Canal gates are closed and the forebay between the trash rack and head gates is slowly dewatered. Annual fish salvage occurs within the dewatered forebay during late October or early November. During the fish salvage, up to 1,500 YOY and older juvenile suckers are captured through seining and electrofishing (Kyger and Wilkens 2011b, 2012b, Reclamation 2018, J. Ross pers. comm.). Continued monitoring (and fish salvage when fish are observed) in the A Canal forebay during the week following initial salvage indicates very few fish remain in the forebay (Kyger and Wilkens 2011b, 2012b). Salvaged suckers were typically measured, tagged, and returned to UKL. Since 2016, salvaged suckers are treated for inflictions by USFWS prior to tagging and releasing to UKL. Adverse impacts to several hundred juvenile suckers are anticipated during this salvage process through stress. Observed mortality of salvaged suckers has been relatively low; however, stranding prior to, or in absence of, fish salvage results in mortality (Kyger and Wilkens 2012b).

7.3.3. Effects of Lost River Diversion Channel Maintenance

Inspection of the gates and canal banks within the LRDC takes place once every six years. Inspections require a drawdown of water within the channel and can occur any time of the year. A drawdown of the channel would be coordinated with fish biologists to ensure adequate water is left to improve fish survival in pools during short term periods of low water levels. During drawdown, pools will be monitored to prevent stress to fish stranded until flows return. Adverse impacts in the form of stress are anticipated at each sucker life history stage but will likely be short term and temporary in nature. If necessary due to inadequate depth or disconnection between remaining pools, suckers will be salvaged from the remaining LRDC pools. Fish salvage is anticipated to result in harassment of up to 50 suckers, usually YOY or older juvenile life stage, during each occurrence. It is likely that stress will lead to harm of fewer than 5 suckers during each occurrence. Fish salvage will be coordinated with USFWS prior to the occurrence to determine the appropriate treatment and release sites for captured suckers. When practical, drawdown of the LRDC will occur during late fall through early winter when fewer suckers may be present in the channel to reduce impacts to suckers.

7.3.4. Effects of Link River Dam Fish Ladder Maintenance

Gates to the LRD fish ladder are exercised twice each year: once between January and April, and again between October and December. While the gates are exercised, the fish ladder is often dewatered and the entire structure is inspected. Fish are salvaged from the ladder while dewatered and returned to either the Link River or UKL. These activities have a short-term, temporary impact to suckers in and adjacent to the ladder. No more than 5 suckers of any life history stage have been encountered in the fish ladder during previous fish ladder inspections.

7.3.5. Effects of Canals, Laterals, and Drains Maintenance

Nearly all canals, laterals, and drains are annually dewatered at the end of irrigation season, as late as November and early December for Project canals in California. Canals remain dewatered until the following spring (as early as late March) except for localized precipitation runoff. In an effort to minimize effects associated with dewatering canals Reclamation has proposed a conservation measure for the salvaging of suckers from Project canals in both Oregon and California as described in Part 4.5.1. Some maintenance of canals occurs during irrigation season such as removal of plant material from trash racks at water control structures. These temporary activities are not anticipated to impact suckers.

Most canal, lateral, and drain maintenance occurs while canals are dewatered and includes removal of sediment, vegetation, concrete repair, and culvert/pipe replacement. Gates, valves, and equipment associated with canals and facilities are exercised before and after the irrigation season (i.e., before April and after October). In the past, these activities have typically occurred after dewatering of the canals and after fish salvage of Project canals. Some activities such as culvert and pipe replacement may temporarily increase sediment transportation. Based on the presence and abundance of suckers in Project canals (Kyger and Wilkens 2011b, 2012b), adverse impacts to suckers are anticipated in regard to seasonal canal dewatering and routine maintenance on canal infrastructure. Most impacts such as increase in sedimentation are temporary and result in stress for fish. Other impacts may include mortality through long-term stranding, such as may occur when canals are dewatered and pools become disconnected. Fish salvage of remaining pools following dewatering has prevented mortality losses of approximately 100 to 1,000 juvenile suckers each year since 2008 (Kyger and Wilkens 2012b).

7.3.6. Effects of Pest Control

Roads and dikes are mowed as necessary from March through October to control plant growth. Some pest control along dikes and on Reclamation property require the application of pesticides. Reclamation applies pesticides annually from February through October at select areas in accordance with our approved Pesticide Use Proposals and product labels. For the most recent Comprehensive Conservation Plan and Environmental Impact Statement regarding the use of pesticides on Reclamation and USFWS property including for Lower Klamath, Clear Lake, Tule Lake, Upper Klamath and Bear Valley NWRs, *see* https://www.fws.gov/refuge/Tule_Lake/what_we_do/planning.html (USFWS 2016). The effects of these activities have also been evaluated in previous section 7 consultations and incidental take coverage was provided in the USFWS's BiOps 1-7-95-F-26, 1-10-07-F-0056, 08—EKLA00-2013-F-0014 dated February 9, 1995, May 31, 2007, and May 2013, respectively. For additional information on pesticide and herbicide applications *see* Part 6.2.4. Effects are consistent with and remain covered under previous BiOps.

7.3.7. Effects of Right-of-Way and Access Maintenance

Right-of-way and access maintenance may temporarily cause sedimentation into adjacent waterways, principally canals. Gravel is periodically added to road beds or boat ramps and vehicle access points. Road beds are periodically re-graded. The impact of sedimentation is likely to have a temporary impact to individual suckers that may be present. When these activities occur, seasonal consideration and soil retention cloth are used to mitigate sedimentation of waterways.

7.3.8. Effects of Water Measurement

Water measurement devices, such as gages, require annual maintenance to flush sediments from stilling wells, replace faulty gages, or modification/replacement of supporting structures. Flushing sediment from stilling wells occurs during irrigation season (April through October) and may temporarily increase sedimentation downstream of the gage. Sediment volumes are often very small and the sediment settles a short distance downstream. In some instances, when a large amount of sediment is present, the sediment is removed from the stilling well and deposited at nearby upland locations. Other activities such as replacement or repositioning of a measurement device and associated infrastructure may require the construction of a small, coffer dam or be conducted during low flow periods. Measurement device sites are anticipated to need replacement or repair once every 5 to 10 years. If construction of a coffer dam is required, then fish will be salvaged from behind the dam prior to replacement of infrastructure. Replacement or repositioning of a site will have short term adverse impacts to suckers. Suckers will likely avoid the disturbance during activity but may need to be captured and moved to a location further from the impacted area. Replacement of equipment and flushing of stilling wells will have temporary impacts to suckers present in the immediate area of the gage. Most of these impacts are anticipated as non-lethal stress during site activity. If fish salvage is necessary, as in the instance that a coffer dam is needed to conduct repairs or replacement, it is anticipated that no more than 50 suckers of all life history stages will be encountered (harassed) for each occurrence. Fish salvage, and its non-lethal impacts, are likely the best approach to removing suckers away from additional harm due to these activities.

7.4. Effects to Critical Habitat

On December 11, 2012 USFWS proposed the designation of critical habitat for LRS and SNS (77 FR 73740, USFWS 2012). Critical habitat designation is defined in section 3 of the ESA as: (1) specific areas within the geographical area occupied by the species, at the time it is listed in accordance with the Act, on which are found physical or biological features (a) essential to the conservation of the species and (b) which may require special management considerations or protection; and (2) specific areas outside the geographical area occupied by the species at the time it is listed, upon a determination that such areas are essential for the conservation of the species.

In defining the physical and biological features and habitat characteristics required for LRS and SNS conservation, USFWS identified physical and biological features essential to the conservation of LRS and SNS in areas occupied at the time of listing, focusing on the features' primary constituent elements. Primary constituent elements are the specific elements of physical and biological features that are essential to the conservation of the species (77 FR 73740, USFWS 2012). Based on our knowledge of the physical or biological features and habitat characteristics required to sustain the species' life-history processes at the time of the proposed critical habitat, the primary constituent elements specific to self-sustaining LRS and SNS populations are: (1) Water; (2) Spawning and rearing habitat; and (3) Food; (77 FR 73740, USFWS 2012). These three primary constituent elements are described as follows (77 FR 73740, USFWS 2012)

1. *Water. A*reas with sufficient water quantity and depth within Lakes, reservoirs, streams, marshes, springs, groundwater sources, and refugia habitats with minimal physical, biological, or chemical impediments to connectivity. Water should exhibit depths ranging from less than 3.28 feet (1.0 m) up to at least 14.8 feet (4.5 m) to accommodate each life stage. The water quality characteristics should include water temperatures of less than 28.0°C (82.4°F); pH less than 9.75; DO levels greater than 4.0 mg per L; low levels of algal

toxins such as microcystin (amount not specified); and un-ionized ammonia (less than 0.5 µg per L). Elements also include natural flow regimes that provide flows during the appropriate time of year or, if flows are controlled, minimal flow departure from a natural hydrograph.

2. *Spawning and rearing habitat*. Streams and shoreline springs with gravel and cobble substrate at depths typically less than 1.3 m (4.3 feet) with adequate stream velocity to allow spawning to occur. Areas identified in PCE1 [sic primary constituent element 1] containing emergent vegetation adjacent to open water that provides habitat for rearing. This 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.

7.4.1. Effects to Critical Habitats in UKL and Tributaries

7.4.1.1. Effects to Water

While there has been some concern that Project operations may affect UKL water quality through management of UKL elevation, the best available science has not demonstrated a clear, discernible, and consistent relationship between UKL elevation and water quality. This does not mean that UKL elevation or water depth does not have an effect on water quality, only that the best available science has not demonstrated a clear, consistent, and discernable relationship especially within the range of UKL elevations observed from 1990 to 2016, nor over the range of UKL elevations analyzed in the KBPM output for the POR. *See* Parts 6.2.3 and 7.1.1.6 for further discussion and analysis. The PA and its resulting surface elevations could potentially influence nutrient cycling within UKL (NMFS and USFWS 2013). At present, the empirical information is lacking a causal link between water quality impacts (both negative and positive) and surface elevations in UKL.

The PA is unlikely to impact sedimentation or nutrient input into UKL because much of the input of lake nutrients occurs upstream of UKL and the area influenced by the PA (NMFS and USFWS 2013). Nutrients available in the lake substrates (e.g., internal nutrient loading) are not likely influenced by the surface elevations in the PA, although the storage and delivery of water from UKL could impact amounts of nutrients both stored and exported from UKL. The net effect of water storage and delivery in UKL on nutrient cycling is not well understood but could have both negative and positive impacts on water quality.

The PA has no effect on water quality in the tributaries to UKL within the critical habitat for LRS and SNS. Much of this critical habitat in the tributaries is above the influence of water storage in UKL. Water management described in the PA will only impact the lower reaches of the Williamson River, those reaches that are influenced by UKL surface elevations of (NMFS and USFWS 2013).

7.4.1.2. Effects to Spawning and Rearing Habitat

As discussed in Part 7.1.1., the PA may result in lake surface elevations that impact sucker spawning at the shoreline spawning area of UKL. This area is critical habitat for LRS that spawn there. An objective of the PA is to store water in UKL from November through March. This objective results in EOM lake elevations in February through May which, in most years, provide sufficient depths for lakeshore spawning LRS populations. The PA maintains surface elevations at or higher than 4,142 feet during LRS spawning from EOM February through EOM May in 80 percent of the years from the POR. In 95 percent of the POR years, lake elevations will be at 4,141.4 feet or greater during the spawning season. Surface elevations by the end of March are above 4,142.0 feet in all model years except one (1992) with implementation of the PA. This elevation has been previously identified as impacting sucker spawning at the shoreline area (NFMS and USFWS 2013). Should hydrologic conditions experienced in 1992 develop during the next decade, operating to the PA will result in a lake elevation that will temporarily reduce the amount of critical habitat at the shoreline spawning area in UKL during that spawning season; however, this condition is expected to be infrequent under this PA.

Lake surface elevations with the PA are anticipated at or above 4,141.4 feet by the end of June and at or above 4,140.1 feet by the end of July in all but the driest years (at the 95 percent exceedance levels; Table 7-4). A lake surface elevation of 4,141 feet provides approximately 70 percent of the emergent vegetation habitat in UKL. Even during dry conditions, such as the 95 percent exceedance level, it is anticipated that greater than 50 percent of emergent vegetation will be inundated with at least one foot of water through the end of June. During low inflow years (drier than 95 percent exceedance levels) declining amounts of emergent vegetation are still available through June and July. This indicates that under the driest hydrologic conditions, the PA will extend the amount of inundated emergent vegetation into early July for larval suckers.

Lake surface elevations under the PA remain near 4,138.9 feet by the end of August (at 95 percent exceedance) in all but the driest of years and at or above 4,138.5 feet by the end of September in all years. While emergent vegetation is diminished as a near-shore habitat below elevations of about 4,140.0 feet based on previous surveys, this habitat is still available to YOY juvenile suckers in most years until late summer. During dry conditions, there is likely to be a loss of diversity of near-shore substrates during late summer and early fall.

Lake surface elevations by the end of September, nearing the end of the period when YOY juveniles are most prevalent in near-shore areas of UKL, are anticipated to be above 4,138.4 feet, and as high as 4,141.1 feet with the PA. Below 4,138.0 feet, near-shore habitat diversity becomes diminished. The PA appears to provide for the diversity of nearshore habitat within UKL critical habitat for both LRS and SNS through the end of September.

The PA will have no effect on critical habitat in tributaries to UKL as this habitat occurs upstream of the active storage and delivery of water in UKL.

7.4.1.3. Food

Entrainment of zooplankton and macro-invertebrates may occur with delivery of water from UKL. However, the PA is not anticipated to appreciably reduce food availability in UKL due to the relatively high abundance of zooplankton and benthic macro-invertebrates in UKL (Hazel 1969). The PA is not anticipated to affect food resources for suckers in UKL (NFMS and USFWS 2013).

7.4.2. Effects to Critical Habitat in Keno Reservoir

7.4.2.1. Water

Under the PA, flows for agriculture and downstream environmental needs will be released from LRD. Surface elevations in the Keno Impoundment are expected to be similar to recent and historic elevations. The PA is not anticipated to impact water depth in the Keno Reservoir.

The quality of water entering, within, and leaving the Keno Reservoir is largely due to poor quality water from UKL containing large amounts of organic matter with an associated high BOD (Doyle and Lynch 2005, Deas and Vaughn 2006). Water from UKL, and the organic matter and nutrients carried with the water, may incrementally reduce water quality in the Keno Reservoir, particularly during warm weather periods.

7.4.2.2. Spawning and Rearing Habitat

Spawning activity in the lower Link River, upstream of the West Side hydropower facility, was observed during May 2007 (Smith and Tinniswood 2007). No other spawning habitat exists between the Link River and Keno dams (Buchanan et al. 2011). The PA releases water fromUKL at LRD for downstream needs. The releases under the PA are anticipated to have no impact to spawning habitat in the Link River.

The ongoing management to operate for stable surface elevations in the Keno Reservoir impacts development of additional wetland habitats and degrades the quality of existing wetlands through controlled water depth (USFWS 2007c). However, stable surface elevations do provide sucker access to the established wetland habitats for rearing during sucker early life history stages. The PA has some negative effects to the recovery-support function of critical habitat in Keno Reservoir for both LRS and SNS (NMFS and USFWS 2013).

7.4.2.3. Food

Abundance of benthic macro-invertebrates is high in the Lost River (Shively et al. 2000b) and UKL (Hazel 1969). There is a lack of information on prey species abundance in the Link to Keno Reservoir reach; however, prey species are assumed to be relatively high as the water at this location arrives from UKL. The PA is not anticipated to appreciably reduce food availability based on the assumption that prey species are abundant.

7.4.3. Effects to Critical Habitat in Clear Lake Reservoir and Tributaries

7.4.3.1. Water

The PA is not anticipated to affect water quality in the Clear Lake Reservoir or its tributaries. Although periodic low water levels at Clear Lake Reservoir could periodically contract the amount of available area in reservoir with water depth that may be utilized by older life history stages of both LRS and SNS. Particularly, in consecutive drought years, the PA may decrease the amount of critical habitat in Clear Lake Reservoir to shallower depths that may become periodically limiting to sucker use. The minimum Clear Lake Reservoir elevation will likely provide adequate protection from drought in most years. Extended drought may result in a significant reduction in lake area and depth.

At Clear Lake Reservoir, lower water levels may result in degraded water quality, particularly higher water temperatures and lower DO. Consequently, very low lake levels in Clear Lake Reservoir during consecutive drought years could adversely impact water quality (USFWS 2008a, NMFS and USFWS 2013). However, water quality monitoring over a wide range of lake levels and years documented water quality conditions that were adequate for sucker survival (Reclamation 1994a, 2001, 2007).

7.4.3.2. Spawning and Rearing Habitat

The PA may periodically impact access to Willow Creek at Clear Lake Reservoir. Sucker access to Willow Creek appears to be a function of lake surface elevation (approximately 4,524.0 feet) and creek discharge during spring months when both LRS and SNS adult ascend Willow Creek to spawn. A minimum lake elevation of 4,520.6 feet above mean sea level by the end of September each year is intended to conserve lake surface area and water depth as fish habitat into the winter months and into the following year. This lake elevation is also intended to reduce the likelihood of reduced spawning access the following spring. Extended drought may result in consecutive years of reduced surface elevations which are likely to adversely impact access to Willow Creek. The PA is not anticipated to affect spawning habitat in the tributaries to Clear Lake Reservoir.

Relatively little is known about rearing habitat requirements at Clear Lake Reservoir. Assuming that lake surface area, water depth, and shoreline are important components of rearing habitat, then the PA may periodically reduce rearing habitat in Clear Lake Reservoir at low surface elevations when habitat contracts.

7.4.3.3. Food

Abundance of benthic macro-invertebrates is high in the Lost River (Shively et al. 2000b) and UKL (Hazel 1969). There is a lack of information on prey species abundance in Clear Lake Reservoir. Based on the abundance of macro-invertebrates in other basin waters, Reclamation assumes that prey species are also relatively high in Clear Lake Reservoir. Prolonged drought may concentrate fish into remaining habitat and reduce food availability through competition in Clear Lake Reservoir. Although prey species may be entrained on water delivery from Clear Lake, the PA is not anticipated to appreciably reduce food availability based on the assumption that prey species are abundant.

7.4.4. Effects to Critical Habitat in Gerber Reservoir and Tributaries

7.4.4.1. Water

The PA may reduce surface area, water depth, and shoreline areas as habitat during periods of prolonged drought at Gerber Reservoir. Low lake elevations may also result in degraded water quality including higher pH values and lower DO concentration. Water quality monitoring over a wide range of lake levels and years has documented water quality conditions that are periodically stressful to suckers but were generally adequate for SNS survival (Reclamation 2001a, 2007, Piaskowski and Buettner 2003, Phillips and Ross 2012).

7.4.4.2. Spawning and Rearing Habitat

The PA is not anticipated to impact spawning habitat at Gerber Reservoir. Sucker access into Barnes Valley and Ben Hall creeks, the principal spawning tributaries for suckers in Gerber

Reservoir, requires a minimum spring (February through April) elevation of about 4,805.0 feet (USFWS 2008a). Surface elevations of at least 4,805.0 feet were reached each spring by end of April in all years for the POR and were reached by the end of March in all years except 1992. However, in very dry years both Barnes Valley and Ben Hall creeks typically have low spring flows that may not provide adequate upstream passage for spawning adults regardless of lake elevations (Reclamation 2001a).

The PA is anticipated to have minimal impact to rearing habitat at Gerber Reservoir. At Gerber Reservoir, larval and juvenile suckers likely utilize lake surface area, water depth, and shoreline as habitat. At 4,800 feet, the surface area of the lake decreases to about 750 surface acres. As lake surface elevation decreases so does the amount of available rearing habitat.

7.4.4.3. Food

It is assumed that zooplankton and benthic macro-invertebrate abundance in Gerber Reservoir is similar to other aquatic environments in the Upper Klamath Basin (Hazel 1969, Shively et al. 2000b). The PA is not anticipated to appreciably reduce food availability except during prolonged drought which may concentrate fish into remaining habitat and reduce food availability through competition in Gerber Reservoir.

7.5. Cumulative Effects

Cumulative effects are those impacts of future state and private actions that are reasonably certain to occur within the area of the action subject to consultation. Future federal actions will be subject to the consultation requirements established in section 7 of the ESA and therefore, are not considered cumulative to the PA.

The federal Clean Water Act (43 U.S.C. §§1251 to 1376) requires states to develop plans with goals and pollution targets for improving water quality in water bodies that are designated as impaired because of excessive quantities of various pollutants. This process includes establishing limits known as Total Maximum Daily Loads (TMDLs) for designated pollutants. Governmental entities (local, state, and federal) and/or private entities are responsible for addressing pollution under their control by developing management strategies, implementation plans, and schedules that are designed to collectively meet TMDL requirements. ODEQ released an updated TMDL analysis and report for the Upper Klamath and Lost River subbasins within the Klamath Basin in 2017 (ODEQ 2017). The mainstem Klamath River TMDL was released by the state of California in 2010 (NCRWQCB 2010). Implementation of the resultant water quality management plans will aid in improving water quality in UKL and its tributaries as well as the mainstem Klamath River in habitats occupied by listed suckers, which is beneficial to listed suckers and their habitats.

7.6. Summary and Determination

7.6.1. Upper Klamath Lake and Tributaries Summary

The PA will adversely impact the amounts of available shoreline spawning habitat, emergent vegetation, and area of preferred lake depth in the northern portion of UKL. It is anticipated that the amount of habitat for success of each sucker life history stage will be adequate in all years except during years of low inflow to UKL when habitat amounts will be reduced. Reduced habitat quantity and quality will impact individual suckers at each life history stage. A large number of individual impacts could result in population level impacts, such as repeat skipped spawning at the shoreline and reduced body condition or survivorship as a result of prolonged periods of limited habitat. These impacts are only anticipated during extreme or consecutive low inflow conditions to UKL (e.g., the early 1990s). It is anticipated that results of dry conditions can be managed through real-time management decisions within the PA.

The PA will also adversely impact individual suckers at each life history stage through entrainment from UKL. Large estimated numbers of larvae and YOY juvenile suckers each year exit UKL through A Canal (larvae still pass the fish screen) and the LRD. Whereas, population impacts are not fully understood, large losses particularly at later life history stages may adversely impact sucker populations in UKL.

The PA is not anticipated to impact water quality in UKL nor is it anticipated to impact access by older juvenile and adult suckers to areas of improved water quality such as Fish Banks and Pelican Bay.

The PA for UKL and tributaries is largely consistent with the historic operations, and therefore the impacts related to reduced surface elevations on habitat availability, predation, and entrainment are anticipated to be similar to those described in the Environmental Baseline. Reclamation anticipates improvements that offset some adverse impacts from the PA as a result of funding the conservation measures, including 1) a captive rearing program with the release of thousands of young suckers that are expected to recruit to the spawning populations in UKL, and 2) sucker recovery efforts that are envisioned for sucker habitat quantity, quality, and fish passage improvements.

7.6.2. Keno Impoundment Summary

The PA will have adverse impacts to individual LRS and SNS in the Keno Impoundment. Unquantified numbers of suckers will become entrained within the Keno Impoundment and downstream of Keno Dam, through unscreened diversions such as the LRDC, Ady Canal, North Canal, and numerous smaller diversions. Past monitoring at locations associated with the LRDC and near Ady and North Canals indicated that larvae and juvenile suckers are the most common sucker life history stage that will be exposed to entrainment and numbers of entrained suckers are expected to be relatively small.

Discharges into the Keno Impoundment from the Project may impact suckers through additions of nutrients, which incrementally degrade water quality, and through herbicide/pesticide exposure. Whereas the Project is a net “sink” for nutrients primarily through diverting water high in nutrients from UKL, return flows through the LRDC and the KSD have nutrient concentrations higher than surface water from UKL. The high nutrient concentrations on the return flows incrementally contribute to deteriorated water quality conditions in the Keno Impoundment; however, the full impact of return flows on water quality in the Keno Impoundment are confounded by the highly eutrophic outflow of UKL. Pesticide and herbicide discharges have not been directly measured in the Keno Impoundment and information from Tule Lake Sump 1A indicates few pesticides are likely present; however, those that are present likely pose a risk to suckers in the Keno Impoundment. Degraded water quality and potentially harmful chemical concentrations impact each sucker life history stage. The PA for the Keno Impoundment is largely consistent with the historic operations, and therefore the adverse impacts are anticipated to be similar to those described in the Environmental Baseline.

The PA is not anticipated to impact sucker physical habitat of surface area and depth in the Keno Impoundment.

7.6.3. Clear Lake Summary

The PA at Clear Lake Reservoir will affect individual suckers through entrainment of larvae and small YOY juvenile suckers. Impact of entrainment of both larvae and YOY juvenile suckers is likely based on the numbers of early life stages present in the lake each year and the amount of irrigation delivery. However, based on one year of entrainment observations, several hundred thousand larvae and several thousand YOY juveniles are likely lost from Clear Lake Reservoir through entrainment at Clear Lake Dam although the outlet is screened. Entrainment of older juvenile and adult suckers is prevented by the fish screen at Clear Lake Dam; however, impingement of some older juvenile suckers may still occur. Relatively large evaporative and seepage losses at Clear Lake Reservoir make evaluating the direct impact of the PA difficult to assess. However, the PA will temporarily and periodically limit habitat during periods of low surface elevations, particularly during prolonged periods of low inflow to Clear Lake Reservoir. Habitat for each sucker life history stage becomes limited when surface area contracts and water depth decreases at low surface elevations. During low surface elevations and low inflow periods, spawning access to Willow Creek appears impeded. The PA is not anticipated to substantially impact water quality at Clear Lake Reservoir. Combined impacts may have population level impacts to both LRS and SNS at Clear Lake Reservoir if large numbers of individuals are impacted and during prolonged, multiple-year drought. A minimum lake elevation of 4,520.6 feet by the end of September each year is intended to conserve lake surface area and depth as fish habitat into the winter months and the following year, and to lessen the impacts from temporary, but periodic, spawning access limitations the following spring. Avian predation at lower lake elevations such as 4,520.6 feet may contribute to reduced survival of juvenile and adult suckers. A minimum surface elevation of 4,520.6 feet is likely to be adequate to protect some individuals of LRS and SNS populations at Clear Lake Reservoir (Reclamation 2007, USFWS 2003, 2008a).

The PA for Clear Lake is largely consistent with the historic operations, and therefore the impacts related to reduced surface elevations on habitat availability, predation, and entrainment are anticipated to be similar to those described in the Environmental Baseline. Reclamation anticipates improvements that offset some adverse impacts from the PA as a result of funding sucker recovery efforts that are envisioned for sucker habitat quantity, quality, and fish passage improvements.

7.6.4. Gerber Reservoir Summary

The PA at Gerber Reservoir will affect approximately 250 individual YOY and older juvenile suckers through entrainment. Although there is limited information, entrainment from Gerber Reservoir may also impact individual larval and adult suckers as Gerber Dam has an unscreened outlet. The PA will temporarily and periodically limit habitat during periods of low surface elevations, particularly during prolonged periods of low inflow to Gerber Reservoir. Habitat for each sucker life history stage becomes limited when surface area contracts and water depth decreases at low surface elevations. The PA for an end of September elevation of no less than 4,798.1 feet appears to provide adequate habitat quantities for and water depths that are protective of SNS. The PA is not anticipated to impact spawning access to tributaries or water quality at Gerber Reservoir. Combined impacts may have population level impacts to SNS at Gerber Reservoir if large numbers of individuals are impacted and during prolonged, multiple-year drought.

The PA for Gerber Reservoir is largely consistent with the historic operations, and therefore the impacts related to reduced surface elevations on habitat availability, predation, and entrainment are anticipated to be similar to those described in the Environmental Baseline. Reclamation anticipates improvements that offset some adverse impacts from the PA as a result of funding sucker recovery efforts that are envisioned for sucker habitat quantity, quality, and fish passage improvements.

7.6.5. Lost River Summary

Fertilizer use within the Project will reduce water quality incrementally in the Lost River above the naturally eutrophic surface waters of the Upper Klamath Basin. Although this could have adverse effects on the LRS and SNS, there is insufficient information on possible effects to conclude that water quality reductions as a result of the PA will result in harm to suckers. Herbicide and pesticide use within the Project have seldom been detected at levels harmful to fish; however, these chemicals pose a risk that may impact both LRS and SNS at each life history stage. Unscreened diversions from the Lost River and the seasonal fluctuation of flows adversely impact suckers, particularly at early life history stages through entrainment and fragmentation of habitat.

The PA for Lost River operations is largely consistent with the historic operations, and therefore the impacts related to reduced surface elevations on habitat availability, predation, and entrainment are anticipated to be similar to those described in the Environmental Baseline. Reclamation anticipates improvements that offset some adverse impacts from the PA as a result of funding sucker recovery efforts that are envisioned for sucker habitat quantity, quality, and fish passage improvements.

7.6.6. Tule Lake Summary

Surface elevation management may adversely affect individual suckers in Tule Lake through a reduction in adult habitat, and possibly water quality; however, surface elevations in the PA are anticipated to preserve adequate depth in summer and winter to reduce the risk to individual suckers associated with low surface elevations at the Tule Lake sumps. Unscreened diversions in Tule Lake may negatively impact individual suckers through entrainment. Entrainment impacts are not likely to occur at vulnerable, early sucker life history stages due to the low numbers of larval and juvenile suckers present in Tule Lake. Entrainment could impact older juvenile and adult suckers at Tule Lake; however, these later life history stages are better adept at avoiding entrainment than early life history stages (i.e., smaller fish) and entrainment impacts are expected to be minimal on Tule Lake suckers. If dry winter conditions reduce surface water and Tule Lake sumps are predicted to be unsuitably low for suckers, then a relocation of suckers may be needed. A relocation of suckers from Tule Lake will adversely impact individual suckers through capture and transportation stress and mortality.

The PA for Tule Lake operations is largely consistent with the historic operations, and therefore the impacts related to reduced surface elevations on habitat availability, predation, and entrainment are anticipated to be similar to those described in the Environmental Baseline. Reclamation anticipates improvements that offset some adverse impacts from the PA as a result of funding sucker recovery efforts that are envisioned for sucker habitat quantity, quality, and fish passage improvements.

7.6.7. Critical Habitat Summary

Nutrient or chemical concentrations from fertilizer or pesticide use within the Project may incrementally worsen water quality conditions in the naturally eutrophic waters at some locations in the Upper Klamath Basin as a result of the PA. Return flows with increased nutrient concentrations may impact proposed critical habitat in the Keno Impoundment; however, the project may be more of a net sink for nutrients (Schenk et al. 2018), and pesticides (and their application) are regulated to minimize impacts (USFWS 2016). Further, due to reductions in agriculture deliveries in the PA, Reclamation anticipates return flows from the Project to the Klamath River may be slightly reduced. The PA is not anticipated to influence water quality at UKL, Clear Lake Reservoir, and Gerber Reservoir.

The PA is not anticipated to reduce access to spawning habitats in UKL most years. Periodic, though infrequent and temporary, low surface elevations as result of low inflows may impact proposed critical habitat through limiting sucker access to spawning habitat at shoreline spawning areas in UKL. However, the PA maximizes shoreline spawning areas in UKL in most years. The PA is not anticipated to reduce rearing habitat in UKL except in the driest of years. The PA is not anticipated to impact spawning or rearing habitat in the Keno Reservoir.

The PA is not anticipated to adversely affect sucker spawning habitat in Clear Lake Reservoir except during prolonged drought. Surface elevations likely to be experienced during prolonged drought under the PA will reduce sucker access to spawning habitat in Willow Creek and through reduction in the amount of nearshore rearing habitat. This impact is expected to be infrequent and temporary under the PA. The PA has no impact to habitat in tributaries to Clear

Lake Reservoir. The PA is not anticipated to affect water quality beyond parameters that are adequate for sucker survival in Clear Lake Reservoir.

The PA is not anticipated to adversely affect sucker spawning habitat in Gerber Reservoir. The PA has no impact to habitat in tributaries to Gerber Reservoir. The PA is not anticipated to affect water quality beyond parameters that are adequate for sucker survival in Gerber Reservoir.

The PA will affect 250 to 300 individual suckers at Gerber Reservoir as they are entrained into Miller Creek through Gerber Dam. Although there is lack of information, it is likely that entrainment may also impact individual larval and adult suckers as they exist Gerber Reservoir through the unscreened outlet at the dam. The PA will temporarily and periodically limit habitat during periods of low surface elevations, particularly during prolonged periods of low inflow to Gerber Reservoir. Habitat for each sucker life history stage becomes limited when surface area contracts and water depth decreases. The PA for an end of September elevation of no less than 4,798.1 feet is likely to provide adequate habitat quantities for and water depths that are protective of shortnose suckers. The PA is not anticipated to impact spawning access to tributaries or water quality at Gerber Reservoir. The PA is not anticipated to tributary habitat conditions or impact food availability within the reservoir, both of which are designated SNS critical habitat. Combined impacts may have population level impacts to shortnose suckers at Gerber Reservoir if large numbers of individuals are impacted, particularly during a multiple-year drought.

Reclamation anticipates some of the adverse impacts to critical habitat can be offset with funding conservation measures described in Part 4.

7.6.8. Determination on Effects of the Proposed Action on Lost River and Shortnose Suckers and Designated Critical Habitat

After considering the best available scientific and commercial information, the analysis indicates that LRS and SNS are likely to be exposed to environmental consequences and will respond in a negative manner to the exposure. Thus, Reclamation concludes that implementing the PA, including the conservation measures intended to offset adverse impacts, may affect, and is likely to adversely affect the LRS and SNS and their designated critical habitat.

8. EFFECTS OF IMPLEMENTING THE PROPOSED ACTION ON COHO SALMON

Part 8 of the BA evaluates if implementing the PA may affect Southern Oregon Northern California Coastal (SONCC) coho salmon and its designated critical habitat.

8.1. Hydro-Modeling

Reclamation will use results generated by WRIMS to identify the Klamath River hydrograph that is likely to occur as a result of implementing the PA. WRIMS is a generalized water resources modeling system, broadly accepted by the hydrologic community, for evaluating flexible operational alternatives for large, complex river basins. WRIMS integrates a simulation language for flexible operational criteria specification, a linear programming solver for efficient water management decisions, and graphics capabilities for ease of use. These combined capabilities provide a comprehensive and powerful modeling tool for water resource systems simulation.

8.2. Period of Record

Reclamation used the POR of October 1, 1980 to November 30, 2016, from which to run the daily time step WRIMS model. October 1, 1980 to November 30, 2016, includes a reasonable distribution of dry, average and wet years. With this range of data, the WRIMS model is able to evaluate a particular water operation strategy across a reasonably foreseeable range of hydrologic patterns. Reclamation's analyses use WRIMS to estimate mainstem Klamath River flows at IGD that would likely be realized through implementation of the PA during the POR. Reclamation considers the resulting model outputs to reflect the range of flows reasonably expected to occur during the 10-year period of the PA (April 1, 2019 through March 31, 2029). However, it is important to note that each year in the POR has unique hydrologic and meteorological characteristics that only occur in that year. While the hydrology observed in the POR captures the range of conditions, the unique sequencing and patterns of meteorological and hydrologic events that will occur in the future cannot be predicted. As such, unique meteorological and hydrologic events not captured in the POR may occur, resulting in conditions not simulated by WRIMS.

While the 36-year POR reflects a range of dry and wet water years, actual conditions may deviate from the representative trend in future years, possibly due to climate change. However, there is currently a lack of reliable forecasting tools available to adequately quantify the influence of global climatic changes on local hydrologic conditions. Therefore, the effects of possible future climate change, and the associated impacts on species and hydrology, are not explicitly incorporated into the analyses.

The historical IGD flows during the POR represent a component of the past and current Baseline. Thus, these historical IGD flows include impacts from past Project operations and current Project operations consistent with the 2013 BiOp. Reclamation also modeled IGD flows as if the PA was implemented during the same POR. As mentioned above, Reclamation considers the resulting model outputs reflective of the range of flows reasonably expected to occur during the 10-year period of the PA (April 1, 2019 – March 31, 2029).

Flows during the POR are available on a daily timestep. Modeling output for the PA is also available on a daily timestep. Model outputs of the PA will provide for a direct comparison with the measured flow during the POR.

8.3. Ecological Effects

In this section, Reclamation assesses the likely impacts to the hydrology and water quality with the implementation of the PA. For reasons discussed in the Baseline, the Effects Analysis will focus on impacts to the hydrology and water quality downstream of IGD. In subsequent sections, the likely impacts of hydrology and water quality on federally listed coho salmon and designated critical habitat will be discussed.

8.3.1. Altered Hydrology

In the following analysis, Reclamation evaluated both historical flows at IGD during the POR (a component of the Baseline) and modeled IGD flows as a result of the PA during the same POR. This section should provide insight into how IGD flows under the PA may alter hydrologic conditions. PA flows at IGD during the POR will be evaluated for the four components of a hydrograph as described in the Baseline: subsistence flows, base flows, high-flow pulses, and overbank flows.

8.3.1.1. Subsistence Flow

Subsistence flow is the minimum flow required during critical drought periods to maintain acceptable water-quality conditions and to provide minimal aquatic habitat space for the survival of aquatic species (NRC 2005) and can change by season and between years. Hardy et al. (2006) considers subsistence flows to represent flows between approximately the 80 and 95 percent exceedance ranges. During the POR at IGD, the average flow between the 80 and 95 percent exceedance was 843.72 cfs. NMFS (2013) determined that a mainstem flow of 1,000 cfs is expected to provide sufficient flow to maintain connectivity to tributaries for re-distributing juvenile coho salmon. An evaluation of the frequency of flows below 1,000 cfs was used to assess potential impacts of the PA on subsistence flows.

When the PA is applied to the POR, 17.7 percent (n = 2,332) of the daily average flows are below 1,000 cfs. Of those modeled flows below 1,000 cfs, the mean value is 937 cfs (range 900 – 999 cfs). Historical flows during the POR had a higher frequency of daily average flows below 1,000 cfs, 24.2 percent (n = 3,197), and the mean of daily flows below 1,000 cfs was 813 cfs (Table 8-1). This suggests that implementation of the PA will result in a reduction in the frequency and magnitude of daily average flows below 1,000 cfs.

8.3.1.2. Base Flow

Base flow is the "normal" flow condition between storms (NRC 2005) and can change throughout the year. For the purpose of this evaluation, we will consider base flow to be between 1,000 cfs and 6,000 cfs. Base flows accounted for 72 percent (n = 9,506) of historical flows during the POR with a mean of 1,866 cfs. When the PA is applied to the POR, 79.0 percent (n = 10,434) of the daily average flows are considered base flow, with mean base flows of 1,766 cfs. The PA would likely provide adequate base flows with a slightly lower mean flow than observed historical values.

8.3.1.3. High-flow Pulses

High-flow pulses are punctuated events, typically following storms (NRC 2005) and can be defined differently throughout the year. Fewer high-flow pulses due to water management may result in the stabilization of gravel bars, promoting thick riparian vegetation at the river edges. The loss of high-flow pulses may also cause alluvial barriers to seasonally form at the mouths of upper Klamath River mainstem tributaries (NMFS 2012a). The reduced frequency and magnitude of high-flow pulses may further increase the flows needed to obtain overbank flow and decrease the likelihood of overbank flow occurrence (Junk et al. 1989, Poff et al. 1997).

For the purpose of this analysis, we determined the frequency of high-flow pulses, which were defined as equal to or greater than 6,000 cfs but less than 12,000 cfs. This range is consistent with the USGS/USFWS mapping protocol in determining split channels, which are defined as a "permanent," vegetated (trees) island that is not inundated even at a "high flow" (approximately 10,000 cfs; Hardy et al. 2006). In addition to the frequency of high-flow pulses, the duration of these events is also an important component of the hydrograph. To address this, we enumerated high-flow pulses that are three consecutive days or more.

When the PA is applied to the POR, 3.2 percent (n = 428) of the daily average flows are characterized as high-flow pulses, with an average value of 7,380 cfs. High-flow pulses accounted for 3.5 percenet (n = 463) of the historic daily average flows, with an average value of 7,721.25 cfs (Table 8-1). When the PA is applied to the POR, there are approximately 50 high-flow pulse events that are at least three days. Historical flows during the POR included 31 high-flow pulse events that were at least three days. Implementation of the PA will likely increase the frequency of high-flow pulse events that are three days or more in duration.

8.3.1.4. Overbank Flow

Overbank flow is an infrequent, high-flow event that breaches riverbanks (NRC 2005). Overbank flows provide for channel and riparian maintenance (Hardy et al. 2006). Geomorphic analyses, including initiation of bed load movement, that suggested the flows threshold for bed mobility below IGD was approximately 13,000 cfs (Hardy et al. 2006). However, Shea et al. (2016) described geomorphically effective flows as those required to maintain channel form and reduce riparian encroachment. They classified discharges exceeding 15,000 cfs as geomorphically effective flows. Furthermore, the duration and magnitude of these overbank or geomorphically effective flows may be critical for channel maintenance (Shea et al. 2016). For the purpose of this discussion, overbank flows are considered equal to or greater than 12,000 cfs.

When the PA is applied to the POR, 0.1 percent (n = 9) of the mean daily flows will be characterized as overbank flow, with an average of 14,637 cfs (range 12,801 – 17,271 cfs with an average duration of 3 days). Overbank flows accounted for 0.08 percent (n = 11) of the historical daily flows, with an average of 14,000 cfs (Table 8-1) Implementation of the PA, would likely result in very infrequent occurrences of overbank flow conditions.

8.3.1.5. Flow Variability

Low variability in flows can result in reduced habitat complexity, and ultimately, a loss of diversity (Poff et al. 1997). Maintaining natural variability in the flow regime is critical for conserving the structure and function of a riverine ecosystem (Sanford et al. 2007). The intent of the increased flow variability with the implementation of the PA is to restore a more natural riverine ecosystem, which is assumed to benefit coho salmon.

In addition, the PA allows for additional flexibility in managing water in-season. In-season adjustments to the modeled PA flows in the coho salmon Effects Analysis are difficult to incorporate because these management determinations are based upon current conditions. In recognition of these limitations, the PA will allow for greater daily IGD flow variability compared to past water management practices during the POR. A summary of IGD daily exceedance flows and flood frequency are included in Appendix 8 tables 8-1 and 8-2.

Table 8-1. Summary of the Iron Gate Dam historical (actual) average daily flows during the Period of Record (October 1, 1980 to November 30, 2016), and for the modeled average daily flows with the implementation of the Proposed Action when applied to the same period.

Criteria	Modeled Proposed Action	Actual	Difference
Count (Total Daily Flows)[1]	13,210.00	13,210.00	0
Average Daily Flow (cfs)[1]	1,810.13	1,824.43	-14.29
Percent of the Modeled Proposed Action[1]	100	100.8	-0.8
Count (Flows <1,000 cfs)[2]	2,332	3,197	-865
Percent of Total Count[2]	17.7	24.2	-6.5
Average Daily Flow (cfs)[2]	937	812.86	124.14
Count (Flows ≥1,000 cfs but <6,000 cfs)[3]	10,434	9,506	928
Percent of Total Count[3]	79.0	72.0	7.0
Average Daily Flow (cfs)[3]	1,766	1,866.19	--100.19
Count (Flows ≥6,000 cfs but <12,000 cfs) [4]	428	463	-35
Percent of Total Count[4]	3.2	3.5	-0.3
Average Daily Flow (cfs) [4]	7,380	7,721.25	-341.25
Count (Flows ≥12,000 cfs) [5]	9	11	-2
Percent of Total Count[5]	0.1	0.08	-0.02
Average Daily Flow (cfs) [5]	14,637	14,000	637

[1] – Total Daily Flows

[2] – Flows less than 1,000 cfs

[3] – Flows greater than or equal to 1,000 cfs but less than 6,000 cfs

[4] – Flows greater than or equal to 6,000 cfs but less than 12,000 cfs

[5] – Flows greater than or equal to 12,000 cfs

8.3.2. Impaired Water Quality

This section evaluates how the implementation of the PA may modify water quality downstream of IGD. In particular, this section discusses impacts on water temperature, nutrient loading, and DO concentrations.

8.3.2.1. Temperature

As discussed in Part 6.4.1.2.5., Klamath River water temperatures are largely correlated with air temperature. Generally, ambient air temperatures in the fall and winter in the Klamath Basin are not at a level that result in water temperatures of concern to salmonids and the effect of the PA on Klamath River water temperatures during these seasons will therefore not be discussed further here.

In addition to air temperature, there is also strong evidence that Klamath River discharge affects water temperature. Asarian and Kann (2013) found statistically significant negative relationships between mean monthly flow and mean water temperature for June and July (2001 – 2011) at Orleans, Weitchpec, Tully Creek, and Turwar. There were no significant relationships between flow and water temperature at the sites most affected by IGD releases (i.e., immediately below IGD, Seiad Valley; Asarian and Kann 2013), suggesting that IGD flow releases influence water temperature less than factors affecting flow below Seiad Valley, such as tributary inflow.

Nevertheless, given the statistically significant relationship between water temperature and discharge below Seiad Valley, Reclamation analyzed the effect of IGD flow releases called for under the PA on Klamath River water temperatures utilizing the River Basin Model-10 (RBM10; Yearsley et al. 2001, Yearsley 2009, Perry et al. 2011). The RBM10 is a heat budget model that allows the user to model the effects of discharge on water temperature at numerous points along a river channel (Perry et al. 2011).

Reclamation analyzed RBM10 output from March – October for RMs 189.8 (IGD), 174.0 (downstream of the confluence with the Shasta River), 136.8 (downstream of the confluence with the Scott River), and 62.5 (downstream of the confluence of the Salmon River) for 1981 to 2014 (Appendix 8, Tables 8-3 through 8-6). Reclamation determined that this combination of sites and months was appropriate to assess the effect of the PA over the time periods and locations relevant for juvenile outmigration, juvenile rearing, and adult migration. The period examined includes 1981 – 2014 because the model is only parameterized (e.g., with meteorological data, etc.) through 2014. The RBM10 output indicates that modeled temperatures expected under the PA from 1981 – 2014 would result in an average decrease or very minor increase (i.e., no more than 0.05°C) in water temperatures at the four sites assessed, relative to modeled temperatures under historical conditions observed during this period (Appendix 8). Given this finding, Reclamation concludes that the IGD releases called for in the PA are not likely to substantially affect water temperature at the four nodes examined.

8.3.2.2. Nutrient Loading

While Project return flows from the LRDC and KSD contribute nutrient load to the Klamath River, UKL is considered the source of greatest nutrient and BOD loads during the irrigation season via export of substantial AFA biomass from UKL (NRC 2004, ODEQ 2017, Schenk *et al*. 2018). During the irrigation season, very little water from the Project and Lost River watershed flows to the Klamath River. Generally, the Project has been characterized as a nutrient sink, rather than source (ODEQ 2017, Schenk *et al.* 2018), given that only 30 percent of UKL/Klamath River water entering the Project is returned to the Klamath River (ODEQ 2017). However, there is evidence to suggest that discharge from the LRDC can have a substantial negative impact on DO concentrations at Miller Island in the Keno Impoundment, though the magnitude and duration of the effect is less than that resulting from releases from UKL (ODEQ 2017) and is highly dependent on Project operations.

Outside of the spring/summer irrigation season, water quality in the Keno Impoundment is greatly improved, owing to lower water temperatures, and an increase DO concentrations as a result of reduced biomass in (and therefore, exported from) UKL and increased oxygen saturation with reduced water temperatures (ODEQ 2017). During this period, the LRDC, which drains the Lost River watershed and the Project, flows towards the Klamath River and thereby contributes some nutrient and BOD load to the Klamath River (Schenk et al. 2018). However, this additional load tends to be relatively small compared to the total load from UKL (Schenk et al. 2018).

In conclusion, although the Project does contribute nutrient load to the Klamath River via the LRDC and KSD, any negative effect of these loads on water quality parameters is largely masked by substantial export of algal biomass from UKL and the fact that water quality is further affected by a series of reservoirs, dams, and meteorological and hydrologic conditions downstream of the Project. Thus, it is not known at this time how this increase in nutrient concentration within the Keno Impoundment impacts the nutrient concentration within PacifiCorp reservoirs and below IGD. Additionally, there is suggestion that the Project acts as a nutrient sink, reducing nutrient load from UKL to the Klamath River through diversions at the A Canal headworks and North and Ady canals. Similarly, improvements in Project infrastructure that allow recirculation of return flows within the Project may reduce the volume of return flow (and nutrient load) reaching the Klamath River. Furthermore, the PA does not count re-diversion of return flows against Project Supply in the spring/summer; Project irrigators are likely to redivert this water which will also likely result in reduced return flow to the Klamath River, relative to that observed with operations under the 2013 BiOp.

8.3.2.3. Dissolved Oxygen

Klamath River DO concentrations are generally inversely correlated with water temperature during the growing season (Asarian and Kann 2013) and can also be affected by periphyton dynamics (Asarian et al. 2015). Discharge can generally be used as a proxy representative for both of these mechanisms in that increased flow can disrupt periphyton productivity (Asarian and Kann 2013, Asarian *et al*. 2015) and can maintain cooler water temperatures (relative to air temperature) in the spring and summer through both water column volume and contributions of cooler water from tributaries (Asarian and Kann 2013). Indeed, Asarian and Kann (2013) found a statistically significant positive relationship between mean daily minimum DO concentrations and discharge during the growing season throughout the Klamath River. In particular, there were significant relationships between DO concentrations and discharge at Seiad Valley (June – August), Orleans (June), Weitchpec (June – August), Tully Creek (June and July), and Turwar (June – August) (Asarian and Kann 2013). Interestingly, Asarian and Kann (2013) did not find a statistically significant relationship between discharge and any measured water quality variables at IGD, suggesting that conditions within PacifiCorp reservoirs, and not as a result of the PA, affect DO concentrations (and other water quality parameters such as pH) immediately downstream of IGD. Indeed, decomposition of algal biomass in Iron Gate Reservoir can lead to DO depletion throughout the entire reservoir water column, and thereby reduce DO concentrations in IGD releases (PacifiCorp 2018). However, this effect likely dissipates 2 – 3 miles downstream of IGD

(PacifiCorp 2018). Additionally, the influence of Project operations on DO conditions within PacifiCorp reservoirs is likely minimal, particularly under this PA (see Parts 8.3.2.2. and 7.1.1.6. for effects to Keno Impoundment and UKL, respectively).

Generally, Klamath River (below IGD) DO concentrations are not a concern in the late fall, winter, and early spring given relatively cold water temperatures (and corresponding increased saturation capacity). As such, DO concentrations during this period will not be considered further in this effects analysis.

Given the statistically significant relationship between DO concentration and discharge at certain Klamath River sites (as described above; Asarian and Kann 2013), the clearest relationship between Project operations and DO concentrations appears to be the effect of the PA on Klamath River discharge. When modeled over the POR, the PA results in an average increase in daily Klamath River discharge at IGD from June – August, relative to what was observed in the POR (Table 8-2). Assuming that these relative differences between modeled and observed IGD discharge would also be reflected throughout the Klamath River, Reclamation expects that an overall increase in IGD releases under this PA during the period in which annual minimum DO concentrations are typically observed would positively affect Klamath River DO concentrations, though it’s important to note that the relative influence of IGD releases decreases substantially with increasing distance downstream (Table 8-3). Given the relationship between discharge and periophtyon described above (and demonstrated in Asarian et al. 2015), Reclamation similarly expects that an overall increase in June – August IGD releases under this PA would result in reduced periphyton activity in the Klamath River, relative to what has been observed in the POR (again with the caveat that the relative influence of IGD releases decreases substantially with increasing distance downstream; Table 8-3). Both of these conclusions rely on the relationships between Klamath River discharge, water quality variables, and periphyton dynamics described in Asarian and Kann (2013) and Asarian *et al*. (2015). Additionally, these conclusions assume that the findings of Asarian and Kann (2013) and Asarian *et al*. (2015) can be applied to the entire POR.

Table 8-2. Daily average modeled and measured Iron Gate Dam discharge for each month from June – August (1981 – 2016).

Month	Modeled Proposed Action (cfs)	Actual (cfs)	Difference (cfs
June	1,449	1,383	66
July	1,046	889	157
August	1,038	963	75

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Table 8-3. Daily average discharge (cfs) at various Klamath River USGS gage sites from June – August (1981 – 2016), and the relative portion of flow attributed to Iron Gate Dam releases.

Month	Near Iron Gate Dam (cfs)	Seiad Valley (cfs)	Iron Gate Dam Release Contribution (%)	Near Orleans (cfs)	Iron Gate Dam Release Contribution (%)	Near Klamath (cfs)	Iron Gate Dam Release Contribution (%)
June	1,380	2,820	49	6,150	22	11,800	12
July	889	1,370	65	2,630	34	5,050	18
August	963	1,150	84	1,800	54	3,240	30

In conclusion, the PA model output indicates an increase in Klamath River discharge at IGD from June – August, which is likely to facilitate slightly higher DO concentrations and reduced periphyton activity in the Klamath River, relative to that observed over the POR and based on relationships between discharge and water quality/periphyton variables described in Asarian and Kann (2013) and Asarian et al. (2015). Given that water quality conditions directly downstream of IGD are likely reflective of PacifiCorp reservoir conditions rather than IGD discharge (Asarian and Kann 2013, PacifiCorp 2018), Reclamation does not expect that the IGD releases called for in the PA would facilitate suboptimal DO concentrations in this reach. Finally, it's critical to acknowledge that the effect of IGD releases on Klamath River discharge decreases longitudinally such that the benefits of increased IGD releases under this PA are also likely to diminish longitudinally. During fall, winter, and spring, with the exception of immediately downstream of IGD, DO concentrations are typically at or near saturation (PacifiCorp 2012). Low DO concentrations immediately downstream of IGD do occur. These low DO concentrations are largely driven by the effects of the PacifiCorp Hydroelectric Project (NMFS 2007a) and the highly eutrophic outflow from UKL.

8.3.3. Stressors Specific to the Implementation of the Proposed Action

Based on the above discussions, the following ecological effects, as measured downstream of IGD, **will not be** carried forward in this analysis as stressors to coho salmon caused by the implementation of the PA.

> *Temperature:* IGD releases called for in the PA should not substantially affect water temperature at the four nodes examined based on output from the RBM10 model.
>
> *Nutrient Load:* The implementation of the PA will reduce the overall nutrient load from UKL downstream of Keno Dam due to diversions of UKL water to the Project at the A Canal headworks. Additionally, the volume of return flows from the Project that enter the Klamath River is likely to decrease with this PA relative to what was observed under past Project operations.
>
> *DO Concentrations:* During the fall, winter, and spring, the influence of the Project operations on DO concentrations downstream of IGD is likely to be negligible. *S*imilarly, the PA is likely to result in increased IGD discharge from

June – August comparatively to historical Project operations, which would likely facilitate improved DO concentrations and reduced periphyton activity, relative to that observed in the POR.

The following ecological effects, as measured downstream of IGD, **will be** carried forward in this analysis as a stressor, adverse or beneficial, on coho salmon with the implementation of the PA.

Subsistence Flows: When compared to the POR, modeling suggests that there will likely be a reduction in the frequency of daily flows that are less than 1,000 cfs with the implementation of the PA. In addition, when compared to the POR, modeling suggests that flows that are less than 1,000 cfs will be greater in magnitude, on average, with the implementation of the PA.

Base Flows: When compared to the POR, modeling suggests that there will likely be an increase in the frequency of daily flows equal to or greater than 1,000 cfs but less than 6,000 cfs with the implementation of the PA. In addition, when compared to the POR, modeling suggests that flows equal to or greater than 1,000 cfs but less than 6,000 cfs will be less in magnitude, on average, with the implementation of the PA.

High-flow Pulses: With the implementation of the PA, modeling suggests that the change in the daily flows from the POR will likely include a decrease in the frequency of flows equal to or greater than 6,000 cfs but less than 12,000 cfs. When compared to the POR, modeling suggests the flows will likely be slightly reduced in magnitude, on average, with the implementation of the PA. However, when compared to the POR, modeling suggests that there will be an increase in the frequency of high-flow pulses that are three days or greater in duration with the implementation of the PA.

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Overbank Flows: When compared to the POR, the frequency of the flows that were equal to or greater than 12,000 cfs will likely decrease with the implementation of the PA. In addition, when compared to the POR, modeling suggests flows will likely be larger in magnitude, on average, with the implementation of the PA.

Flow Variability: When compared to past and current water management practices during the POR, the PA will allow for greater flow variability for the intended benefit of coho salmon.

Nutrient Concentration: The Project's return of a higher concentration of nutrients increases the nutrient concentration within the Keno Impoundment. It is not known at this time how the increase in nutrient concentration within the Keno Impoundment impacts the nutrient concentration below IGD.

Temperature: Although the water temperature released from IGD are primarily the result of a series of reservoirs, dams, and meteorological conditions, compared to the POR during the summer, increased IGD releases as a result of the PA would lower the mean and maximum water temperatures further downriver. In addition, the minimum daily water temperature would also increase through reduced effects of nocturnal cooling. When compared to the POR, on average, flow will increase during the summer with the implementation of the PA.

DO Concentrations: When compared to the POR, on average, flows will increase during the summer with the implementation of the PA. Increased summer flows will increase the water depth. Increased water depth may result in higher daily minimum DO concentrations further downriver..

8.4. Effects on Coho Salmon Survival, Growth, and Reproduction

Reclamation used a literature-based approach to assess the potential influence of the PA on different life stages of coho salmon in the mainstem Klamath River. The effects of the PA on coho salmon and salmonid disease conditions were examined first in the context of WRIMS model output, which modeled IGD flows if the PA was implemented during the POR from October 1980 – November 2016. Second, we used a similar literature-based approach to assess the potential influence of water temperatures under the PA on coho salmon and salmonid disease conditions from October 1980 – November 2014 using the River Basin Model-10 (RBM10) model (Yearsley et al., 2001; Yearsley, 2009), parameterized for the Klamath River by Perry et al. (2011).

8.4.1. Flow Effects

Metadata: This meta-analysis of existing literature provides a tool for assessing flow ranges that have been investigated for some aspects of coho life history. The utility of a metadata approach is to examine the temporal relationship between specific flow conditions and generalized positive and negative effects on coho salmon. Reclamation examined predicted flows under the PA in 2002 and 1997 to represent examples of low and high water-years, respectively.

Figure 8-1 shows the intersection between the 90 percent, 50 percent, and 10 percent exceedance flows at IGD if the PA was implemented during the POR (1980 – 2016) and the generalized effects of flow on coho salmon adults, embryos, juveniles, smolts, and disease risks to fish based on existing literature. Positive effects are defined as flow ranges that promote survival, successful reproduction, and or growth and negative effects are defined as flow ranges that reduce survival, successful reproduction, and or growth. The length of each rectangle represents the period (months) that each life-stage is active in the freshwater environment while the height indicates the range of flows described as having either a positive or negative effect.

Effects on adult coho salmon: Adult freshwater migration occurs from mid-September through mid-January (Hardy et al. 2006). Guillen (2003) asserted that adult Chinook migration was inhibited in 2002 as a result extreme low flows, which can limit the depth of water available for cover and navigation as well as olfactory cues from natal streams. Coho have been shown to respond similarly to low-flow conditions (Sandercock 1991) and therefore we have assumed that the observations of Guillen (2003) apply to coho as well (Figure 8-1). Flow releases in September 2002 at IGD averaged 759 cfs (Lynch & Risley 2003); a significant reduction in flow from unimpaired discharges (>1,110 cfs) estimated by Hardy and Adley (2001). When the 2002 water-year was related to the metadata (Figure 8-2), simulated flows were likely to have a negative impact on adult migration during most of October – December 2001 and all of September 2002, roughly 83 percent of the migration period. Conversely, during the simulated high-flow scenario, conditions were favorable for adult migration during approximately 86 percent of the migration period (Figure 8-3, Table 8-4).

Effects on embryos: Coho embryo development typically occurs from November through the end of March (Hardy et al. 2006). Only a small portion of natural coho salmon spawning occurs in the mainstem Klamath River (Dunne et al. 2011), thus minimizing the effects of the PA on this life stage. Nevertheless, high flows are likely to affect embryos via mechanical damage as substrate is moved or by physical displacement from the redd. Erickson et al. (2007) estimated that scouring of spawning gravels (gravels with a median diameter of 2 inches) would occur at flows above 5,163 cfs in the Klamath River. There is a dearth of literature on the effects of flows below 5,163 cfs and, therefore, the effects of a low-flow scenario are unclear (Figure 8-2).

Effects on fry: Coho fry emerge as free-swimming fish February through mid-May (Hardy et al. 2006). Hardy et al. (2006) estimated maximum fry habitat availability occurs at flows between 1,302 cfs and 4,607 cfs. The fry life stage typically overlaps temporally with spring freshets in the Klamath River (Figure 8-1). As a result, flows are mostly adequate for fry even in a dry water-year (Figure 8-2, Table 8-4). Similarly, during wet water years, flows mostly correspond with positive effects for juveniles (Figure 8-3) with the exception of flows in February. High flows during the early spring could potentially displace fry in the absence of adequate refugia, however, there is a data gap for the effects of high flow ranges on coho fry in the Klamath.

Effects on juvenile coho (parr): Juvenile coho are present year-round in the Klamath River (Hardy et al. 2006). Hardy et al. (2006) estimated maximum parr habitat availability occurs at flows between 1,384 cfs and 5,507 cfs. Daily flow estimates for 2002 frequently fell below this optimized ranged, however, there are punctuated flows during winter and spring pulse events that create positive effects for juveniles (Figure 8-2) amounting to roughly 30 percent of the period they were active. During wet water years, there is an increase in the number of days that flows are likely to have a positive effect on juvenile coho to approximately 43 percent of the period juveniles are present (Figure 8-3, Table 8-4), however, there is a data gap for flows exceeding 5,507 cfs and falling below 1,384 cfs.

Effects on smolts: Smolts typically out-migrate from February to mid-June (Hardy et al. 2006). Smolt migration was negatively affected by the low flows that occurred between March and August. Beeman et al. (2012) predicted hatchery coho smolt survival to exceed 80 percent at flows ~1,500 cfs to 10,000 cfs. During a particularly low-flow year in spring of 2015, observations of coho were scarce when flows fell below 1,500 cfs (David et al. 2017). During 2002, flow conditions were predicted to potentially negatively affect coho smolt survival during roughly 62 percent of the emigration period (Figure 8-2), whereas flows remained within the optimum range for smolt survival during 1997 (Figure 8-3).

Effects on disease (*C. shasta*): Salmonids in the Klamath River are exposed to a number of pathogens and diseases that can impact all coho salmon life stages. C. *shasta* is the focal disease of this meta-analysis, which is regarded as a prominent threat to juvenile salmonids in the Klamath River. As discussed in Part 6.3.1.7., high velocities can potentially disrupt the parasite's life-cycle by disrupting and constraining suitable polychaete habitat and thereby limiting effective parasite transmission (Bjork and Bartholomew 2008; Malakauskas et al. 2013; Alexander et al 2016). Under the PA, both wet and dry water years produced polychaete-disrupting flows in excess of 6,000 cfs at IGD (Figure 8-2 and Figure 8-3). However, high flows exceeding 5,000 cfs were sustained for a much longer duration in 1997. Disease mitigation minimums of 5,000 cfs were achieved roughly 6 percent of days during 2002, whereas flows in 1997 were above 5,000 cfs for approximate 35 percent of days (Table 8-4). Flows between 2,500 cfs and 5,000 cfs represent a large portion of the water-year and fall into flow ranges for which there is a large gap in the literature; therefore, the effects of these flow ranges on coho are unclear.

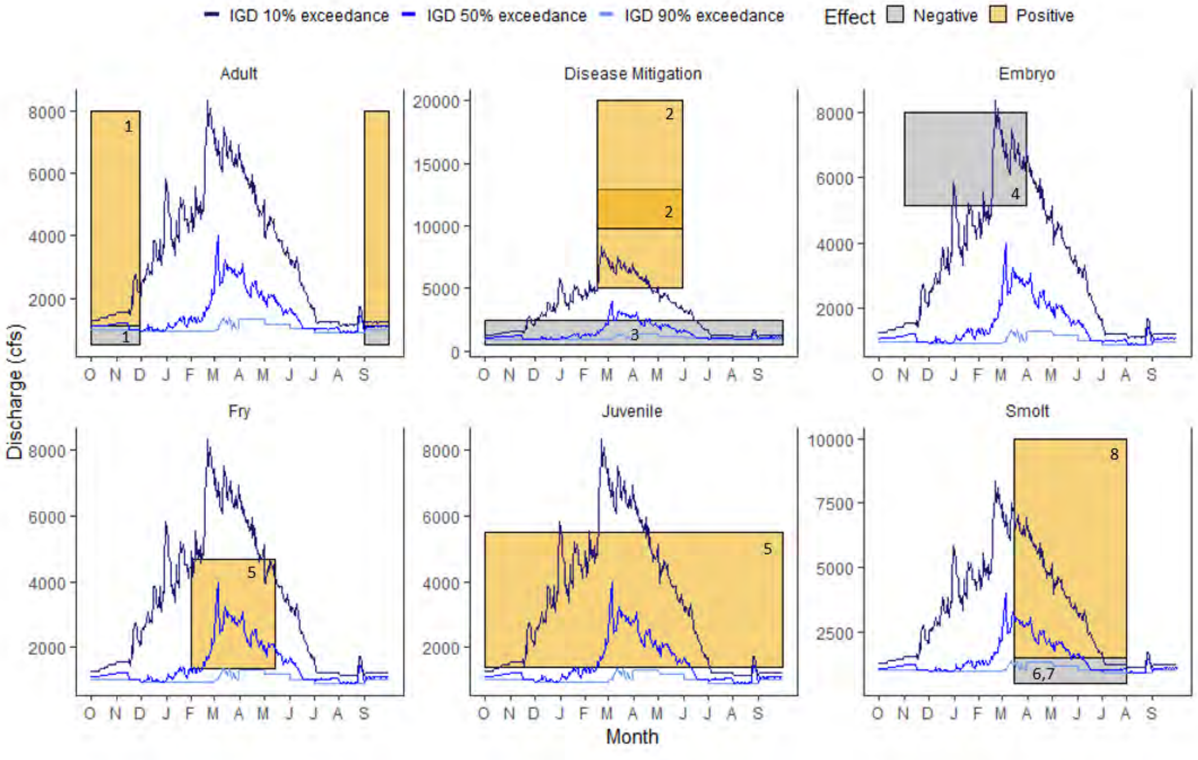

Figure 8-1. Analysis of the temporal effects of different flow ranges on coho salmon adults, embryos, juveniles, and smolts, and fish affected by disease. Numbers in the plotting area indicate the metadata references**:** 1. Guillen (2003); 2. Shea et al. (2016); 3. Holmquist & Johnson (2010); 4. Erickson et al. (2007); 5. Hardy (2006); 6. David et al. (2016); 7. David et al. (2017); 8. Beeman et al. (2012). The 90%, 50%, and 10% exceedance flows from IGD are indicated by the colored lines.
Source: Mount Hood Environmental 2018

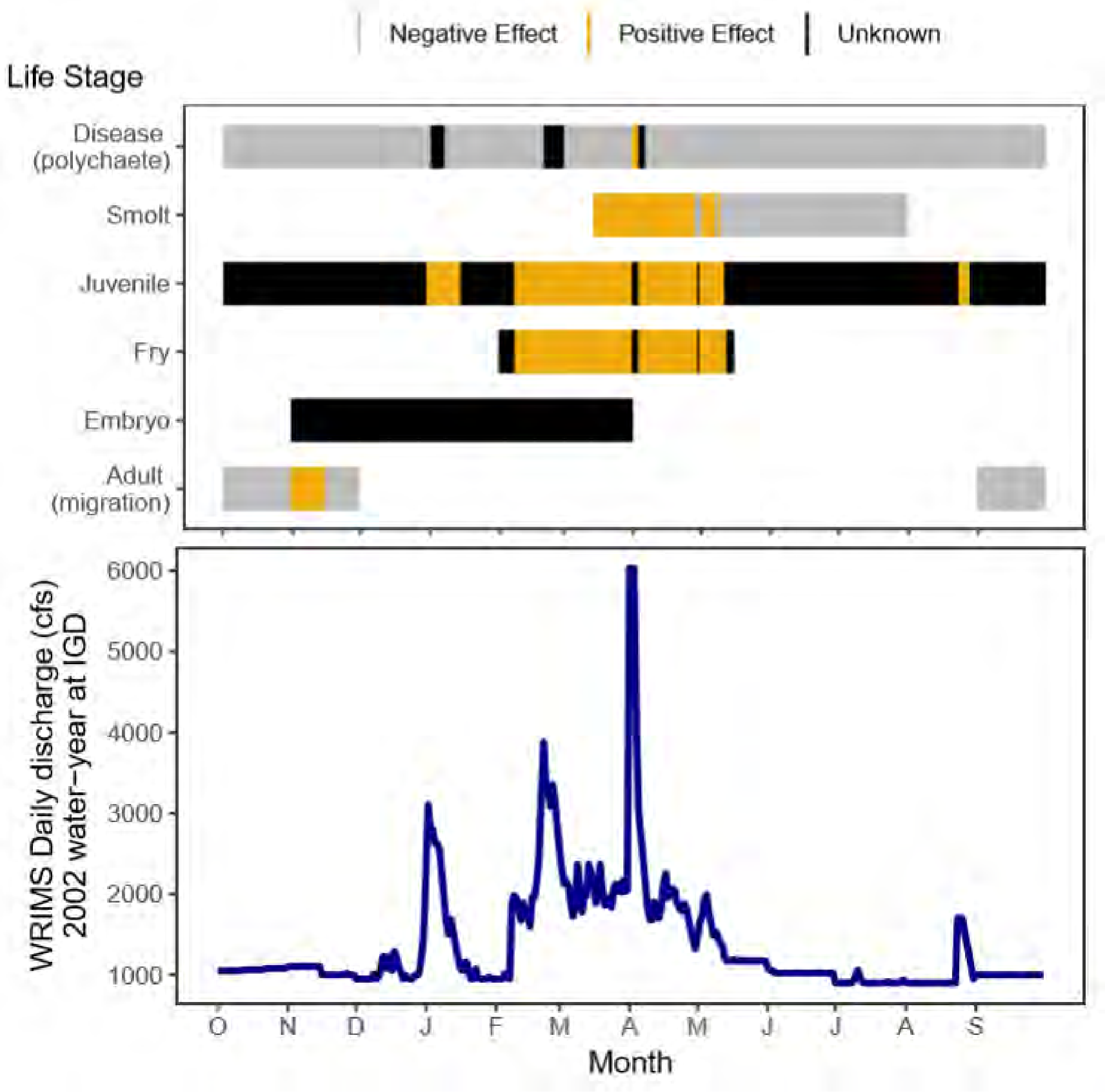

Figure 8-2: Low flow water year (2002) effects on coho salmon based on meta-data (upper plot). Black regions indicate coho life stage is active but a data gap exists in the literature at the given discharge.
Source: Mount Hood Environmental 2018

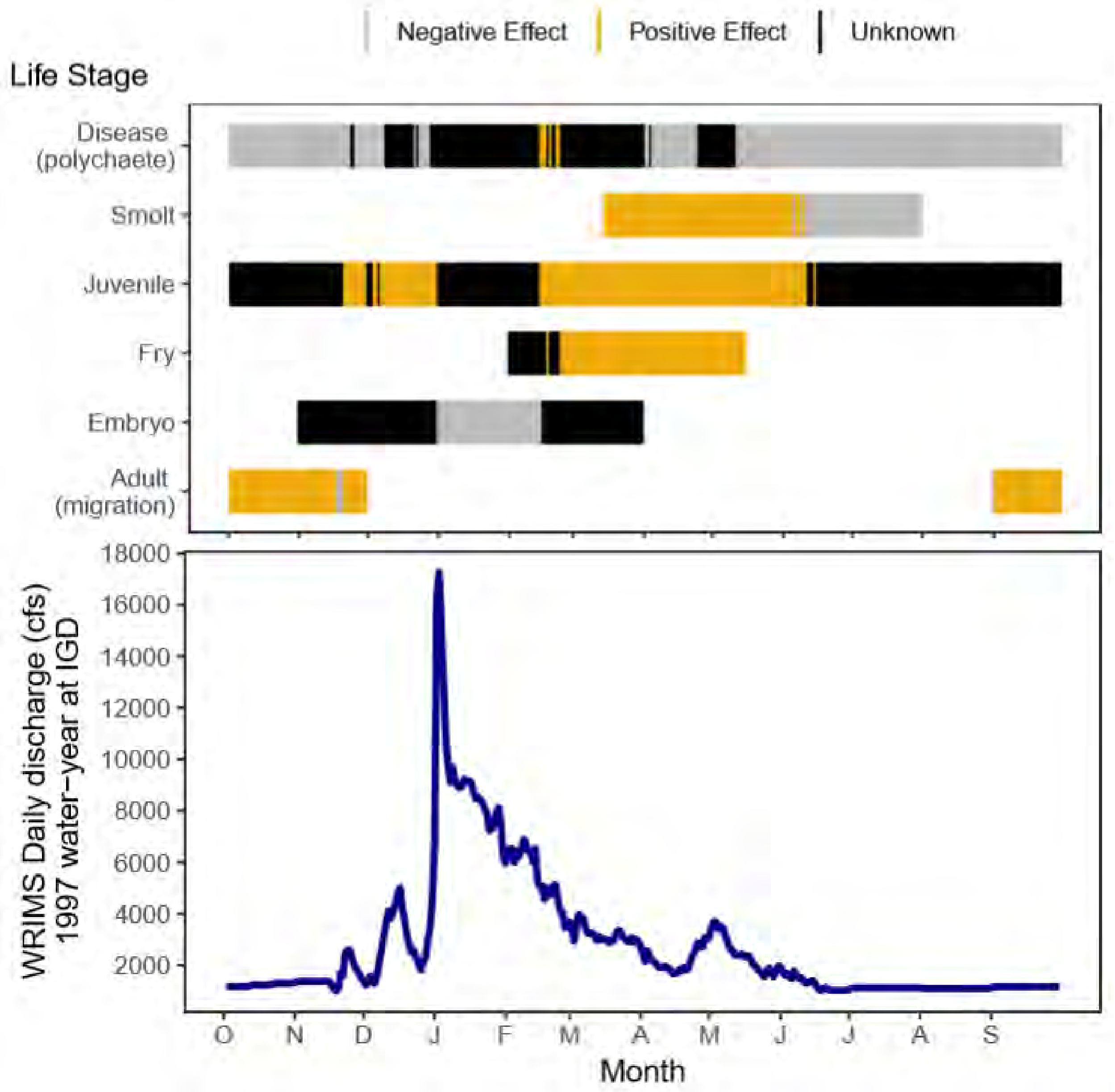

Figure 8-3. High flow water-year (1997) effects on coho salmon based on meta-data. Black regions indicate coho life stage is active but a data gap exists in the literature at the given discharge.
Source: Mount Hood Environmental 2018

Table 8-4. The number of days coho salmon are positively or negatively affected by simulated WRIMS flow scenarios based on meta-analysis. Parentheses indicate the percentage of days effected of the total days each life stage is active.
Source: Mount Hood Environmental 2018

Life Stage	**Simulated High Flow 1997**		**Simulated Low Flow 2002**	
	- days (%)	**+ days (%)**	**- days (%)**	**+ days (%)**
Adult (migration)	4 (4.4)	86 (95.6)	75 (83.3)	15 (16.7)
Disease (polychaete)	236 (64.8)	6 (1.6)	343 (94.2)	3 (0.8)
Embryo	46(30.5)	0	0	0
Fry	0	82 (78.8)	0	90 (86.5)
Juvenile	0	155 (42.6)	0	109 (29.9)
Smolt	53(38.1)	86 (61.9)	87 (62.6)	52 (37.4)

8.4.2. Temperature Effects

Metadata: Modeled and historic temperatures were compared in the mainstem Klamath River for five locations between IGD and Humbug Creek: IGD to Bogus Creek (rm 189.8), Bogus Creek to Willow Creek (rm 187.3), Willow Creek to Cottonwood Creek (rm 183.6), Cottonwood Creek to the Shasta River (rm 179.4), and the Shasta River to Humbug Creek (rm 174). Because tributaries downstream of IGD (e.g. the Shasta River, the Scott River, and the Salmon River) significantly influence flow and temperature in the mainstem Klamath River our analysis will focus on the section of river between IGD and just below the confluence of the Shasta River where the PA is most likely to impact fish. A meta analysis of existing literature in the Klamath River basin, as well as other locations, provides a tool for assessing temperature effects on discrete coho salmon life-stages. There was no appreciable difference between the historic observed temperatures and the RBM10 modeled temperatures for the PA. Given the congruence between these temperature scenarios, the following sections regarding specific life stages of coho will only examine the effects of temperature in the context of the PA.

Figure 8-4 shows the intersection between the 34-year average of historic, mean daily temperatures between IGD and Humbug Creek (1980 – 2014) and the generalized effects of temperature on coho salmon adults, embryos, juveniles, smolts, and fish infected with *C. shasta* based on existing literature. Positive effects are defined as temperature ranges that promote survival, successful reproduction, and or development and negative effects are defined as temperature ranges that reduce survival, successful reproduction, and or development. The length of each rectangle represents the period (months) that each life-stage is active in the freshwater environment while the height indicates the range of temperatures described as having either a positive, negative, or lethal effects.

Effects on adult coho salmon: Adult freshwater migration occurs from mid-September through mid-January (Hardy et al. 2006). Peak river entry of migrating coho adults was observed after temperatures fell below 20 °C (Strange 2004), and 21 to 22 °C was reported as the lethal limit for migrating adult coho in the Columbia River during summer (Richter and Kolmes 2005). The modeled temperature scenario indicated more than 90 percent of the migration period had temperatures that would positively affect migrating adults (Figure 8-5, Table 8-5). However, modeled temperatures only include the river reach between IGD and just below the confluence of the Shasta River, which includes only a portion of the migratory pathway for some fish. Downstream reaches, though minimally influenced by flow releases at IGD, periodically have temperatures that exceed 20 °C in the fall.

Spawning adults are typically active from October through the end of December. Optimal temperatures for spawning range from 10 to 13 °C and when temperatures exceed 20 °C, ova will rapidly deteriorate (Richter and Kolmes 2005). More than 85 percent of the spawning season had mean daily temperatures that were optimal for spawning adults (Figure 8-5, Table 8-5). In early October, there were approximately 13 days where the temperature exceeded the optimal range, however, it was well below the temperature threshold for negative effects.

Effects on embryos: Coho embryo development typically occurs from November through the end of March (Hardy et al. 2006). Only a small portion of natural coho salmon spawning occurs in the mainstem of the Klamath River (Dunne et al. 2011) thus minimizing the effects of the PA on this life stage. Nevertheless, extreme temperatures can affect embryo survival when they fall below 1.3 °C (Tang et al. 1987) or when they exceed 11 °C (Richter and Kolmes 2005). The lethal limit for coho embryos is 14 °C (Richter and Kolmes 2005). The PA was predicted to produce favorable conditions for embryo development for 98 percent of the incubation period (Figure 8-5, Table 8-5)

Effects on fry: Coho fry emerge as free-swimming fish February through mid-May (Hardy et al. 2006), preferring temperatures between 4.0 °C and 10.9 °C (Tang et al. 1987). Fry were positively affected by modeled temperatures for approximately 70 percent of their presence in the mainstem Klamath River (Figure 8-5, Table 8-5). While temperatures in April and May exceeded the preferred thermal range, there is a data gap for temperature effects on coho salmon fry outside the optimal range.

Effects on juveniles (*parr*): Juvenile coho are present year-round in the Klamath River (Hardy et al. 2006). Foote et al. (2014) indicated that with adequate energy inputs, juvenile coho in the Klamath River showed positive growth and normal plasma protein levels at a thermal range of 1.7 – 21.3 °C. Stenhouse (2012) contradicts the lower end of that range, from 1.7 – 4.4 °C, citing increased mortality, reduced growth rates, and feeding cessation. For our meta-analysis, we considered the positive range of temperatures for juvenile coho rearing to be 4.4 – 17.0 °C, which was consistent across several studies (Foote et al. 2014, Stenhouse 2012, Reiser and Bjornn 1979, Richter and Kolmes 2005). The upper range used for negative effects of temperature on juvenile coho was 17.0 – 25.8 °C, which combined thermal ranges from several studies (>17.0 °C, Richter and Kolmes 2005; >19.0 °C, Sutton and Soto 2012, Hillemeier et al. 2000; >20.0 °C, NRC 2004; Adams and Bean 2016; 25.8 °C lethal limit, Beschta et al. 1987). Temperature conditions were predicted to negatively affect juvenile coho for more than 30 percent of their rearing period (Figure 8-5, Table 8-5), primarily during the summer and early fall. They were positively affected by temperatures approximately 56 percent of the year, mostly in fall and spring when temperatures were moderate.

Effects on smolts: Smolts typically out-migrate from February to mid-June (Hardy et al. 2006). Richter and Kolmes (2005) suggested the threshold temperature range for smoltification is 2.5 – 15.5 °C. Beeman et al. (2012) observed increased coho salmon smolt survival at temperatures >10.0 °C, however, a review of temperature effects on chinook salmon smolts indicated that physiological processes involved in smoltification are inhibited at temperature >13.0 °C (McCullough 1999). For the purposes of this analysis, we will consider temperatures from 15.5 – 20.0 °C to foster negative effects. Temperatures were favorable to smolts ~66 percent of their active period, and likely to have negative effects about 12 percent of their active period (Figure 8-5, Table 8-5). Similar to migrating adults, these estimations only pertain to a small portion of the migratory pathway that is used by some smolts.

Effects on disease (*C. shasta*) *infection*: Salmonids in the Klamath River are exposed to a number of pathogens and diseases that can impact all life stages. In this meta-analysis, we will focus on *C. shasta* infection in coho. Fryer and Pilcher (1974) suggested that coho infected with *C. shasta* exhibited high survival at a temperature range of 3.9 to 15.5 °C and low survival at temperatures above 15.5 °C. Similarly, Ray et al. (2012) found that temperatures between 18.0 °C and 21.0 °C were positively related to mortality. Our analysis indicated that 37 percent of the water-year had temperatures that would negatively affect coho salmon based on the aforementioned literature (Figure 8-5, Table 8-5). Conversely, 54 percent of the year included temperatures that were favorable for survival of coho juveniles infected with *C. shasta.*

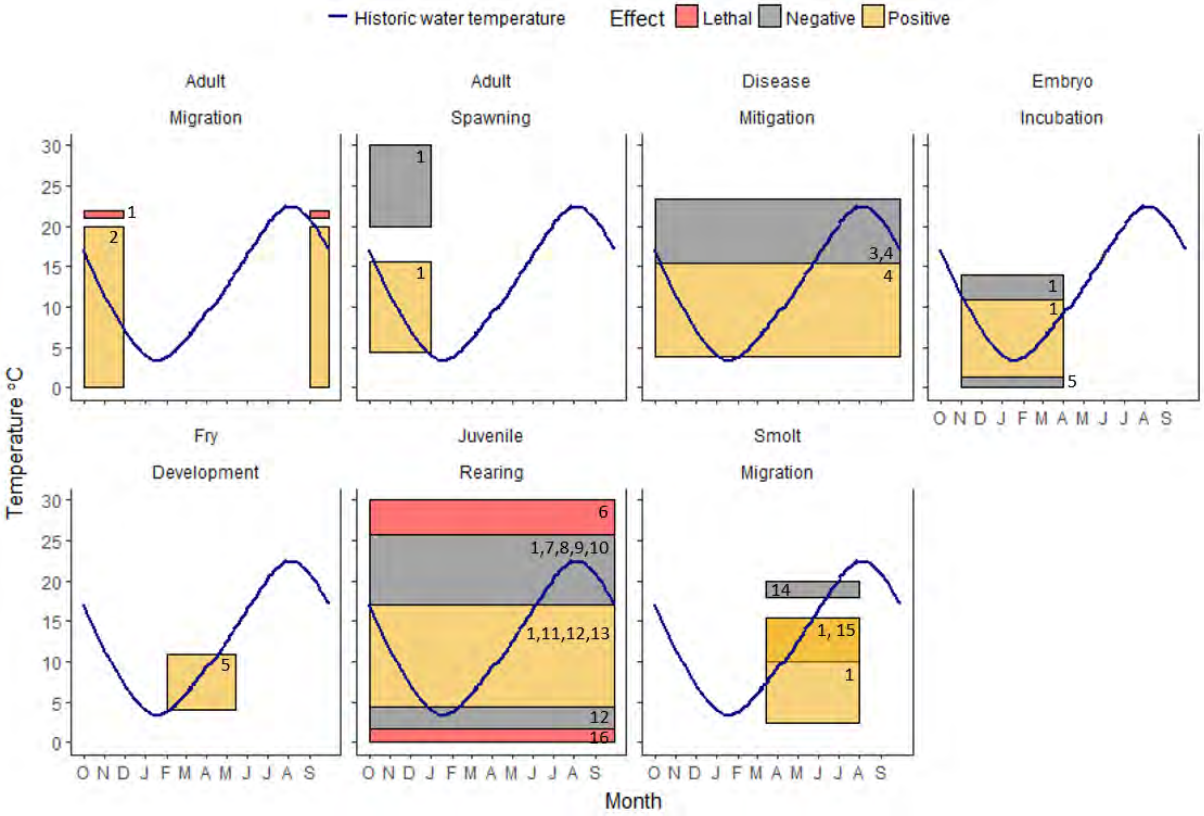

Figure 8-4. Analysis of the temporal effect of water temperatures on coho salmon adults, embyros, juveniles, and smolts, and fish affected by *C. shasta*. Temperatures are daily averages of five sites located between IGD and Humbug Creek [rm 189.8 – 174.0], 1980-2014. Numbers in the plotting area indicate the metadata references**:** 1. Richter and Kolmes (2005); 2. Strange (2004); 3. Ray et al. (2012); 4. Fryer and Pilcher (1974); 5. Tang et al. (1987); 6. Beschta et al. (1987); 7. Sutton and Soto (2012); 8. Hillemeier et al. (2000); 9. NRC (2004);10. Adams and Bean (2016); 11. Foote et al. (2014); 12. Stenhouse (2012); 13. Reiser and Bjornn (1979); 14. McCullough (1999); 15 Beeman et al. (2012); 16. Brett (1952). The average of modeled, mean daily temperatures from IGD to Humbug Creek are indicated by the blue line.

Source: Mount Hood Environmental 2018

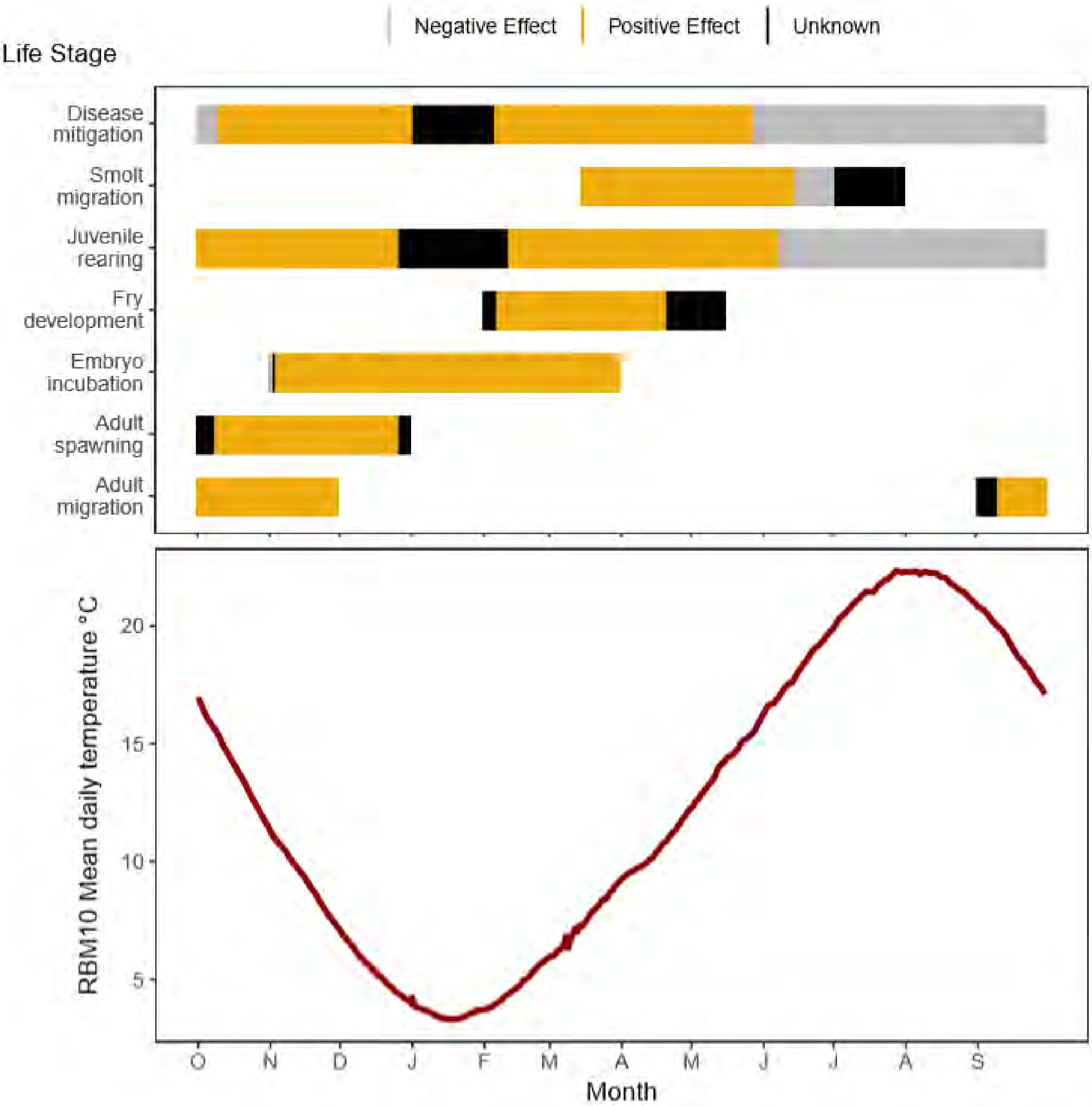

Figure 8-5. Temperature effects on coho salmon based on meta-data. Black regions indicate coho life stage is active but a data gap exists in the literature at the given temperature. Temperatures are modeled mean daily values averaged across five sites located between IGD and Humbug Creek [rm 189.8 – 174.0] and across the period of record from 1980-2014.
Source: Mount Hood Environmental 2018

Table 8-5. The number of days coho are positively or negatively affected by temperature for historic and RBM10 modeled temperature data based on meta-data. Parentheses indicate the percentage of days effected of the total days each life stage is active.

Source: Mount Hood Environmental 2018

Life Stage	Historic Temperature		Modeled Temperature	
	- days (%)	+ days (%)	- days (%)	+ days (%)
Adult (migration)	0	82 (90.1)	0	82 (90.1)
Adult (spawning)	0	79 (85.9)	0	79 (85.9)
Disease Infection	137 (37.4)	194 (53.0)	135 (36.9)	196 (53.6)
Embryo	3 (2.0)	149 (98.0)	2 (1.3)	149 (98.0
Fry	0	72 (69.2)	0	73 (70.2)
Juvenile	117 (32.0)	201 (54.9)	115 (31.4)	203 (55.5)
Smolt	17 (12.2)	91 (65.5)	17 (12.2)	92 (66.2)

8.4.1. Determination of Effects on Coho Salmon Survival, Growth, and Reproduction

After considering the best available scientific information, implementing the PA may affect, and is likely to adversely affect coho salmon survival, growth, and reproduction. Reclamation anticipates improvements that offset some adverse impacts from the PA as a result of funding the Klamath Coho Restoration Program. This conservation measure will result in aquatic habitat restoration designed to improve conditions for adult and juvenile coho salmon in the areas most likely to result in improved survival, growth, and reproduction.

8.5. Effects on Designated Coho Salmon Critical Habitat

Effects of the PA on coho salmon critical habitat were assessed with a similar analytical approach to the 2013 BiOp (NMFS 2013; *see* sections 11.4.1.2.3.1 and 11.4.1.2.3.2). A habitat quantification tool for the mainstem Klamath River developed by Texas State University, USGS, and USFWS was used to estimate habitat availability across a range of IGD discharges from 100 to 10,000 cfs in increments of 100 cfs. Estimates of habitat availability were summarized for fry and parr for three river reaches (IGD to Shasta River, Shasta River to Scott River, and Scott River to Salmon River) and four sites (R Ranch, Trees of Heaven, Seiad Valley, and Rogers Creek) downstream of IGD[10]. Effects of the PA on habitat area were assumed to be negative if there was both a positive relationship between flow and habitat area, and if habitat area was less than 80 percent of the maximum prediction. Exceedance tables were used to highlight flow volumes predicted for the PA within each river reach and site that would be expected to reduce habitat availability relative to a natural flow regime. The exceedance table is intended to predict the frequency and timing of reductions in coho habitat caused by the PA. This approach assumed the PA always reduced flows relative to a natural flow regime. Moreover, it is beyond the scope of this analysis to quantify the magnitude of potential negative effects on coho habitat availability under a natural flow regime.

8.5.1. Habitat Area Simulation Methods

IGD flows (100 cfs increments) were used as inputs in a hydrodynamic model developed for the main stem Klamath River (Hardy et al. 2006) to generate habitat availability predictions for coho fry and parr. The model estimated fine-scale changes in daily depth, velocity, and surface area in eight distinct geomorphic river reaches[11] as a function of IGD discharge and river accretions. Weighted usable area (WUA) curves[12] were generated for 86 unique, meso-habitat units by (1) running two-dimensional

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[10] This analysis excluded reaches below the Salmon River since IGD water releases represent the majority of river flow volume in the Klamath River and downstream inputs could potentially mask the effects of the PA on salmon habitat in upstream reaches.

[11] A "reach" is a spatially explicit section of river with distinct geomorphic and stream flow properties. The eight river reaches selected during hydrodynamic model development were representative of the diversity of habitat types found throughout the Klamath River between IGD and the Klamath River mouth.

[12] A WUA curve is the plotted relationship between WUA (habitat suitability index) and river flow.

hydrodynamic models over a range of river flows, (2) calculating univariate habitat suitability criteria (HSC) for each life stage based on distance to nearest cover, water velocity, and depth, for each computational cell in the model, (3) calculating the geometric mean of the univariate HSCs, and (4) estimating the weighted usable area (WUA) for each habitat unit as the sum of the product of the computational cell's surface area and geometric mean HSC for all cells. Model results were extrapolated for the entire length of the Klamath River downstream of IGD by applying one of the modeled WUA curves to each remaining habitat unit. WUA curves were chosen for each habitat unit based on geomorphic similarity to one of the modeled habitat units. These assignments were made by consensus within a team of fish habitat experts from the USFWS, USGS, and Texas State University. Finally, to rescale a WUA curve from source to target, WUA (expressed as units of area m^2) was divided by channel length to produce weighted useable width curves, representing the mean width of the unit that is suitable habitat. Once expressed as channel width, the WUA curves were scaled from source to target unit by multiplying by the ratio of channel widths between source and target, as calculated using a "downriver" continuity equation at common exceedance flows among units, following modified methods in Leopold and Maddock (1953). Lastly, the re-scaled weighted usable width was multiplied by the target unit's length to convert it to WUA.

The resulting WUA curves for the three reaches of the Klamath River (IGD to Shasta River, Shasta River to Scott River, and Scott River to Salmon River) that underlie our critical habitat analysis differ from NMFS (2013) [Appendix 8, Figures 8-8 through 8-14]. While the HSC values are the same in both analyses (Figure 8-6), the 2013 BiOp WUA curves are derived from a methodology designed to develop reach-scale WUA estimates, rather than mesohabitat scale estimates used in this analysis. More specifically, 2013 the BiOp methodology assumed an average of site-specific values, whereas the approach for this BA used an extrapolation method. The WUA data presented here represents the best and most current information available on the relationship between river discharge and coho fry and parr habitat availability.

Coho salmon juveniles are present in the mainstem Klamath River throughout the year. They are most abundant from March to June (Justice 2007) and limited in the summer to habitat that provides thermal refugia. Consequently, our analysis includes output for the entire year, but our discussion is limited the PA's effects on coho salmon parr rearing habitat during spring.

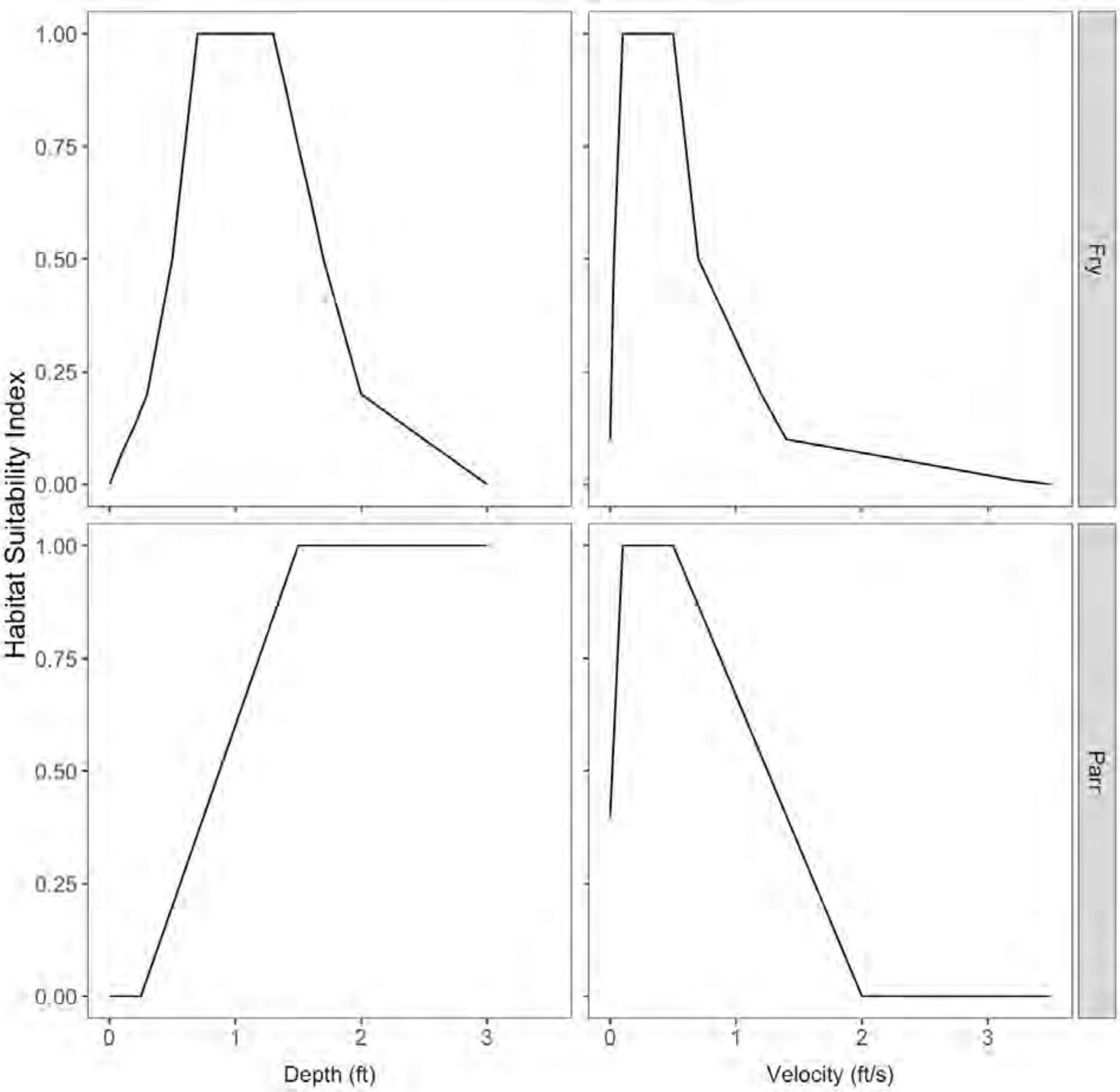

Figure 8-6. Coho salmon fry and parr depth and velocity habitat suitability criteria (Hardy et al. 2006).
Source: Mount Hood Environmental 2018

8.5.2. Habitat Area Simulation Results

The Proposed Action is expected to reduce discharge below IGD throughout the year, relative to historic conditions. The effects of reduced flows on habitat availability for coho salmon fry and parr depends on the flow volume and habitat area at each site (Figure 8-7). For example, flow increases at the R Ranch site between 100 and 3,000 cfs were predicted to increase fry habitat availability, while flow increases above 3,000 cfs were predicted to reduce habitat availability. The following discussion provides general observations about potential flow impacts and Figure 8-7 provide specific flow volumes predicted to reduce coho fry and parr habitat availability as a result of the Proposed Action.

The PA reduces coho fry habitat availability in the mainstem Klamath River between IGD (rkm 310) and the Salmon River (rkm 107) in March-June with the highest frequency of negative effects occurring between IGD and the Shasta River (rkm 289) and from the Scott River (rkm 232) to the Salmon River (Figure 8-7, Table 8-6). While the magnitude of habitat reduction is unclear, the effects of the PA would likely be most influential during dry years when average daily spring flows range from 1,000 - 2,600 cfs because negative effects on habitat availability March-May were predicted to occur most frequently at flows from 75-95 percent exceedance.

The PA reduces parr habitat availability across a broad range of flow exceedance values at the R Ranch, Trees of Heaven, Seiad Valley, and Rogers Creek sites during the spring (Tables 8-7 through 8-10; Appendix 8, Figures 8-8 through 8-11). Negative effects were predicted to occur most frequently at the Trees of Heaven and Seiad Valley sites.

Despite declines in habitat availability for coho salmon fry and parr, the PA provides flow variability during precipitation and snowmelt events in the mainstem Klamath River that resemble features of a natural flow regime. The PA also includes regulated flushing flows and water allocated for instream uses, including potential *C. shasta* spore dilution to mitigate disease impacts on coho salmon. These flow measures are expected to improve survival of rearing and migrating coho salmon in the mainstem Klamath River.

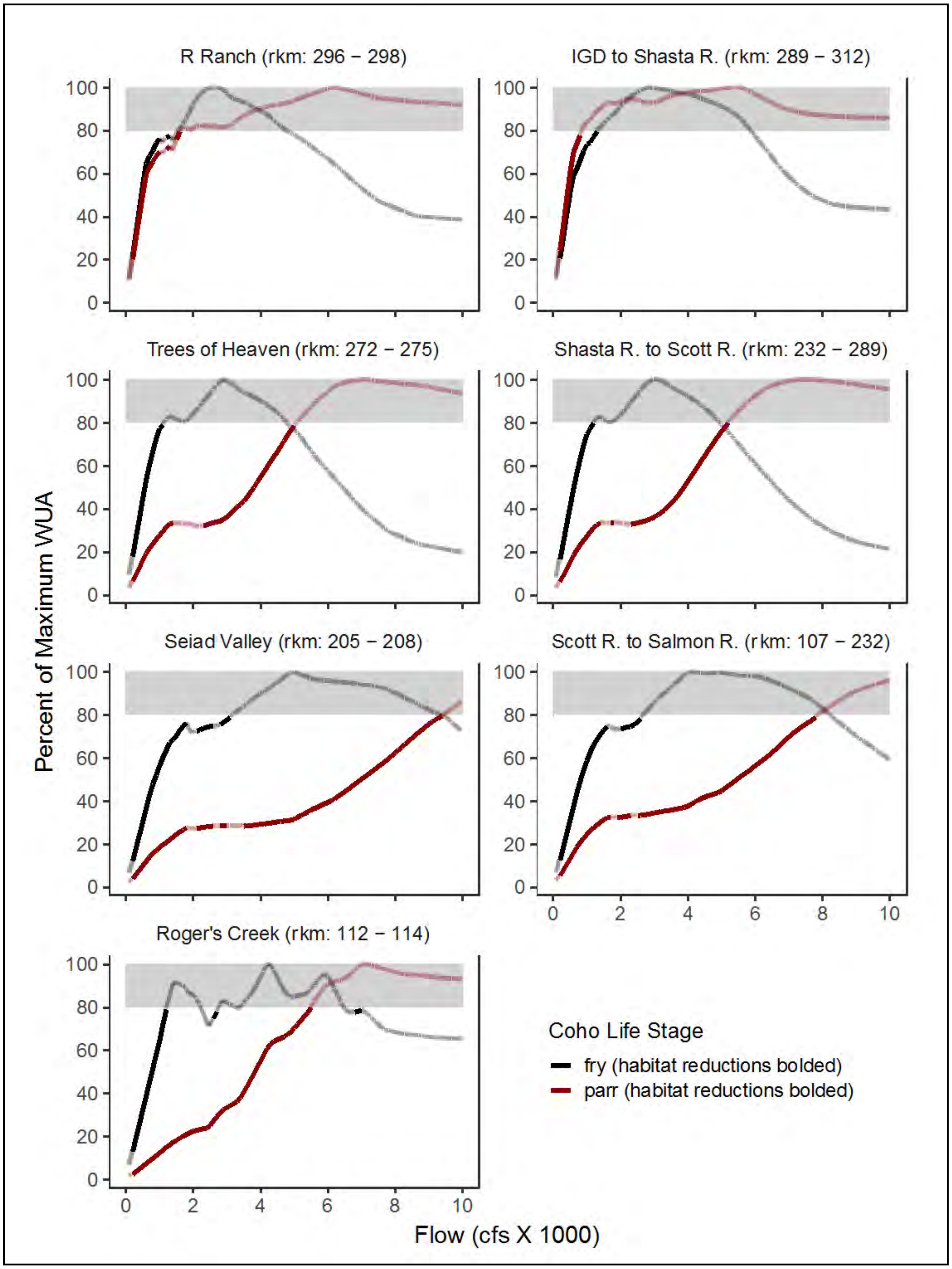

Figure 8-7. Coho salmon fry and parr habitat availability relative to mainstem flows for three reaches and four sites downstream of IGD. Flows account for tributary accretions and were estimated for each habitat unit when calculating WUA. Gray horizontal bands indicate WUA values ≥ 80% of maximum. Potential habitat reductions due to the Proposed Action are bolded.

Source: Mount Hood Environmental 2018Table 8-6. Daily average mainstem flows (cfs) within nearest 5% exceedance where the Proposed Action will likely reduce coho salmon fry habitat availability to below 80 percent of maximum (orange highlight). Flows estimated for the midpoint of each reach with Reach 1 from river km 289 to 312 (totaling 23 km), Reach 2 from river km 232 to 289 (totaling 57 km), and Reach 3 river km 107 to 232 (totaling 125 km).
Source: Mount Hood Environmental 2018

Exceedance Rates	Reach 1 March	Reach 1 April	Reach 1 May	Reach 1 June	Reach 2 March	Reach 2 April	Reach 2 May	Reach 2 June	Reach 3 March	Reach 3 April	Reach 3 May	Reach 3 June
95%	**1117**	1429	**1240**	**1056**	1435	1640	1387	**1126**	**2584**	**2492**	1881	**1341**
90%	1316	1461	**1269**	**1068**	1707	1702	1448	**1159**	2933	2708	**2127**	**1454**
85%	1578	1507	**1290**	**1081**	1947	1832	1504	**1195**	3230	3002	**2317**	**1536**
80%	1789	1551	1317	**1091**	2167	1934	1579	1224	3642	3394	**2509**	1624
75%	1945	1684	1359	**1103**	2347	2087	1677	1256	3978	3858	2837	1739
70%	2155	1852	1409	**1116**	2608	2303	1794	1299	4362	4138	3214	1821
65%	2348	2016	1501	**1132**	2869	2453	1928	1335	4741	4473	3540	**1968**
60%	2587	2232	1610	**1147**	3204	2737	2098	1386	5302	4856	3893	**2108**
55%	2884	2426	1810	**1174**	3561	2995	2282	1440	6159	5405	4201	**2297**
50%	3213	2680	2001	**1203**	3914	3306	2483	1518	6738	5847	4459	**2527**
45%	3452	2996	2221	**1269**	4278	3662	2735	1600	7241	6461	5083	2773
40%	3805	3282	2531	1416	4662	3956	3156	1746	7720	6985	5728	3076
35%	4241	3637	2742	1570	5204	4468	3450	1956	8424	7705	6429	3367
30%	4672	3982	2979	1737	5830	4882	3698	2142	9195	8308	6860	3759
25%	5234	4627	3245	1902	6453	5539	4024	2372	10143	8939	7288	4382
20%	6085	5076	3550	2042	6851	6067	4388	2670	11247	9604	7881	4928
15%	6467	5602	3974	2407	7669	6532	4936	3024	12419	10199	8815	5536
10%	7148	6088	4411	2818	8694	7084	5475	3589	14273	11237	9801	6470
5%	8583	6671	5066	3463	10588	7806	6325	4271	17532	12322	10759	7754

Reach 1 = The mainstem Klamath River from Iron Gate Dam to the confluence of the Shasta River (rkm 289-312).

Reach 2 = The mainstem Klamath River from the confluence of the Shasta River to the confluence of Scott River (rkm 232-289).

Reach 3 = The mainstem Klamath River from the confluence of the Scott River to the confluence of the Salmon River (rkm 107-232).

Table 8-7. Daily average mainstem flows (cfs) within nearest 5% exceedance where the Proposed Action will likely reduce coho salmon juvenile habitat availability (blue highlight) in the R Ranch reach.
Source: Mount Hood Environmental 2018

Exceedance	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
95%	1008	1024	**983**	1003	1027	**1117**	1325	**1175**	1025
90%	1015	1032	**992**	1018	1050	1316	1325	**1175**	1025
85%	1031	1040	1001	1038	1073	**1578**	1325	**1175**	1025
80%	1053	1045	1009	1061	**1102**	1789	1350	**1175**	1025
75%	1079	1052	1021	1084	**1151**	1945	**1501**	**1175**	1025
70%	**1102**	1066	1030	**1104**	**1207**	2155	1654	**1175**	1025
65%	**1115**	1096	1042	**1132**	**1284**	2348	1770	**1241**	1025
60%	**1134**	**1117**	1060	**1197**	1399	2587	1938	1392	1025
55%	**1147**	**1161**	1086	**1283**	**1576**	2884	2130	**1562**	1025
50%	**1166**	**1208**	**1131**	**1409**	1846	3213	2349	1722	1025
45%	**1181**	**1240**	**1189**	**1581**	2115	3452	2628	1959	1078
40%	**1196**	**1259**	**1279**	1781	2417	3805	2936	2156	**1227**
35%	**1212**	**1275**	**1466**	2057	2755	4241	3208	2369	1347
30%	**1227**	1319	1704	2427	3054	4672	3503	2589	**1503**
25%	**1255**	1369	1933	2761	3487	5234	4147	2834	1652
20%	**1296**	**1433**	2313	3233	4087	6085	4520	3095	1786
15%	1318	**1527**	2694	3731	4773	6467	5044	3418	2055
10%	1382	1699	3385	4894	5866	7148	5565	3844	2438
5%	**1486**	3243	5380	6563	8624	8583	6095	4501	3018

Table 8-8. Daily average mainstem flows (cfs) within nearest 5% exceedance where the Proposed Action will likely reduce coho salmon juvenile habitat availability (blue highlight) in the Trees of Heaven reach.
Source: Mount Hood Environmental 2018

Exceedance	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
95%	**1114**	**1184**	**1146**	**1187**	**1229**	**1330**	**1543**	**1323**	**1095**
90%	**1135**	**1198**	**1163**	**1213**	**1267**	**1565**	**1586**	**1360**	**1118**
85%	**1166**	**1213**	**1188**	**1253**	**1305**	1816	1690	**1399**	**1142**
80%	**1191**	**1229**	**1199**	**1280**	**1348**	2017	1760	1450	**1162**
75%	**1211**	**1244**	**1218**	**1320**	1407	2181	1913	**1516**	**1182**
70%	**1235**	**1265**	**1241**	**1356**	1483	**2428**	2070	**1598**	**1206**
65%	**1253**	**1292**	**1263**	**1399**	**1575**	**2666**	**2254**	1726	**1233**
60%	**1271**	**1327**	**1293**	1462	1731	**2929**	**2481**	1836	**1271**
55%	**1297**	**1366**	**1336**	**1584**	1939	**3248**	**2722**	2038	**1311**
50%	**1325**	1401	**1396**	1711	**2230**	**3594**	**2989**	**2235**	**1362**
45%	**1344**	1425	1461	1917	**2465**	**3909**	**3333**	**2476**	1437
40%	**1367**	1452	**1577**	2144	**2782**	**4333**	**3628**	**2838**	**1587**
35%	**1389**	1474	1779	**2473**	**3132**	**4773**	**4022**	**3103**	1773
30%	1408	**1538**	2027	**2823**	**3474**	5243	**4436**	**3322**	1948
25%	1440	1601	**2299**	**3244**	**4032**	5947	5115	**3590**	2139
20%	1466	1663	**2705**	**3781**	**4749**	6462	5560	**3959**	**2351**
15%	**1511**	1779	**3191**	**4378**	5561	7146	6153	**4416**	**2683**
10%	**1572**	1959	**4048**	5740	6937	7974	6549	**4848**	**3222**
5%	1712	**3813**	6122	7861	10689	9810	7220	5693	**3875**

Table 8-9. Daily average mainstem flows (cfs) within nearest 5% exceedance where the Proposed Action will likely reduce coho salmon juvenile habitat availability (blue highlight) in the Seiad Valley reach.
Source: Mount Hood Environmental 2018

Exceedance	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
95%	**1154**	**1265**	**1290**	**1390**	**1577**	1997	**2065**	**1644**	**1210**
90%	**1180**	**1330**	**1340**	**1474**	**1710**	**2276**	**2201**	1867	**1295**
85%	**1215**	**1360**	**1390**	**1640**	1848	**2577**	**2467**	**2027**	**1361**
80%	**1258**	**1390**	**1437**	**1756**	1970	**2844**	**2735**	**2156**	**1438**
75%	**1289**	**1420**	**1490**	1853	**2112**	**3119**	**2963**	**2398**	**1524**
70%	**1314**	**1460**	**1576**	1949	**2221**	**3423**	**3187**	**2705**	**1603**
65%	**1334**	**1501**	**1653**	**2069**	**2446**	**3756**	**3475**	**2986**	**1708**
60%	**1367**	**1539**	**1739**	**2209**	**2792**	**4190**	**3904**	3205	1816
55%	**1400**	**1561**	1852	**2384**	**3150**	**4835**	**4347**	**3471**	1993
50%	**1429**	**1612**	**2009**	2646	**3502**	**5272**	**4673**	**3718**	**2177**
45%	**1461**	**1643**	**2180**	**2972**	**3803**	**5695**	**5126**	**4073**	**2380**
40%	**1501**	**1712**	**2379**	3342	**4233**	**6201**	**5619**	**4694**	2612
35%	**1536**	**1782**	2649	**3695**	**4607**	**6891**	**6291**	**5180**	**2868**
30%	**1576**	1867	**2964**	**4426**	**5213**	**7567**	**6849**	**5555**	**3179**
25%	**1615**	1969	**3473**	**5246**	**6088**	**8197**	**7391**	**5950**	**3719**
20%	**1669**	**2076**	**4337**	**6011**	**7257**	**9015**	**7961**	**6578**	**4153**
15%	**1739**	**2261**	**5153**	**7365**	**8463**	10232	**8555**	**7109**	**4734**
10%	1845	**2773**	**7130**	**9201**	10357	11443	**9171**	**8165**	**5503**
5%	**2008**	**5691**	10546	12603	16578	14180	10192	**9110**	**6526**

Table 8-10. Daily average mainstem flows (cfs) within nearest 5% exceedance where the Proposed Action will likely reduce coho salmon juvenile habitat availability (blue highlight) in the Rogers Creek reach.
Source: Mount Hood Environmental 2018

Exceedance	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
95%	1256	1519	1686	1935	2749	3718	3222	2494	1639
90%	1324	1625	1858	2405	3184	4297	3799	2754	1765
85%	1362	1738	2013	3011	3674	4867	4405	2942	1932
80%	1419	1812	2254	3368	4081	5437	4830	3260	2098
75%	1511	1882	2516	3661	4506	**6088**	**5653**	3831	2251
70%	1564	1935	2792	4021	5004	**6596**	**6226**	4375	2429
65%	1609	1978	3111	4498	**5549**	**7273**	**6741**	4781	2607
60%	1653	2041	3502	4947	**6118**	**8168**	**7422**	5303	2795
55%	1684	2102	3948	5397	**6713**	**9262**	**8008**	**5809**	3054
50%	1724	2182	4366	**6079**	**7176**	**10140**	**8594**	**6329**	3347
45%	1786	2295	4873	**6999**	**7825**	**10773**	**9338**	**7255**	3735
40%	1809	2476	**5506**	**7763**	**8748**	**11487**	**10285**	**8131**	4160
35%	1867	2662	**6214**	**8625**	**9695**	**12764**	**11073**	**9042**	4571
30%	1934	3003	**7275**	**9974**	**11401**	**14051**	**11988**	**9712**	5097
25%	2095	3320	**8641**	**11837**	**12890**	**15519**	**12888**	**10420**	**5820**
20%	2185	3945	**9958**	**14596**	**15269**	**16899**	**13495**	**11617**	**6469**
15%	2424	4811	**12895**	**17401**	**18376**	**18165**	**14741**	**12515**	**7492**
10%	2666	**7492**	**18247**	**20933**	**22986**	**20624**	**16245**	**13657**	**8706**
5%	3553	**12458**	**27055**	**26670**	**31399**	**25082**	**18268**	**14706**	**10791**

8.5.3. Determination of Effects on Designated Coho Salmon Critical Habitat

After considering the best available scientific information, implementing the PA may affect, and is likely to adversely affect coho salmon critical habitat. Reclamation anticipates improvements to desigated critical habitat that offset some adverse impacts from the PA as a result of funding the Klamath Coho Restoration Program.

8.6. Effects of UKL Control and Flushing Flows on Coho Habitat Availability

There is a tradeoff between releasing stored water to generate flushing flows for fish disease mitigation and releasing water to maximize juvenile coho rearing habitat availability. Simulation of May and June coho habitat availability downstream of IGD revealed that flow reductions, if they occur following flushing flow events, would be expected to reduce rearing habitat area, especially for parr in the Shasta River to Scott River and Scott River to Salmon River reaches (Figure 8-8, Table 8-11 and Table 8-12). To evaluate the combined effect of managing UKL levels for suckers and flushing flows for fish disease mitigation on coho habitat availability downstream of IGD, a WRIMS model simulation was produced whereby the UKL control logic was turned off for the months of May and June, allowing lake levels to drop below minimum targets for suckers. All other attributes of the Proposed Action remained intact during the simulation. Predicted flows downstream of IGD 1980 to 2016 were then provided to USGS for coho habitat area estimation using the hydrodynamic model described in section 8.5. Two sets of habitat data, one for the Proposed Action and one for the Proposed Action without UKL control in May-June, were then compared for dry water years during the POR. 1991 and 2001 were chosen as examples of dry years where habitat area may be impacted by UKL control following a flushing flow event of 6,030 cfs.

Comparing the with and without May to June UKL control simulations, UKL control had the largest simulated impact on river flows in May of 1991 when average flow was reduced by over 800 cfs due to UKL control following a flushing flow event. However, river flows in most years during the POR were unaffected by removal of UKL control in May and June. The average increase of May Iron Gate flow due to the removal of UKL control was 36 cfs, and no change was predicted in average June IGD flow due to removal of UKL control.

Effects of UKL control on coho salmon habitat area in May and June varied by reach for the two water years chosen for our analysis. Between IGD and the Shasta River, coho salmon fry and parr habitat area decreased as a result of UKL control in May 1991 but remained about the same in June 1991 (Figure 8-9). Simulated habitat area was greater as a result of UKL control in May 1991 between the Shasta and Scott Rivers (Figure 8-10), and differences were insignificant for the reach between the Scott and Salmon Rivers (Figure 8-11). UKL control did not have an appreciable effect on habitat area in any of the reaches during the 2001 water year.

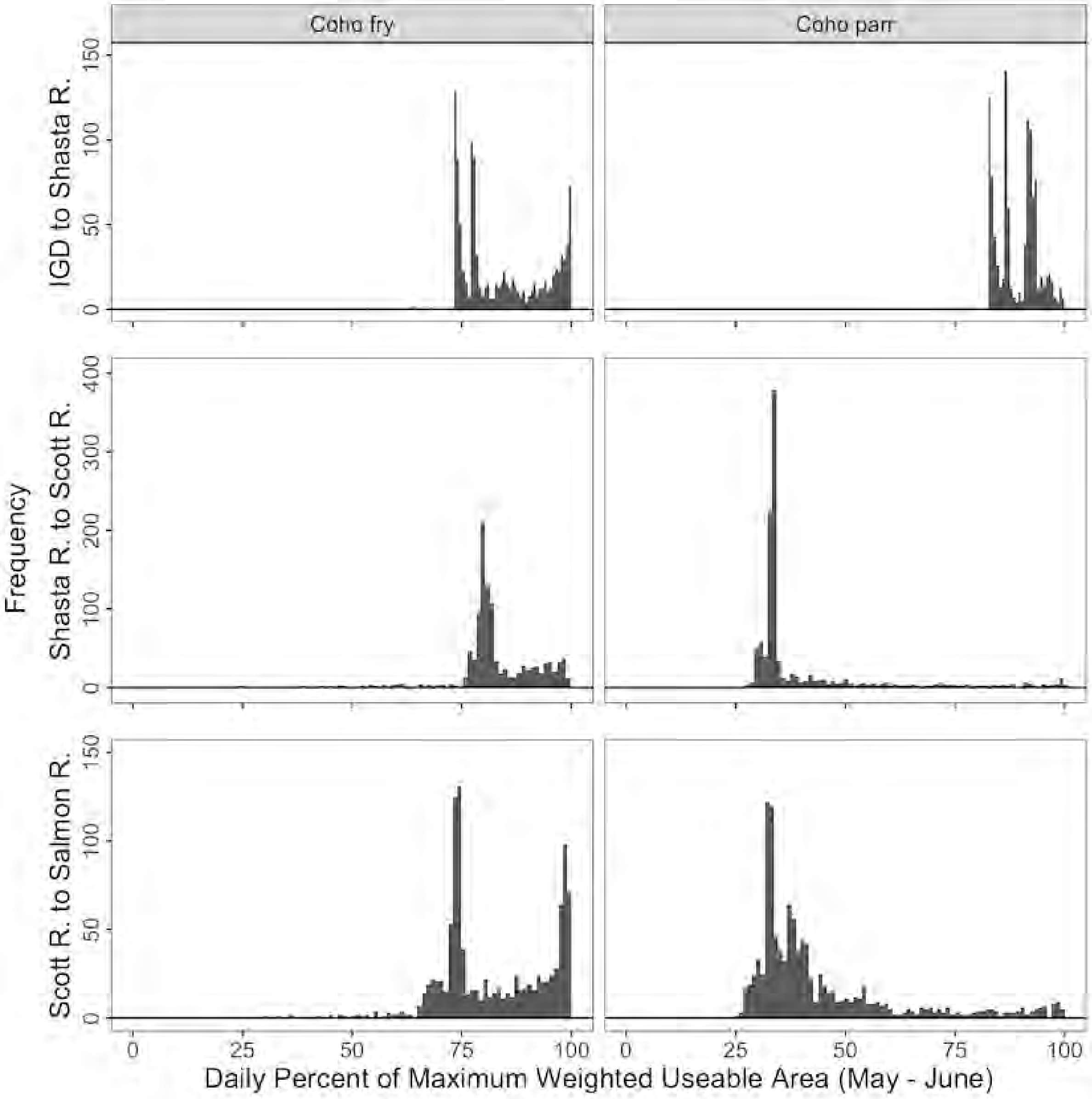

Figure 8-8. Predicted frequency of daily percent of maximum WUA values for coho salmon fry and parr in three reaches downstream of IGD during the months of May and June 1980-2016.

Source: Mount Hood Environmental 2018

Table 8-11. Exceedance flows and corresponding WUA values for coho parr in three reaches downstream of IGD. Flows were estimated at the midpoint of each reach.
Source: Mount Hood Environmental 2018

	IGD		IGD-Shasta (rkm 289-312)						Shasta-Scott (rkm 232-289)						Scott-Salmon (rkm 107-232)					
	May	June	May			June			May			June			May			June		
Exceedance	Flow (cfs)	Flow (cfs)	Flow (cfs)	WUA	% of Max	Flow (cfs)	WUA	% of Max	Flow (cfs)	WUA	% of Max	Flow (cfs)	WUA	% of Max	Flow (cfs)	WUA	% of Max	Flow (cfs)	WUA	% of Max
0.95	1,175	1,025	1,240	3,262	87%	1,056	3,120	83%	1,387	18,222	34%	1,126	16,076	30%	1,881	14085	32%	1,341	12055	28%
0.9	1,175	1,025	1,269	3,271	87%	1,068	3,125	83%	1,448	18,182	33%	1,159	16,346	30%	2,127	14238	33%	1,454	12700	29%
0.85	1,175	1,025	1,290	3,250	86%	1,081	3,134	83%	1,504	18,101	33%	1,195	16,699	31%	2,317	14318	33%	1,536	12915	30%
0.8	1,175	1,025	1,317	3,253	87%	1,091	3,143	84%	1,579	18,094	33%	1,224	16,962	31%	2,509	14704	34%	1,624	13342	31%
0.75	1,175	1,025	1,359	3,264	87%	1,103	3,154	84%	1,677	18,193	33%	1,256	17,192	32%	2,837	14955	34%	1,739	13718	32%
0.7	1,175	1,025	1,409	3,337	89%	1,116	3,166	84%	1,794	18,333	34%	1,299	17,592	32%	3,214	16066	37%	1,821	14006	32%
0.65	1,241	1,025	1,501	3,437	91%	1,132	3,180	85%	1,928	18,262	34%	1,335	17,842	33%	3,540	16479	38%	1,968	14179	33%
0.6	1,392	1,025	1,610	3,457	92%	1,147	3,192	85%	2,098	18,041	33%	1,386	18,106	33%	3,893	17012	39%	2,108	14170	33%
0.55	1,562	1,025	1,810	3,426	91%	1,174	3,211	85%	2,282	17,623	32%	1,440	18,146	33%	4,201	17673	41%	2,297	14600	34%
0.5	1,722	1,025	2,001	3,483	93%	1,203	3,221	86%	2,483	17,897	33%	1,518	18,113	33%	4,459	17597	41%	2,527	14586	34%
0.45	1,959	1,078	2,221	3,515	94%	1,269	3,271	87%	2,735	18,415	34%	1,600	18,072	33%	5,083	19053	44%	2,773	15346	35%
0.4	2,156	1,227	2,531	3,489	93%	1,416	3,355	89%	3,156	19,594	36%	1,746	18,196	33%	5,728	19548	45%	3,076	15427	36%
0.35	2,369	1,347	2,742	3,434	91%	1,570	3,462	92%	3,450	21,323	39%	1,956	18,165	33%	6,429	22338	52%	3,367	16184	37%
0.3	2,589	1,503	2,979	3,434	91%	1,737	3,449	92%	3,698	23,044	42%	2,142	17,771	33%	6,860	23851	55%	3,759	16856	39%
0.25	2,834	1,652	3,245	3,504	93%	1,902	3,444	92%	4,024	27,230	50%	2,372	17,968	33%	7,288	25725	59%	4,382	17590	41%
0.2	3,095	1,786	3,550	3,580	95%	2,042	3,486	93%	4,388	31,851	59%	2,670	18,249	34%	7,881	30302	70%	4,928	18415	42%
0.15	3,418	2,055	3,974	3,630	97%	2,407	3,524	94%	4,936	38,423	71%	3,024	19,060	35%	8,815	33384	77%	5,536	19609	45%
0.1	3,844	2,438	4,411	3,642	97%	2,818	3,448	92%	5,475	44,174	81%	3,589	22,528	41%	9,801	37503	86%	6,470	22977	53%
0.05	4,501	3,018	5,066	3,716	99%	3,463	3,564	95%	6,325	50,882	94%	4,271	29,608	54%	10,759	39914	92%	7,754	29102	67%

Table 8-12. Exceedance flows and corresponding WUA values for coho fry in three reaches downstream of IGD. Flows were estimated at the midpoint of each reach.
Source: Mount Hood Environmental 2018

	IGD		IGD-Shasta (rkm 289-312)						Shasta-Scott (rkm 232-289)						Scott-Salmon (rkm 107-232)					
	May	June	May			June			May			June			May			June		
Exceedance	Flow (cfs)	Flow (cfs)	Flow (cfs)	WUA	% of Max	Flow (cfs)	WUA	% of Max	Flow (cfs)	WUA	% of Max	Flow (cfs)	WUA	% of Max	Flow (cfs)	WUA	% of Max	Flow (cfs)	WUA	% of Max
0.95	1,175	1,025	1,240	2,515	77%	1,056	2,388	74%	1,387	33,814	82%	1,126	31,655	77%	1,881	19145	74%	1,341	17164	66%
0.9	1,175	1,025	1,269	2,526	78%	1,068	2,393	74%	1,448	33,447	81%	1,159	31,942	77%	2,127	18887	73%	1,454	17852	69%
0.85	1,175	1,025	1,290	2,522	78%	1,081	2,401	74%	1,504	33,093	80%	1,195	32,319	78%	2,317	18972	73%	1,536	18053	70%
0.8	1,175	1,025	1,317	2,530	78%	1,091	2,409	74%	1,579	32,888	80%	1,224	32,611	79%	2,509	19015	74%	1,624	18548	72%
0.75	1,175	1,025	1,359	2,541	78%	1,103	2,418	74%	1,677	32,786	79%	1,256	32,923	80%	2,837	19639	76%	1,739	18948	73%
0.7	1,175	1,025	1,409	2,609	80%	1,116	2,427	75%	1,794	32,814	79%	1,299	33,393	81%	3,214	20967	81%	1,821	19185	74%
0.65	1,241	1,025	1,501	2,680	83%	1,132	2,438	75%	1,928	33,149	80%	1,335	33,603	81%	3,540	21579	84%	1,968	19066	74%
0.6	1,392	1,025	1,610	2,720	84%	1,147	2,447	75%	2,098	33,904	82%	1,386	33,648	81%	3,893	22939	89%	2,108	18862	73%
0.55	1,562	1,025	1,810	2,798	86%	1,174	2,463	76%	2,282	35,501	86%	1,440	33,427	81%	4,201	23065	89%	2,297	18907	73%
0.5	1,722	1,025	2,001	2,924	90%	1,203	2,473	76%	2,483	36,880	89%	1,518	33,126	80%	4,459	24983	97%	2,527	19270	75%
0.45	1,959	1,078	2,221	3,040	94%	1,269	2,526	78%	2,735	39,004	94%	1,600	32,778	79%	5,083	25539	99%	2,773	19437	75%
0.4	2,156	1,227	2,531	3,146	97%	1,416	2,626	81%	3,156	40,857	99%	1,746	32,517	79%	5,728	25516	99%	3,076	20518	79%
0.35	2,369	1,347	2,742	3,172	98%	1,570	2,717	84%	3,450	40,123	97%	1,956	33,230	80%	6,429	25334	98%	3,367	22192	86%
0.3	2,589	1,503	2,979	3,222	99%	1,737	2,780	86%	3,698	39,599	96%	2,142	34,447	83%	6,860	25226	98%	3,759	22622	88%
0.25	2,834	1,652	3,245	3,231	100%	1,902	2,847	88%	4,024	37,985	92%	2,372	35,933	87%	7,288	24986	97%	4,382	24766	96%
0.2	3,095	1,786	3,550	3,195	98%	2,042	2,921	90%	4,388	36,670	89%	2,670	38,358	93%	7,881	23624	91%	4,928	25696	99%
0.15	3,418	2,055	3,974	3,155	97%	2,407	3,124	96%	4,936	33,723	82%	3,024	40,090	97%	8,815	22771	88%	5,536	25506	99%
0.1	3,844	2,438	4,411	3,085	95%	2,818	3,221	99%	5,475	30,215	73%	3,589	39,475	96%	9,801	20002	77%	6,470	25215	98%
0.05	4,501	3,018	5,066	2,966	91%	3,463	3,210	99%	6,325	23,856	58%	4,271	37,366	90%	10,759	18229	71%	7,754	24100	93%

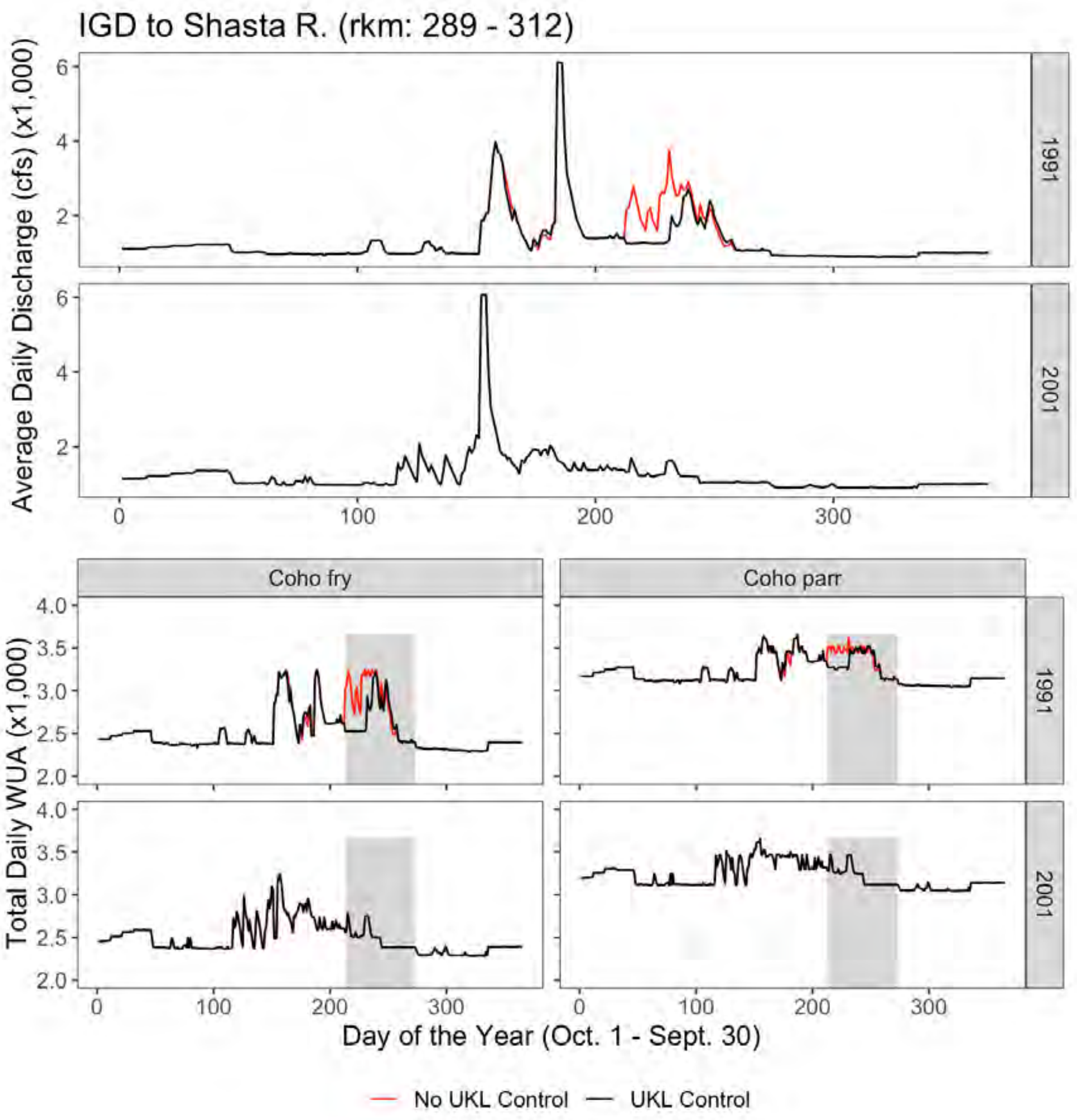

Figure 8-9. Coho salmon fry and parr habitat availability relative to mainstem flows from IGD to the Shasta River with and without UKL control. Flows account for tributary accretions and were estimated for each habitat unit when calculating WUA. Gray horizontal bands indicate dates from May 1 – June 30. Source: Mount Hood Environmental 2018

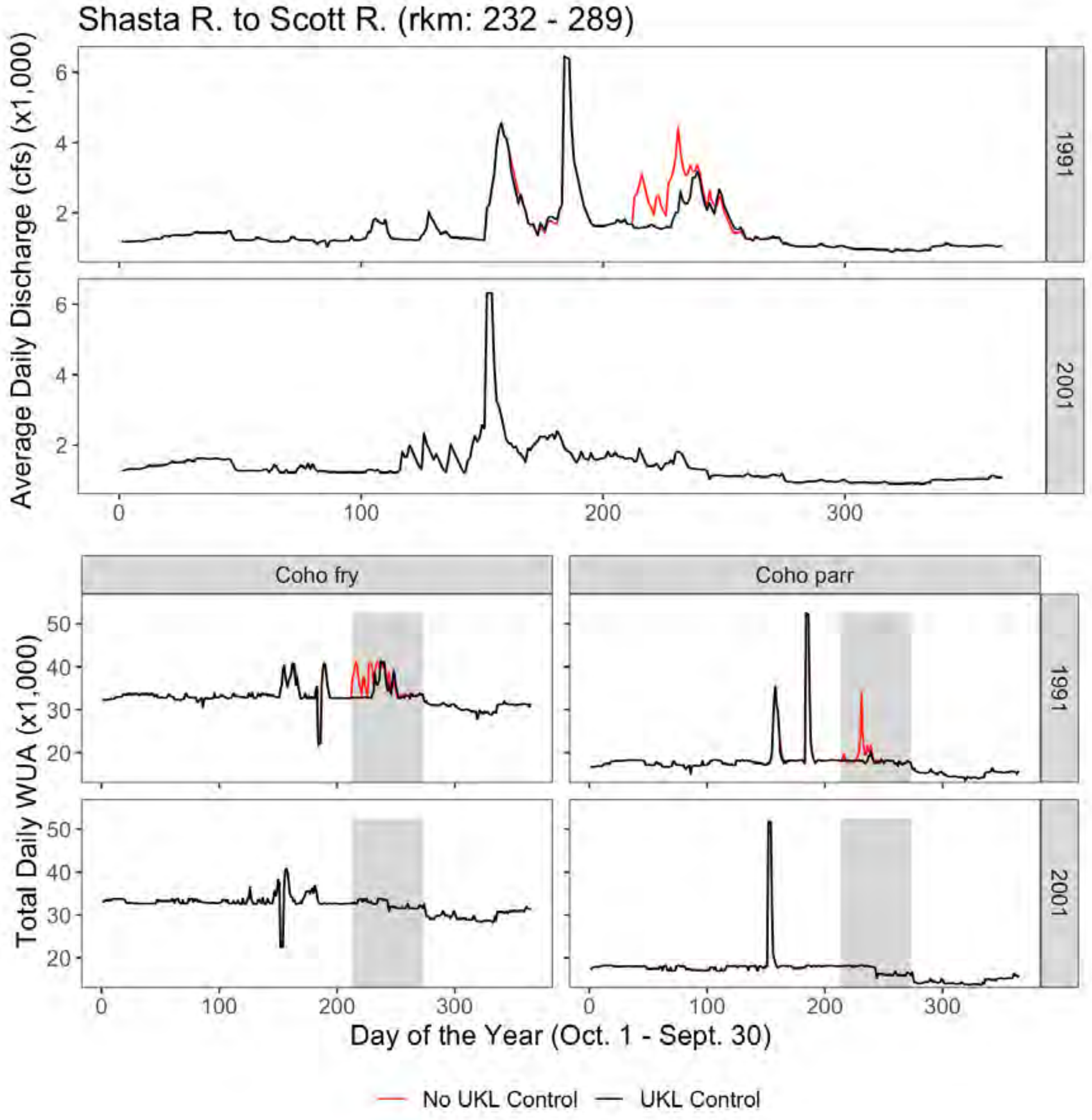

Figure 8-10. Coho salmon fry and parr habitat availability relative to mainstem flows from Shasta River to the Scott River with and without UKL control. Flows account for tributary accretions and were estimated for each habitat unit when calculating WUA. Gray horizontal bands indicate dates from May 1 – June 30.
Source: Mount Hood Environmental 2018

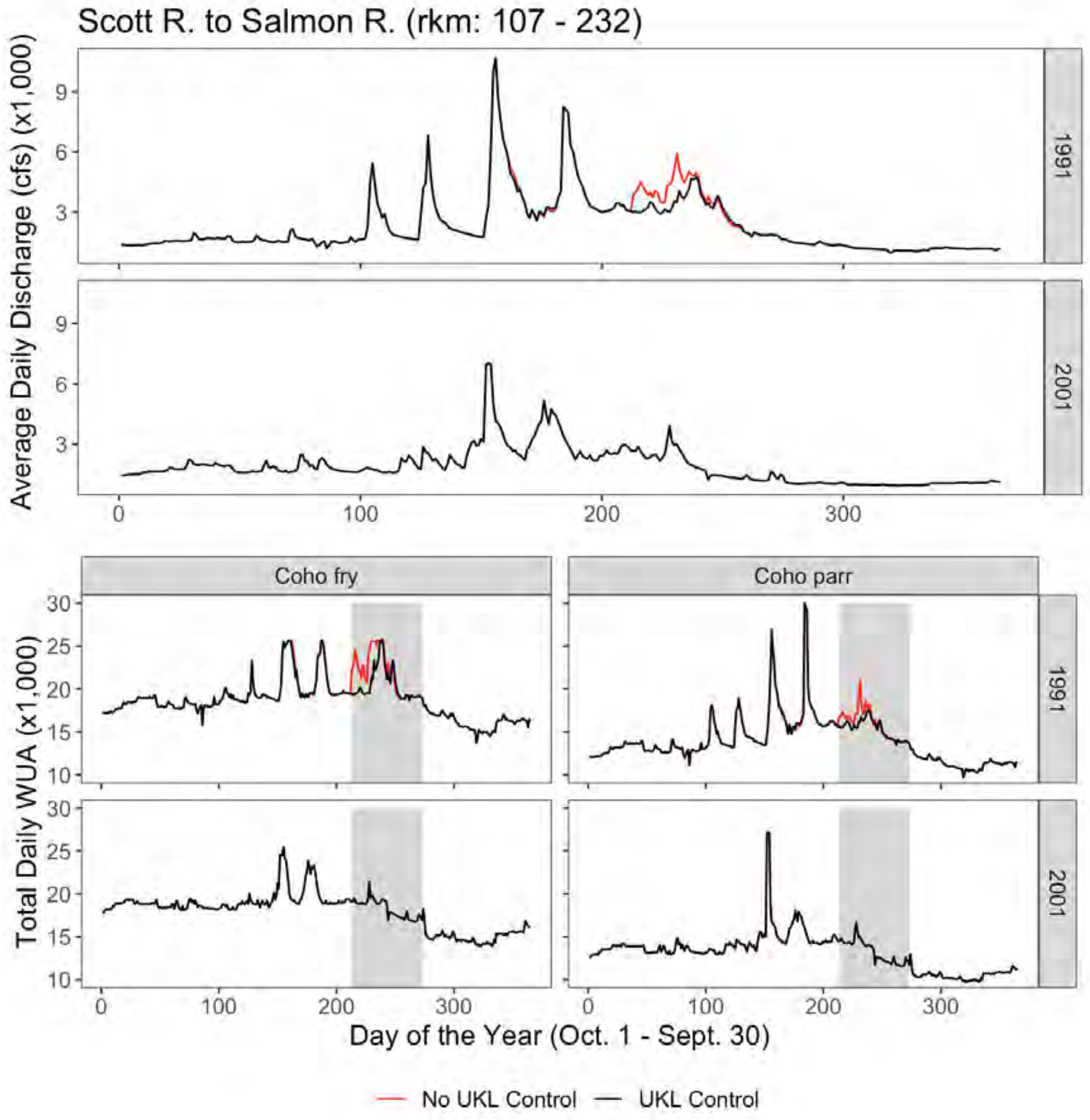

Figure 8-11. Coho salmon fry and parr habitat availability relative to mainstem flows from the Scott River to the Salmon River with and without UKL control. Flows account for tributary accretions and were estimated for each habitat unit when calculating WUA. Gray horizontal bands indicate dates from May 1 – June 30.
Source: Mount Hood Environmental 2018

8.7. Effects of Disease Mitigation Flows on Disease (C. shasta) Conditions for Coho Salmon

The PA includes flow measures for juvenile coho salmon disease mitigation between March 1 and September 30. Here we explore the potential effect of the proposed disease mitigation flows on salmonid disease associated with *C. shasta* infection.

8.7.1 Surface Flushing Flow

As described in Part 4.3.2.2.2.4, Reclamation has modeled use of the approximately 50,000 AF of EWA in dry years as a surface flushing flow and the narrative below will therefore focus on analysis of the modeled surface flushing flows.

The objective of the surface flushing flow is to mobilize sediment to scour *M. speciosa* from benthic substrate, thereby decreasing *M. speciosa* density in preferred habitat. It has been asserted that decreased *M. speciosa* density leads to diminished *C. shasta* actinospore production and decreased disease incidence in salmonids (Hillemeier et al. 2017, Reclamation 2018). The surface flushing flow constitutes a release of at least 6,030 cfs from IGD for at least 72 consecutive hours. Surface flushing flows in the KBPM reflect those described as Disease Management Guidance #1 in the Disease Management Guidance document (Hillemeier et al., 2017), with the exception that Reclamation is proposing the time period for managed surface flushing flows is limited to March 1 – April 15 (*see* Part 4.3.2.2.2.4 for additional details).

In 2011, 2016, and 2017, court ordered spring surface-flushing flows occurred, where IGD releases were at or near the proposed 6,030 cfs target flow (Table 8-13). *M. speciosa* density and actinospore concentrations were quantified by Oregon State University prior to and following flushing flows (Bartholomew et al. 2012, 2016, 2017), revealing a significant reduction in *M. speciosa* density after surface-flushing flows. For example, in 2016, *M. speciosa* density at Beaver Creek (KBC) was approximately 150,000 per m^2 prior to a 9,610 cfs flow event and was reduced to 10,000 per m^2 after the flushing flow event (Bartholomew et al. 2017). Furthermore, *M. speciosa* density reduction was sustained through the end of summer and recolonization occurred in November. A similar pattern was observed in 2017 (Bartholomew et al. 2018).

In 2018, Reclamation implemented two flow measures to mitigate for *C. shasta* in response to a that was largely based on the Klamath River Disease Guidance Document (Hillemeier *et al.* 2017). In early April, a surface flushing flow was released from IGD to scour preferred *M. speciosa* fine sediment habitat. Additionally, a subsequent dilution flow (3,000 cfs until 50,000 AF was expended) was implemented in May to prevent POI from increasing further (the trigger for this flow was POI greater than 20 percent). Following the surface flushing flow event, *M. speciosa* density decreased relative to spring densities (Julie Alexander, pers. comm., July 12, 2018). However, by May 2018, *M. speciosa* density rebounded to pre-event conditions. These observations suggest that surface flushing flows are effective in reducing *M. speciosa* density. However, the data also suggests surface flushing flows occurring in late winter or early spring may allow *M. speciosa* populations to rebound during the coho outmigration period (April/May). However the population of *infected M. speciosa* may not rebound to the same pre-disturbance levels (Julie Alexander, pers. comm., July 12, 2018). This information partially informed the time period proposed for surface flushing flows in the PA.

While past surface flushing flows have achieved the objective of reducing *M. speciosa* densities, *M. speciosa* density was inversely related to surface water actinospore concentrations and salmonid mortality following a flushing flow event in 2016 (Table 8-13). In particular, as *M. speciosa* density decreased, spore concentrations increased (>10 spores/L) within a month following the flushing flow event (Table 8-13). Coincidently, *C. shasta*-associated disease and mortality in IGH Chinook increased from low (0 percent, 30 days post-release) to moderate (30 to 60 percent, 60 days post-release) to high (60 to 80 percent, 180 days post-release) (Table 8-8). However, survival data suggested minimal risk of loss of coho salmon during that same period (Table 8-13), possibly due to factors such as actinospore genotype. Conversely, actinospore concentrations and salmon POI and mortality remained relatively low following the 2017 surface flushing flow (Table 8-13). This is despite similar water temperatures (Table 8-13) and the occurrence of similarly-timed deep flushing flows in both 2016 and 2017. Therefore, evidence from 2011-2018 suggests that surface-flushing flows reduce *M. speciosa* densities. However, evidence for a negative correlation between *M. speciosa* densities and disease incidence in coho salmon is lacking, perhaps due to the confounding effect of temperature on spore concentrations and fish infection rates.

Despite these uncertainties, the PA attempts to mitigate disease impacts by providing surface flushing flow conditions more frequently than historic conditions in accordance with recommendations provided by Hillemeier et al. (2017), because flow stability is thought to promote *C. shasta* proliferation. Specifically, the PA resulted in surface flushing flows in 35 of the 36 years within the modeled POR (approximately a one-year recurrence interval), which is likely to result in lower *M. speciosa* densities (and theoretically lower actinospore concentrations, POI, and *C. shasta*-related mortality per Hillemeier et al. 2017 and Reclamation 2018) than observed over the last decade when monitoring has occurred. Additionally, the natural recurrence interval of the 6,030 cfs flow at IGD is 2 years, meaning that the PA is implementing this flow approximately twice as frequently as it has been observed in the past (POR for recurrence interval is 1961 – 2009). The highest actinospore concentrations and salmon POI and *C. shasta*-related mortality observed in the last decade (since monitoring began) occurred from 2013 – 2015 (Bartholomew et al. 2018), a sequence of drought years with homogenous Klamath River flow regimes and few (if any) flows that would have effectively reduced *M. speciosa* densities in the Klamath River. The PA resulted in surface flushing flows in all three of these years (an average increase in March and April daily IGD discharge of 499 and 335 cfs, respectively, relative to what was observed) (Appendix 8, Table 8-1 and 8-2).

While implementation of a surface flushing flow may result in an average decrease in May and June discharge over the entire modeled POR, the 80 percent outmigration dates in 2013 – 2015 occurred in April or very early May such that the benefit of the surface flushing flow likely outweighs any subsequent decrease in habitat availability in May and June when few juvenile salmon remain in the system. As such, Reclamation concludes that the surface flushing flows in 35 of the 36 years in the modeled POR will likely result in reduced *M. speciosa* densities, which theoretically may result in reductions in actinospore concentrations, POI and *C. shasta*-related mortality (Hillemeier et al. 2017, Reclamation 2018).

8.7.2 Deep Flushing Flow

As with surface flushing flows, there is clear empirical evidence that deep flushing flows are effective in reducing *M. speciosa* densities and decreasing preferred *M. speciosa* habitat in the Klamath River (Bartholomew et al. 2018). Similarly, there is theoretical evidence that these impacts to *M. speciosa* populations lead to reductions in actinospore concentrations, POI, and *C. shasta*-related mortality in Klamath River salmon (Hillemeier et al. 2017, Reclamation 2018). Specifically, IGD flows between 8,700 and 11,250 cfs are critical in removing fine sediment deposited within the armored layer of the riverbed (i.e., large boulders, bedrock), which is something that cannot be accomplished with surface-flushing flows alone (Shea et al. 2016). Given this information, Reclamation recognizes the important potential positive impacts of deep flushing flows on the disruption of the *C. shasta* life-cycle, although such flows are not specifically accommodated in the PA. Water availability will determine the timing and frequency Reclamation is able to implement a deep-flushing flow; as such, Reclamation is unable to “guarantee” a managed deep flushing flow, but will attempt to do so as hydrologic conditions and public safety allow.

Flows meeting the criteria of a deep flushing flow (11,250 cfs for 24 hours) occur in 4 years (1982, 1986, 1996, and 1997) of the 36-year modeled POR (cite something in Appendix 8?), which is far less than the approximately 5-year recurrence interval for this discharge below IGD (Shea et al. 2016). However, it’s important to note that historically, flows approaching 11,250 cfs only occurred in 2 additional years: 2006 and 2016 (approximately 11,100 and 9,610 cfs, respectively). The PA does not result in a deep flushing flow in 2006 due to a difference in how inflow data was treated in the KBPM (i.e., it was smoothed to remove noise) relative to observed inflow that fluctuated widely during that particular period in 2006. This is a legacy of time step and operational rules in the model, and in real-time operations, Reclamation would respond to real-time hydrology (i.e., in real-time operations, under these conditions, Reclamation would likely implement a much higher flow). Similar conditions as described in 2006 occurred in 2016. In model year 2016, the PA implemented a surface flushing flow just before the deep flushing flow occurred historically, thereby reducing the extent to which UKL elevation increased (i.e., reduced head behind LRD and the amount of water that needed to be evacuated for flood control operations) as a result of a hydrologic event. This highlights a tradeoff in the PA in which Reclamation is guaranteeing a surface flushing flow in all by one year in the POR rather than maximizing UKL storage in all years in the hope that the suite of conditions necessary for a deep flushing flow occur. It is possible that in real-time operations, Reclamation would choose to delay the surface flushing flow with the knowledge that a major hydrologic event was on the horizon (there was advanced knowledge of this event in 2016). Finally, the current KBPM includes revised LRD stage-discharge information that was not accurate in the 2013 Biological Opinion; as such, it is not necessarily appropriate to compare the frequency of deep flushing flows between the PA and the 2013 Biological Opinion output since the 2013 Biological Opinion output included flows that were not operationally feasible.

While the model output indicates two fewer deep flushing flows with the PA relative to what was observed historically, it is likely that Reclamation would have been able to implement similar flows in 2006 and 2016 under this PA as were observed historically. Additionally, the frequency of surface flushing flows may offset to some extent the effect a lack of deep flushing flows at the natural recurrence interval has on M. speciosa habitat and densities. Regardless, deep flushing flows are difficult to implement even with maximum UKL storage, and therefore there is little more this PA can do to maximize the occurrence of such flows. Given this information, Reclamation concludes that the use of professional judgement to implement deep flushing flows when possible under this PA is likely to result in as many deep flushing flows as were observed historically. Additionally, the combination of deep flushing flows and surface flushing flows in this PA is likely to reduce *M. speciosa* density and preferred habitat in the Klamath River, relative to those observed historically (i.e., observed conditions from 1981 – 2016), which would theoretically reduce actinospore concentrations, POI, and *C. shasta*-related mortality in Klamath River salmon (Hillemeier et al. 2017, Reclamation 2018).

8.7.3 Dilution Flow

There is some evidence that increased discharge can directly dilute spore concentrations and thereby reduce POI and *C. shasta*-related mortality in Klamath River coho (Som et al. 2016b), though a substantial amount of uncertainty exists relative to the effectiveness of this measure (USFWS 2018). For example, an increase in flow in late May 2014 appears to have effectively diluted spore concentrations, however the effect was relatively short-lived (Bartholomew et al. 2014). Relative to the effectiveness of the May 2018 dilution flow, Oregon State University scientists are currently analyzing monitoring data collected before, during, and after the 2018 dilution flow and are planning to release a report in the near future detailing the effectiveness of this flow in diluting spore concentrations and reducing POI.

Reclamation has provided the opportunity for flexible implementation of approximately 50,000 AF in dry years such that water could be reserved for a ‘dilution-like’ flow, if it is determined to provide the best benefit for coho. Dilution flow measures during the spring/early summer operational period have been used to mitigate disease by increasing flows to dilute waterborne spore concentrations at times when juvenile coho salmon are most abundant in the main stem Klamath River (March-May). Dilution flow measures may be effective in reducing spore concentrations; however, this effect is often short-lived and large uncertainties remain regarding the corresponding effect to coho POI (Table 8-14) (USFWS 2018).

This PA generally emphasizes disease prevention (i.e., a surface flushing flow) and does not explicitly implement (i.e., model) disease mitigation flows (i.e., dilution flows), as described above. Given the empirical evidence (described above and in Part 6.4.1.4.1) that surface flushing flows are effective in reducing *M. speciosa* densities, Reclamation has included operational rules within the PA such that the preventative measures (surface flushing flows) are implemented frequently. Still, the PA allows for flexibility in shaping approximately 50,000 AF in dry years, such that a ‘dilution-like’ flow could be implemented if it is determined to provide the best benefit for coho.

Table 8-13. Flushing flow effects on *M. speciosa* density and surface water *C. shasta* spore concentration in the lower Klamath River “infectious zone”.
Source: Mount Hood Environmental 2018

Regulated Flow Event Timing	**Sampling Dates**	**Average IGD Flow (cfs)**	**% Mortality by *C. shasta* infection (sentinel studies)**[13]				**[*C. shasta*] (mean spores/L)**		**Approx. Polychaete Density**[14] **(#m^{-2})**		**Temp. (deg C)**	
			KBC		**KSV**		**KBC**	**KSV**	**KBC**	**KSV**	**KBC**	**KSV**
			Chinook	coho	Chinook	coho						
Feb 9-12, 2011	Pre-Flow (**Oct.**’10)	1620	NS	NS	NS	NS	<1	NS	5,000	24,000	6.8-12.9	6.3-12.6
	During	3200	NS	NS	NS	NS	<1	NS	250	NS	4.5	4.5
	Post-Flow (04/25-28)	4310	0	NS	0	NS	NS	<1	300	NS	10.6-11.3	10.6-11.1
	Post-Flow (05/17-20)	3215	0	8	0	0	<1	<1	200	0	12.8-14.4	11.6-13.8
	Post-Flow (06/21-24)	2060	18	55	10	60	<3	<5	13,000	2,000	19.1-19.4	16.1-16.4
March 15-18, 2016[15]	Pre-Flow (Nov. ’15)	1020	NS	NS	NS	NS	5	10	150,000	150,000	6.1-14.1	4.6-14.2
	During (03/16)	9610	NS	NS	NS	NS	0	0	NS	NS	8	8.3
	Post-Flow (03/21)	4480	NS	NS	NS	NS	0	0	10,000	NS	9	8.2
	Post-Flow (04/24)	2140	NS	NS	NS	NS	38	18	NS	NS	13.9	11.9
	Post-Flow (05/16-19)	1520	0	NS	5	NS	60	17	NS	NS	16.7-18.1	12.8-13.9
	Post-Flow (06/07)	1200	NS	NS	NS	NS	50	40	15,000	10,000	22	17.7
	Post-Flow (06/21-24)	1040	30	0	60	0	53	68	NS	NS	20.4-20.9	20.8-21.7
	Post-Flow (08/07)	1000	NS	NS	NS	NS	10	10	17,500	15,000	22.2	22.5
	Post-Flow (09/17-20)	1000	30	NS	80	NS	13	18	NS	NS	19-20	19-20
Feb 10-13, 2017	Pre-Flow (Nov.’16)	1000	NS	NS	NS	NS	0	0	100,000	1,000,000	12-15	12-15
	Pre-Flow (02/07)	4000	NS	NS	NS	NS	0	0	NS	NS	6.1	6
	During (02/11)	8280	NS	NS	NS	NS	NS	NS	NS	NS	6.2	5.9
	Post-Flow (03/08)	2980	NS	NS	NS	NS	0	0	NS	NS	7.4	6.8
	Post-Flow (Apr.)	4680	NS	NS	NS	NS	<1	<2	1,000	10	10-12	10-12
	Post-Flow (05/25-28)	2380	0	NS	0	NS	5-6	2	NS	NS	18	15
	Post-Flow (06/24-27)	1020	7.5	20	2.6	0	9	3	1,000	1,000	22	20
	Post-Flow (09/14-17)	1200	0	NS	0	NS	0	0	100,000	10,000	19	19

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[13] Bartholomew et al 2012 report to BOR.

[14] Approximate density, derived from, Bartholomew et al reports to BOR (2016, 2017).

[15] Deep flushing flow

Table 8-14. Dilution flow effects on surface water *C. Shasta* spore concentration and salmonid infection in the lower Klamath River "infectious zone".
Source: Mount Hood Environmental 2018

Regulated Flow Event Timing	**Sampling Dates**	**Average IGD Flow (cfs)**	**% Mortality by *C. shasta* infection (sentinel studies)**				**[*C. shasta*] (spores/L)**		**Temp. (deg C)**	
			KBC		**KSV**		**KBC**	**KSV**	**KBC**	**KSV**
			Chinook	coho	Chinook	coho				
May 25-31, 2014 [16]	Pre-Flow (05/13-17)	1150	41	49	33	93	15	47	17.1-18.5	17-19
	Pre-Flow (05/19)	1170	NS	NS	NS	NS	32	38	17.1	17
	Pre-Flow (05/26)	1150	NS	NS	NS	NS	65	31	18.5	19.5
	During (05/28)	1700	NS	NS	NS	NS	NS	NS	17.8	17.9
	Post-Flow (06/03)	990	NS	NS	NS	NS	9	18	20	20.8
	Post-Flow (06/10)	1160	NS	NS	NS	NS	13	22	21.7	21.7
	Post-Flow (06/16)	1270	NS	NS	NS	NS	32	NS	19.6	20
	Post-Flow (06/17-20)	1220	40	42-52	67	72	NS	NS	20	20
	Post-Flow (09/18-21)	1010	2.4	NS	5	NS	<1	<1	20	20
May 7-29, 2018 [17]	Pre-Flow (05/07)	1270	0	NS	2.6	NS	4	3.8	11.5 - 13.9	11.5 - 13.9
	During (05/09)	2980	0	NS	0	NS	2.5	NS	18 - 20	18 - 20
	Post-Flow (05/29)	1130	NS	NS	NS	NS	2.5	0.1	19.8	19.7
	Post –Flow (06/18)	1120	12.5	NS	2.5	NS	4.3	1.8	19.7	20.1
	Post-Flow (09/14-17)	990	0	NS	0	NS	1.7 (09/17)	2.9 (09/14) 0 (9/17)	18.1-18.6	17.9-18.5
	Post-Flow (09/24)	1010	NS	NS	NS	NS	5.0	2.3	17.3	17.3

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[16] Bartholomew et al 2014 report to BOR.
[17] https://microbiology.science.oregonstate.edu/content/monitoring-studies

8.8. Effects of Conservation Measure – Klamath Basin Coho Restoration Grant Program

Restoration activities that require instream activities will be implemented during low flow periods between June 15 and November 1. The specific timing and duration of each individual restoration project will vary depending on the project type, specific project methods, and site conditions. However, the duration and magnitude of effects to coho salmon and their designated critical habitat associated with implementation of individual restoration projects will be significantly minimized due to the multiple proposed avoidance and minimization measures.

Implementing individual restoration projects during the summer low-flow period will significantly minimize exposure to emigrating coho salmon smolts and coho salmon adults at all habitat restoration project sites. The total number and location of restoration projects funded annually will vary from year to year depending on various factors, including project costs, funding and scheduling. Assuming the number of restoration activities is similar to PacifiCorp's coho enhancement fund, the total number of projects expected to be funded each year should range between four and six, depending on what projects get selected and the cost of each of those projects.

Except for some riparian habitat restoration and water conservation measures, all proposed restoration types, while implemented for the purpose of benefiting coho salmon and restoring their designated critical habitat on a long-term basis, have the potential to result in short-term adverse effects. Despite the different scope, size, intensity, and location of these proposed restoration actions, the potential adverse effects to coho salmon all result from dewatering, fish relocation, structural placement, and increased sediment. Dewatering, fish relocation, and structural placement may result in direct effects to listed salmonids, where a small percentage of individuals may be injured or killed. The effects from increased sediment mobilization into streams are usually indirect effects, where the effects to habitat, individuals, or both, are reasonably certain to occur and are later in time.

Riparian Habitat Restoration: Riparian habitat restoration techniques if done properly are not likely to adversely affect listed salmonids or their habitat. All vegetation planting or removal (in the case of exotic species) will likely occur on streambanks and floodplains adjacent to the wetted channel and activities should not in flowing water. Thus, the long-term benefit from riparian restoration will be the establishment of a vibrant, functional riparian corridor providing juvenile and adult fish with abundant food and cover. By restoring degraded riparian systems, listed salmonids will be more likely to survive and recover in the future.

Riparian fencing and vegetation restoration projects will result in increased stream shading and instream cover habitat for rearing juveniles, moderated stream temperatures, and improved water quality through pollutant filtering. Beneficial effects of constructing livestock exclusionary fencing in or near streams include the rapid regrowth of grasses, shrubs, and other vegetation released from overgrazing, and reduced nitrogen, phosphorous, and sediment loading into the stream environment (Line et al. 2000; Brenner and Brenner 1998). Further, Owens et al. (1996) found that stream fencing has proven to be an effective means of maintaining appropriate levels and of sediment in the streambed. Another documented, beneficial, long-term effect is the reduction in bankfull width of the active channel and the subsequent increase in pool area in streams (Magilligan and McDowell 1997). Most restoration projects will contribute to a more properly functioning ecosystem for listed species by providing additional spawning and cover habitat relative to their current condition.

Water Conservation: Implementing water conservation measures will wholly benefit coho salmon by returning some flow to the stream at a time when coho salmon require adequate habitat to rear and migrate. Increasing instream flow levels by diminishing water diversions will provide juvenile coho salmon with better access to suitable rearing and spawning habitat, especially during the summer and early fall when flows are lowest. Water conservation projects are most likely to occur in the tributaries, such as the Shasta and Scott Rivers. Therefore, short-term restoration of flows is expected to affect only the tributaries because the next priority water right user or riparian water right user is likely to divert those flows and water conserved at the restoration site is likely to increase instream flows in a relatively small reach of these tributaries.

Summary: Reclamation's funding for restoration activities will likely result in short-term adverse effects during implementation, and the expectation is that the suite of restoration activities will result in long-term improvements to the function and role of critical habitat in the action area. Based on information on Reclamation's implementation of the Klamath Basin Coho Restoration Grant Program over the past several years and PacifiCorp's coho enhancement fund (PacifiCorp 2013), it is estimated that approximately four to six restoration projects will be funded each year throughout the mainstem Klamath River and major tributaries. Approximately 71 percent of the restoration projects that include an on-the-ground aspect of restoration should be successful at increasing the conservation value for coho salmon fry and juveniles. Projects given the highest priority under this program include access improvement and barrier removal, improved habitat and access to coldwater refugia, instream habitat enhancement and protections, and water conservation. Restoration projects minimize habitat related effects of the Project by individually and comprehensively improving critical habitat conditions for coho individuals, populations, and overall.

Because of inflation, as the cost of restoration increases, the proposed $500,000 annual base funding with an additional $700,000 in the fiscal years 2018 and 2020 restoration fund will be able to fund fewer restoration projects in the latter half of the PA duration. However, the ecological needs of coho salmon will likely continue to be better understood over the 10-year action period, and that restoration activities are likely to become more effective at benefiting coho salmon habitat throughout that period. Therefore, the increased understanding of coho salmon and habitat restoration is likely to approximately offset the effects of inflation with the result that the restoration benefits to coho salmon are likely to be reasonably similar over the 10-year PA period.

8.8.1. Grant Program

Restoration and recovery actions in the Klamath Basin are improving habitat and water quality conditions for anadromous salmonids. Reclamation has provided $500,000 per year since 2013 (approximately $3 million) for the Klamath Coho Habitat Restoration Program (Tables 8-15 through 8-18). The NFWF has completed three grant cycles (2016, 2017, and 2018) for restoration and research/monitoring projects, selecting a total of 21 projects (Tables 8-15 and 8-19). Of these projects, seven of the 16 grantees have received the "Notice to Proceed" (NTP) from Reclamation, and one partial NTP for pre-implementation activities for the grant years of 2016 and 2017; however, no grant contracts and/or NTPs have been completed for the 2018 grant year. Of those seven with NTPs, three grantees have begun implementing their projects.

NFWF uses metric objectives for categorizing projects, and these includes: 1) Planning, Research, and Monitoring; 2) Habitat Restoration; 3) Habitat Management; and 4) Capacity, Outreach, Incentives categories (Table 8-16 in Appendix 8), and projects' report on various units of measure (acres restored, miles restored, number of structures installed, etc.) depending on the objectives. However, Reclamation uses project planning, design and implementation to track projects (*see* Table 8-16). Of the grantees that have reported implementation outcomes for their projects, the units reported are:

1. California Trout for "Parks Creek Fish Passage Design and Planning: Cardoza Ranch" project (NFWF EZG Number: 51674 in the 2016 Grant Year):
   a. 0.65 design plans developed.

2. Siskiyou Conservation District for "Lower French Creek Off-Channel Habitat Development" project (NFWF EZG Number: 51708 in the 2016 Grant Year):
   a. 17 in-stream habitat structures (e.g., beaver dam analogues, woody debris structures) installed.
   b. 0.27 acres of off channel ponds restored for coho habitat.

3. Trout Unlimited for "Bogus Creek Fish Passage" project (NFWF EZG Number: 52139 in the 2016 Grant Year):
   a. 3 fish passage barriers rectified.
   b. 9 miles of stream opened.

The budget details and funding amounts (Tables 8-17 and 8-18) were described using the grantee's full proposal, unless otherwise noted. Consequently, some of the budget numbers in these tables may not reflect the final grant amount or contract figures. NFWF requested proposals in 2016, 2017, and 2018, where they received a total of 62 pre-proposals (Table 8-19). Of these proposals, they requested full-proposals for 31 applications and have funded 20 projects with 1 project still being considered for funding. A total of $2,690,414 has been allocated based on the amounts listed in the full-proposal budget tables (Table 8-17). There are also matching contributions of $3,179,541 (cash and in-kind), making the total amount slated for coho restoration approximately $5.9 million (Table 8-18).

In the full-proposals, budget tables delineate expenses based on several categories: Personnel Costs; Travel Costs; Equipment Costs; Material Costs; Contractual Services; Direct Costs; and Indirect Costs; all of which make up the NFWF grant request (or NFWF Project Costs) (Table 8-17). Of these categories, contractual services in the largest expenditure at 56.7 percent (approximately $1.5 million) followed by personnel costs 21.8 percent (approximately $585,000). Construction (or implementation) costs are addressed under the contractual services category and comprise only 19.8 percent (approximately $532,000) of total NFWF grant funds allocated with the remainder of the category including subcontractors (consultants, contractors, permitting entities, oversight personnel, contract administrators, etc.) for a variety of tasks; such as planning, designs, research, monitoring, oversight, and permitting. Therefore, while contractual services comprise the greatest expenditure (56.7 percent), approximately 65 percent is for personnel costs and 35 percent is for construction (excavators, dump trucks, materials, etc.). However, some materials (e.g., rock, rootwads, trees, coir fabric, etc.) were listed under the material costs category. Of the 21 funded projects, only 12 projects contain some aspect of restoration construction/implementation.

The total amount allocated for coho restoration ($5.9 million - Total Project Costs) includes both the cash contribution from NFWF award and all listed matching funds (cash and in-kind) (Table 8-18). The NFWF funding comprises 45.8 percent ($2.7 million) of the total project costs with matching funds equating to 54.2 percent ($3.2 million). Of the matching funds, 86.5 percent is from cash contributions ($2.8 million) with 13.5 percent coming from in-kind contributions ($429,260). Cash contribution in matching funds category did include: (1) previously awarded funds from Reclamation restoration programs; (2) use of owned/previously purchased equipment; and (3) previously expended funds on other portions of the project. Several proposals listed in-kind contributions that included materials for restoration (from landowners and other sources), which were not part of project construction/implementation. However, the in-kind matching funds category also included non-cash project contributions, donations, and personnel volunteer hours with the same personnel completing identical tasks in different budget sections.

The grant program is still in its infancy and therefore has not had sufficient time to implement many of its funded restoration projects. Overtime, it is anticipated that the program will implement more on-the-ground restoration projects that may benefit coho populations. Unfortunately, Dunne et al. (2011) speculated that the degree of mitigation provided by restoration efforts might not be sufficient to offset climate change adverse effects that will occur within the system (e.g., loss of thermal refugia) and in the ocean, especially on coho salmon. Dunne et al. (2011) further concluded that under climate change, it is reasonable to expect tributaries to warm by a few degrees, although neither measurements nor model predictions were available for these critical spawning and rearing environments. Consequently, if restoration efforts are to improve coho populations, then more projects will need to address the limiting factors by implementing on-the-ground solutions which is addressed by adding approximately $700,000 funding in the first two years in addition to the $500,000 base funding provided annual.

Table 8-15. The Bureau of Reclamation Klamath Coho Habitat Restoration Program has funded approximately 21 projects in the Klamath River Basin via National Fish and Wildlife Foundation (NFWF). The grant program provided funds in 2016, 2017, and 2018, as described below. This information is from the full proposal grant applications and therefore may be different than the actual grant award and contract.

Grant Year[1]	NFWF EZG Number[2]	Project Title	Total Project Costs[3]	NFWF Project Descriptions
2016	52200	Middle Klamath Coho Refuge Habitat Enhancement - Planning and Design Team Support	$75,000	Enhance coho refuges and off-channel refuge habitats along the middle Klamath River corridor by continuing planning and design efforts. The project will form a Coho project planning and design team to improve the efficiency and effectiveness of Coho salmon project implementation.
2016	52177	Horse Creek Wood Loading	$184,993	Create restoration plans for the upper mile and a half of Horse Creek Valley to address the lack of in-stream wood, floodplain connectivity and off-channel sites that limit the survival of coho in the Upper Klamath River Basin.
2016	52170	Increasing Year-Round Rearing Capacity and Habitat Quality for Natal and Non-Natal Populations of Coho Salmon in a Priority Lower Klamath Tributary (McGarvey Creek)	$214,284	Evaluate the restoration effectiveness of beaver dam analogues (BDA) to increase the amount of slow velocity rearing habitat available to juvenile coho throughout the Klamath Basin. The project will improve understanding of the potential for BDAs to provide much needed ecosystem benefits, such as increased juvenile coho rearing capacity, growth, and survival.
2016	52166	Parks Creek Fish Passage Implementation Project	$479,302	Re-establish fish passage for all life stages of salmonids in Parks Creek, the last significant spawning and refugia area in the Shasta River watershed for coho salmon, by re-designing the current fish passage barrier.
2016	52141	Development of Cold Water Habitat for Coho Salmon	$291,573	Provide a dependable cold-water rearing habitat for coho salmon akin to cold spring water sources found throughout the Upper Shasta River. Project will develop a low velocity backwater channel and habitat feature located between the Cross Canal and the Shasta River.
2016	52139	Bogus Creek Fish Passage for Coho Salmon	$1,188,620	Improve fish passage in Bogus Creek by eliminating three flashboard irrigation dams and installing roughened channels that will provide year-round fish passage and accommodate irrigation diversions.
2016	52070	Cold Creek Coho Passage and Screening Project	$212,775	Improve passage and habitat for adult and juvenile coho salmon in Cold Creek in the Klamath River Watershed. Project will install a roughened channel at the diversion site to allow for irrigation deliveries while providing volitional stream-wide passage for over-summering juveniles, outmigrating smolts and adults moving into spawning grounds.
2016	51708	Lower French Creek Off-Channel Habitat Development	$114,736	Restore the natural channel form and function and increase the carrying capacity and condition of juvenile coho salmon by constructing an off-channel pond with coarse woody debris structures and associated riparian vegetation in the floodplain of lower French Creek.
2016	51703	Klamath National Forest Coho Habitat Enhancement in Horse Creek, China Creek and Little Horse Creek	$484,057	Provide high quality rearing and spawning habitat for coho salmon and other salmonid species' sub-basins and provide direct and proven benefits to both natal and non-natal juvenile salmonids throughout the Middle Klamath. Project will create both off-channel and instream rearing and spawning habitat for

Grant Year[1]	NFWF EZG Number[2]	Project Title	Total Project Costs[3]	NFWF Project Descriptions
				Horse Creek, China Creek, and Little Horse Creek.
2016	51674	Parks Creek Fish Passage Design and Planning: Cardoza Ranch	$185,990	Provide continuous fish passage and reduce summer water temperatures in Parks Creek which will result in reduction of limiting factors facing Southern Oregon/Northern California Coast coho salmon and provide sustainable and lasting ecological benefits. Project will develop final construction plans and environmental compliance for a Shasta River Pump Station, which will provide continuous fish passage for juvenile coho salmon at the current Cardoza point of diversion.
2016	51627	Lower Yreka Creek Restoration Project	$158,259	Increase spawning and rearing habitat for coho salmon and other salmonids. Project will install 650 feet of new side channels and restore two acres of floodplain where Yreka Creek meets the Shasta River.
2016	51545	Lower Beaver Creek Coho Salmon Off-Channel Habitat Restoration	$137,428	Reconnect and restore a continuum of off-channel habitats along the length of the Mid-Klamath River and select tributaries that provide important winter and summer rearing refugia critical for the recovery of Klamath River Southern Oregon/Northern California Coast Coho salmon populations. Project will survey for optimum sites for off-channel habitat and pond creation on National Forest system lands adjacent to the lowest 5.7 miles of Beaver Creek.
2017	57875	Lower Mill Creek Habitat Enhancement for Coho Salmon - Phase II	$66,119	The Shackleford-Mill stream system supports a significant population of native Scott River coho salmon (Southern Oregon Northern California Coast Evolutionary Significant Unit) on an annual basis. The Siskiyou Resource Conservation District proposes to assess a 20-acre section of lower Mill Creek that will inform the planning and development of various stream enhancement treatments aimed at increasing the volume of rearing habitat available to the limiting freshwater life stage of coho salmon.
2017	57953	Lower Scott Valley Stream Habitat Restoration	$330,333	The Scott River supports a core, functionally independent population of Southern Oregon Northern California Coast coho salmon, that has been identified as the most productive stock in the upper Klamath River Basin. The Siskiyou RCD proposes to complete a habitat assessment and hydraulic analysis of a 200-acre section of the mainstem Scott River in order to plan and prioritize stream restoration treatments within an important coho salmon migratory corridor. The Siskiyou RCD also proposes to implement an off-channel pond as refuge for over-wintering and over-summering juvenile coho salmon. This work provides an important opportunity for partnership building between local landowners, private organizations, federal agencies and the Karuk Tribe.
2017	57952	Horse Creek Supplemental Design Project	$236,182	The purpose of this Horse Creek Supplemental Design Project is to supplement existing design funds. Design efforts and landowner outreach completed so far have indicated interest in a large valley-wall-to-valley-wall project executed in a phased approach. In order to develop this higher level of design, the Mid Klamath Watershed Council and collaborators need to engage specialist

Grant Year[1]	NFWF EZG Number[2]	Project Title	Total Project Costs[3]	NFWF Project Descriptions
				support from: civil engineering, diversion specialist, power-line engineering and geotechnical investigation.
2017	57608	Restoring a critical population of coho salmon in the Klamath River Basin (CA) by restoring floodplain habitat, monitoring, and designing additional restoration features.	$466,478	For the purposes of enhancing coho salmon summer and winter rearing habitat, this project has three primary elements: 1) Sugar Creek Floodplain Restoration Project; 2) Monitoring of Restoration at Sugar Creek; and 3) Tailings Cold Water Refugia Connection Design Project. The first project restores floodplain along and existing terrace adjacent to Sugar Creek. The second project monitors the response to restoration and habitat enhancement in Lower Sugar Creek. The third project develops an alternative analysis, designs, and construction documents for connecting a tailings pond to Sugar Creek or the Scott River. The expected outcome includes, creation of .6 acres of high quality floodplain winter rearing habitat for coho salmon (and other aquatic organisms); collecting valuable data and analyzing response enhancement and restoration projects; and developing construction documents to connect an additional 2 acres of coldwater refugia to Sugar Creek or the Scott River.
2018	61742	Klamath River at Horse Trough Springs: Floodplain Connection Design Project	$255,791	This is a fisheries design project that aims to restore a ½ mile section of the Klamath River at Horse Trough Springs with the intent of connecting the Klamath River to its floodplain. Methods used to connect the Klamath River to its floodplain will include increasing surface water elevation by adding boulders to the upstream ends of riffles, decreasing the floodplain elevation through grading with heavy equipment, enhancing and connecting existing cold water features, and adding roughness elements to the floodplain bar. Connecting the Klamath to its floodplain at this location will provide thermal refuge, overwintering rearing habitat and spawning habitat and will benefit Klamath Basin coho and Chinook salmon and steelhead.
2018	61728	South Fork Scott River Floodplain Restoration Project	$270,328	The South Fork Scott River Floodplain Restoration Project is a collaborative effort between California Trout, the Siskiyou RCD, the U.S. Fish and Wildlife Service, and the Western Rivers Conservancy (landowner) to restore floodplain function and instream habitat complexity within a 1-mile reach of the South Fork Scott River for the benefit of coho salmon. Phase 2 treatments are planned for implementation in the fall of 2020 and will include the excavation of inset floodplains, the installation of large-wood structures/jams (spanning approximately 800 feet of stream), the removal of historic mining tailings, and the planting of native riparian vegetation.
2018	61688**	Fort Goff Fish-Passage and Diversion Improvement	$231,111	The Siskiyou Resource Conservation District, in coordination with multiple agency partners, is working with the water-users of the only active point of diversion from Fort Goff Creek (tributary to the Klamath River) to address environmental compliance measures for the purpose of improving anadromous fish access to 0.75 miles of spawning and rearing habitat as well as reduce the potential for impacts to coho salmon through the act of diverting water. This will

Grant Year[1]	NFWF EZG Number[2]	Project Title	Total Project Costs[3]	NFWF Project Descriptions
				be achieved by modifying the water diversion method to provide unimpeded fish-passage at the point of diversion, improved water conveyance from the point of diversion to the earthen ditch system, and the installation of a permanent fish-screen and bypass return.
2018	61495	Patterson Creek, Scott Valley, CA. Accelerated Wood Recruitment Project Phase 2	$178,934	The project will treat a 280 meter of Patterson Creek, a Scott River westside, perennial cold water tributary with large wood utilizing the accelerated, unanchored wood technique in order to provide short term habitat benefits to coho by converting the current exclusively riffle/run habitat type to a steam morphology that includes pools, while simultaneously providing immediate cover and in-stream nutrients to improve juvenile rearing, while long-term benefits of improved geomorphic function, floodplain connectivity and increased side channel and off channel rearing habitat and habitat cover and complexity accrue. Eco Forest Management, USFWS, NOAA, CCC will be partners in this project with the goal of maintaining and improving habitat cover and complexity at this important coldwater refugia site.
2018	61488	Restoration design on French Creek, Scott Valley to address limiting factors for recovery of coho salmon and provide sustainable and lasting ecological benefit.	$107,664	In order to enhance coho salmon summer and winter rearing habitat, this project will undertake a professional geomorphic and biological evaluation of existing conditions of a 800 ft long, 4.5 acre reach of French Creek, tributary to the Scott River, a high value coho (and other salmonid) spawning and rearing cold water tributary of the Scott River, Siskiyou County, and its adjacent floodplain, leading to a 100 percent restoration design, and state permitting with planned implementation within 2 years. Building on information gathered in the CEF Funded "Watershed-Scale Floodplain Restoration to Enhance and Increase Juvenile Coho Salmon Off-Channel Summer Rearing and Overwintering Habitat in the Scott River Watershed—Phase 1, Restoration Planning", and other restoration investments on French Creek, project partners will leverage the on-going efforts by NOAA, USFWS, CDFW, SRCD, NCRWQCB and NRCS to continue restoration in the reach.

[1] – There have been 3 grant cycles (2016, 2017, and 2018) and the grant year is based on the grant cycle (year in which application is due) not the year the contract is signed or funds awarded.

[2] – NFWF EZG Number is a unique identifier from the National Fish and Wildlife Foundation for the Bureau of Reclamation's Klamath Coho Habitat Restoration Program to tack grant processes.

[3] – The Total Project Costs are based on the full proposal grant application as submitted to NFWF and may be different than the actual grant award and contract amount.

** - Full funding for NFWF EZG Number 61488 in the 2018 grant year has not been approved due to continuing evaluations. It was included in the tables and summaries because it is still under consideration.

Table 8-16. The Reclamation's Klamath Coho Habitat Restoration Program funds restoration projects in the Lower and Middle Klamath River Basin (downstream of IGD including all tributaries) through the National Fish and Wildlife Foundation (NFWF). The restoration program improves coho habitats and provides funds for planning, design and implementation of projects. The information is from the full proposal grant applications and therefore may be different than the actual grant award and contract (*see* red text).

Grant Year	NFWF EZG Number	Project Title	Basin[1]	Stream[2]	Reclamation Project Type[3]	Coho Funding[4, 5]	Matching Funds[4]
2016	52200	Middle Klamath Coho Refuge Habitat Enhancement - Planning and Design Team Support	Klamath	Klamath River	Planning Design	$60,000	$15,000
2016	52177	Horse Creek Wood Loading	Klamath	Horse Creek	Planning Design	$99,429	$85,565
2016	52170	Increasing Year-Round Rearing Capacity and Habitat Quality for Natal and Non-Natal Populations of Coho Salmon in a Priority Lower Klamath Tributary (McGarvey Creek)	Klamath	McGarvey Creek	Planning Design Implementation	$108,911	$105,373
2016	52166	Parks Creek Fish Passage Implementation Project	Shasta	Parks Creek	Design Implementation	$114,979	$364,322
2016	52141	Development of Cold Water Habitat for Coho Salmon	Shasta	Shasta River	Design Implementation	$235,573	$56,000
2016	52139	Bogus Creek Fish Passage for Coho Salmon	Klamath	Bogus Creek	Implementation	$61,005	$1,137,615
2016	52070	Cold Creek Coho Passage and Screening Project	Klamath	Cold Creek	Implementation	$116,055	$96,720
2016	51708	Lower French Creek Off-Channel Habitat Development	Scott	French Creek	Implementation	$74,981	$39,755
2016	51703	Klamath National Forest Coho Habitat Enhancement in Horse Creek, China Creek and Little Horse Creek	Klamath	Horse Creek China Creek Little Horse Cr	Planning Design	$184,497	$299,560
2016	51674	Parks Creek Fish Passage Design and Planning: Cardoza Ranch	Shasta	Parks Creek	Planning Design	$160,984	$25,006
2016	51627	Lower Yreka Creek Restoration Project	Shasta	Yreka Creek	Implementation	$96,000	$62,259
2016	51545	Lower Beaver Creek Coho Salmon Off-Channel Habitat Restoration	Klamath	Beaver Creek	Planning Design	$72,428	$65,000
2017	57875	Lower Mill Creek Habitat Enhancement for Coho Salmon - Phase II	Shasta	Mill Creek	Design	$63,019	$3,100
2017	57953	Lower Scott Valley Stream Habitat Restoration	Scott	Scott River	Planning Design Implementation	$185,348	$144,985
2017	57952	Horse Creek Supplemental Design Project	Klamath	Horse Creek	Design	$131,541	$104,641
2017	57608	Restoring a critical population of coho salmon in the Klamath River Basin (CA) by restoring floodplain habitat, monitoring, and designing additional restoration features.	Scott	Sugar Creek	Planning Design Implementation	$255,875	$121,452

Grant Year	NFWF EZG Number	Project Title	Basin[1]	Stream[2]	Reclamation Project Type[3]	Coho Funding[4, 5]	Matching Funds[4]
2018	61742	Klamath River at Horse Trough Springs: Floodplain Connection Design Project	Klamath	Klamath – Horse Trough Springs	Planning Design	$115,615	$140,176
2018	61728	South Fork Scott River Floodplain Restoration Project	Scott	South Fork Scott River	Design Implementation	$167,567	$102,761
2018	61688	Fort Goff Fish-Passage and Diversion Improvement	Klamath	Fort Goff Creek	Design Implementation	$121,861	$109,250
2018	61495	Patterson Creek, Scott Valley, CA. Accelerated Wood Recruitment Project Phase 2	Scott	Patterson Creek Scott River	Design Implementation	$104,299	$74,635
2018	61488**	Restoration design on French Creek, Scott Valley to address limiting factors for recovery of coho salmon and provide sustainable and lasting ecological benefit.	Scott	French Creek	Design	$81,299	$26,365

[1] – The basin is separated by mainstem Klamath and its tributaries, except Scott, Shasta, and/or Trinity River Basins. Those basins are listed separately.

[2] – The stream is the actual waterbody the work is being conducted on and any associated tributary reaches.

[3] – The project type is from Reclamation's tracking sheets on project types. NFWF uses different tracking metrics, which includes: 1) Planning, Research, and Monitoring; 2) Habitat Restoration; 3) Habitat Management; and 4) Capacity, Outreach, Incentives categories.

[4] – The costs listed are from the full proposals submitted to NFWF, except those in red text. These amounts may be different than the actual grant award and contract amount.

[5] – Funding amounts in red text are different from the full proposal amounts and are based on amounts listed by NFWF as awarded amounts in their annual reviews.

** - Full funding for NFWF EZG Number 61488 in the 2018 grant year has not been approved due to continuing evaluations. It was included in the tables and summaries because it is still under consideration.

Table 8-17. The amount of NFWF's awards is based on several budgetary items listed in the applicant's full proposal. These costs in these categories are estimated by the applicant and are the basis of the NFWF's award amounts and may vary from the amount in

Grant Year	NFWF EZG Number	Personnel Cost[1]	Travel Costs	Equipment Cost	Materials & Supplies Costs[2]	Contractual Services[3] (Construction)[4]	Other Direct Costs[5]	Indirect Costs[6]	NFWF Project Costs[7]
2016	52200	$14,600.25	$980.00	$0.00	$194.75	$38,500.00 (0)	$0.00	$5,725.00	$60,000.00
2016	52177	$52,196.80	$4,968.00	$0.00	$7,971.00	$20,159.00 (0)	$0.00	$14,133.35	$99,428.15
2016	52170	$75,736.31	$0.00	$0.00	$11,742.00	$0.00 (0)	$0.00	$21,432.19	$108,910.50
2016	52166	$14,372.36	$762.30	$0.00	$1,225.00	$20,320.00 **($15,000)***	$58,639.50	$19,660.07	$114,979.23
2016	52141	$9,270.78	$0.00	$0.00	$60,302.00	$166,000.00 **($135,000)**	$0.00	$0.00	$235,572.78
2016	52139	$800.03	$0.00	$0.00	$0.00	$43,000.00 **($38,000)**	$0.00	$7,205.10	$51,005.13
2016	52070	$8,000.28	$1,200.42	$0.00	$26,250.00	$47,600.00 **($37,600)**	$16,610.00	$16,394.07	$116,054.77
2016	51708	$17,833.20	$575.00	$0.00	$0.00	$43,450.00 **($32,250)**	$6,306.25	$6,816.44	$74,980.89
2016	51703	$55,448.88	$7,829.46	$0.00	$10,193.00	$84,800.00 **($81,000)**	$0.00	$26,225.56	$184,496.90
2016	51674	$9,413.52	$540.00	$0.00	$0.00	$148,030.00 (0)	$3,000.00	$0.00	$160,983.52
2016	51627	$0.00	$0.00	$0.00	$0.00	$87,272.70 **($87,272)***	$0.00	$8,727.30	$96,000.00
2016	51545	$22,427.88	$0.00	$0.00	$0.00	$50,000.00 (0)	$0.00	$0.00	$72,427.88
2017	57875	$34,491.60	$594.00	$0.00	$3,121.00	$17,843.00 (0)	$1,240.00	$5,728.91	$63,018.51
2017	57953	$30,279.48	$810.00	$0.00	$9,325.00	$124,025.00 **($25,000)**	$4,059.00	$16,849.85	$185,348.33
2017	57952	$45,572.80	$3,635.12	$0.00	$1,885.00	$54,140.00 (0)	$0.00	$26,308.23	$131,541.15
2017	57608	$62,098.40	$3,392.00	$0.00	$9,710.00	$235,106.00 **($34,400)**	$14,000.00	$20,719.54	$345,025.94
2018	61742	$37,076.00	$2,278.10	$0.00	$0.00	$54,057.00	$0.00	$22,203.82	$115,614.92

Grant Year	NFWF EZG Number	Personnel Cost[1]	Travel Costs	Equipment Cost	Materials & Supplies Costs[2]	Contractual Services[3] (Construction)[4]	Other Direct Costs[5]	Indirect Costs[6]	NFWF Project Costs[7]
						(0)			
2018	61728	$16,448.00	$0.00	$0.00	$0.00	$131,228.00 **($59,473)**	$0.00	$19,890.54	$167,566.54
2018	61688	$16,460.10	$1,150.05	$0.00	$15,175.00	$72,770.00 **($56,790)**	$500.00	$15,805.72	$121,860.87
2018	61495	$29,640.00	$545.00	$0.00	$2,850.00	$58,600.00 **($32,800)**	$2,025.00	$10,639.20	$104,299.20
2018	61488	$33,215.00	$273.00	$0.00	$7,300.00	$28,800.00 (0)	$3,000.00	$8,710.56	$81,298.56
Total Costs	---	$585,382	$29,532	$0	$167,244	$1,525,701 **($532,313)**	$109,380	$273,175	$2,690,414
Percent Of Total	---	21.8%	1.1%	0.0	6.2%	56.7% **(19.8%)**	4.1%	10.2%	100.0%

[1] – Personnel Costs include a variety of tasks; such as project oversight, permitting, data collection and management, office personnel for administering the grant, etc.

[2] – Material Costs include a variety of items; such as water quality meters, temperature monitoring devices, office software, waders, other field equipment, and materials for actual project implementation (e.g., rock, rootwads, trees, coir fabric, etc.).

[3] – Contractual Services includes hired subcontractors (consultants, contractors, permitting entities, oversight personnel, contract administrators, etc.) for a variety of tasks; such as planning, designs, research, monitoring, oversight, permitting, and construction services (e.g., excavators, dump trucks, materials, etc.).

[4] – Construction costs listed **(bolded text in parentheses)** in the contractual services category were separated to delineate the actual amount of funds being used to build/implement a project, especially since most of the allocated funds have been for project planning and design. Construction costs included contractors for excavators, dump trucks, materials acquisition and installation, etc. that were in the Contractual Services category. Some construction costs were listed in the Materials Costs category (denoted by an *) and were not included in the separated amounts.

[5] – Direct Costs include a variety of items; such as office materials and expenses, office rent, software upgrades, company insurance, permitting, audits, etc.

[6] – Indirect Costs includes the Modified Total Direct Cost and is a percentage (range 10%-25%) of the total direct costs less several items.

[7] – The NFWF Project Costs were taken from the full proposals; however, funding amounts in red text are different from the full proposal amounts and are based on amounts listed by NFWF as awarded amounts in their annual reviews. The $51,005.13 was increased to approximately $61,005 and the $345,025.94 was decreased to approximately $255,875.

Table 8-18. NFWF grants also have matching fund requirements that can be either in-kind or a cash match. These amounts were listed in the applicant's full proposal, and the red text numbers were different than those in the award agreements. These costs in these categories are estimated by the applicant and are the basis of the NFWF's award amounts and may vary from the amount in the full proposal.

Grant Year	NFWF EZG Number	NFWF Project Costs (in Cash)[1]	Matching Funds Cash[2]	Matching Funds In-Kind[3]	Total Matching Funds (Cash + In-Kind)	Total Project Costs[4]
2016	52200	$60,000.00	$0.00	$15,000.00	$15,000.00	$75,000.00
2016	52177	$99,428.15	$85,565.00	$0.00	$85,565.00	$184,993.15
2016	52170	$108,910.50	$105,373.40	$0.00	$105,373.40	$214,283.90
2016	52166	$114,979.23	$364,322.30	$0.00	$364,322.30	$479,301.53
2016	52141	$235,572.78	$0.00	$56,000.00	$56,000.00	$291,572.78
2016	52139	$51,005.13	$1,137,615.00	$0.00	$1,137,615.00	$1,188,620.13
2016	52070	$116,054.77	$96,720.00	$0.00	$96,720.00	$212,774.77
2016	51708	$74,980.89	$34,375.00	$5,380.00	$39,755.00	$114,735.89
2016	51703	$184,496.90	$234,560.00	$65,000.00	$299,560.00	$484,056.90
2016	51674	$160,983.52	$0.00	$25,006.00	$25,006.00	$185,989.52
2016	51627	$96,000.00	$62,259.00	$0.00	$62,259.00	$158,259.00
2016	51545	$72,427.88	$0.00	$65,000.00	$65,000.00	$137,427.88
2017	57875	$63,018.51	$0.00	$3,100.00	$3,100.00	$66,118.51
2017	57953	$185,348.33	$112,720.00	$32,265.00	$144,985.00	$330,333.33
2017	57952	$131,541.15	$78,541.00	$26,100.00	$104,641.00	$236,182.15
2017	57608	$345,025.94	$62,708.00	$58,744.00	$121,452.00	$466,477.94
2018	61742	$115,614.92	$140,176.00	$0.00	$140,176.00	$255,790.92
2018	61728	$167,566.54	$85,761.00	$17,000.00	$102,761.00	$270,327.54
2018	61688	$121,860.87	$109,250.00	$0.00	$109,250.00	$231,110.87
2018	61495	$104,299.20	$30,335.00	$44,300.00	$74,635.00	$178,934.20
2018	61488**	$81,298.56	$10,000.00	$16,365.00	$26,365.00	$107,663.56
Total Costs	---	$2,690,413.77	$2,750,280.70	$429,260.00	$3,179,540.70	$5,869,954.47
Percent Of Total[5]	---	45.8	46.9	7.3	54.2	100.0

[1] – The costs listed are from the full proposals submitted to NFWF, including those in red text. Funding amounts in red text may be different from amounts listed by NFWF as awarded amounts in their annual reviews. These amounts may be different than the actual grant award and contract amount.

[2] – Matching Funds Cash includes all cash contributions from other funding sources, but also includes: (1) previously awarded funds from Reclamation restoration programs (including the Bureau of Reclamation Klamath Coho Habitat Restoration Program); (2) use of owned equipment; and (3) previously expended funds on other portions of the project.

[3] – Matching Funds In-Kind includes all non-cash project contributions, donations, and personnel volunteer hours. Some projects listed matching funds for the same personnel completing identical tasks in different budget sections. Since materials can be donated by a landowner, some projects used materials as in-kind contributions.

[4] – The Total Project Costs category includes both the cash contribution from NFWF award and all listed matching funds (Cash and In-Kind).

[5] – The “Percent of Total” row does not add up to 100 percent because two columns (Matching Funds Cash and Matching Funds In-Kind) are a subset of the Total Matching Funds category.

** - Full funding for NFWF EZG Number 61488 in the 2018 grant year has not been approved due to continuing evaluations. It was included in the tables and summaries because it is still under consideration.

Table 8-19. There have been three grant cycles (2016, 2017, and 2018) and each year NFWF solicits applications/interest through a pre-proposal process. Pre-proposals are evaluated and a select number are invited to submit full-proposals. Once full-proposals are submitted, these are evaluated and rated and then certain full-proposals are selected for funding.

Grant Cycle Or Year	**Number of Pre-Proposals**	**Number of Full-Proposals**	**Number of Proposals Funded (NFWF and PacifiCorp)**	**Number of Proposals Funded (PacifiCorp)***
2016	31	12	12	0
2017	20	9	4	4
2018	11	10	4 (1**)	5
Totals	62	31	21	9

* - PacifiCorp's funding was not in-place for the 2016 grant cycle (year).

** - Full funding for NFWF EZG Number 61488 in the 2018 grant year has not been approved due to continuing evaluations. It was included in the tables and summaries because it is still under consideration.

8.9. Cumulative Effects (Impacts of Future State, Tribal, Local, or Private Actions)

Cumulative effects include the impacts of future state, tribal, local, or private actions that are reasonably certain to occur in the Action Area (50 C.F.R. 402.02). Tribal lands are excluded from the designation of critical habitat for the SONCC coho salmon ESU, and there are no Tribal actions that are reasonably certain to occur within the area of the action subject to consultation. Future federal actions will be subject to the consultation requirements established in section 7 of the Act, and therefore are not considered cumulative to the PA. Cumulative effects are discussed below.

The action area for Cumulative Effects analyses for SONCC coho salmon includes the mainstem Klamath River and all tributaries downstream of IGD. Many of the Cumulative Effects occur in the tributary basins, especially for restoration, mining, timber harvest, and agricultural activities. The impacts to the mainstem Klamath River and tributaries upstream of IGD were not evaluated in this BA for coho salmon due to restricted upstream access; however, if the dams are removed, then a re-initiation trigger will be met and the Keno Impoundment to IGD will need to be incorporated for anadromous fish species.

8.9.1. Fish Hatcheries

The information available indicates that the influence of the hatchery stocking program on the genetic fitness of natural-origin coho salmon populations in the Klamath and Trinity Rivers is significant. NMFS (2010, 2013) stated that they anticipated hatchery releases to remain constant into the near future. However, the primary factors affecting the diversity of SONCC ESU coho salmon can be attributed to low population abundance, the influence of hatcheries, and out-of-basin introductions (NMFS 2013). Furthermore, the future condition for naturally produced coho salmon populations may be continually degraded due to detrimental impacts from density-dependent mechanisms in the freshwater environment. For example, mainstem natural-origin juvenile coho salmon during the winter rearing period may be significantly impacted when the effects of future releases of juvenile salmonids from IGH are added to the environment.

There are differences between hatchery and wild fish due to the differences between artificial and natural environments (Hey et al. 2005) that manifest in changes in morphology and life-history traits (Kostow 2004) and behavior (Fleming et al. 1997, Olla et al. 1998). Flagg et al. (2000) found that, depending on the carrying capacity of the system, increasing release numbers of hatchery fish often negatively impacts naturally-produced fish because these fish can get displaced from portions of their habitat. Competition between hatchery and naturally-produced salmonids can also lead to reduced growth of naturally produced fish (McMichael et al. 1997). Reclamation’s PA may lead to increased use and competition for limited suitable habitat for juvenile coho (fry and parr) due to altered flow regimes. Also, habitat conditions of refugia zones are not always conducive for coho salmon because several thousand fish can be crowded into small areas, particularly during hatchery releases. Crowding leads to predator aggregation and increased competition, which triggers density dependent mechanisms.

8.9.2. Habitat Restoration – PacifiCorp

PacifiCorp, which owns and operates the Klamath Hydroelectric Project, developed a Habitat Conservation Plan for coho salmon. As part of PacifiCorp's conservation strategy, the Klamath River Coho Enhancement Fund was developed to fund projects that will restore, enhance, and improve habitat, flows, and fish passage for the SONCC coho salmon in the Klamath River and/or its tributaries downstream of Iron Gate Dam. In order to be eligible for funding, projects must have a direct benefit to SONCC coho salmon and address one or more of PacifiCorp's Habitat Conservation Plan for coho Salmon goals.

Funding priorities for this program include:

- Barrier removal projects that improve access to critical habitat;
- Rearing habitat creation and enhancement;
- Water transaction funding to increase instream flows during low water levels to improve water quality and quantity; and
- Mainstem and tributary habitat creation, enhancement and protection projects.

PacifiCorp provides approximately $500,000 annually to the Coho Enhancement Fund. Since 2009, the Klamath River Coho Enhancement Fund has awarded over $2.4 million to 26 projects. These projects will leverage over $6.4 million in additional matching funds and in-kind contributions. The projects awarded meet the Habitat Conservation Plan goals, including the improvement of fish passage and connectivity, spawning and rearing habitat enhancements, and flow augmentation through water transactions.

For the past two years, PacifiCorp and Reclamation have combined their Request for Proposal process since both programs enhance the survival and recovery of coho salmon.

8.9.3. Agriculture Practices

Off-project agricultural operations on Klamath River tributaries, if unaltered, will continue to reduce the quantity, and alter the timing, of water availability and may negatively affect riparian and wetland habitats through upland modifications that lead to increased siltation or reductions in water flow in stream channels. Grazing activities from dairy and cattle operations can degrade or reduce suitable critical habitat for ESA-listed coho salmon by increasing erosion and sedimentation, as well as introducing nitrogen, ammonia, and other nutrients into the watershed. Storm water and irrigation discharges related to both agricultural and urban activities contain numerous pesticides and herbicides that may negatively affect salmonid reproductive success and survival rates. Furthermore, agricultural practices can alter the hydrograph (e.g., timing of peak runoff, base flows, return flows and contamination, etc.) and therefore impact salmonid habitats.

Also with agricultural practices, the cultivation of marijuana, legal and illegal, can also impact salmonid habitats. Watersheds within the action area have been used to produce marijuana crops both legally and illegally. Illegal marijuana production within the action area can result in grow operations of over 100,000 plants; often these illegal grow operations occur on federal lands. These grow operations can adversely affect coho salmon habitat by diversion of water for irrigation, resulting in the drying of streams or draining of pools that provide rearing habitat for coho salmon juveniles. The operations can also contaminate nearby streams by the discharge of pesticides, rodenticides, and fertilizers to nearby streams. Such influx of contaminants can be lethal to exposed coho salmon or result in the alteration of stream habitats via eutrophication.

8.9.4. Timber Harvest

Timber harvest/management activities allow more water to reach the ground and alters the timing of water releases. These impacts may alter water infiltration into forest soils such that less water is absorbed or the soil may become saturated faster, thereby increasing surface flow. Road systems, skid trails, and landings where the soils become compacted also accelerates runoff (NMFS 2010). Although the adverse effects from timber harvest are expected to continue for the 10-year duration of the PA, and for years to follow, the adverse effects from past timber management practices should decrease through implementation of improved Best Management Practices and via allowing time for poor land management activities to heal.

Timber harvest has effected fish habitat conditions in the Klamath River Basin by removal of streamside vegetation, providing avenues for sediment delivery, increases in disturbances, and alteration of vegetative communities, which can affect large woody debris recruitment and fire regimes. Timber harvest of streamside trees during the early and middle 1900s reduced large woody debris recruitment and contributed to elevated stream temperatures, particularly along the Klamath mainstem and along the lower reaches of the Scott River.

Sedimentation from modern-day harvest units, harvest-related landslides and an extensive road network continues to impact habitat although at much reduced levels as compared to early logging. Ground disturbance, compaction, and vegetation removal during timber harvest has modified drainage patterns and surface runoff resulting in increased peak storm flows which has increased occurrences of channel simplification and channel aggradation. Simplification of stream channels and sediment aggradation results in loss or destruction of salmonid habitat as pool complexes and side channel winter rearing habitat are often lost or degraded to such an extent as to no longer provide refugia for developing juveniles.

Control of wildland fires may include the removal or modification of vegetation due to the construction of firebreaks or setting of backfires to control the spread of fire. This removal of vegetation can trigger post-fire landslides as well as chronic sediment erosion that can negatively affect downstream coho salmon habitat. Also, the use of fire retardants may adversely affect salmonid habitat if used in a manner that does not sufficiently protect streams causing the potential for coho salmon to be exposed to lethal amounts of the retardant. This exposure is most likely to affect summer rearing juvenile coho salmon. As wildfires are unpredictable events but are increasing in frequency and severity, it cannot be determined the extent to which suitable coho salmon habitat may be degraded or modified by these wildfire and suppression activities.

8.9.5. Mining

Although the adverse effects from mining are expected to continue for the 10-year duration of the PA, and for years to follow, future Baseline conditions will likely improve as adverse effects from past poor mine management practices decrease through time. Mining activities within the Klamath River Basin began prior to 1900. Many of the communities in the Klamath River Basin originated with the gold mining boom of the 1800s. Water was diverted and pumped for use in sluicing and hydraulic mining operations. This resulted in dramatic increases in turbidity levels altering stream morphology. The negative impacts of stream sedimentation on fish abundance were observed as early as the 1930s. Mining operations adversely affected spawning gravels, which resulted in increased poaching activity, decreased survival of fish eggs and juveniles, decreased benthic invertebrate abundance, adverse effects to water quality, and impacts to stream banks and channels. Since the 1970s, large-scale commercial mining operations have been eliminated due to stricter environmental regulations.

Since August 6, 2009, all California instream suction dredge mining was suspended following the Governor's signature on a new state law. The moratorium on instream suction dredge mining took effect immediately as an urgency measure, prohibiting the use of vacuum or other suction dredging equipment for instream mining in reliance on any permit previously issued by CDFW (CDFG 2010). On July 26, 2011, Assembly Bill 120 was signed into State law, which extended the moratorium until June 30, 2016. On August 25, 2018, Assembly Bill 120 was amended and extended until the 2019-2020 budget session.

Mining, even historic mining, can alter sediment inputs and transport of gravels needed for salmonid habitat. Many reaches of Klamath River and its tributaries have been placer mined and the remnant tailings piles indirectly affect the diversity of stream habitat that might otherwise be available. Many of these tailing piles are too large for the adjacent watercourse to reshape. These reaches may also alter the quantity and quality of spawning gravels and therefore impact salmonid production. Altering the hydrograph, can impair sediment transport and impact gravel accumulation in critical areas for salmonids.

8.9.6. Residential Development and Infrastructure

Human population growth in the action area is expected to remain relatively stable and some development will continue to occur which, on a small-scale, can impact coho salmon habitat. Once development and associated infrastructure (e.g., roads, drainage, and water development) are established, the impacts to aquatic species are expected to be permanent. Anticipated impacts to aquatic resources include loss of riparian vegetation, changes to channel morphology and dynamics, altered hydrologic regimes (increased storm runoff), increased sediment loading, and elevated water temperatures where shade-providing canopy is removed. The infrastructure and roads waters may lead to the removal of large woody debris. There are also effects of home pesticide use, roadway runoff of automobile pollutants, introductions of invasive species to nearby streams and ponds, attraction of salmonid predators due to human occupation (e.g., raccoons), increased incidences of poaching, and loss of riparian habitat due to land clearing activities. These factors associated with residential development can have negative impacts on salmon populations.

8.9.7. Recreation

Expected recreation impacts to salmonids include increased turbidity, impacts to water quality, barriers to movement, and changes to habitat structures. Streambanks, riparian vegetation, and spawning redds can be disturbed wherever human use is concentrated. Campgrounds can impair water quality by elevating nutrients in streams. Construction of summer dams to create swimming holes causes turbidity, destroys and degrades habitat, and blocks migration of juveniles between summer habitats. Impacts to salmonid habitat are expected to be localized, mild to moderate, and temporary. Fishing within the action area, typically for steelhead or Chinook salmon, is expected to continue subject to CDFW regulations. Fishing for coho salmon directly is prohibited in the Klamath River. The level of impact to coho salmon within the action area from angling is unknown, but is expected to remain at current levels.

8.10. Determination on Effects of the Proposed Action on Coho Salmon and Designated Critical Habitat

After considering the best available scientific and commercial information, the analysis indicates that coho salmon are likely to be exposed to environmental consequences and will respond in a negative manner to the exposure. Thus, Reclamation concludes that implementing the PA may affect, and is likely to adversely affect coho salmon and their designated critical habitat.

9. SOUTHERN RESIDENT DISTINCT POPULATION SEGMENT KILLER WHALE

9.1. Southern Resident Killer Whale Species Status

SRKWs are a DPS within the genus *Orcinus*. They differ from other resident killer whales genetically, in culturally transmitted traits such as vocal behavior, and in range. Residents differ from other killer whales in diet and morphology as well. SRKWs consist of three pods (matrilineally related whales that normally travel together) known as J, K, and L.

SRKWs spend most of their time between Central California and Southern British Columbia but have been sighted as far north as Southeast Alaska. They feed on fish, primarily salmon, with a strong preference for Chinook salmon. They are listed as “Endangered” under the ESA in the United States and the Species at Risk Act in Canada. Both countries have designated most of their respective portions of the Salish Sea as Critical Habitat. Prey are a Primary Constituent Element of Critical Habitat. National Oceanic and Atmospheric Administration (NOAA) Fisheries is reviewing a petition to expand Critical Habitat to include Pacific coastal waters from Monterey Bay in California to Neah Bay in Washington.

Recent data on movement patterns indicate K and L pods regularly travel back and forth between Washington and California in the winter and spring, while J Pod remains in Washington and British Columbia year-round (https://www.nwfsc.noaa.gov/news/features/killer_whale_report/pdfs/bigreport62514.pdf). While on the Pacific coast, K and L pods move back and forth between Cape Mendocino and the Oregon-California line, presumably to take advantage of concentrations of Chinook salmon returning to the Klamath River. Subadult Klamath River Chinook range more widely and would be part of the SRKW diet while they are moving from the Klamath to the Sacramento or Columbia Rivers. The overlap in range between SRKWs and salmon reared in the Klamath River form a discontiguous Action Area where impacts of operations on juvenile salmon later influence survival and reproduction of SRKWs.

9.1.1. Legal Status and Trend

The SRKW was listed as “depleted” under the Marine Mammal Protection Act on May 29, 2003 (68 FR 31980), and “endangered” under the ESA on November 18, 2005 (NMFS 2005b). A Proposed Conservation Plan was announced in 2005 (70 FR 57565). NMFS (2008b) subsequently published a recovery plan for SRKWs in 2008.

NMFS (2006b) designated critical habitat for SRKWs on November 29, 2006. The following physical or biological critical habitat features are identified as essential to this species 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. NMFS (2006b) identified three “specific areas” within the geographical area occupied by the species, which contain these important physical or biological features: (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. These critical habitat areas comprise approximately 2,560 square miles of marine habitat within the area occupied by SRKWs in Washington.

Although K and L pods constitute most of the SRKW population and spend most of the year on the Pacific coast from Central California to the West Coast of Vancouver Island, none of this area is currently included in critical habitat. (An update on critical habitat has been prepared by the Western Region and is working through approvals as of October 2018. Due to the length of time it is taking to update the Critical Habitat decision, the Center for Biological Diversity filed a 60-day notice of intent to sue to try to expedite the decision.).

Prior to European contact, there probably would have been between 1,000 and 2,000 SRKWs, based on estimated historical prey, current genetic diversity, and the limited viability of small populations (Bain 2013). In the mid nineteenth century, the prey base began a long-term decline due to spawning habitat damage, increased commercial fishing, and dams and other developments restricting access to spawning habitat (Heise et al. 2008).

By 1960, the SRKW population was probably reduced to about 100 individuals. Collections for public display further reduced the population to 67. Following the end of captures, the population quickly rebounded to 79, and then fluctuated up to 98, marking recovery from the collections for public display by 1995 (Bain and Balcomb 1999). Then there was a nearly 20 percent decline to 81 individuals in 2001. Subsequently, the population fluctuated and then experienced another rapid decline (10 percent in 18 months), reducing the population to 75 individuals in July of 2018 (Center for Whale Research, unpublished data). An additional individual was lost later in the summer.

Annual census results for SRKWs are shown in Table 9-1 and Figure 9-1.

Table 9-1. Southern Resident Killer Whale population and pod sizes in Washington and British Columbia, 1974 to 2018. Source: Center for Whale Research.

Year	J POD	K POD	L POD	TOTAL
1974	15	16	39	70
1975	15	15	41	71
1976	16	15	40	71
1977	18	16	46	80
1978	18	16	46	80
1979	19	16	47	82
1980	19	16	49	84
1981	19	16	47	82
1982	19	15	45	79
1983	19	14	43	76
1984	17	14	43	74

Year	J POD	K POD	L POD	TOTAL
1985	18	14	45	77
1986	17	16	48	81
1987	18	17	49	84
1988	19	18	48	85
1989	18	17	50	85
1990	18	17	53	88
1991	20	17	55	92
1992	19	16	56	91
1993	21	17	59	97
1994	20	19	57	96
1995	22	18	58	98
1996	22	19	56	97
1997	21	19	52	92
1998	22	18	49	89
1999	20	17	48	85
2000	19	16	47	82
2001	20	17	41	78
2002	20	18	41	79
2003	22	19	41	82
2004	22	20	41	83
2005	23	21	44	88
2006	24	21	44	89
2007	25	19	42	86
2008	25	19	41	85
2009	26	19	40	85
2010	28	19	39	86
2011	26	19	42	87
2012	25	19	40	84
2013	26	19	37	82
2014	25	19	34	78
2015	27	19	35	81
2016	29	19	35	83
2017	24	18	35	77
2018	23	18	34	75
OCT. 1, 2018	22	18	34	74

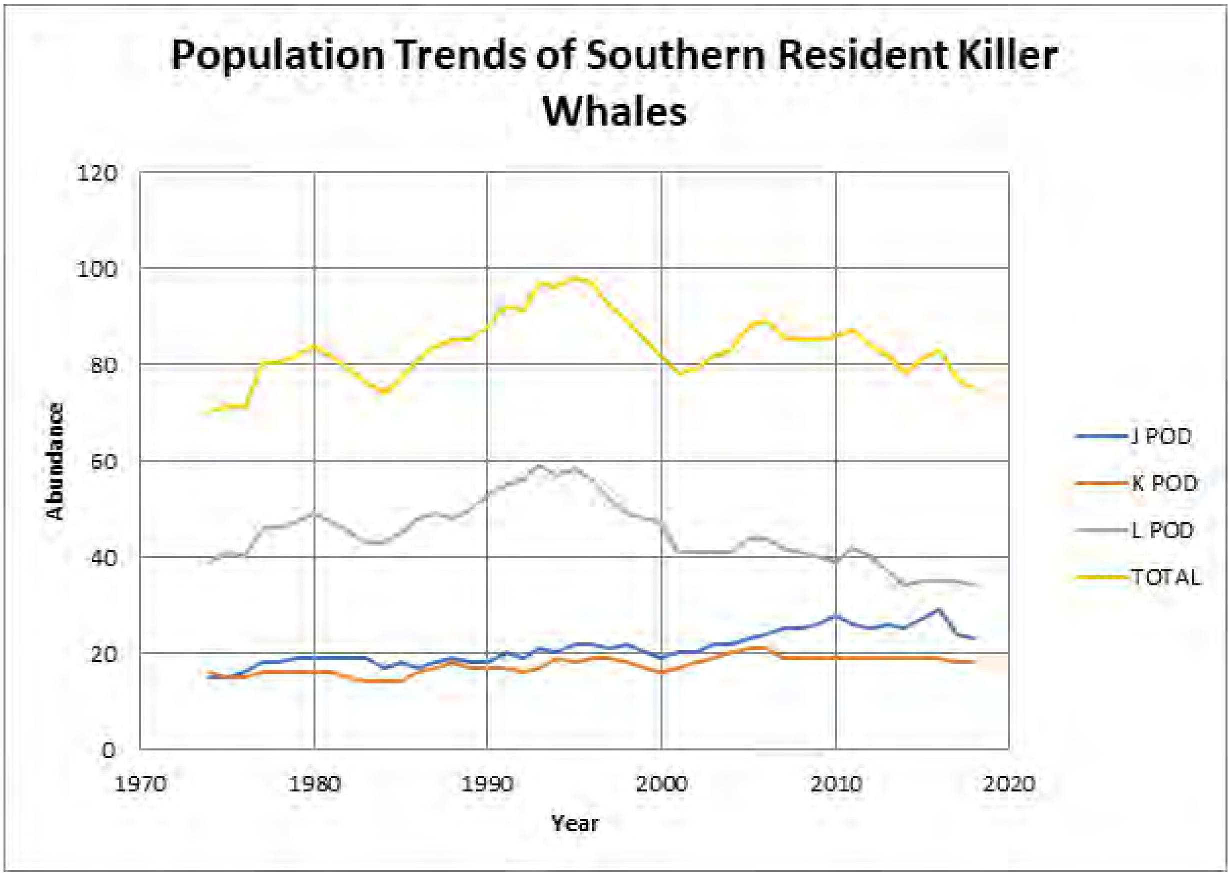

Figure 9-1. Population trends of Southern Resident Killer Whales. Counts are based on July 1st population size for all years. The current population shown is for October 1, 2018.
Source: Center for Whale Research (https://www.whaleresearch.com/orcasurvey).

9.1.2. Southern Resident Distinct Population Segment Killer Whale Species Current Condition

The Southern Resident DPS is endangered. It was at 74 individuals as of October 1, 2018 and had declined over 10 percent over the previous two years. It declined by over 20 percent over the last generation (25 years). Viable calves have been recruited in only two of the last 7 years. They are among the populations threatened with collapse due to PCBs (Desforges et al. 2018). The lasting population bottleneck has raised concerns over inbreeding depression.

9.1.3. Description and Distribution

Killer whales (*Orcinus orca)* are the largest members of the family Delphinidae, which includes 17 genera of marine dolphins (Committee on Taxonomy 2017). The sexes show considerable size dimorphism, with males attaining maximum lengths and weights of 9.0 m and 5,568 kg, respectively, compared to 7.7 m and 3,810 kg for females (Wiles 2004). Adult males develop larger pectoral flippers, dorsal fins, tail flukes, and girths than females (Clark and Odell 1999 in Wiles 2004). The dorsal fin reaches heights of 1.8 m and is pointed in males but grows to only 0.7 m and is more curved in females. Killer whales have large paddle-shaped pectoral fins and broad rounded heads with only the hint of a facial beak. The flukes have pointed tips and form a notch at their midpoint on the trailing edge.

Killer whales are easily identifiable by their distinctive black-and-white color pattern, which is among the most striking of all cetaceans. Animals are black dorsally and have a white ventral region extending from the chin and lower face to the belly and anal region (Figure 9-2). The underside of the tail fluke is white or pale gray and may be thinly edged in black. Several additional white or gray markings occur on the flanks and back. These include a small white oval patch behind and above the eye, a larger area of white connected to the main belly marking and sweeping upward onto the lower rear flank, and a gray or white "saddle" patch usually present behind the dorsal fin (Figure 9-2).

9.1.4. Classification in the Pacific Northwest

Three distinct forms of killer whales- residents, transients, and offshores- are recognized in the Pacific Northwest. Although there is considerable overlap in their ranges, these forms display significant genetic differences due to a lack of interchange between member animals (Stevens et al. 1989, Hoelzel and Dover 1991, Hoelzel et al. 1998, Barrett-Lennard 2000, Barrett-Lennard and Ellis 2001, Krahn et al. 2004, Morin et al. 2010). Important differences in ecology, behavior, morphology, and acoustics also exist (Baird 2000, Ford et al. 2000). Members of all three lineages are present from California to eastern Asia (Parsons et al. 2013).

Federally-listed SRKWs are the form being evaluated in this document. Additional lineages of killer whale are now recognized around the world, but older literature did not distinguish among the different types of killer whale. Other forms of killer whale will be discussed briefly below to clarify what information about killer whales in general applies to SRKWs in particular.

9.1.5. Resident Killer Whales

In the northern Pacific, resident killer whales are recognized in four distinct communities: southern, northern, southern Alaska, and western Alaska (Krahn et al. 2002), with additional communities being found off Russia and Japan (Parsons et al. 2013). Stranding records (Morin et al. 2006), along with historical descriptions (Scammon and Cope 1869, Scammon 1874), suggest the range has been stable for at least 150 years. Resident killer whales differ from transient and offshore animals by having a dorsal fin that is more curved and rounded at the tip (Ford et al. 2000). Residents also exhibit at least five patterns of saddle patch pigmentation (Baird and Stacey 1988). They feed primarily on fish, occur in large stable pods typically comprised of 10 to about 60 individuals, and also differ in vocalization patterns (Ford 1989, Felleman et al. 1991, Ford et al. 1998, 2000, Saulitis et al. 2000).

9.1.6. Transient Killer Whales

Transients are not part of the Southern Resident DPS and do not associate with resident and offshore whales despite having a geographic range that is largely sympatric with both forms (Figure 9-3). Recent genetic investigations using both nuclear DNA and mtDNA have found significant genetic differences between transients and other killer whale forms, confirming the lack of interbreeding (Stevens 1989, Hoelzel and Dover 1991, Hoelzel et al. 1998, Barrett-Lennard 2000, Barrett-Lennard and Ellis 2001), with an estimated divergence date from other killer whales of around 700,000 years ago (Morin et al. 2010).

Transients feed on marine mammals, and hence are important in regulating population sizes of competitors to SRKWs.

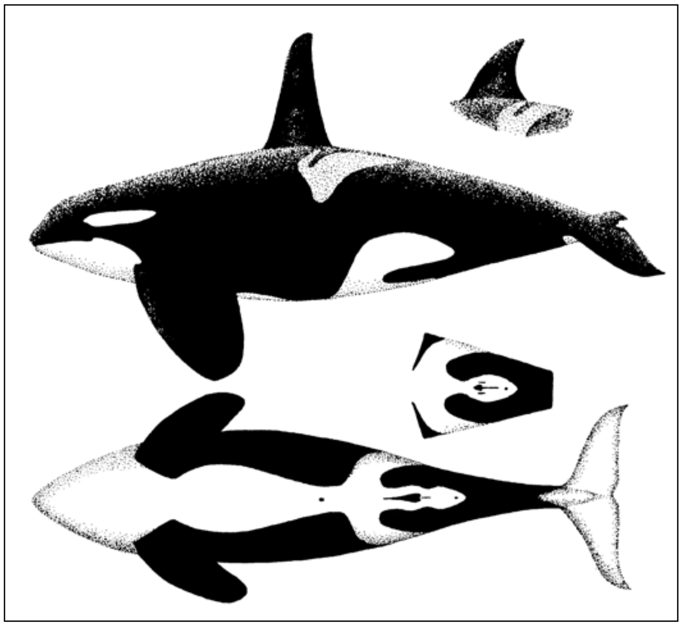

Figure 9-2. Southern Resident Killer Whale Morphological Characteristics.
Source: NMFS 2008.

9.1.7. Offshore Killer Whales

Offshore killer whales are not part of the Southern Resident DPS. Due to a scarcity of sightings, much less information is available for the offshore killer whale population, which was first identified alive in the late 1980's (Ford et al. 1992, 1994, Walters et al 1992), although earlier strandings were subsequently determined to have involved this type (Carl 1946). Records are distributed from southern California to Alaska, including many from western Vancouver Island and the Queen Charlotte Islands (Ford and Ellis 1999, Krahn et al. 2002). Recent data from Alaska has extended the population's range to the western Gulf of Alaska and eastern Aleutians (Wiles 2004, Dahlheim et al. 2008).

9.1.8. Distribution

The southern Resident DPS killer whales consist of three pods, identified as J, K, and L pods. All three pods reside for part of the year in the inland waterways of Washington State and British Columbia (Strait of Georgia, Strait of Juan de Fuca, and Puget Sound), principally during the late spring, summer, and fall (Heimlich-Boran 1988, Felleman et al. 1991, Olson 1998, Osborne 1999, Ford et al. 2000, Krahn et al. 2002). Pods visit coastal sites off Washington and Vancouver Island (Ford et al. 2000) but travel as far south as central California and as far north as Southeast Alaska.

These findings are based on photo-identification. There has been dedicated effort in the Salish Sea since 1974. California sightings reflect opportunistic encounters. Likewise, the Southeast Alaska sighting was opportunistic.

To update distribution data, directed efforts were initiated off the Pacific coasts of California, Oregon, and Washington. Multiple approaches were employed. Ship-based transects were conducted annually in the spring. Bottom-mounted acoustic recorders were placed to detect vocally active Southern Residents that passed within a few miles. Satellite tags were deployed to track selected individuals. In addition, opportunistic sightings by the public were solicited.

Ship-based transects in early spring resulted in sightings of Southern Residents off the Washington Coast.

Bottom mounted recorders revealed K and L pods traveled back and forth between Point Reyes and the outer coast of Washington. J Pod is not known to occur in Oregon or California, although an aerial survey sighting of a large group of killer whales in Northern California (Dohl 1980) may have been of all three SRKW pods.

Satellite tagging of K25 in the winter of 2012 to 2013 revealed repeated trips between Juan de Fuca Strait in Washington and Point Reyes in California. There were back and forth movements across the mouths of the Klamath and Columbia Rivers (NMFS unpublished data, *see* Figure 9-3). The timing of K25's movements correlated with a peak in Klamath River Chinook returns (*see* Figures 9-4 and 9-5).

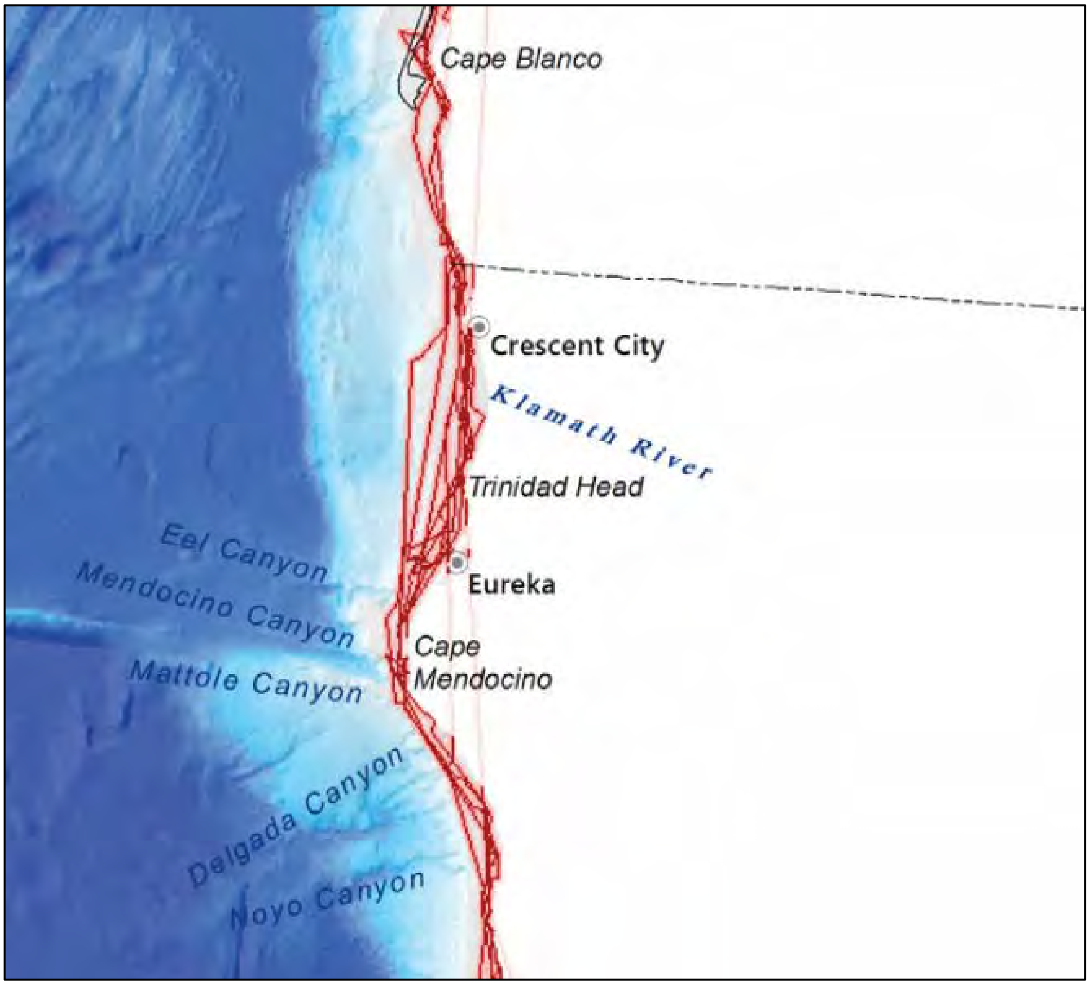

Figure 9-3. Satellite tag track of a Southern Resident showing movement between the Strait of Juan de Fuca and Pt. Reyes. Note repeated short excursions across the mouths of the Klamath and Columbia Rivers.
Source: NOAA Fisheries
https://www.nwfsc.noaa.gov/news/features/killer_whale_report/pdfs/bigreport62514.pdf.

9.1.9. Life History

Social Organization: Killer whales are highly social animals that form long-term associations based on kin called pods, and recurring but intermittent associations based on non-kin factors (Bain 1988, Dahlheim and Heyning 1999, Baird 2000). Mean pod size varies among populations, but often ranges from 2 to 15 animals (Kasuya 1971, Condy et al. 1978, Mikhalev *et al*. 1981, Braham and Dahlheim 1982, Dahlheim *et al*. 1982, Baird and Dill 1996). Larger aggregations of up to several hundred individuals occasionally form but are usually considered temporary groupings of smaller social units that probably congregate near seasonal concentrations of prey, for social interaction, or breeding (Dahlheim and Heyning 1999, Baird 2000, Ford et al. 2000). Of the three SRKW pods, J Pod has ranged in size from 15 to 25, K Pod has varied from 14 to 22, and L Pod has ranged up to 59 individuals since the mid 1970s.

Single whales, usually adult males, also occur in many populations (Norris and Prescott 1961, Hoelzel 1993, Baird 1994). Differences in spatial distribution, abundance, and behavior of food resources probably account for much of the variation in group size among killer whale populations. For example, sympatric populations of resident and transient whales in Washington and British Columbia vary substantially in average pod size. Resident subgroup size is also related to prey density (Lusseau et al. 2004).

Large groups of resident whales are able to detect widely scattered schools of fish, enabling individual members to increase food consumption (Ford et al. 2000) through food sharing. The age and sex structure of killer whale social groups has been reported for populations at several locations. Olesiuk et al. (1990a) reported that pods in Washington and British Columbia were comprised of 19 percent adult males, 31 percent adult females, and 50 percent immature whales of either sex (the SRKWs that travel across the mouth of the Klamath are part of this population). In Alaska, 24 percent of the animals in pods were adult males, 47 percent were either adult females or subadult males, and 29 percent were younger animals (Dahlheim 1997, Dahlheim *et al.* 1997). Globally, calves less than one year of age typically constitute 5 percent of the population (Bain 1990), but high mortality of SRKW calves (Wasser et al. 2017) has resulted in a lower percentage in SRKWs in most years since 1990.

Some of the most detailed studies of social structure in killer whales have been made in British Columbia, Washington, and Alaska during the past few decades, with much information available on group size, structure, and stability, and vocal traits (Ford 1989, 1991, Bigg *et al.* 1990, Matkin et al. 1999b, Ford *et al*. 2000, Yurk et al. 2002). Social organization in this region is based on maternal kinship and may be characteristic of killer whale populations throughout the world (Ford 2002). Few data are available from California and Oregon, but what does exist are consistent with data from British Columbia and Washington.

Vocalizations: Vocal communication is particularly advanced in killer whales and is an essential element of the species’ complex social structure. Like all dolphins, killer whales produce numerous types of vocalizations that are useful in navigation, communication, and foraging (Dahlheim and Awbrey 1982, Ford 1989, Barrett-Lennard et al. 1996, Ford *et al*. 2000). Sounds are made by air forced through structures in the nasal passage and are enhanced and directed forward by a fatty enlargement near the top of the head, known as the melon. Most calls consist of both low- and high frequency components (Bain and Dahlheim 1994). The low-frequency component is relatively omnidirectional, with most energy directed forward and to the sides (Schevill and Watkins 1966).

Diving and Swimming Behavior: Respiration rates of killer whales vary with activity level (Ford 1989). Resident whales have long dives averaging about 3 minutes and rarely exceeding 5 minutes (Morton 1990, Ford and Ellis 1999), followed by a series of short dives lasting 10 to 20 seconds.

Southern residents spend 95 percent of their time underwater, nearly all of which is between the surface and a depth of 30 m (Baird et al. 1998, 2003, Baird 2000). Preliminary information March 2004, 14 Washington Department of Fish and Wildlife indicates that up to two dives per hour are made below 30 m. However, these represent fewer than 1 percent of all dives and occupy less than 2.5 percent of an animal’s total dive time. In the vicinity of the San Juan Islands, maximum dive depths averaged 141 m per animal among seven individuals tagged with time-depth recorders in July 2002 (Baird et al. 2003). One juvenile whale twice exceeded 228 m, causing Baird et al. (2003) to speculate that members of this population are probably capable of diving to 350 m, which is the approximate maximum bottom depth of the core inland waters of their summer range. Miller *et al*. (2010) found both residents and transients dove to over 250 m. The deepest dive reported for a killer whale is over 750 m (Reisinger et al. 2015).

Killer whales normally swim at speeds of 5 to 10 km per hour but can attain maximum speeds of 40 km per hour (Lang 1966, Erickson 1978, Kruse 1991, Williams et al. 2002a). Diving animals reach a velocity of 22 km per hour, or 6 m per second, during descents and ascents. Bursts in speed during dives commonly occur when prey are chased (Baird et al. 2003),

Dispersal/Movements: SRKWs have been sighted in coastal waters from Central California to Southeast Alaska. They have a summer home range in the Salish Sea, which has been recognized as Critical Habitat by the U.S. under ESA and Canada under the Species at Risk Act and has been linked to Chinook salmon returning to the Fraser River (Balcomb et al. 1980, Heimlich-Boran 1986a, 1988, Felleman et al. 1991, Nichol and Shackleton 1996). Defended territories have not been observed around these or other food sources (Dahlheim and Heyning 1999, Baird 2000).

Movement patterns of K and L Pods differ from those of J Pod. K and L Pod are typically seen in the Salish Sea from June through November. In some years, sightings of these pods extend into January. The remainder of the year is typically spent in the Pacific Ocean between Vancouver Island and Monterey Bay.

J Pod appears to remain in British Columbia and Washington throughout the year. They have been seen in the Salish Sea year around, but sightings in inland waters are more common from April through October, and they appear to spend more time in Pacific coastal waters than the Salish Sea the rest of the year.

All three pods have been spending less time in the Salish Sea in the last few years than in the preceding 40 years (Shields et al. 2018).

Killer whales can swim over 200 km per day (Bain unpublished data, with published reports of travel of 160 km per day also reported Erickson 1978, Baird 2000), allowing rapid movements between areas. For example, members of K and L pods once traveled a straight-line distance of about 940 km from the northern Queen Charlotte Islands to Victoria, Vancouver Island, in seven days (J. K. B. Ford and G. M. Ellis, unpubl. data).

Reproduction: Killer whales are believed to mate in the North Pacific from May to October (Nishiwaki 1972, Olesiuk et al. 1990, Matkin et al. 1997). However, small numbers of conceptions apparently happen year-round, as evidenced by births of calves in all months. Gestation periods in captive killer whales average about 17 months (Asper et al. 1988, Duffield et al. 1995). Mean interval between viable calves is four years (Bain 1990). Newborns measure 2.2 to 2.7 m long and weigh about 200 kg (Nishiwaki and Handa 1958, Olesiuk *et al*. 1990, Clark et al. 2000, Ford 2002). Calves remain close to their mothers during their first year of life, often swimming slightly behind and to the side of the mother’s dorsal fin. Weaning age is variable, ranging from 6 months to perhaps 10 years, but nursing typically ends between 1 and 2 years of age (Kastelein et al. 2003). Calves are most vulnerable to mortality in the neonatal period and when their mothers give birth to the next sibling (Bain 1990). In residents, mothers and offspring maintain highly stable social bonds throughout their lives and this natal relationship is the basis for the matrilineal social structure (Bigg et al. 1990, Baird 2000, Ford et al. 2000), although the bond is stronger between mothers and sons than between mothers and daughters (Bain 1988).

Habitat Use: Killer whales frequent a variety of marine habitats with adequate prey resources and do not appear to be constrained by water depth, temperature, or salinity (Baird 2000). Although the species occurs widely as a pelagic inhabitant of open ocean, many populations spend large amounts of time in shallower coastal and inland marine waters, foraging even in inter-tidal areas in just a few meters of water. Killer whales tolerate a range of water temperatures, occurring from warm tropical seas to polar regions with ice floes and near freezing waters. Brackish waters and rivers are also occasionally entered (Scheffer and Slipp 1948, Tomilin 1957). Individual knowledge of productive feeding areas and other special habitats (e.g., beach rubbing sites in the Johnstone Strait) is probably an important determinant in the selection of locations visited and is likely a learned tradition passed from one generation to the next (Ford et al. 1998).

Resident and transient killer whales exhibit somewhat different patterns of habitat use while in protected inland waters, where most observations are made (Heimlich-Boran 1988, Morton 1990, Felleman *et al*. 1991, Baird and Dill 1995). Residents generally spend more time in deeper water and only occasionally enter water less than 5 m deep (Heimlich-Boran 1988, Baird 2000, 2001). Distribution is strongly associated with areas of greater salmon abundance (Heimlich-Boran 1986a, 1988, Felleman *et al*. 1991, Nichol and Shackleton 1996), but research to date has yielded conflicting information on preferred foraging habitats. Several studies have reported that SRKWs feed heavily in areas characterized by high-relief underwater topography, such as subsurface canyons, seamounts, ridges, and steep slopes (Heimlich-Boran 1988, Felleman et al. 1991). Such features may limit fish movements, thereby resulting in greater prey availability, and be used by the whales as underwater barriers to assist in herding fish (Heimlich-Boran 1988).

Diet: As top-level predators, killer whales feed on a variety of marine organisms ranging from fish to squid to other marine mammal species. Chinook salmon reportedly comprise over 71 percent of the identified salmonids taken by resident killer whales (Ford and Ellis 2006). Ford and Ellis (2006) and Hanson et al. (2010) found that Chinook salmon comprise at least 84 percent of the diet of SRKWs while the whales are in the Puget Sound/Juan de Fuca Strait area. SRKW survival and fecundity are correlated with Chinook salmon abundance, further indicating a Chinook salmon dietary preference (Ward et al. 2009, Ford *et al*. 2009). Ford and Ellis (2006) indicated that coastal killer whale populations also consume other salmonids in smaller proportions, including chum (*O. keta*, 22 percent of the diet) pink (*O. gorbuscha*, 3 percent), coho (*O. kisutch*, 2 percent), and sockeye (*O. nerka*, less than 1 percent) salmon, and steelhead (*O. mykiss*, less than 1 percent) while in British Columbia waters. Chemical analyses of killer whale fatty acids and contaminant ratios are also consistent with a salmon diet in killer whales (OCAP BA, 2008). The primary prey at greater depths may be Chinook salmon, which swim at depths averaging 25-80 m and extending down to 300 to 400 m (Candy and Quinn 1999). Other salmonids mostly inhabit the upper 30 m of the water column (Quinn and Hart 1987, Quinn et al. 1989, Ruggerone et al. 1990).

Resident killer whales exhibit two basic foraging patterns. One is hotspot based. Salmon concentrate where physical barriers force them to reverse direction. They also concentrate where upwelling blocks the flow of surface freshwater that salmon use to home. In inland waters, upwelling is driven by currents, leading to ephemeral concentrations of prey. On the outer coast, salmon would concentrate as they approach river mouths.

The other approach to foraging takes advantage of ambient concentrations of prey. While foraging success is lower in these areas, they form a larger portion of the range than hot spots and are less vulnerable to tidal changes in prey density. Residents move seasonally to take advantage of spatiotemporal variation in prey density (Nichol and Shackleton 1996).

Satellite tag data suggest these strategies apply on the Pacific Coast as well. Whales travel back and forth between Monterey Bay and Vancouver Island. They spend extended periods going back and forth across major river mouths (Sacramento, Klamath and Columbia), while traveling relatively directly along the coast in between.

Hoelzel (1993) has reported no correlation between the feeding behavior of SRKWs and bottom topography and found that most foraging took place over deep open water (41 percent of sightings), shallow slopes (32 percent), and deep slopes (19 percent). Ford et al. (1998) described residents as frequently foraging within 50 to 100 m of shore and using steep nearshore topography to corral fish. Both of these studies, plus those of Baird et al. (1998, 2003), have reported that most feeding and diving activity occurs in the upper 30 m of the water column, where most salmon are distributed (Stasko et al. 1976, Quinn and Hart 1987, Quinn et al. 1989, Ruggerone et al. 1990, Olson and Quinn 1993, Nichol and Shackleton 1996, Candy and Quinn 1999, Baird 2000). Additionally, Chinook salmon occupy nearshore habitats more so than other salmonids (Stasko et al. 1976, Quinn et al. 1989). Other behaviors, such as resting and socializing, are performed in open water with varied bathymetry (Heimlich-Boran 1988, Felleman et al.1991).

When prey is not available near the surface, whales will attempt long, deep, foraging dives. The whales do not appear able to repeat these in rapid succession. As a result, an unsuccessful dive not only represents a failure to find food, it also precludes opportunities to forage subsequently. Thus, it is important that foraging dives be likely to succeed. If not, whales are unlikely to forage at all (Lusseau et al. 2009), ensuring that they do not find food, but minimizing energy expenditure until foraging prospects improve. Foraging dives are unlikely to succeed when prey density is low, or noise limits echolocation detection range.

Coho salmon are known to compose approximately 10 percent of the diet over the summer in the U.S. portion of the Salish Sea. Changes in the prey base may affect the ability of killer whales to reproduce successfully (Wasser et al. 2017), as well as grow and maintain sufficient body mass to survive illnesses.

SRKWs are present and feeding on prey between Fort Bragg, California, and Florence, Oregon, in late winter and early spring. This is the time of year when calves are most likely to be born, and females need maximal prey intake (2 to 4 times as much as during other phases of the reproductive cycle [Kriete 1995]) to nourish and support assisted locomotion of neonates (Waite 1987). SRKWs satellite-tagged in recent years have consistently moved back and forth between the Washington and Northern California coasts.

Klamath River Chinook are known to occur in the SRKW diet (NMFS unpublished data). Wild spring run Chinook salmon populations are reportedly a remnant of their historical abundance and primarily occur in the South Fork Trinity River and Salmon River Basins (NMFS 2011), with returns below 1,000 fish. NMFS (2011) indicates fall run Chinook in the last several decades have ranged from below 50,000 to 225,000 fish. Naturally produced (i.e, non-hatchery) smolt production is largely unknown but has also dropped due to the significant decline in wild adult Chinook salmon runs over the last several decades. Recent trends in total run size (combined catch and escapement of both wild and hatchery Chinook) and escapement for Fall Chinook are shown in Figure 9-4. Data for spring Chinook are shown in Figure 9-5. Catch of Chinook in the Southern Resident range (from California through British Columbia runs) is shown in Figure 9-6 in comparison to combined (fall and spring) Klamath River Chinook run size.

Chinook salmon from the Klamath River spring run potentially affected by the PA constitute only a small portion of the potential SRKW prey base (currently about 1 percent, although historically it may have been about 5 percent). Counting the fall run as well, the Klamath produces 1 to 10 percent of salmon from California through British Columbia.

Most Klamath River fall Chinook adults return to spawn between September and November, suggesting SRKWs would feed on younger age classes of this run. Klamath River spring Chinook would be returning to spawn while SRKWs are present.

The coastal area off the Klamath River is reportedly where the greatest concentration of Klamath origin Chinook salmon occurs (Reclamation 2011). The Klamath River stock is estimated to make up to 37 percent of the adult Chinook salmon off of Fort Bragg during the spring and up to about 45 percent off of the southern Oregon coast in July depending on (1) the inter-annual variability in strength of salmon runs, (2) the month, and (3) the location (Reclamation 2011). No information is available regarding ocean Chinook salmon stock composition during the winter months.

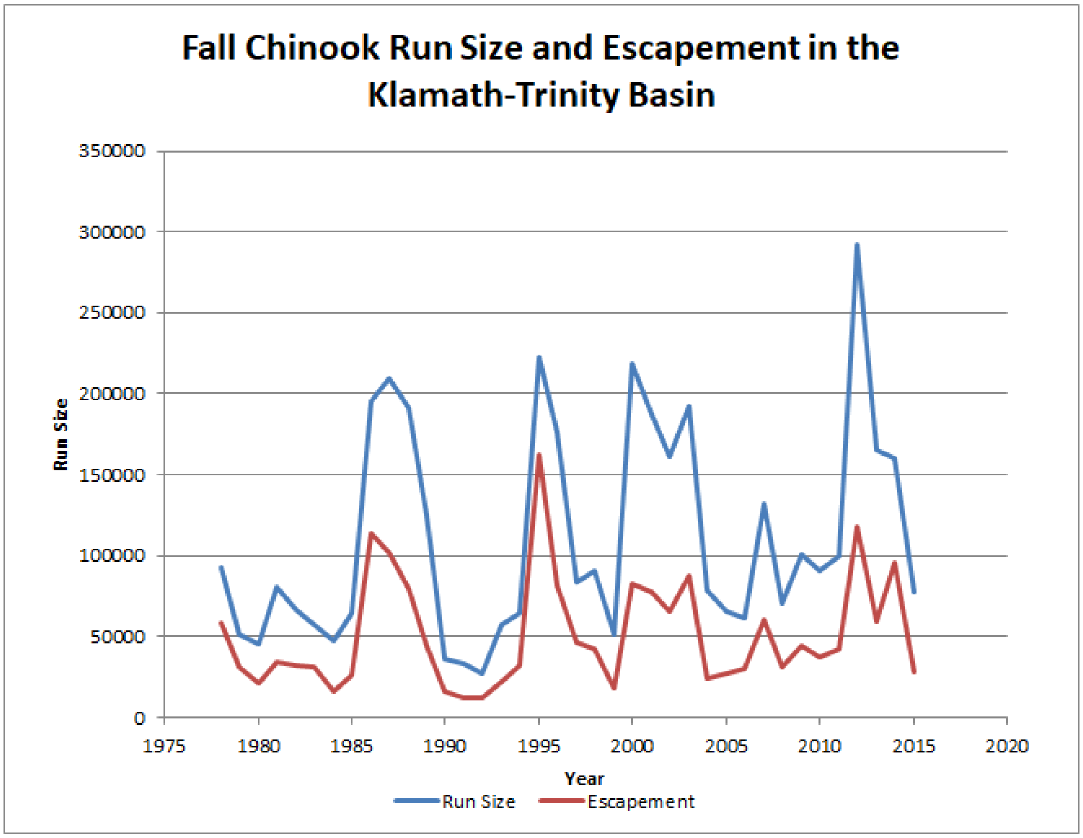

Figure 9-4. Fall Chinook Run Size and Escapement in the Klamath-Trinity Basin.
Source: after NOAA Fisheries 2011.

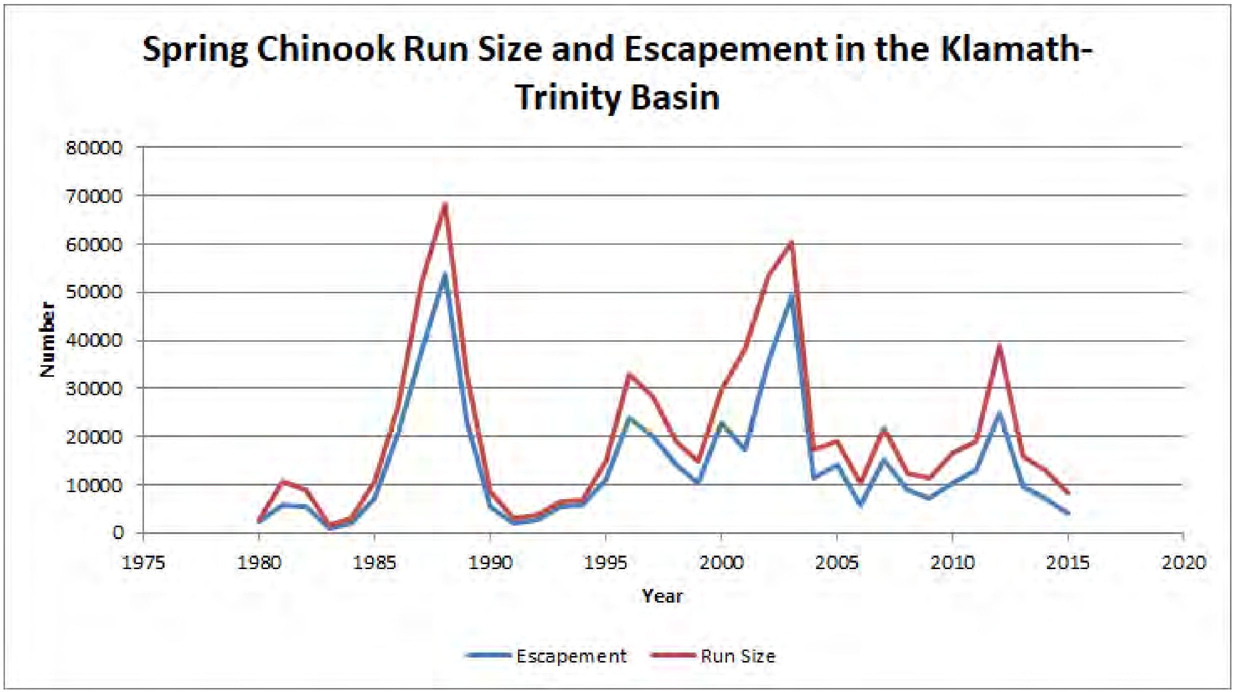

Figure 9-5. Spring Chinook Run Size and Escapement in the Klamath Trinity Basin.
Source: (after NOAA Fisheries 2011).

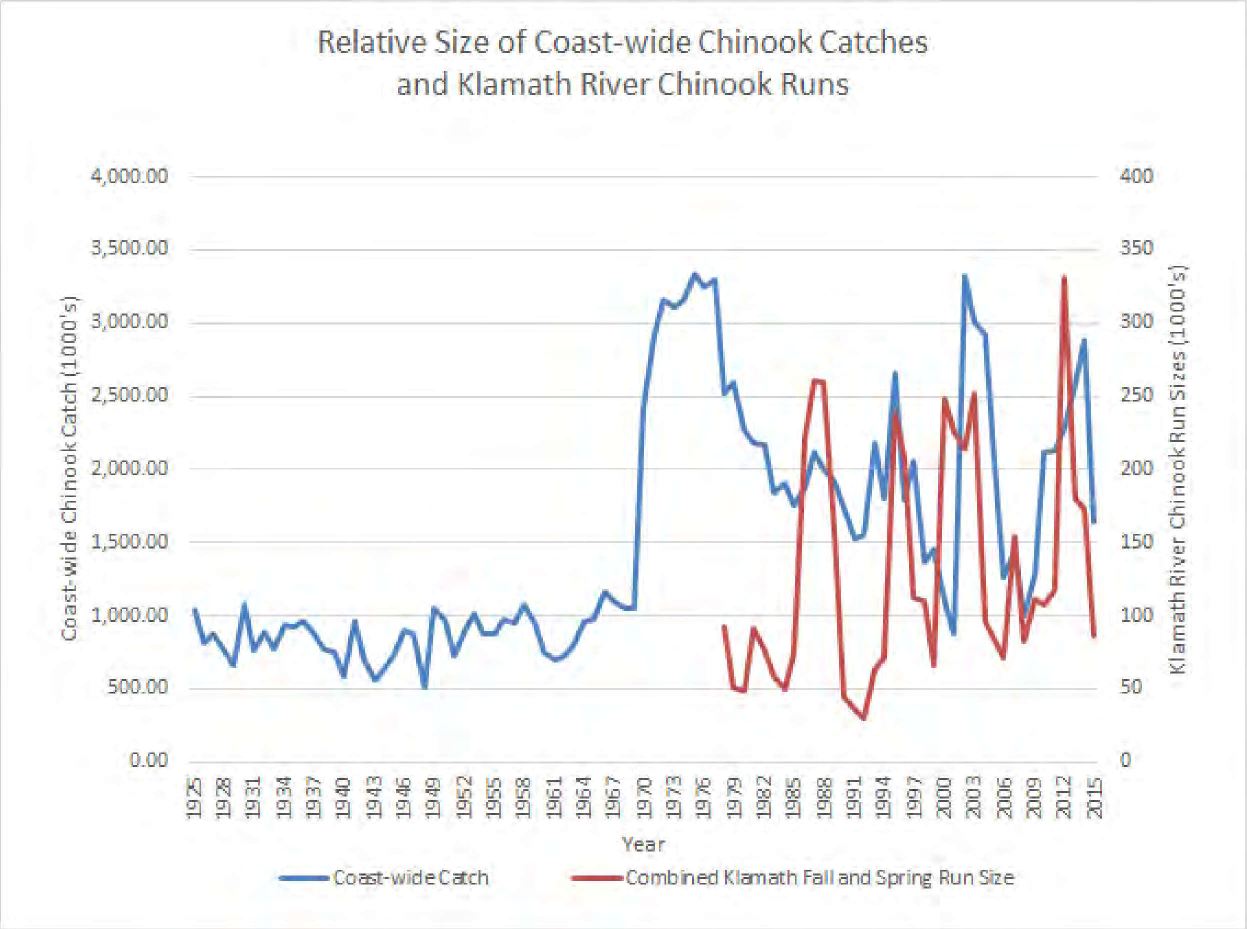

Figure 9-6. Total Reported Chinook Catch in California, Oregon, Washington, and British Columbia in comparison to Klamath River run sizes. Note that the coast-wide data do not include escapement, so are an underestimate of run size.
Source: (data from North Pacific Anadromous Fish Commission https://npafc.org/statistics/ and NOAA Fisheries 2011).

In summary, Klamath Basin Chinook and coho salmon contribute to the status of SRKWs both as components of the overall, coast-wide prey base, and as a seasonal source of nutrition for lactating females.

9.2. Southern Resident Killer Whale Environmental Baseline

9.2.1. Factors Affecting Southern Resident Distinct Population Segment Killer Whale and their Habitat

Three primary risk factors appear to have contributed to the endangered status of SRKWs. The three can act synergistically (Bain et al. 2014, Lacy et al. 2017). The most significant is the decline in salmon abundance. Disturbance is also of importance. Toxin load is another factor. Disturbance impairs foraging and requires increased energy expenditure, aggravating problems with prey abundance. Further, when prey is scarce, disturbance increases stress hormones, although this does not occur when prey abundance is adequate. Lipid soluble toxins can be stored in blubber and cell membranes. When the blubber has high lipid content, it is a place to harmlessly store toxins. However, when blubber lipid is consumed to offset inadequate prey availability, the toxins relocate to cell membranes where they are biologically active and can suppress the immune system and cause abnormalities in developing fetuses.

The result of these factors is increased mortality at all life stages. Of particular concern is the failure of females to rear calves successfully. Wasser et al. (2017) estimated that fewer than 25 percent of SRKW conceptions result in calves that survived to six months of age, and most were probably not born alive. However, relatively strong Klamath River Chinook returns in 2013 and 2014 resulted in normal survival for calves born the following years, despite 0 percent survival in the preceding and following three years.

Another possible impact of inadequate effective prey availability is a male biased sex-ratio at birth. Trivers and Willard (1973) proposed that females in poor condition would be more likely to produce offspring of the less expensive sex. Although at first glance, production of large males would appear to be more expensive, sons are less likely to compete with their mothers for food than daughters making them the less expensive sex. Balcomb (unpublished data) has suggested that SRKWs have been disproportionately producing sons in recent years, suggesting that not only are many females in too poor condition to rear calves, most of those that are giving birth are producing sons, who do not increase the reproductive capacity of the population (Center for Whale Research, unpublished data).

Other factors may intermittently affect population dynamics. There was die-off Southern Residents coincident with the New Charissa spill on the Oregon Coast in 1999. It is unknown whether the spill caused the die-off, but the Exxon Valdez spill is believed responsible for numerous killer whale deaths. Another die-off was coincident with an Unusual Mortality Event of harbor porpoises in the Salish Sea. Porpoise deaths were attributed to *Cryptococcus gatii*, but it is unknown whether this disease also caused the killer whale deaths. Whales entrapped in Dye’s Inlet (perhaps by traffic noise) exhibited a higher mortality rate than the rest of the population the following winter.

9.3. Effects of Implementing the Proposed Action on Southern Resident Distinct Population Segment Killer Whale

9.3.1. Southern Resident Killer Whale Effects Analysis

Several factors identified in the final recovery plan for SRKWs may be limiting recovery including quantity and quality of prey, toxic chemicals that accumulate in top predators, and disturbance from sound and vessels. Oil spills are also a risk factor. It is likely that multiple threats are acting together to impact the whales. All of the threats identified are potential limiting factors in their population dynamics (NMFS 2008). Of these, the PA will only affect prey quantity and quality.

Most of the direct effects of the PA occur within the freshwater system and plume of the Klamath River; and Southern Residents will not be directly affected by changes in salinity, so effects experienced by Southern Residents in the coastal area are therefore indirect.

Relationship of Klamath Run Size to SRKW Population Dynamics. The best available information indicates that salmon are the preferred prey of killer whales year around, including in coastal waters, and that Chinook are the preferred salmon species. Any changes in prey abundance could affect the entire population of SRKWs. Prey abundance is a concern for killer whales both in the near and long term. To survive in the near term, killer whales require regular supplies of adult Chinook prey in the ocean, and to recover over the longer term, killer whales require abundant Chinook stocks coast-wide, including stocks from the Klamath River, which are especially important to lactating females in K and L pods.

The PA will affect population sizes of Klamath River Chinook and coho salmon. Subadult Chinook occupy coastal waters along the travel route of SRKWs between Central California and Washington (primarily between Fort Bragg, CA and Florence, OR), and are likely to be taken opportunistically. Adult Chinook returning to the Klamath River would be preferred prey, as they would be present in higher density and have more nutritional value than subadults and would be taken closer to the river mouth than subadults. The timing of whale presence suggests the spring run was more important than the fall run, historically. However, the spring run has declined to levels where it is being considered for listing under the ESA. Reduced prey availability could lead to reduced calf survivorship (and to lesser extent, reduced survivorship of older individuals) and slower growth rates. However, prey availability is also influenced by runs in coastal rivers from Central California to Central British Columbia. Other fish also form a small part of the diet.

Analysis approach. Spill regimes influence the area available for Chinook salmon rearing. The area was used as an index of parr production. While other factors that affect survival are influenced by spill regime, such as water temperature and disease, such influences are likely to be in the same direction as changes in area. Factors beyond the scope of the PA, such as ocean temperature and primary productivity, influence marine survival. The correlation of run size to the index of parr production was used to estimate the relative importance freshwater to marine conditions in determining prey available to SRKWs. The size of Klamath River runs relative to other runs in the SRKW range was used to estimate the overall importance of conditions in the

Klamath River to SRKWs. A separate consideration was the influence of Klamath River runs on calf survival in K and L pods.

Spill Regimes. S3 was used to calculate habitat area from 1981 through 2016 under the existing spill regime and what it would have been under the PA. If the PA had been in place, habitat area would have been slightly larger, on average, by 2.4 percent. Further, the minimum area would have been 63 percent of the maximum area, as opposed to 55 percent under actual protocols, meaning area would have been slightly more consistent under the PA than under the actual protocol that was employed. The PA would have improved habitat area available to Chinook in 29 of 36 years relative to the practices currently followed.

River versus Ocean Conditions. Parr production based on area was correlated with adult returns ($R^2 = 0.3$). Marine survival rates typically vary from 0.5 percent to 4 percent, which is larger than the 82 percent range in in-river habitat under the actual spill regime. Thus, this level of correlation suggests that the index is a good approximation of the overall effect of spill regime on in-river survival and average juvenile condition.

Relative Importance of Klamath River Runs. Historically, Klamath River Chinook runs totaled around 1,000,000 adults in each the fall and spring runs. These runs may have been 5 to 10 percent of total coastal returns historically. Under current conditions, runs have been reduced to under 100,000 in the fall, and less than 10,000 in the spring (with returns below 1,000 in some years).

Under the PA, the expected range in area correlates with a range in predicted run size from 50,000 to 200,000. With approximately 50 SRKWs using the waters off the Klamath, this is a range of almost 3,000 Chinook per whale. That is, in good years, the Klamath River will be a significant source of prey for SRKWs, but in bad years it will be a negligible source of food. It is not clear what the corresponding range would be in the absence of water operations, nor the degree to which the predicted range is due to causation from conditions driven by the spill regime.

Klamath River wild runs have been reduced to about 1 percent of coastwide returns, with spring runs down to less than 0.01 percent of coastwide returns. Hatchery supplementation allows the Klamath River to produce over 5 percent of coast-wide returns. The decline of Klamath River returns corresponds to declines in calf survivorship and overall numbers in K and L pods, which spend far more time off California and Oregon than J Pod. J Pod appears to rely primarily on Fraser River salmon and other runs that pass through the Salish Sea.

Overall Effects. Chinook salmon at least 3 years of age are suitable prey for SRKWs. These will be present as subadults and returning adults. SRKWs pass through the action area during the spring run. Thus, their potential prey are subadult fall Chinook and both subadult and adult spring Chinook.

The overall effect is likely to be a small improvement in prey availability that will have little or no impact on SRKW population size. Freshwater survival would be expected to exhibit an average increase of 2.4 percent. The PA would have improved freshwater conditions for

Chinook in 29 of 36 years. Due to variation in marine survival, a fraction of this increase is likely to remain by the time adults return to where they can be fed upon by SRKWs. The significance of this increase will be small, as cumulative returns in other watersheds, such as the Fraser, Columbia, Sacramento, and many smaller rivers, will have a much larger impact on overall prey availability.

Other Considerations and Cumulative Effects. Historically, Klamath River runs were much larger than they are at present. While a slight increase in in-river survival will not adversely affect SRKWs, the longer they experience a population bottleneck, the more genetic diversity will be lost, and the less likely SRKWs will be to recover.

Klamath River Spring Chinook are important to calf survival. Only one viable calf has been produced in K and L pods in the last 7 years, compared to an expected value of almost 3 per year. While the overall population size is driven by coast-wide returns, survival of older rather than younger individuals will reduce the population's reproductive potential in future years.

While habitat area is an index of parr production, other factors are important to consider. Water temperature was not explicitly considered in this analysis; however, the PA impacts to water temperatures below IGD were thoroughly analyzed in Part 8.3.2.1. Reclamation concluded that the IGD releases included in the PA are not likely to substantially affect water temperature at the four nodes examined in the Klamath River. Thus, water temperature effects of the PA are not likely to influence the availability of prey for SRKW. Additionally, the quantitative effect of flushing flows on disease reduction was not explicityly considered in this analysis: however, Part 8.7 examines the role of disease mitigation flows on disease dynamics in coho salmon. In that Part, Reclamation concludes that the surface flushing flows in 35 of the 36 years in the modeled POR will likely result in reduced actinospore concentrations, POI and *C. shasta*-related mortality. Given that the same mechanisms (spore concentration, duration of exposure, water temperature, etc) influence coho and Chinook infection and mortality, it is also likely that the PA will result in reduced *C. shasta*-related mortality for Chinook salmon, the preferred prey of SRKW.

There are numerous other recovery actions throughout the range currently being considered. Dam removal is being considered as a way to increase available habitat and improve in river survival. NOAA Fisheries is considering whether to expand Critical Habitat to include the SRKW range in the Pacific Ocean. It is also considering listing Klamath River spring Chinook under the ESA. The Washington Governor's Task Force on SRKW Recovery proposed over 30 different actions. The Canadian Department of Fisheries and Oceans has begun implementing extensive recovery actions. While most of these potential actions will not affect the action area directly, they would influence SRKW population dynamics if implemented, and hence the threshold for jeopardy.

Synthesis. While the 40 percent interannual variation in rearing habitat area under the PA is substantial, by the time variation in marine survival is considered, along with the small overall contribution of the Klamath River to coastwide salmon abundance, the overall contribution of the PA to prey availability will be small. With escapement expected to increase under the PA, it is more likely that egg production will be sufficient to fully utilize available habitat. Further, prey availability is only one of three major factors affecting SRKW population dynamics (in addition to disturbance and toxins), along with a number of smaller factors. Thus, the overall effect on SRKW population size of the PA is likely to be small.

Due to the needs of lactating females for 2 to 4 times as much food as non-lactating females, the impact of the PA on calf survival may be larger. Improved survival of young individuals is essential to recovery of the population.

Therefore, the PA "may affect, but is not likely to adversely affect" SRKW

10. OTHER SPECIES

The following discusses the impacts of implementing the PA, on southern DPS of green sturgeon, southern DPS of North American Pacific eulachon, bull trout, Oregon spotted frog, and Applegate's milkvetch.

10.1. Southern Distinct Population Segment Green Sturgeon

Green sturgeon are members of the class of bony fishes, and the skeleton is composed mostly of cartilage. Sturgeon lack scales; however, they have five rows of characteristic bony plates on their body called scutes. The green sturgeon backbone curves upward into the caudal fin, forming their shark-like tail. On the ventral, or underside, of their flattened snouts are sensory barbels and a siphon-shaped, protrusible, toothless mouth. Recent genetic information suggests that green sturgeon in North America are taxonomically distinct from morphologically similar forms in Asia.

10.1.1. Legal Status

NMFS (2006a) published a final rule listing the southern DPS of green sturgeon as threatened. NMFS (2008) defined two DPSs for green sturgeon – a southern DPS that spawns in the Sacramento River and a northern DPS with spawning populations in the Klamath and Rogue rivers. The southern DPS includes all green surgeon spawning populations south of the Eel River in California, of which only the Sacramento River currently contains a spawning population. NMFS (2008a) has declared the northern DPS a Species of Concern.

NMFS designated critical habitat for the southern green sturgeon DPS in 2009 (NMFS 2009). NMFS in its critical habitat listing designated the following specific primary constituent elements (PCEs) which are essential for the conservation of the southern green sturgeon DPS in freshwater river systems:

Food resources: abundant prey items for larval, juvenile, sub-adult, and adult life stages.

Substrate: substrates suitable for egg deposition and development, larval development, and sub-adults and adults. Spawning is believed to occur over substrates ranging from clean sand to bedrock, with preferences for cobble (Moyle et al.1995).

Water: a flow regime (i.e., the magnitude, frequency, duration, seasonality, and rate-of change of fresh water discharge over time) necessary for normal behavior, growth, and survival of all life stages.

Water quality: suitable water quality for normal behavior, growth, and viability of life stages, including temperature, salinity, oxygen content, and other chemical characteristics.

10.1.2. Life History

Green sturgeon is believed to spend the majority of their lives in nearshore oceanic waters, bays, and estuaries. Early life-history stages reside in fresh water, with adults returning to freshwater to spawn when they are more than 15 years of age and more than 4 feet (1.3m) in size. Spawning is believed to occur every 2 to 5 years (Moyle 2002). Adults typically migrate into fresh water beginning in late February; spawning occurs from March to July, with peak activity from April to June (Moyle et al., 1995). Females produce 60,000 to 140,000 eggs (Moyle et al., 1992). Juvenile green sturgeon spend 1 to 4 years in fresh and estuarine waters before dispersal to saltwater (Beamsesderfer and Webb, 2002). They disperse widely in the ocean after their out-migration from freshwater (Moyle et al., 1992).

Spawning: Green sturgeon spawn every three to five years (Tracy 1990). Their spawning period is March to July, with a peak in mid-April to mid-June (Moyle et al. 1992). Preferred spawning areas are associated with deep pools in large, turbulent river mainstems (Moyle et al. 1992). Spawning habitat preferences are likely large cobble substrates but may range from clean sand to bedrock substrates. Green sturgeon broadcast their eggs over the large cobble substrates where they settle into the interstitial spaces between cobbles. Green sturgeon females produce 60,000 to 140,000 eggs (Moyle et al. 1992), the largest eggs (diameter 4.34mm) of any sturgeon species (Cech et al. 2000). Temperatures above 20°C is lethal to green sturgeon embryos (Cech et al. 2000).

Recently, green sturgeon spawning has only been documented in the Klamath, Sacramento (Moyle et al. 1992, CDFG 2002) and Rogue (Erickson et al. 2002, Rien et al. 2001) rivers. The Klamath Basin is thought to support the largest green sturgeon spawning population (Moyle et al. 1992). In the Klamath River, sturgeon courtship behaviors such as breaching have been observed in “The Sturgeon Hole” upstream of Orleans, CA (rkm 96). Larvae and juveniles have been caught in the Karuk Tribe’s Big Bar trap (rkm 80) on the Klamath and in the Willow Creek trap (rkm 40) on the Trinity River. In the Sacramento River, green sturgeon spawn in late spring and early summer above Hamilton City and perhaps as far upstream as Keswick Dam (CDFG 2002).

Early Life History: Green sturgeon larvae first feed at 10 days post hatch, and metamorphosis to the juvenile stage is complete at 45 days. Larvae grow fast, reaching a length of 66 mm and a weight of 1.8 g in 3 weeks of exogenous feeding. Juveniles averaged 29 mm at the peak of occurrence in June/July at the Red Bluff Diversion Dam (California) fish trap and 36 mm at their peak abundance in July at the Glenn-Colusa Irrigation District (GCID) trap (NMFS 2005a). These growth rates are consistent with rapid juvenile growth to 300mm in 1 year and to over 600mm within 2 to 3 years in the Klamath River (Nakamoto et al. 1995). Juvenile green sturgeon in the Klamath River appear to spend 1 to 3 years in freshwater before they enter the ocean (Nakamoto et al. 1995).

Ocean Residence: Green sturgeon disperse widely in the ocean after outmigrating from freshwater (Moyle et al. 1992). Tagged green sturgeon from the Sacramento and Columbia Rivers are primarily captured to the north in coastal and estuarine waters, with some fish tagged in the Columbia River being recaptured as far north as British Columbia (Washington State Department of Fish and Wildlife [WDFW] 2002a). The pattern of a northern migration is supported by the large concentration of green sturgeon in the Columbia River estuary, Willapa Bay, and Grays Harbor which peaks in August. These fish tend to be immature; however, mature fish and at least one ripe fish have been found in the lower Columbia River (WDFW 2002a). Genetic evidence suggests that Columbia River green sturgeon stocks are a mixture of fish from at least the Sacramento, Klamath, and Rogue Rivers (Israel et al. 2004).

Age and Growth: Green sturgeon are long lived and slow growing, similar to other sturgeon species (Nakamoto et al. 1995, Farr et al. 2002). Size-at-age is consistently smaller for fish from the Klamath River (Nakamoto et al. 1995) in comparison to fish from Oregon until around age 25, but thereafter the pattern is reversed. This could be the result of actual differences in growth or in ageing techniques. The asymptotic length for Klamath fish of 218 cm is close to the maximum observed size of 230cm reported by Moyle et al. (1992 in Adams et al. 2002) and substantially larger than other Sturgeon species captured in Oregon (females 182cm, males 168cm).

Feeding: Little is known about green sturgeon feeding in the Klamath River as most feeding studies have occurred in other watersheds. Adults in the Sacramento-San Joaquin delta feed on benthic invertebrates including shrimp, mollusks, amphipods, and even small fish (Houston 1988; Moyle et al. 1992). Juveniles in the Sacramento River delta feed on opossum shrimp (*Neomysis mercedis)*, and *Corophium* amphipods (Radtke 1966). Adams (2002) reported opisthobranch mollusks (*Philline* sp.) were the most common prey for one 100 cm green sturgeon from the Sacramento-San Joaquin estuary.

10.1.3. Distribution

Green sturgeon is a widely distributed and marine-oriented species found in nearshore waters from Baja California to Canada (NMFS 2008a), but its estuarine/marine distribution and the seasonality of estuarine use range-wide are largely unknown. Southern DPS green sturgeon populations are known to congregate in coastal waters and estuaries, including non-natal estuaries, such as the Rogue River. Bemis and Kynard (1997) suggested that green sturgeon move into estuaries of non-natal rivers to feed. Information from fisheries-dependent sampling suggests that green sturgeon only occupy large estuaries during the summer and early fall in the northwestern United States.

Green sturgeon is known to enter estuaries along the Washington coast during summer (Moser and Lindley 2007). Commercial catches peak in October in the Columbia River estuary, and records from other estuarine fisheries (Willapa Bay and Grays Harbor, Washington) support the idea that sturgeon are only present in these estuaries from June until October (Moser and Lindley 2007). This information suggests that southern DPS green sturgeon are likely to use the Klamath River estuary only during the summer and fall months. As southern DPS sturgeon spend the majority of their life in the ocean, and individuals spend some time in a number of estuaries along the West Coast in the summer and fall, only a small proportion of the southern DPS green sturgeon would be expected to be present in the Klamath River estuary in any given year.

San Francisco Bay and its associated river systems contain the southern-most spawning population of green sturgeon. White sturgeon supports a large fishery in this area, particularly in San Pablo Bay, which has been extensively studied by California Department of Fish and Game

(CDFG) since the 1940s. While green sturgeon are not common in San Pablo Bay, they are collected incidentally in trammel net monitoring during most years in numbers ranging from 5 to 110 fish. Green sturgeon juveniles are found throughout the Delta and San Francisco Bay.

The Columbia River has supported a large white sturgeon fishery for many years in which green sturgeon are taken as bycatch. In the mid-1930s before Bonneville Dam was constructed, green sturgeon were found as far upsteam as the Cascade Rapids. Green sturgeon are presently found as far upstream as Bonneville Dam (rkm 235), but are predominately found in the lower 60 rkm. Tagging studies indicate a substantial exchange of fish between the Columbia River and Willapa Bay (WDFW 2002). Willapa Bay, along with the Columbia River and Grays Harbor, is one of the estuaries where green sturgeon populations concentrate in summer. Generally, green sturgeon are more abundant than white sturgeon in Willapa Bay (Emmett et al. 1991).

Grays Harbor in Washington is the northernmost estuary where green sturgeon populations concentrate in the summer months. Tribal and commercial fisheries for green sturgeon occur in Grays Harbor. Green sturgeon occur sporadically in small numbers throughout coastal Washington (WDFW 2002a) and are routinely encountered in the coastal Washington trawl fishery as minor incidental catch (WDFW 2002a).

10.1.4. Species Current Condition

Population size and trends in the Southern DPS have been estimated by comparing the relative size of the Sacramento-San Joaquin green sturgeon population (Southern DPS) with the Klamath River population (Northern DPS) (Beamesderfer et al. (2005). Using Klamath River tribal fishery harvest data and assuming that adults represent 10 percent of the population at equilibrium, the Klamath green sturgeon population (Northern DPS) estimate is approximately 19,000 individuals with an annual recruitment of 1,800 age-1 fish (Reclamation, 2008b).

Based on tagging data and visual observations of adults in pools, Woodbury (2010, as cited in NMFS 2010a) estimates a total of 1,500 spawning adults in the Klamath River. Assuming that spawning adults represent 10 percent of the population, the number of individuals in the Southern DPS is approximately 15,000 individuals, or somewhat smaller than the estimate for the Klamath population.

10.1.5. Effects to Green Sturgeon

Project operations, depending on hydrological conditions in a given year, may reduce the cumulative flow in the lower Klamath River during spring and summer when southern DPS green sturgeon are known to occupy the Klamath River estuary. Variation in flows to the estuary resulting from the PA will not inhibit marine migration of southern DPS green sturgeon to the Klamath River estuary zone. Project operations are not expected to alter, reduce, or change the availability of food resources or meaningfully modify water temperature in the estuary zone during the summer months when green sturgeon can be expected to be in the estuary. Due to the relatively small contribution of IGD releases to the overall flow in the lower Klamath River (*see* Figure 4-3), Reclamation concludes that the PA may affect, but is not likely to adversely affect the green sturgeon southern DPS.

10.2. Southern Distinct Population Segment Pacific Eulachon

Eulachon *Thaleichthys Pacificus* (commonly called smelt, candlefish, or hooligan) are a small, anadromous fish from the eastern Pacific Ocean that are a short-lived, highly-fecund forage fish, that tend to have extremely large population sizes. NMFS (2012c) describes the following distinguishing physical features: large canine teeth on the vomer (bone in the roof of the mouth) and 18 to 23 rays in the anal fin; sickle-shaped adipose fin; fins have well-developed breeding tubercles (raised tissue "bumps") in ripe males, but these are poorly developed or absent in females; adult coloration is brown to blue on the back and top of the head, lighter to silvery white on the sides, and white on the ventral surface; speckling is fine, sparse, and restricted to the back. Eulachon feed on plankton only while at sea.

10.2.1. Legal Status

NMFS listed the southern DPS Pacific eulachon as threatened under the ESA on March 18, 2010 (75 FR 13012). This DPS encompasses all populations within the states of Washington, Oregon, and California and extends from the Skeena River in British Columbia (inclusive) south to the Mad River in Northern California (inclusive). The DPS is divided into four sub-areas: Klamath River, Columbia River, Fraser River, and British Columbia coastal rivers south of the Nass River.

NMFS proposed to designate approximately 470.2km (291.1 miles) of riverine and estuary habitat in California, Oregon, and Washington within the geographical area occupied by the southern DPS Pacific eulachon as critical habitat (NMFS 2010b). NMFS designated critical habitat for eulachon based upon areas which contain one or more physical or biological features essential to the conservation of the species that may require special management considerations or protection (NMFS 2011b). NMFS (2011b) has designated critical habitat for 10.7 miles of the Klamath River from the mouth upstream to the confluence with Omogar Creek.

10.2.2. Life History

Eulachon typically spend three to five years in saltwater before returning to fresh water to spawn. Eulachon generally spawn in rivers that are rain and snowmelt dominated systems that experience spring freshets. Spawning grounds are typically in the lower reaches of larger rivers (Hay and McCarter 2000). Spawning typically occurs at night. Spawning occurs between zero to 10°C throughout the range of the species and is largely limited to river reaches that are tidally influenced (Lewis et al. 2002).

Spawning cues and entry into rivers appear to be related to water temperature and the occurrence of high tides (Ricker et al. 1954, Smith and Saalfeld 1955, Spangler 2002) in January, February, and March in the northern part of the DPS, and later in the spring in the southern parts of the DPS. Most eulachon adults die after spawning. Eulachon broadcast their eggs which are fertilized in the water column, sink, and adhere to the river bottom typically in areas of gravel and coarse sand. It has been argued that because freshets rapidly move eulachon eggs and larvae to estuaries, it is likely that eulachon imprint and home to estuaries (Hay and McCarter 2000). Eulachon eggs hatch in 20 to 40 days. Newly hatched young, transparent and 4 to 7 mm in length, are carried to the sea with the current (Hay and McCarter 2000).

Juvenile eulachon enter the ocean once they move from shallow nearshore areas to deeper areas over the continental shelf. Larvae and young juveniles become widely distributed in coastal waters, where they are typically found near the ocean bottom in waters 20 to150m deep (66 to 292 feet) (Hay and McCarter 2000) and sometimes as deep as 182m (597 feet) (Barraclough 1964). There is currently little information available about eulachon movements in nearshore marine areas and the open ocean. However, eulachon occur as bycatch in the pink shrimp fishery (Hay et al. 1999, Olsen et al. 2000, NWFSC 2008, Hannah and Jones 2009), which indicates that the distribution of these organisms overlaps in the ocean. Adult Pacific eulachon have been recorded from several locations on the Washington and Oregon coasts, and were previously common in Oregon's Umpqua River, and the Klamath River in northern California (Hay and McCarter 2000, Willson et al. 2006, NMFS 2010b).

10.2.3. Species Current Condition

There are few direct estimates of abundance available for eulachon, and there is an absence of monitoring programs in the U.S. Most population data comes from fishery catch and landing records, which when combined with anecdotal information, indicate eulachon historically were present in large annual runs and that significant declines in abundance have occurred (Reclamation 2011). The Columbia River, estimated to have historically represented half of the taxon's abundance, experienced a sudden decline in its commercial eulachon fishery landings in 1993–1994 (Washington Department of Fish and Wildlife [WDFW] and ODFW 2001, Joint Columbia River Management Staff 2007). Similar declines in abundance have occurred in the Fraser River and other coastal British Columbia rivers (Hay and McCarter 2000, Moody 2008). In the Klamath River and the Umpqua River, eulachon were once abundant, but have declined to the point where detecting them has become difficult (NMFS 2010b).

There has been no long-term monitoring program targeting eulachon in California, making estimates of historical abundance and abundance trends difficult to generate (Gustafson et al. 2008).

10.2.4. Effects to Pacific Eulachon

The southern DPS Pacific eulachon are only known to occupy the Action Area in the lower Klamath River during the winter and spring for spawning, incubation, and early rearing. Potential effects of the PA on this species are limited to the lower Klamath River. The PA and resulting downstream winter/spring flows in the lower Klamath River could affect southern DPS Pacific eulachon populations by impacting essential habitat features for spawning, incubation, and migration. Eulachon are documented to spawn in the lower Klamath River reach in association with spring freshets and rearing does occur in the estuarine and near-shore areas at the mouth of the Klamath River. Project operations, depending on hydrological conditions in a given year, could reduce the rate of flow in the Klamath River during times when southern DPS Pacific eulachon are present. However, because the winter/springtime flows in the lower 10.7 miles of the Klamath River are largely driven by tributary accretions below IGD, Project operations and resultant effects to flow in the lower Klamath River are not expected to substantially alter habitat elements for the southern DPS Pacific eulachon. These accretions include flows from the Shasta, Scott, Salmon and Trinity rivers, and provide the vast majority of flow (*see* Figure 4-3), particularly during the winter and spring months.

Flow releases at IGD do contribute to the cumulative flows in the lower Klamath River upstream of the estuary (*see* figure 4-3) where eulachon can be present. Therefore, Reclamation concludes that the PA may affect, but is not likely to adversely affect the southern DPS Pacific eulachon.

Critical habitat has been finalized in the lower Klamath River for the southern DPS Pacific eulachon. Flows as a result of implementing the PA may alter the physical or biological features for migration and spawning in the lower Klamath River that have been designated for the southern DPS Pacific eulachon. Therefore, the PA may affect, not likely to adversely affect designated critical habitat of the southern DPS Pacific eulachon.

10.3. Bull Trout

Bull trout (*Salvelinus confluentus)* are listed under the ESA as a threatened species in the Klamath River basin due to habitat isolation, loss of migratory corridors, poor water quality, and the introduction of nonnative species (64 FR 58910). Bull trout are native to the Pacific Northwest and occurred historically throughout much of the Oregon portion of the Klamath Basin with observations in several tributaries to UKL, including Sevenmile Creek and the Wood River. In a late-1800's account, Gilbert (Buchanan et al., 1997) reported observing bull trout in the Williamson River. The Smithsonian Institute has a preserved 330 mm bull trout specimen which was captured in 1876 from Fort Creek, a tributary of the Wood River (Buchanan et al., 1997).

10.3.1. Legal Status

Bull trout (*Salvelinus confluentus)* are listed under the ESA as a threatened species in the Klamath River basin (64 FR 58910). The USFWS designated critical habitat for the Klamath River and Columbia River distinct population segments of bull trout in 2002. In the Klamath Basin, USFWS revised critical habitat designation to protect foraging, migration, and overwintering habitat considered essential to re-connect isolated bull trout populations (USFWS 2010; 75 FR 63898).

10.3.2. Life History

Bull trout are members of the char sub-group of the family *Salmonidae* and are native to the Pacific northwest and western Canada. Bull trout adults typically range in size from an average of 200 to 305 mm for resident individuals, 405 to 610 mm in length for migratory river spawning individuals, and over 685 mm (27 inches) in length for adfluvial individuals (McPhail and Baxter 1996 in USFWS 2002(b)).

Bull trout adults normally reach sexual maturity in 4 to 7 years and live as long as 12 years. Bull trout typically spawn from August to November during periods of decreasing water temperatures. Spawning temperatures generally range from 4 to 10°C (39 to 51°F), with redds often constructed in stream reaches fed by springs or near other sources of cold groundwater (Goetz 1989, Pratt 1992, Rieman and McIntyre 1996 in USFWS 1998). Bull trout require spawning substrate consisting of loose, clean gravel relatively free of fine sediments (Fraley and Shepard 1989 in USFWS 1988). Egg incubation is normally 100 to 145 days (Pratt 1992 in

USFWS 1998) and fry typically emerge from gravel early April through May depending upon water temperatures and increasing stream flows (Pratt 1992, Ratliff and Howell 1992 in USFWS 1988).

Bull trout exhibit a number of life history strategies. Stream-resident bull trout complete their entire life cycle in the tributary streams where they spawn and rear. Most bull trout are migratory, spawning in tributary streams where juvenile fish usually rear from one to four years before migrating to either a larger river (fluvial) or lake (adfluvial) where they spend their adult life, returning to the tributary stream to spawn (Fraley and Shepard 1989 in USFWS 1988).

10.3.3. Current Conditions

Bull trout in the Klamath Recovery Unit currently occur only as resident forms isolated and separated by long distances in higher elevation headwater streams within three core areas: (1) Sycan River core comprised of Sycan Marsh, Sycan River, and their tributaries, (2) Upper Sprague River core comprised of the North Fork and South Fork of the Sprague River upstream of their confluences, inclusive of Deming, Boulder, Dixon, Brownsworth, and Leonard creeks, and (3) UKL core comprised of the northern portion of the lake and its immediate major and minor tributaries (USFWS 2015). Factors contributing to reduced distribution within this recovery unit are habitat degradation and fragmentation, past and present land use practices, water diversions, and past fisheries management practices (USFWS 2015).

10.3.4. Effects to Bull Trout

The PA, which includes the storage of water in UKL, will create seasonal fluctuations of lake surface elevation (and water depth) in UKL and Agency Lake. Agency Lake is identified as a foraging, migration, and overwintering habitat type for bull trout. For much of the year, occupancy of bull trout in Agency Lake is likely water temperature or water quality limited. However, bull trout may migrate through this habitat during winter months. Reclamation anticipates the seasonal lake level fluctuations will have no effect on bull trout that may use Agency Lake as a migration corridor.

The primary constituent elements of bull trout critical habitat include: (1) Springs, seeps, groundwater and subsurface water connectivity, (2) Migration habitats with minimal physical, biological, or water quality impediments, (3) Abundant food base, (4) Complex river, stream, lake, reservoir, and marine shoreline aquatic habitats,(5) Water temperatures that range from 2 to 15° C, (6) Sufficient substrate amount and composition in spawning and rearing areas, (7) Natural hydrograph, (8) Sufficient water quality and quantity, and 9. Sufficiently low levels of nonnative predatory, interbreeding, or competing species (75 FR 63898). The three critical habitat subunits in the Klamath Basin are identified as the UKL, Sycan River, and Upper Sprague River critical habitat subunits.

The PA to store water in and divert water from UKL may influence lake surface elevations in Agency Lake (northern portion of surface water considered part of UKL) and to a lesser extent the lowest reaches of tributaries to Agency and Upper Klamath Lakes. These lake surface elevation changes are seasonal and temporary in nature and can be characterized as high elevations in late winter through early summer and low elevations in late summer through early winter (*see* Table 6-1 in Part 6.3 and Table 7-1 in Part 7.1 for historic and proposed range of lake surface elevations in UKL).

The seasonal lake elevations in UKL resulting from the PA are not likely to adversely affect designated critical habitat in Agency Lake or the lowest reaches of tributaries such as Wood River and Sevenmile Canal, which bull trout could potentially utilize as migratory habitat (*see* Part 6.3.2.1 for discussion on water quality in UKL). Therefore, Reclamation concludes that the PA may affect, but is not likely to adversely affect bull trout.

10.4. Oregon Spotted Frog

10.4.1. Legal Status

The Oregon spotted frog *Rana pretiosa* was listed as threatened under the Endangered Species Act in 2014 (79 FR 51658).

10.4.2. Life History

Historically, the Oregon spotted frog (OSF) ranged from British Columbia to the Pit River drainage in northeastern California. Oregon spotted frog habitat in Oregon was historically found in Deschutes, Klamath, Lane, Wasco, and Jackson counties.

Oregon spotted frog is an aquatic frog that seldom strays from areas of standing water. Upland habitat is avoided by the OSF relative to wetland habitats. Oregon spotted frogs are generally found in slow-moving aquatic edge habitat along streams and marshes or beaver ponds. Water depth is usually one to three feet (Hayes 1995). This frog is often associated with submergent, floating, and low emergent vegetation, which it uses for basking sites and escape cover. Springs and spring-fed stream reaches are likely overwintering sites and may be a key habitat component.

During the breeding season (February through May), OSF prefer sedge-dominated and sedge/rush mix (*Carex* spp. and *Juncus* spp.) wetland vegetation for oviposition. During this season, OSF emerge from winter habitats and move into breeding areas of hardhack (*Spiraea douglasii*) and sedge-dominated vegetation. Within wetlands, OSF select sedge and hardhack dominated vegetation and avoid dense stands of reed canarygrass (cover greater than 50 percent) and areas of other grasses where closure is greater than 75 percent (Watson et al 2003). Oregon spotted frogs typically deposit egg masses in aggregations in shallow water that is exposed to sunlight (Pearl et al. 2009). Oviposition sites tend to be above gently sloping substrates with herbaceous vegetation such as sedges, rushes, and grasses (McAllister and Leonard 1997, Pearl et al. 2009). Oviposition sites usually lack significant vertical vegetation comports and structures; however, taller vegetation (e.g., cattails, *Typha* spp.) can be nearby and used as cover.

Adults are thought to return to the same general breeding location across years, although actual locations of eggs shift within these regularly used areas based on water depth at the time of breeding. Eggs are generally laid in water less than 30 centimeters (cm) deep but can be laid in as little as 4-5 cm. However, it is not unusual for the tops of egg masses to be exposed above the water surface. Water-level fluctuations after oviposition can result in egg masses being stranded or inundated by deeper water (Pearl et al. 2010). In drought years, eggs laid on the margins of deeper, permanent waters may be the only source of population recruitment. Most OSFs avoid laying eggs in permanent waters, perhaps because eggs and hatching tadpoles are more vulnerable to predation at these locations, and water temperatures are colder compared to the temporary, shallow pools used in the floodplain wetlands (Watson et al. 2003).

After breeding, OSFs often redistribute themselves across a broader summer range. This summer range can include wetlands more than 0.3 km from the original breeding site (Watson et al. 2003, Pearl et al. 2010). Oregon spotted frogs inhabit relatively shallow water with cover from emergent or aquatic plants and will redistribute in response to changing water levels. During periods of prolonged and severe cold, they may become inactive, possibly burying themselves in silty substrates or clumps of emergent vegetation (McAllister and Leonard 1997).

After relocating to summer habitat, adult OSFs often stay within a relatively small area until fall. In summer, adult OSF’s bask and forage near moderate to dense vegetation; deeper pools or flocculant substrates are used by adults as retreats when disturbed (Watson et al. 2003). Summer is the season of maximum growth but also highest predation. Frogs may balance basking and feeding opportunities against vulnerability of predators such as garter snakes (Pearl et al. 2010), herons, nonnative fish and bullfrogs (McAllister and Leonard 1997). The diet of OSFs at a site in British Columbia included slugs, snails, spiders, crickets, grasshoppers, dragonflies, damselflies, true bugs, beetles, butterflies, moths, bees, ants, and wasps (Pearl et al. 2010).

Oregon spotted frogs are generally inactive during the winter season, although some individuals may be observed at the water surface on warmer days (Hayes 1994) and in lowland habitats that do not freeze. At higher elevations with harsher winters, OSFs appear to use nonfreezing aquatic environments such as springs, channels, beaver runs, and areas of deep water. Telemetry studies at montane sites in Washington and Oregon suggest that OSF’s can be active under ice during portions of the winter (Pearl et al. 2010). In areas where snow and ice cover their habitat for months, OSF’s are believed to retreat to springs where they spend the winter in a state of torpor in the highly oxygenated and ice-free water (McAllister and Leonard 1997).

10.4.3. Current Conditions

Critical habitat for OSF was designated in 2016 and includes three occupied habitat units in Klamath Basin (81 FR 29335). The Williamson River unit consists of the Williamson River (and a tributary, Jack Creek) and seasonally wetted areas along the river in Klamath Marsh NWR to the northeast of UKL. The Upper Klamath unit consist of lakes and creeks in Jackson and Klamath counties near Buck Lake and Spencer Creek and Parsnip Lakes and seasonally wetted areas near Keene Creek (81 FR 29335).

The UKL unit includes multiple areas in the Wood River and Sevenmile Creeks areas north of UKL. The Wood River area is inclusive of the Wood River to the levee road near its confluence with Agency Lake and all of Fort Creek and Annie Creek downstream of the Annie Creek Sno-park to its confluence with the Wood River. This unit also includes portions of Sevenmile, Crane, and Fourmile creeks and associated wetted areas and springs that are located to the northwest of UKL (81 FR 29335).

The UKL unit has all of the essential physical or biological features found within the unit but are impacted by invasive plants, woody vegetation plantings and succession, hydrological changes, and nonnative predators (81 FR 29335).

10.4.4. Effects to Oregon Spotted Frog

Oregon spotted frog populations are far enough upstream, or behind a levee near the Wood River, that proposed fluctuations in lake elevations in UKL (and Agency Lake) will have no affect to individual frogs or populations as a result of the PA.

The PA, to store water in and divert water in the Upper Klamath Basin (particularly from UKL), will not adversely modify critical habitat in the Upper Klamath and Williamson River critical habitat units. Implementation of the PA will result in a seasonal range of surface elevations in UKL (Table 7-1 in Section 7.1), and the lowest portions of tributaries to UKL such as the Williamson and Wood rivers, that can be generalized as relatively high-water surface elevations in late winter through early summer and low surface elevations from late summer through early winter. Both the Upper Klamath and the Williamson River critical habitat units, while in the proposed action area, are upstream from impacted areas relative to lake surface elevations in UKL or river flows in the Klamath River. The UKL critical habitat unit includes several tributaries to Agency Lake and includes an area along the Wood River adjacent to Agency Lake (i.e., UKL) that may be impacted during February through June by relatively high surface elevations in UKL and in the lower Wood River. The influence of UKL surface elevations could extend as far up the Wood River to the BLM south levee road but is expected to have diminishing influences of slowing current and raising water levels any further upstream of this location. The influence of lake surface elevations does not extend upstream to areas of OSF critical habitat on other tributaries to Agency Lake within the UKL critical habitat unit.

The PA may result in changes to OSF critical habitat nearest the south end of the Wood River wetland through reducing the Wood River currents and increasing river stage as water backs up as a result of high surface elevations in UKL and Agency Lake. These impacts are anticipated to occur in spring months are small seasonal increases to habitat identified as primary constituent elements (PCE) 1 and 2 for OSF (81 FR 29335). More specifically, increased river stage and slower currents could improve wetted movement corridors for OSF (PCE 2) or increase the amount of seasonal non-breeding habitat if the river stage inundates adjacent depressions (PCE 1). Reclamation concludes that the PA is not likely to adversely affect OSF critical habitat resulting from the PA.

Given the distribution of Oregon spotted frog populations – at elevations higher than the water fluctuations anticipated under the PA – Reclamation concludes there will be no affect to individual frogs or populations as a result of the PA.

10.5. Applegate's Milkvetch

10.5.1. Legal Status

Applegate's milkvetch *Astragalus applegatei* was federally listed as endangered without critical habitat in 1993 (58 FR 40547). The USFWS subsequently published a recovery plan for Applegate's milkvetch in 1998 (USFWS 1998).

10.5.2. Life History

Applegate's milkvetch is a slender, low growing, vine-like herbaceous perennial plant in the Fabaceae (pea) family. The plant's physical appearance is characterized with multiple sprawling stems 12 to 36 inches long and small white to light-pink to lavender pea-like flowers, measuring up to 7mm (0.3 inch). The tip of the keel is faintly lilac-tinged. Flowers are present from June to September. The anthers and stigma ripen simultaneously, enabling self-pollination. The leaves are typically 3.5 to 7cm (1.4 to 2.8 inches) long with 7 to 11 leaflets, with stems 3 to 4 decimeters (12 to 16 inches) long. Plants produce 0.3- to 0.5-inch seed pods during June and July and are widely spreading or declined.

10.5.3. Current Conditions

Applegate's milkvetch is a narrowly distributed endemic plant known to occur only in southern Klamath County, Oregon, with currently 8 occupied sites located within 13 miles of the city of Klamath Falls. Applegate's milkvetch was believed extinct up until its re-discovery in 1983. At the time of the Services listing decision, it was known from two extant sites and one historical site (USFWS 2009). These extant sites were identified as Miller Island and Ewauna Flat Preserve, which supported an estimated 30 to 80 and 30,000 plants, respectively. The historical occurrence identified in the listing was the Keno site. Herbarium records indicate this site was last found in 1931 and was located approximately two miles east of the town of Keno, Oregon (USFWS 2009).

Populations today are known to primarily colonize three large sites; however, presence has also been documented at several smaller sites south of Klamath Falls, Oregon. Sites where populations occur in highest numbers are OC & E, Ewauna Flats Preserve, Collins Tract, and the Klamath Falls Airport (Figure 10-1). It is thought this species was historically more prevalent, based on habitat surveys. Urban development, agriculture, weeds, fire suppression, flood control and land reclamation have contributed to the decline of this species (USFWS 2009).

10.5.4. Effects to Applegate's milkvetch

Each of the three sites of Applegate's milkvetch is within the Project boundaries. However, Reclamation does not anticipate effects to the sites or individual plants as a result of water storage and delivery within the Project. Routine O&M activities of the PA described in Element Three of the PA (Part 4.3.3.) are also not expected to impact Applegate's milkvetch or habitats in the 13 sites where it is known to occur. Reclamation's activities such as road maintenance, seasonal mowing and weed abatement will not occur at occupied sites or near known plants; thus the PA will have no effect to designated critical habitat. The PA is anticipated to have no effect on Applegate's milkvetch.

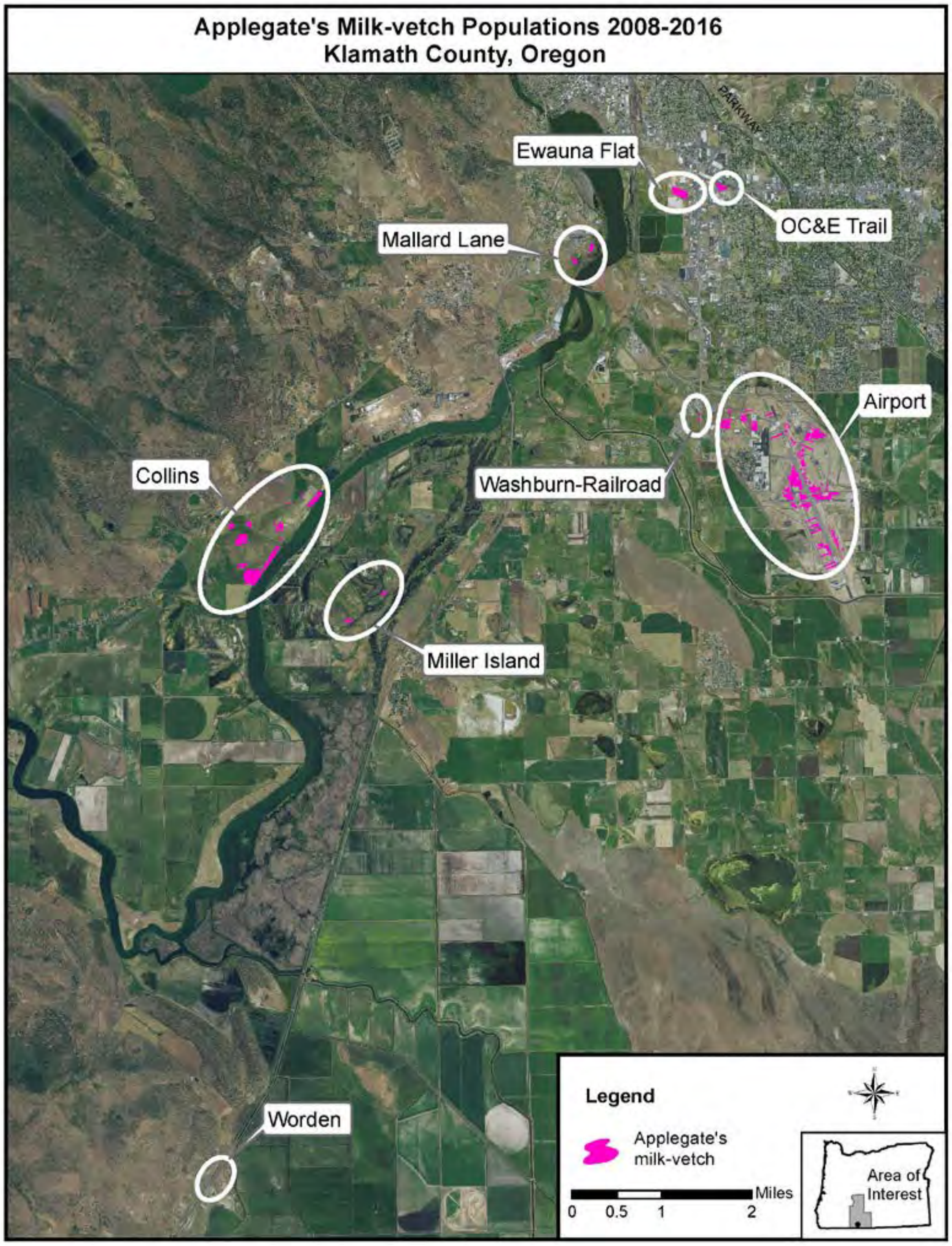

Figure 10-1. Map of the area near Klamath Falls and the Keno Reservoir, Oregon, showing both the known populations of Applegate's milkvetch and locations of historic populations (source: pers. comm. J. Spaur, 19 December 2018).

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11. CONCLUSION

Reclamation has analyzed the effects of the PA (50 C.F.R. § 402.02) using the best scientific and commercial data available and has made the following effects determinations shown in the table.

Table 11-1. Determination of Effects.

Species	Scientific Name	Status	Effect of the Proposed Action
SONCC coho salmon	*Oncorhynchus kisutch*	Threatened	May affect, likely to adversely affect
Lost River sucker	*Deltistes luxatus*	Endangered	May affect, likely to adversely affect
Shortnose sucker	*Chasmistes brevirostris*	Endangered	May affect, likely to adversely affect
Southern Resident DPS killer whale	*Orcinus orca*	Endangered	May affect, not likely to adversely affect
Southern DPS North American green sturgeon	*Acipenser medirostris*	Threatened	May affect, not likely to adversely affect
Southern DPS Pacific eulachon	*Thaleichthys Pacificus*	Threatened	May affect, not likely to adversely affect
Bull trout	*Salvelinus confluentus*	Threatened	No effect
Oregon spotted frog	*Rana pretiosa*	Threatened	No effect
Applegate's milk-vetch	*Astragalus applegatei*	Endangered	No effect
SONCC Coho salmon Critical Habitat	*Oncorhynchus kisutch*	Designated	May affect, likely to adversely affect
Lost River sucker Critical Habitat	*Deltistes luxatus*	Designated	May affect, likely to adversely affect
Shortnose sucker Critical Habitat	*Chasmistes brevirostris*	Designated	May affect, likely to adversely affect
Southern DPS Pacific eulachon Critical Habitat	*Thaleichthys Pacificus*	Designated	May affect, not likely to adversely affect
Southern DPS North American green sturgeon	*Acipenser medirostris*	Designated	Not in Proposed Action Area and not analyzed
Bull trout	*Salvelinus confluentus*	Designated	Not likely to adversely affect
Oregon spotted frog Critical Habitat	*Rana pretiosa*	Designated	Not likely to adversely affect
Applegate's milk-vetch Critical Habitat	*Astragalus applegatei*	Endangered	No effect

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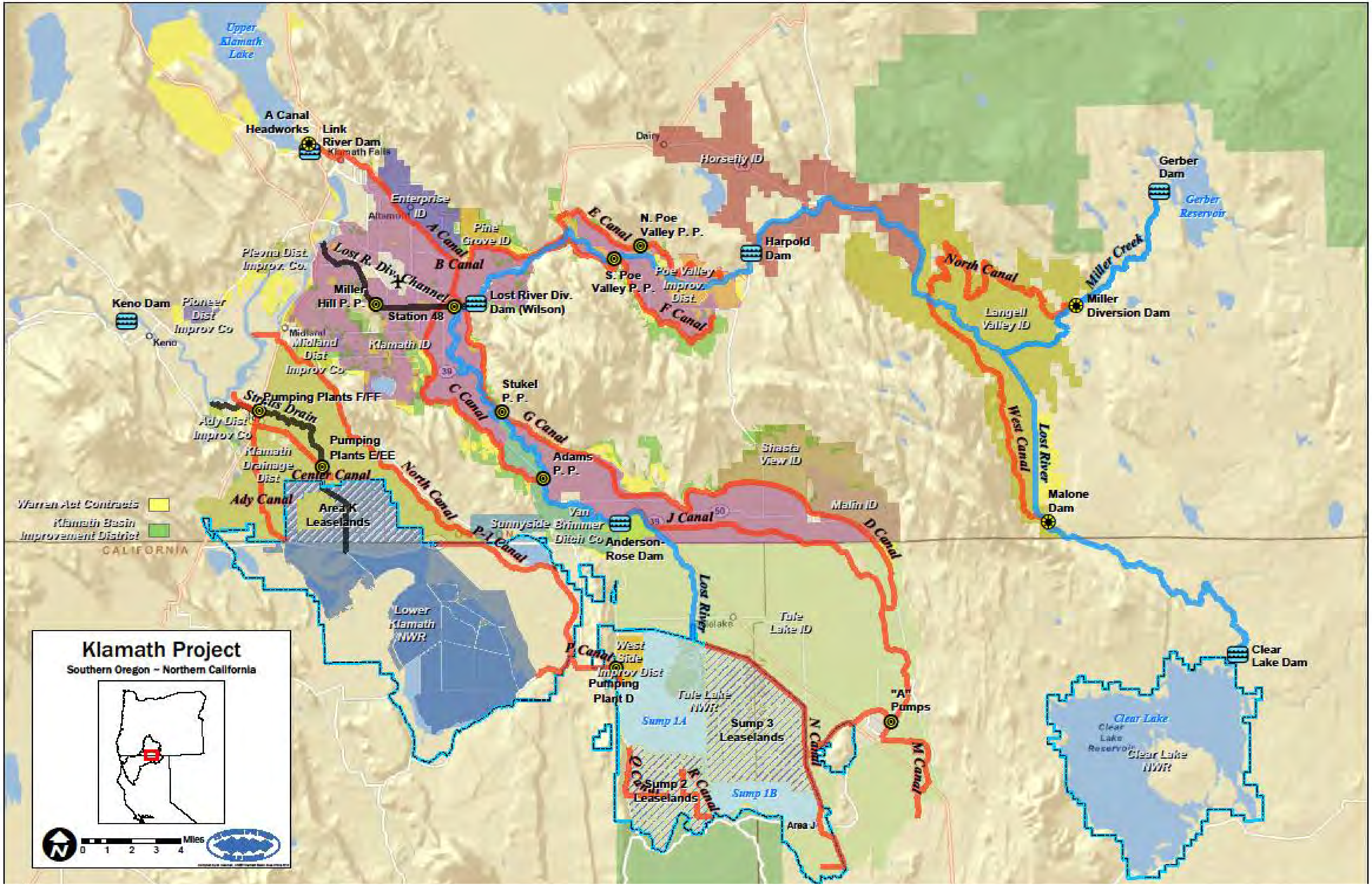
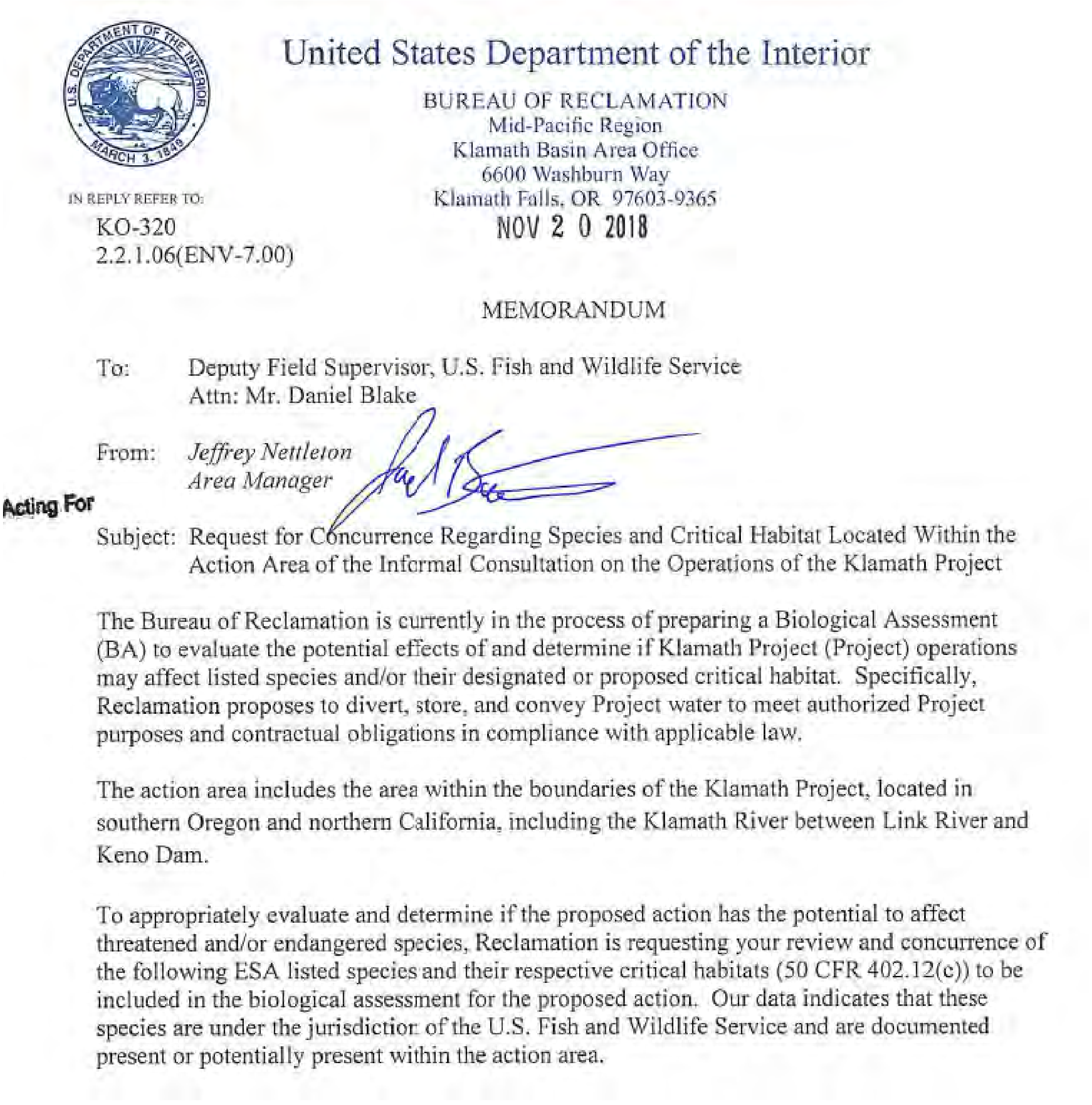
Appendix 1A: Project Map


Klamath Project
Southern Oregon – Northern California
Upper Klamath Lake
A Canal Headworks
Link River Dam
Klamath Falls
Enterprise ID
Altamont
A Canal
Pine Grove ID
B Canal
Plevna Dist. Improv. Co.
Lost R. Div. Channel
Miller Hill P. P.
Station 48
Lost River Div. Dam (Wilson)
Keno Dam
Keno
Pioneer Dist Improv Co
Midland
Midland Dist Improv Co
Klamath ID
Dairy
Horsefly ID
E Canal
N. Poe Valley P. P.
S. Poe Valley P. P.
Poe Valley Improv. Dist.
F Canal
Harpold Dam
North Canal
Langell Valley ID
Miller Creek
Miller Diversion Dam
Gerber Dam
Gerber Reservoir
Straits Drain
Pumping Plants F/FF
Ady Dist Improv Co
Klamath Drainage Dist
Pumping Plants E/EE
Center Canal
Ady Canal
Area K Leaselands
North Canal
C Canal
Stukel P. P.
G Canal
Adams P. P.
Shasta View ID
Malin ID
West Canal
Lost River
Malone Dam
Warren Act Contracts 🟨
Klamath Basin Improvement District 🟩
CALIFORNIA
Sunnyside
Van Brimmer Ditch Co
Anderson-Rose Dam
J Canal
D Canal
P-1 Canal
Lower Klamath NWR
Lost River
Tulelake
Tule Lake ID
P Canal
West Side Improv Dist
Pumping Plant D
Tule Lake NWR
Sump 1A
Sump 3 Leaselands
N Canal
"A" Pumps
M Canal
Q Canal
Sump 2 Leaselands
R Canal
Sump 1B
Area J
Clear Lake Dam
Clear Lake
Clear Lake Reservoir
Clear Lake NWR
N
Miles
0 1 2 3 4

Appendix 1B: Species List Correspondence



United States Department of the Interior

BUREAU OF RECLAMATION
Mid-Pacific Region
Klamath Basin Area Office
6600 Washburn Way
Klamath Falls, OR 97603-9365

IN REPLY REFER TO:
KO-320
2.2.1.06(ENV-7.00)

NOV 2 0 2018

MEMORANDUM

To: Deputy Field Supervisor, U.S. Fish and Wildlife Service
Attn: Mr. Daniel Blake

From: *Jeffrey Nettleton*
Area Manager

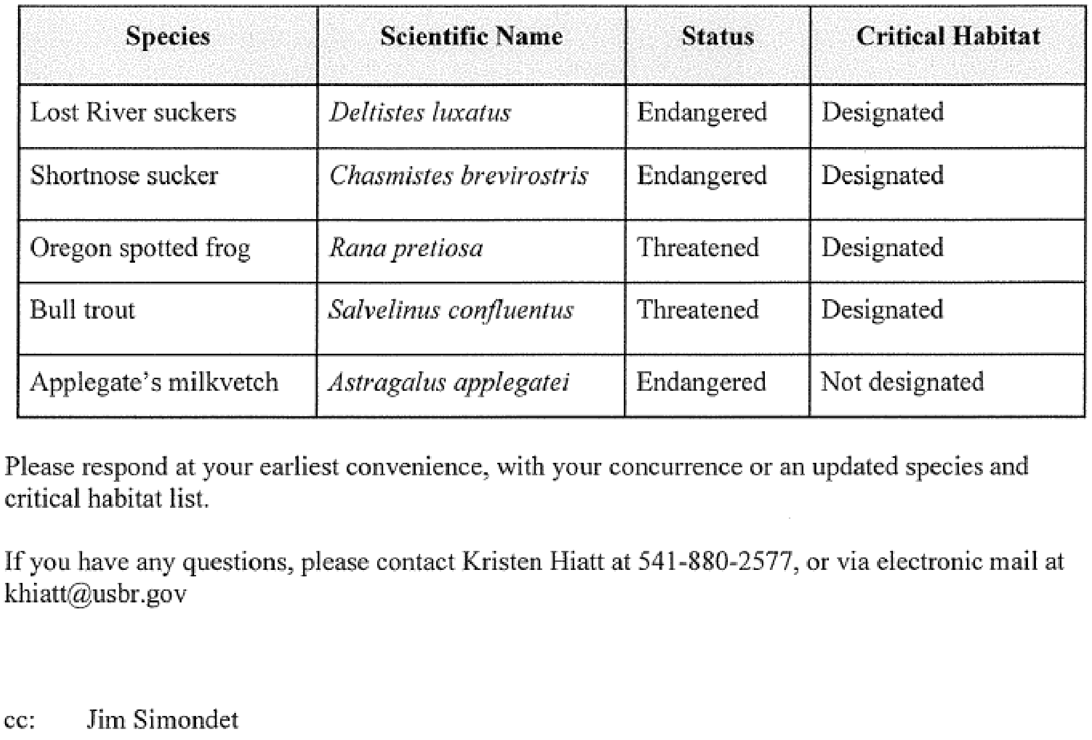
Acting For

Subject: Request for Concurrence Regarding Species and Critical Habitat Located Within the Action Area of the Informal Consultation on the Operations of the Klamath Project

The Bureau of Reclamation is currently in the process of preparing a Biological Assessment (BA) to evaluate the potential effects of and determine if Klamath Project (Project) operations may affect listed species and/or their designated or proposed critical habitat. Specifically, Reclamation proposes to divert, store, and convey Project water to meet authorized Project purposes and contractual obligations in compliance with applicable law.

The action area includes the area within the boundaries of the Klamath Project, located in southern Oregon and northern California, including the Klamath River between Link River and Keno Dam.

To appropriately evaluate and determine if the proposed action has the potential to affect threatened and/or endangered species, Reclamation is requesting your review and concurrence of the following ESA listed species and their respective critical habitats (50 CFR 402.12(c)) to be included in the biological assessment for the proposed action. Our data indicates that these species are under the jurisdiction of the U.S. Fish and Wildlife Service and are documented present or potentially present within the action area.



Species	Scientific Name	Status	Critical Habitat
Lost River suckers	*Deltistes luxatus*	Endangered	Designated
Shortnose sucker	*Chasmistes brevirostris*	Endangered	Designated
Oregon spotted frog	*Rana pretiosa*	Threatened	Designated
Bull trout	*Salvelinus confluentus*	Threatened	Designated
Applegate's milkvetch	*Astragalus applegatei*	Endangered	Not designated

Please respond at your earliest convenience, with your concurrence or an updated species and critical habitat list.

If you have any questions, please contact Kristen Hiatt at 541-880-2577, or via electronic mail at khiatt@usbr.gov

cc: Jim Simondet

United States Department of the Interior

FISH AND WILDLIFE SERVICE

Klamath Falls Fish and Wildlife Office
1936 California Avenue
Klamath Falls, Oregon 97601
(541) 885-8481 FAX (541) 885-7837

In Reply Refer To:
8-10-10-TAILS#
08EKLA00-2019-E-00015

NOV 27 2018

Memorandum

To: Area Manager, Bureau of Reclamation Klamath Basin Area Office, Klamath Falls, Oregon

From: Field Supervisor, Klamath Falls Fish & Wildlife Office
Klamath Falls, Oregon

Subject: Species and Critical Habitat Located within the Action Area of the Operations of the Klamath Project

This responds to your memorandum dated November 20, 2018, which we received on November 21, 2018, requesting confirmation of the species listed under the Endangered Species Act (Act) of 1973, as amended (16 U.S.C. 1531 et seq.) and their critical habitat located within the action area of the operations of the Klamath Project (Project). Our understanding is you will use this information as part of the consultation process under section 7 of the Act.

To provide an accurate list of species and their critical habitat, we first verified the action area. Federal regulations define the action area for consultation under section 7 of the Act as "all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action" (50 C.F.R. § 402.02). Based on our understanding of the Project, the action area would include all Project reservoirs, water transport structures, and irrigated lands, as well as the Klamath River downstream to the Pacific Ocean. Although Project operations do not occur in tributaries to Upper Klamath Lake, the Sprague River below the former Chiloquin Dam site would also be included in the action area if conservation measures for listed suckers are proposed to occur in this tributary.

Based on our understanding of the Project, federally listed, proposed, and candidate species and critical habitat that may be present within the action area and are under U.S. Fish and Wildlife Service jurisdiction are listed in Table 1 below. Also potentially present in the vicinity of the project are bald eagle (*Haliaeetus leucocephalus*) and golden eagle (*Aquila chrysaetos*). Although the bald eagle is no longer protected under the Act, the bald eagle and golden eagle are protected under the federally-administered Bald and Golden Eagle Protection Act (BGEPA) and Migratory Bird Treaty Act (MBTA). Information on these acts is available at: www.fws.gov/migratorybirds/baldeagle.htm. This webpage contains information relevant to your responsibilities to conserve eagles and their habitats. Similarly, the MBTA prohibits the taking, killing, possession, and transportation among other actions of migratory birds, their eggs, parts, and nests, except when specifically permitted by regulations. Additional information on MBTA is available from this website: https://www.fws.gov/birds/policies-and-regulations/laws-legislations/migratory-bird-treaty-act.php.

If you have any questions or need additional information, please contact Evan Childress at (541) 885-2506.

Table 1. Federally endangered (E), threatened (T), proposed (P), and candidate (C) species and critical habitat under U.S. Fish and Wildlife Service jurisdiction documented present or potentially present in the action area.

Species	Scientific Name	Status	Critical Habitat Status
Lost River sucker	*Deltistes luxatus*	E	Designated
Shortnose sucker	*Chasmistes brevirostris*	E	Designated
Bull trout	*Salvelinus confluentus*	T	Designated
Oregon spotted frog	*Rana pretiosa*	T	Designated
Gray wolf	*Canis lupus*	E	Designated
Fisher	*Pekania pennant*	P	N/A
North American Wolverine	*Gulo gulo luscus*	P	N/A
Northern spotted owl	*Strix occidentalis caurina*	T	Designated
Yellow-billed cuckoo	*Coccyzus americanus*	T	Proposed
Applegate's milk-vetch	*Astagalus applegatei*	E	None
Greene's tuctoria	*Tuctoria greenei*	E	Designated
Slender Orcutt grass	*Orcuttia tenuis*	T	Designated
Whitebark pine	*Pinus albicaulis*	C	N/A

United States Department of the Interior

BUREAU OF RECLAMATION
Mid-Pacific Region
Klamath Basin Area Office
6600 Washburn Way
Klamath Falls, OR 97603-9365

IN REPLY REFER TO:
KO-300
2.2.1.06(ENV-7.00)

NOV 2 0 2018

Mr. Jim Simondet
National Marine Fisheries Service
1655 Herndon Road
Arcata, CA 95521

Subject: Request for Concurrence Regarding Species and Critical Habitat Located Within the Action Area of the Informal Consultation on the Operations of the Klamath Project

Dear Mr. Simondet:

The Bureau of Reclamation is currently in the process of preparing a Biological Assessment (BA) to evaluate the potential effects of and determine if Klamath Project (Project) operations may affect Endangered Species Act (ESA) listed species and/or their designated or proposed critical habitat. Specifically, Reclamation proposes to divert, store, and convey Project water to meet authorized Project purposes and contractual obligations in compliance with applicable law.

Current analysis indicates the action area associated with Reclamation's proposed action includes the area within the boundaries of the Project located in southern Oregon and northern California, and the Klamath River from Upper Klamath Lake to the mouth of the river at Klamath, California.

To appropriately evaluate and determine if the proposed action has the potential to affect threatened and/or endangered species, Reclamation is requesting your review and concurrence of the following ESA listed species and their respective critical habitats (50 CFR 402.12(c)) to be included in the biological assessment for the proposed action. Our data indicates that these species are under the jurisdiction of the National Marine Fisheries Service and are documented present or potentially present within the action area.

Species	Scientific Name	Status	Critical Habitat
Southern Oregon/Northern California Coasts coho Salmon	*Oncorhynchus kisutch*	Threatened	Designated
Southern Resident DPS Killer Whale	*Orcinus orca*	Endangered	Designated
Southern DPS North American green sturgeon	*Acipenser medirostris*	Threatened	Designated
Southern DPS Pacific eulachon	*Thaleichthys Pacificus*	Threatened	Designated

Please respond at your earliest convenience, with your concurrence or an updated species and critical habitat list.

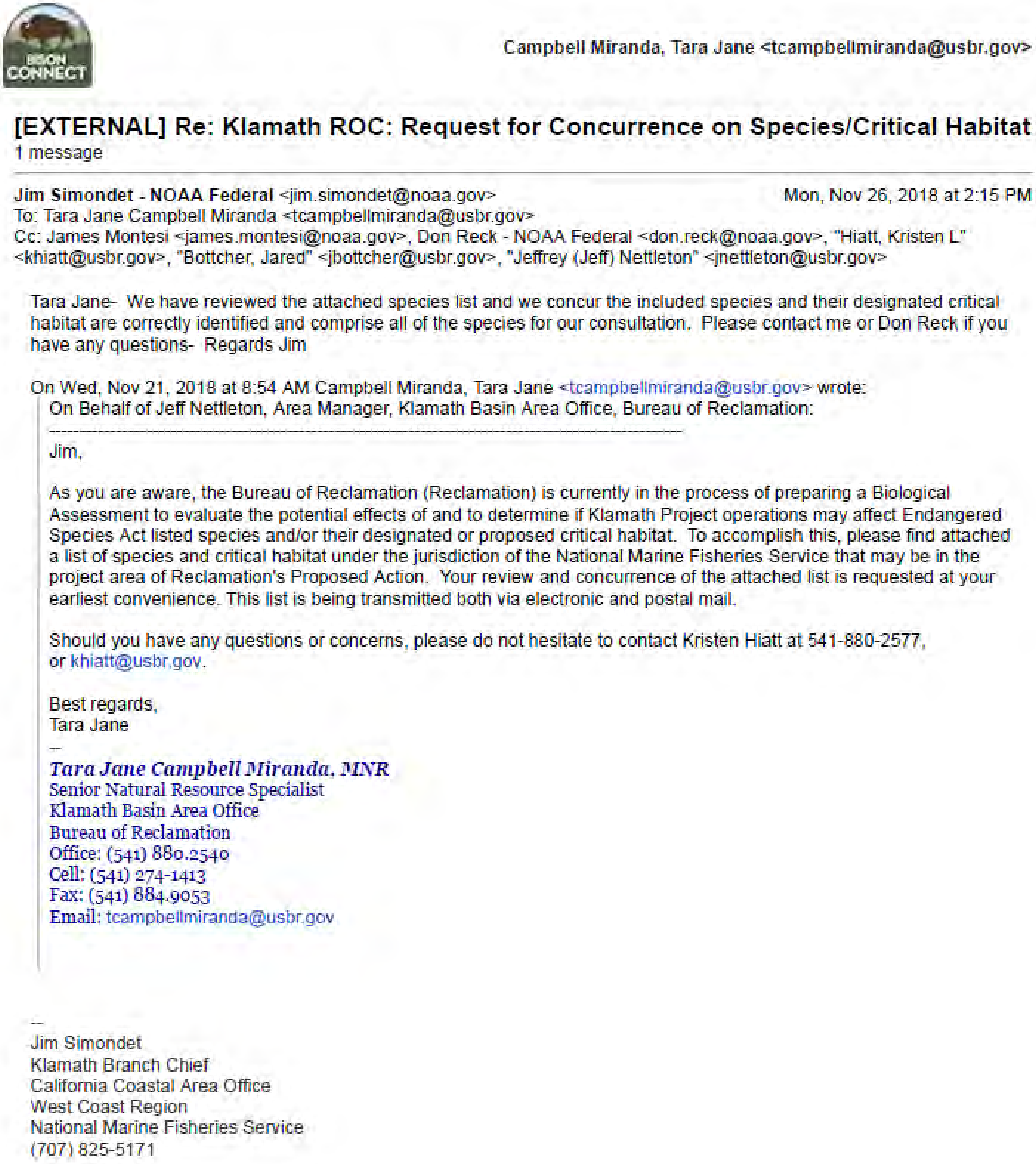
If you have any questions, please contact Kristen Hiatt at 541-880-2577, or via electronic mail at khiatt@usbr.gov.

Sincerely,

Acting For

Jeffrey Nettleton
Area Manager

cc: Daniel Blake
Evan Childress



Campbell Miranda, Tara Jane <tcampbellmiranda@usbr.gov>

[EXTERNAL] Re: Klamath ROC: Request for Concurrence on Species/Critical Habitat

1 message

Jim Simondet - NOAA Federal <jim.simondet@noaa.gov> Mon, Nov 26, 2018 at 2:15 PM
To: Tara Jane Campbell Miranda <tcampbellmiranda@usbr.gov>
Cc: James Montesi <james.montesi@noaa.gov>, Don Reck - NOAA Federal <don.reck@noaa.gov>, "Hiatt, Kristen L" <khiatt@usbr.gov>, "Bottcher, Jared" <jbottcher@usbr.gov>, "Jeffrey (Jeff) Nettleton" <jnettleton@usbr.gov>

Tara Jane- We have reviewed the attached species list and we concur the included species and their designated critical habitat are correctly identified and comprise all of the species for our consultation. Please contact me or Don Reck if you have any questions- Regards Jim

On Wed, Nov 21, 2018 at 8:54 AM Campbell Miranda, Tara Jane <tcampbellmiranda@usbr.gov> wrote:

> On Behalf of Jeff Nettleton, Area Manager, Klamath Basin Area Office, Bureau of Reclamation:
>
> ---
>
> Jim,
>
> As you are aware, the Bureau of Reclamation (Reclamation) is currently in the process of preparing a Biological Assessment to evaluate the potential effects of and to determine if Klamath Project operations may affect Endangered Species Act listed species and/or their designated or proposed critical habitat. To accomplish this, please find attached a list of species and critical habitat under the jurisdiction of the National Marine Fisheries Service that may be in the project area of Reclamation's Proposed Action. Your review and concurrence of the attached list is requested at your earliest convenience. This list is being transmitted both via electronic and postal mail.
>
> Should you have any questions or concerns, please do not hesitate to contact Kristen Hiatt at 541-880-2577, or khiatt@usbr.gov.
>
> Best regards,
> Tara Jane
> --
> ***Tara Jane Campbell Miranda, MNR***
> Senior Natural Resource Specialist
> Klamath Basin Area Office
> Bureau of Reclamation
> Office: (541) 880.2540
> Cell: (541) 274-1413
> Fax: (541) 884.9053
> Email: tcampbellmiranda@usbr.gov

--
Jim Simondet
Klamath Branch Chief
California Coastal Area Office
West Coast Region
National Marine Fisheries Service
(707) 825-5171

Appendix 4: Proposed Action

Contents

Figures

TABLES

Section A - Key Model Variables

Section B - Proposed Action Model Output Graphs

Section C - LKNWR Historical Deliveries

Section D - Clear Lake Reservoir and Gerber Reservoir Water Supply Forecast Models

Table D2. Gerber Reservoir Operational Forecast Model

A.4.1. Model Overview

The Klamath Basin Planning Model (KBPM) was used to simulate the operation of the Klamath River system over a range of hydrologic conditions. The model is a generalized reservoir-river basin simulation model that allows for specification and achievement of user-defined goals. Figure A.4.1.1 shows the overall Klamath River watershed and the Klamath and Lost rivers. The KBPM extent covers from Upper Klamath Lake (UKL) to Iron Gate Dam (IGD), just upstream of the Shasta River confluence.

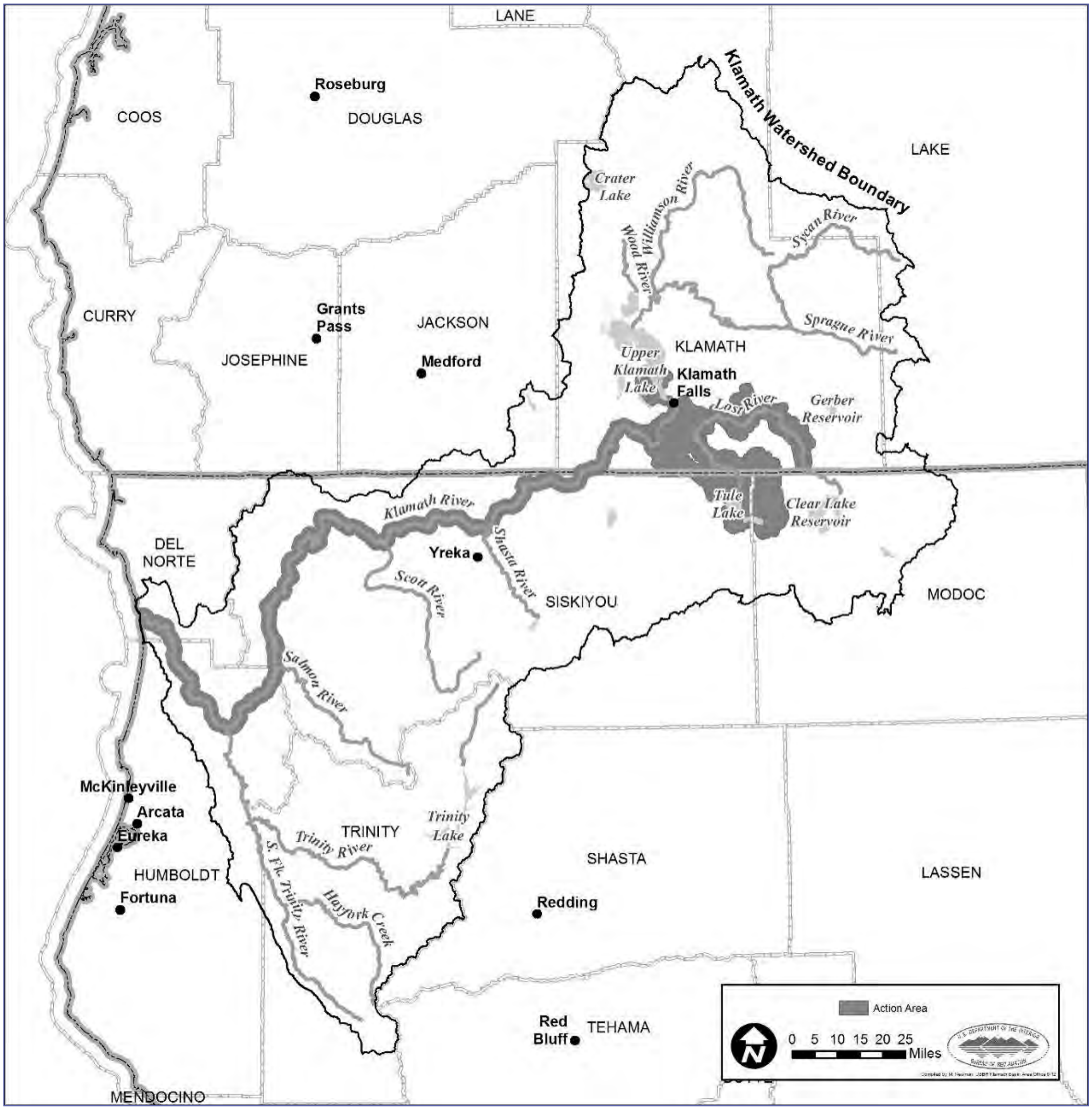


Figure A.4.1.1 Location of Upper Klamath Basin, Oregon and California, and locations of major rivers.

Inputs to the KBPM were developed at a daily timestep and include water diversion requirements (demands), system gains and losses (accretions), UKL net inflows, inflow from the Lost River through the Lost River Diversion Channel (LRDC) and return flow ratios. The Klamath Basin daily inflow data set was developed by a working team of hydrologists and modelers from various organizations using historical data from a variety of sources for the 36-year period of record (POR) including water years 1981 through 2016. The resulting hydrology represents the water supply available from the Klamath River system, including UKL, to the service area at the current level of development. This data development is discussed further in Section A.4.3.

The KBPM produces daily outputs for river flows, Klamath Project (Project) diversions (including deliveries to the Lower Klamath National Wildlife Refuge [LKNWR]) and reservoir storage. The model output also serves as input data for other analysis tools.

It's important to note that the KBPM is a planning tool that assisted in the development of the Proposed Action and, though modelers have strived to make modeled actions implementable in actual operations, some of the processes built into the model cannot be implemented. For example, perfect foresight of Project diversion of return flows was used to ensure that all water available to the Project in a given year was utilized. While the assumption that the Project will utilize all water made available for irrigation under this management regime is sound, there is no assurance that all available return flows will be captured and reused for irrigation purposes in real-time operations. Real-time implementation of the Proposed Action may not result in fully efficient use of these flows. The actual availability and efficiency of use of Project return flows is heavily dependent upon current hydrologic and meteorological conditions and will vary from year to year. This is just one example of how some of the processes built into a planning model may not be implemented during actual operations. Therefore, although much effort has been made to make the KBPM as operationally realistic as possible, its output cannot be viewed as the certain outcomes that will be realized when implementing the Proposed Action.

A.4.2 WRIMS and WRESL Code

The KBPM is built on the Water Resources Integrated Modeling System (WRIMS) platform. WRIMS uses a mixed integer linear programming solver to route water through a user-defined network of flow arcs and nodes representing locations in the river system. Policies and priorities for water routing are implemented through user-defined weights applied to flow arcs and storage nodes in the network. System variables and the constraints on them are specified with a scripting language called the "water resources engineering simulation language" (WRESL). WRESL code is developed in simple ascii text files. Time series input data and model results are stored in HEC-DSS files. Relational data (lookup tables) are stored in ascii text files.

A.4.3 Model Representation

A.4.3.1 Modeled Rivers, Lakes, Conveyance Facilities, and Model Schematic

The KBPM simulates water-supply related operations of the Project within the Klamath River system. Because this model operates on a mass-balance basis, Project operations which do not affect water supply such as pesticide use or intermittent maintenance operations were not modeled. Within this system, the components that are specifically modeled include UKL, Lake Ewauna (i.e., Keno Reservoir), the Klamath River from Keno Dam to IGD, and all associated Reclamation-owned facilities that are expected to be operable over the time period covered by this Biological Assessment. Facilities include the Link River Dam (LRD), A Canal, LRDC, North Canal, Ady Canal, Klamath Straits Drain (KSD), and all associated pumping facilities. Note that Reclamation does not own the North Canal headworks, and Reclamation therefore has limited control over deliveries through this canal.

The model does not simulate the Lost River system upstream of Harpold Dam. After runoff from the Lost River catchment has subsided, the area upstream of Harpold Dam is typically operated as a closed system during the irrigation season when the releases from Clear Lake and Gerber reservoirs (and any natural flow) equal the water used prior to flows reaching Harpold Dam. Harpold Dam is a flash board dam where the flash boards are added and removed as needed. The boards are up when releases are being made from Clear Lake and Gerber reservoirs (typically during the spring/summer operational period) and are removed once Clear Lake and Gerber dams stop releases for the fall/winter operational period.

Downstream of Harpold Dam, agricultural water diversions are largely supplied by A Canal diversions from UKL. Flow passing Harpold Dam mixes with return flow, and the combined flow is measured at the headworks of the LRDC at Lost River Diversion Dam, into which the Lost River is diverted. This diversion either flows into Station 48 or Miller Hill pump station (when open) or continues flowing into the Klamath River. The KBPM accounts for flows from the Lost River to the LRDC through a historical daily input time-series (I91). This value is very low when Harpold Dam is operational because it is comprised only of Harpold Dam leakage, runoff and return flows between Harpold and Wilson Dams. When Harpold Dam is not operational, this value can be very high as it includes the entire flow of the Lost River.

Return flows from the Area A2 (which receives water from North and Ady canals) and the LKNWR are also incorporated (Figure A.4.3.1.1) as flows through the Klamath Straits Drain (pumping plants E/EE and F/FF). The direct effect of Project operations ends at the KSD above Keno Dam, Oregon, which is the last feature of Project infrastructure, although the model itself simulates operations down to IGD with the daily accretion between Keno Dam and IGD based on historical data. The model schematic is shown in Figure A.4.3.1.2. For a more detailed description of each link and object referenced in the schematic, please see the definitions in Table A.4.3.4.1 – Key Model Variables.

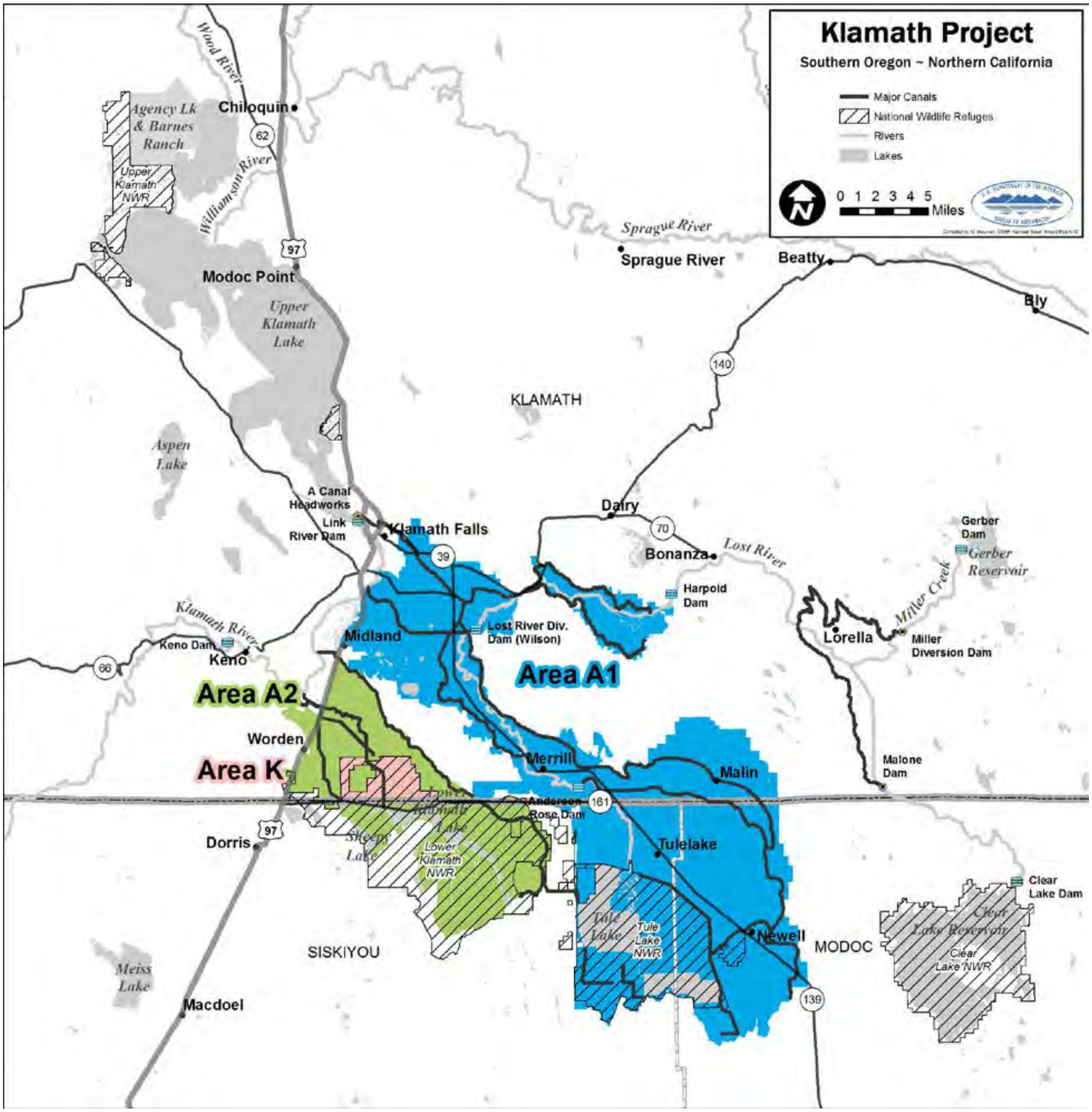
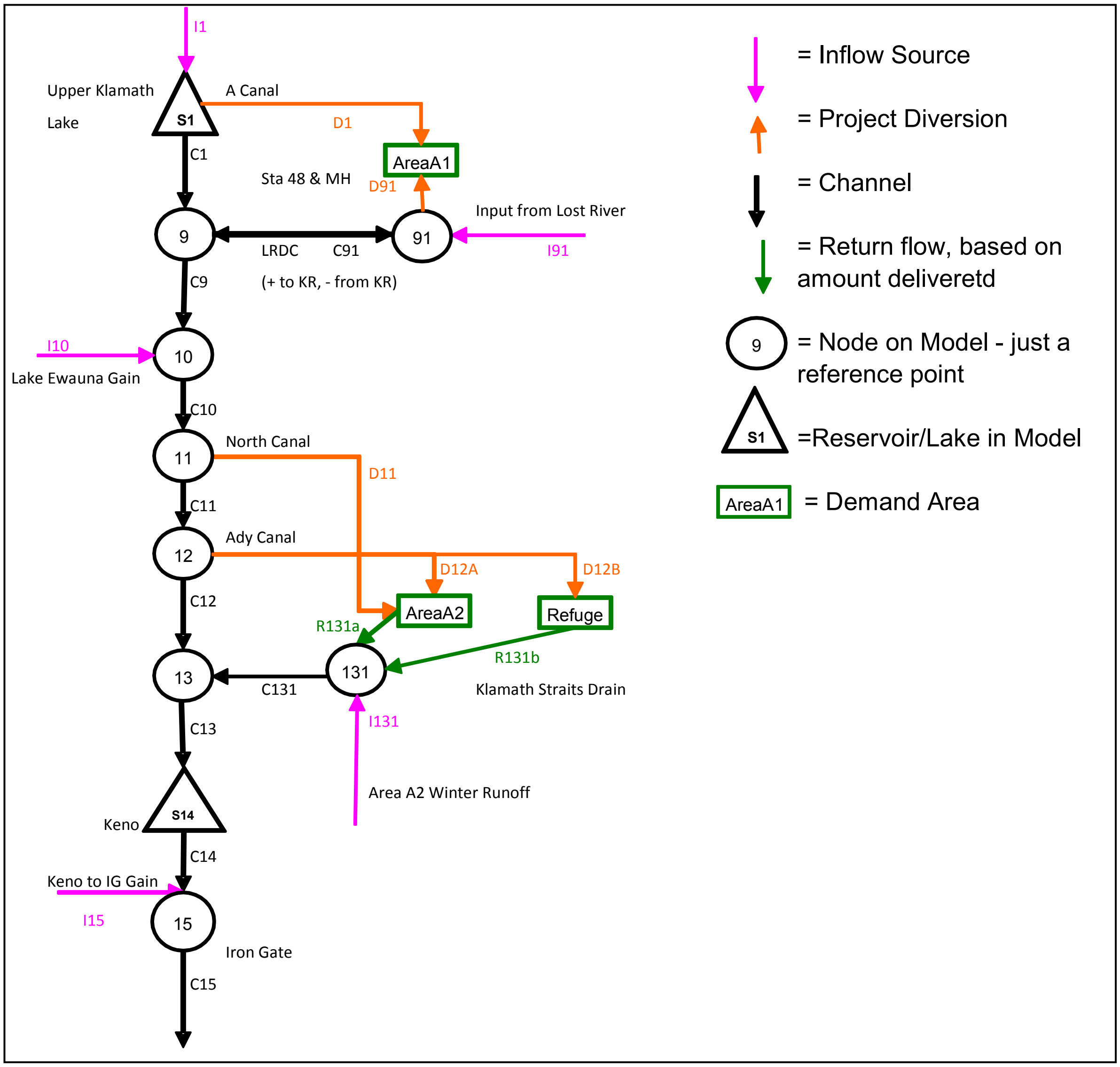


Figure A.4.3.1.1 Upper Klamath Lake and the portion of the Klamath Project served by UKL and the Klamath River in southern Oregon and northern California.


I1
Upper Klamath
Lake
S1
A Canal
D1
AreaA1
C1
Sta 48 & MH
D91
Input from Lost River
9
LRDC
C91
91
I91
(+ to KR, - from KR)
C9
I10
10
Lake Ewauna Gain
C10
North Canal
11
D11
C11
Ady Canal
12
D12A
D12B
C12
AreaA2
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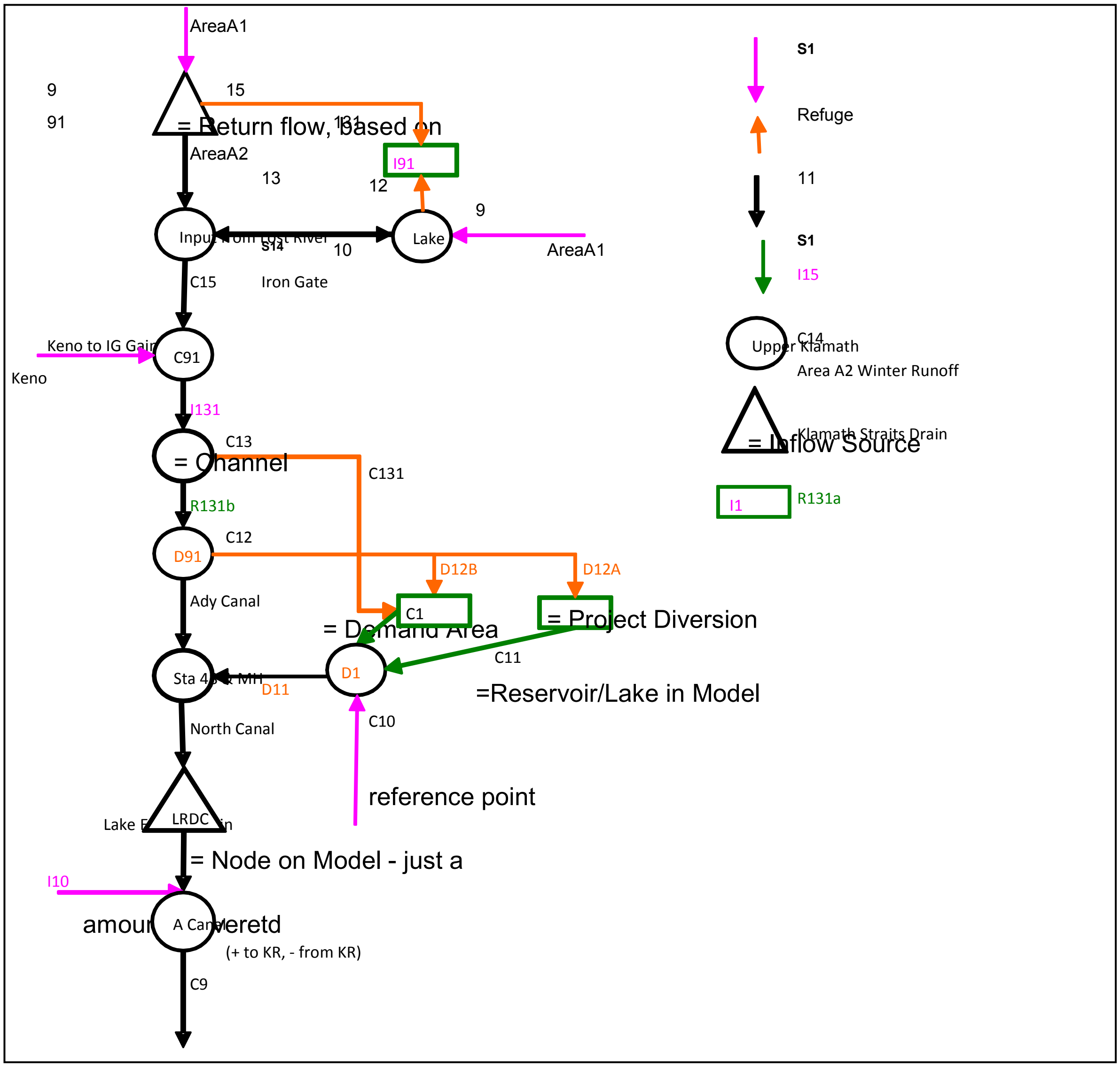
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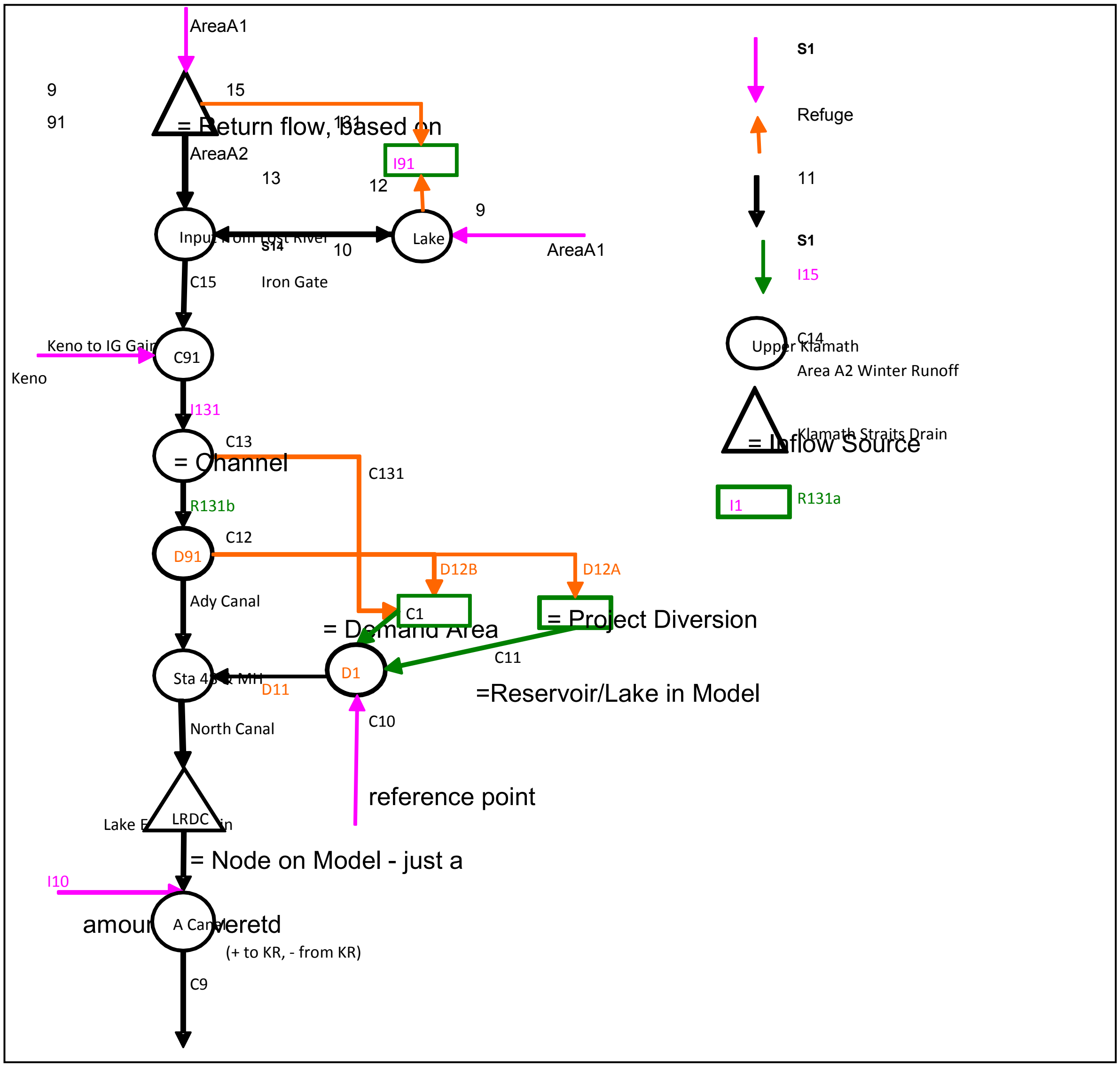
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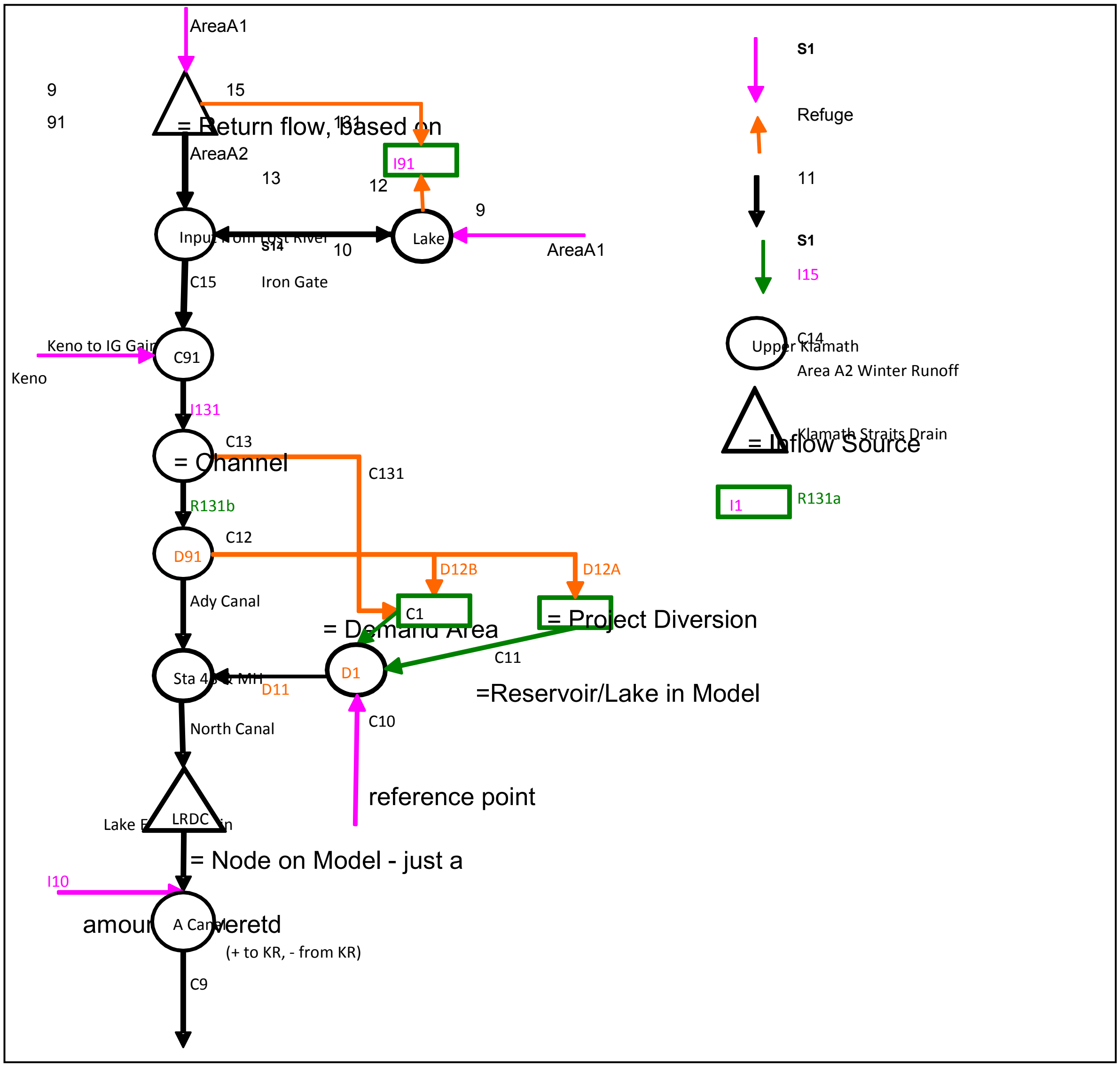
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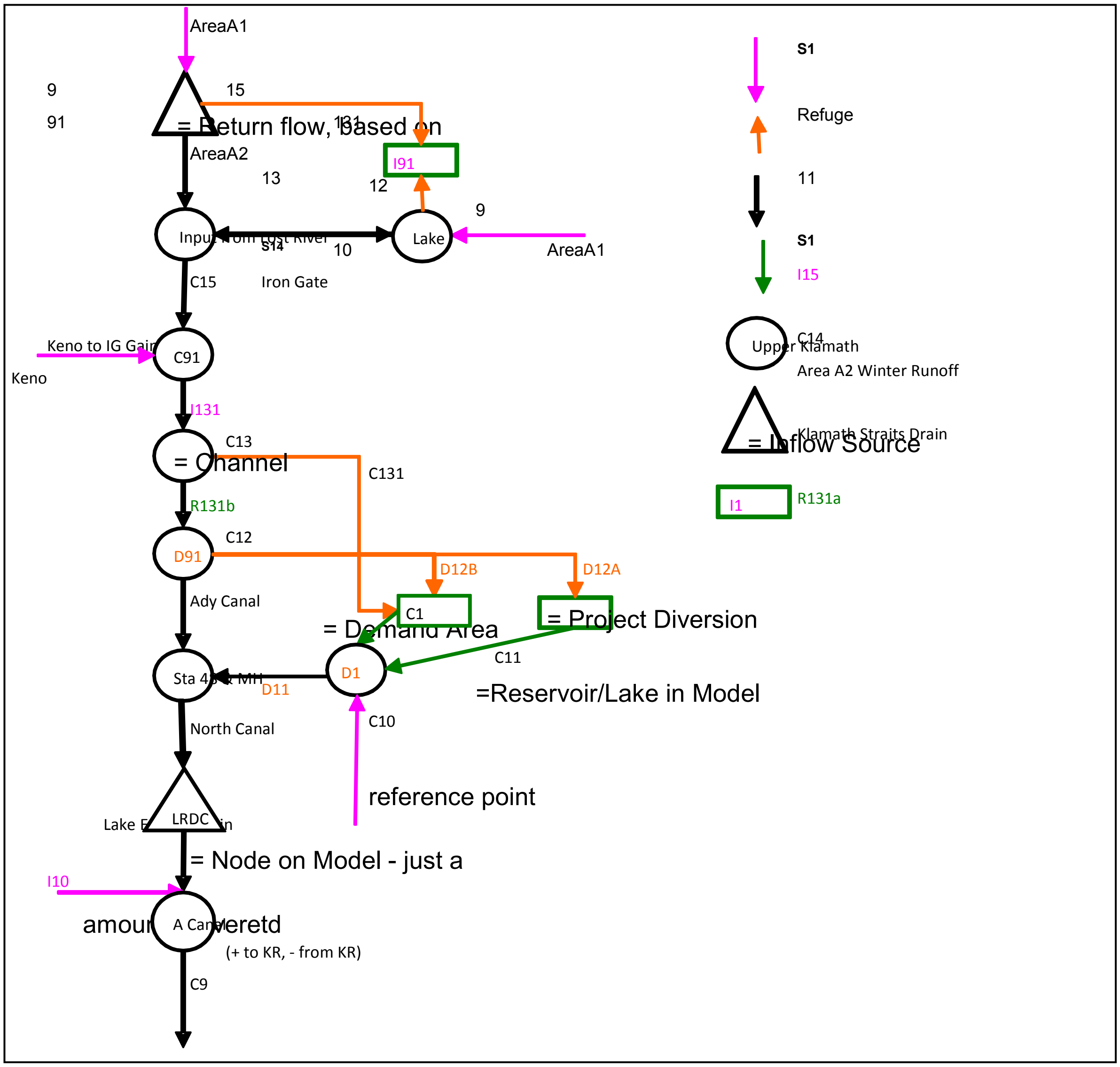
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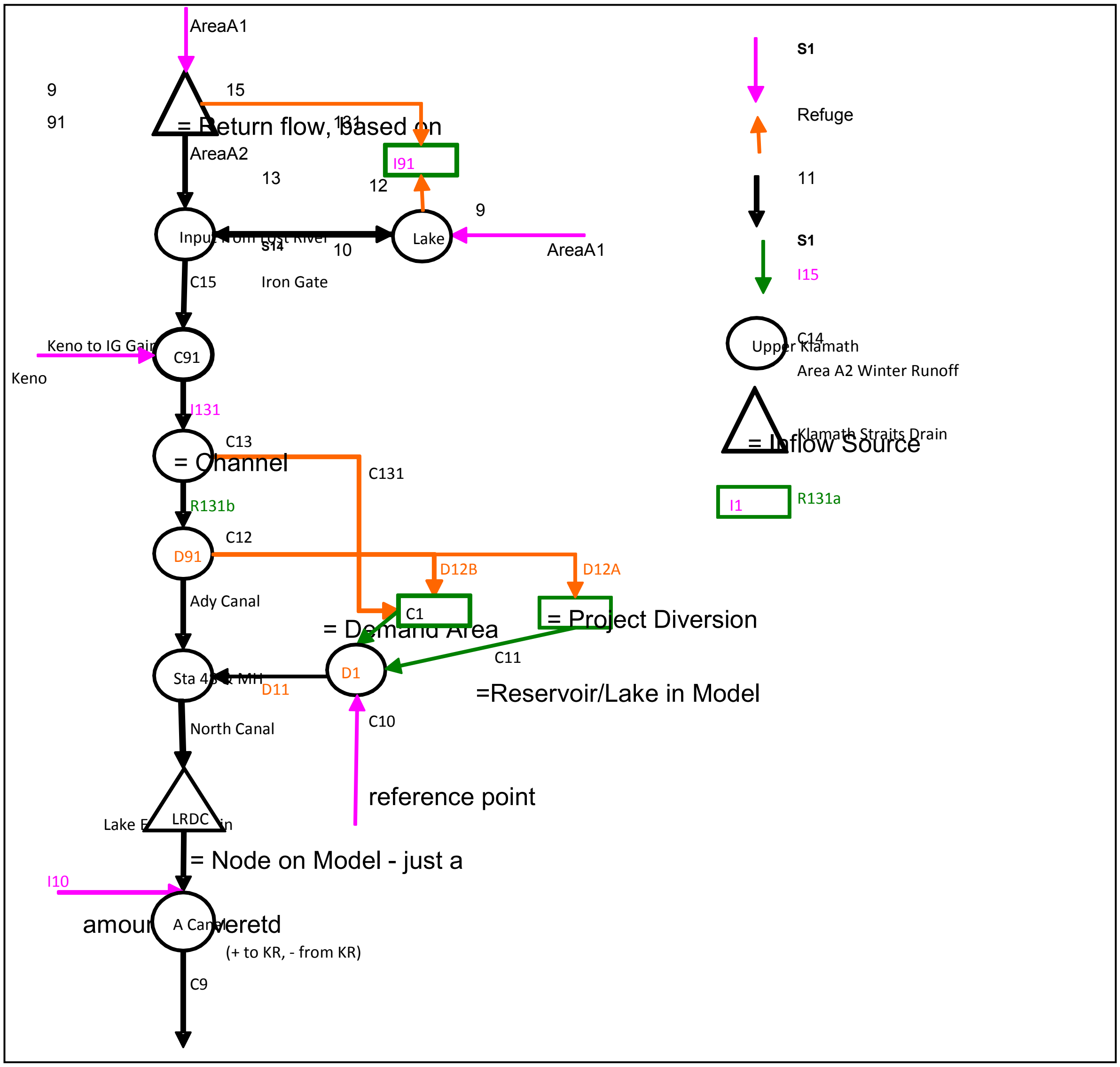
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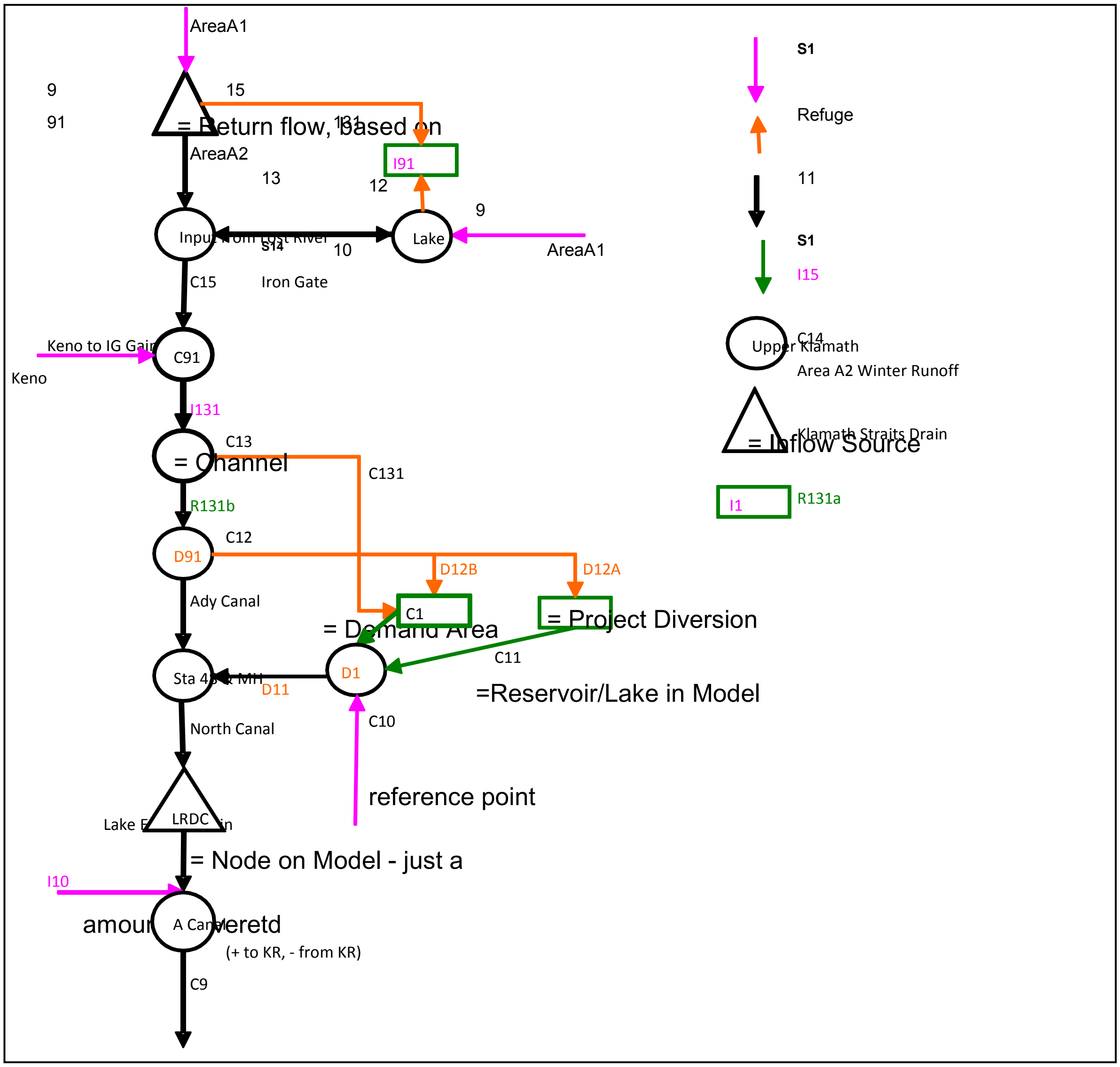

Figure A.4.3.1.2 Model schematic

A.4.3.2 Period of Record

The current KBPM uses a daily timestep, starting October 1, 1980 and running through November 30, 2016. The period between water years 1981 through 2016 includes a reasonable distribution of wet, average and dry years. With this range of data, the model can evaluate a particular operations strategy across the full available range of inflows.

The daily timestep 36-year input data set provides the following advantages over the previous 31-year iteration of the daily timestep model utilized in the 2012 BA:

- Essential daily data inputs are available electronically for water years 1981-2016. These data sets have been extensively evaluated for quality assurance and subjected to quality control over the full POR and are significantly improved over those utilized in the 2012 BA.

- An improved UKL bathymetry addresses important issues from the 2012 BA relating to the relationship between lake elevation and storage volume.

- Forecasts from the Natural Resources Conservation Service (NRCS) for March, April, May, and June have been updated including the additional years in the POR. These forecasts were updated based on the new, current forecasting methods and include several years in which the state of Oregon regulated diversions in accordance with calls to determined claims from The Klamath Tribes and the Project.

- 1981-2016 still include a wide range of hydrologic conditions (lowest [1992] and highest [1983] inflow years), and includes various multi-year hydrologic cycles:

    - Oscillating extreme years such as 1992/1993/1994 when UKL net inflows for April-September measured 141,000/658,000/167,000 acre-feet (AF), respectively.

    - Repetitive wetter years such as 1982/1983/1984 when UKL net inflows for April-September measured 713,000/893,000/833,000 AF, respectively.

    - Repetitive drier years such as 2013/2014/2015 when UKL net inflows for April-September measured 295,000/225,000/195,000 AF, respectively.

A.4.3.3 Hydrology Inputs

A.4.3.3.1 Definitions

Area 1 is the portion of the Project that includes lands served by A Canal and the LRDC including Klamath Irrigation District (KID), Tulelake Irrigation District, and Warren Act contractors and Districts served by KID.

Area 2 is the portion of the Project that includes Klamath Drainage District and LKNWR served by the Ady and North canals.

Quality Assurance is process oriented to ensure the correct steps are completed in the correct manner. Additionally, planned and systematic activities are implemented in a quality system so that quality requirements for a product or service will be fulfilled. In the context of data sets for the WRIMS model, quality assurance will relate to the configuration of the physical infrastructure of water diversions structures, gauging systems, and how data are collected.

Quality Control (QC) is product oriented to ensure the results meet the expectations of the project. It includes the techniques and activities used to fulfill requirements for quality. QC emphasizes testing of products to uncover defects. In the context of data sets for the WRIMS model, quality control will relate to proofing of the data and correcting/adjusting data so that a final reliable dataset is created.

A.4.3.3.2 Data Sets

1. Project Daily Data and Project Historical Use Data
2. UKL net inflow
3. Lake Ewauna (Keno Reservoir) accretions
4. Keno Dam to IGD accretions
5. LRDC inflow from the Lost River
6. Area 2 winter runoff
7. NRCS forecasts

A.4.3.3.3 Project Daily Data and Project Historical Use Data

All data sets utilized in the 2012 Biological Assessment were updated to include the additional years (2012-2016) in the POR, and all data were subjected to extensive QC. As a term and condition of the 2013 Biological Opinion, gages at A Canal, LRDC, Ady Canal at Highway 97 (Klamath Drainage District delivery), Ady Canal above LKNWR (Refuge delivery), North Canal, and KSD are regularly maintained and recalibrated. Using these more accurate gage data, all relevant data from the 2012 BA was QC'ed via comparison with the new data sets. Comprehensive detail on all data analysis and correction to Project diversion data can be found in Dunsmoor (2017a). Quality control was conducted and finalized on daily data for A Canal, LRDC total flow, Station 48, Miller Hill Pump, Miller Hill Spill, North Canal, Ady Canal, Ady Canal to LKNWR, and F/FF pumps via KSD.

The QC'ed daily dataset was finalized for October 1, 1974 through November 30, 2016 for Area 1, and January 1, 1980 through November 30, 2016 for Area 2. Where possible, approved daily data from U.S. Geological Survey (USGS) gages have been used, replacing older data. Where these records do not exist, other approaches were taken. For the most recent time periods, provisional USGS data were used. For older time periods that predate USGS monitoring, appropriate corrections have been applied to existing data sets to bring them in line with USGS measurements and/or other best available measurement standards. All gaps in the record have been examined and appropriately filled. For more detail see Dunsmoor (2017a).

Project daily data are contained in the spreadsheet:
Daily_Project_Diversions_Final_Dec2016_corrected_Jun2017.xlsx.

A.4.3.3.4 Upper Klamath Lake Net Inflow and Maximum Release

The UKL daily net inflow dataset is calculated from QC'ed data (Dunsmoor, 2017b) for (1) A Canal diversions (Reclamation), (2) average daily flows for the Link River at LRD (USGS), (3) Westside Power Canal (often referred to as the Keno Canal) flows (PacifiCorp), (4) Agency Lake Ranch operations (Reclamation), and (5) active storage data for UKL (Reclamation). Revisions to this data set include an altered elevation-capacity relationship, based on a new UKL bathymetry, corrected A Canal diversions, and a more accurate accounting of flows through the Westside Power Canal.

The UKL daily net inflow is calculated using the following equation:

Net Inflow = {(UKL storage volume today – UKL storage volume yesterday) + (Link River + Westside Canal) + A Canal +/- (Volume pumped to/from Agency Lake Ranch) – (Volume from Caledonia Marsh)}.

The KBPM uses both raw daily data and a single exponential smooth of daily data for UKL inflow, utilizing an alpha value of 0.22. The raw daily data input variable is I1_raw and is used in a calculation of cumulative inflow into UKL. The single exponential smooth of inflow input variable is I1 and defines the inflow element of the mass balance equation for UKL, as well as being a key factor in computation of the UKL central tendency and the daily IGD release.

Upper Klamath Lake net inflow data and data for the UKL area-capacity curve are contained in the spreadsheet: **Daily_UKL_net_inflow_Apr2017_FINAL.xlsx**. In the KBPM, the time series I1_raw and I1, for UKL daily net inflow and single exponential smooth data are contained in the file: **PA_4Jan2017_newBathy_I1ExpSm1x_SV.dss**. In KBPM, these data are contained in the files: **res_info.table** and **res_info2.table**.

In addition to changes to UKL net inflow datasets, a new relationship was developed describing the maximum possible release from LRD relative to the range in possible lake elevations and the associated head behind the dam. The basis for these data are contained in the Upper Klamath Lake Flood Operations Review and Risk Assessment, table 3.2-2 (PacifiCorp 1996). This document provided maximum UKL discharge at 1 ft. intervals; releases were then linearly interpolated to 0.01 ft. intervals for use in the KBPM. The UKL elevation/maximum discharge relationship can be found in the file: **20170502_UKLElev_LinkQ_Relation.xlsx**. In KBPM, these data are in the file: **Link_max.table**.

A.4.3.3.5 Lake Ewauna (Keno Reservoir) Accretions

The Lake Ewauna daily accretion dataset is calculated from QC'ed data for (1) LRDC spill to the Klamath River, (2) LRDC delivery to Area 1 from the Klamath River, (3) pumps F/FF, (4) North Canal, (5) Ady Canal, (6) ungauged Area 2 diversions, (7) PacifiCorp data for the Westside Power Canal, and (8) USGS average daily flow data for Link River at LRD and Klamath River at Keno Dam.

The Lake Ewauna accretions are calculated using the following equations:

Accretions = (Measured Keno Flow) – (Computed Keno Flow), and
Computed Keno Flow = [(Link River + Westside Canal) + (LRDC spill to the Klamath River) + (Pumps F/FF) – (LRDC delivery to Area 1 from the Klamath River) – (North Canal) – (Ady Canal) – (Ungauged Area 2 diversions)]

The WRIMS model uses a 3-day moving average of the daily Lake Ewauna accretion data. The input variable is I10.

Lake Ewauna accretions data are contained in the spreadsheet: **Keno Reservoir accretions Oct2017 revision.xlsx**. In KBPM, Lake Ewauna accretion data are contained in the file: **PA_4Jan2017_newBathy_I1ExpSm1x_SV.dss**.

A.4.3.3.6 Keno Dam to Iron Gate Dam Accretions

In the version of the KBPM used to develop the Proposed Action analyzed in the 2013 Biological Opinion, accretions to the reach of the Klamath River between Keno Dam and IGD (the KIG reach) were treated as known inputs. That is, a time series of daily estimates of the KIG accretions was developed and assigned to the KBPM variable named I15. When calculating such things as the release from LRD necessary to provide the targeted flow at IGD, the KBPM used the value of this variable from the previous day.

Several shortcomings have become apparent in the prior treatment of KIG accretions. First, the I15 variable was developed in a manner that did not account for the change in storage of the three hydroelectric reservoirs (JC Boyle, Copco, and Iron Gate reservoirs) in the KIG reach. Second, prior estimates of I15 did not account for travel time through the KIG reach. Finally, use of I15 was confined to its value on the prior day. Now that surface flushing flow events (flows of 6,030 cfs or greater for at least 72 hours measured at the IGD gauge) are management targets, it is important to use forecasted KIG accretions as part of the calculation of LRD releases needed to achieve a targeted flow at the IGD gauge. Use of forecasts will allow managers to use water stored in UKL more efficiently by triggering surface flushing flows when KIG accretions are forecasted to be relatively high, thereby requiring less UKL water to achieve the IGD flow target.

In this section, the time series of historical KIG accretions is recomputed, taking account of travel time and daily change in reservoir storage, and development of sub-models used to forecast KIG accretions is described. Incorporation of KIG accretion forecasts into the KBPM is addressed in subsequent sections. Before the KIG accretion forecast model could be developed, a model estimating the combined daily storage of the hydroelectric reservoirs had to be developed to fill gaps in the storage record, a necessary precursor to computing a daily time series of accretions to the KIG reach.

A.4.3.3.6.1. Temperature and Precipitation Variables

Temperature and precipitation variables were developed from data obtained from the PRISM Climate Group. Parameter-elevation Relationships on Independent Slopes Model (PRISM) is an interpolation method that estimates precipitation and temperature variables at gridded locations across the conterminous United States based on measurements from a large network of meteorological stations (Daly et al., 2008). Because the PRISM web page (http://prism.oregonstate.edu/explorer/) providing access to daily time series uses a map overlaid by the 4km PRISM grids, a map from this web page was used to delineate the approximate boundaries of sub-basin 18010206 along the edges of the PRISM grids (Figures A.4.3.3.6.1.1 and A.4.3.3.6.1.2). The closed basin of Butte Valley was excluded, as were the areas draining to the Klamath River downstream of the IGD gauge or upstream of the Keno gauge, thus crudely delineating the catchment within the KIG reach. This area was stratified by the PRISM grid elevations as being either lower or higher than 4,500 ft. Four PRISM grids were then randomly selected from each elevation stratum, conditioned on selected grids being separated by at least 3 grids (Figure A.4.3.3.6.1.1). Daily time series of average temperature (°F) and precipitation (inches) were downloaded for these 8 grids for the period from 1/1/1981-11/30/2016.

Monthly PRISM data for total monthly precipitation and average temperature at the same locations were downloaded for the period from 10/1/1980-12/31/1980. These monthly data were disaggregated to daily data, as follows. Daily data for precipitation and maximum temperature for the period from 10/1/1980-12/31/1980 were downloaded from the National Climatic Data Center, Climate Data Online (https://www.ncdc.noaa.gov/cdo-web/) for three stations (Figure A.4.3.3.6.1.1): Howard Prairie Dam, OR (Station USC00354060), Copco #1 Dam, CA (Station USC00041316), and Keno, OR (precipitation only; Station USC00354403). Across these stations within each month, the daily average of maximum temperature or precipitation was divided by the monthly average maximum temperature or monthly total precipitation, as appropriate. Monthly PRISM variables were disaggregated to daily values by multiplying them by this daily proportion. Use of the maximum daily temperature to disaggregate the average daily temperature variable was unintentional; clearly, average daily temperature should have been used instead. This mistake was not discovered until after the entire analysis was complete but has been retained in the analysis because it affects only the first 3 months of the POR, and average daily and maximum daily temperatures display very similar patterns.

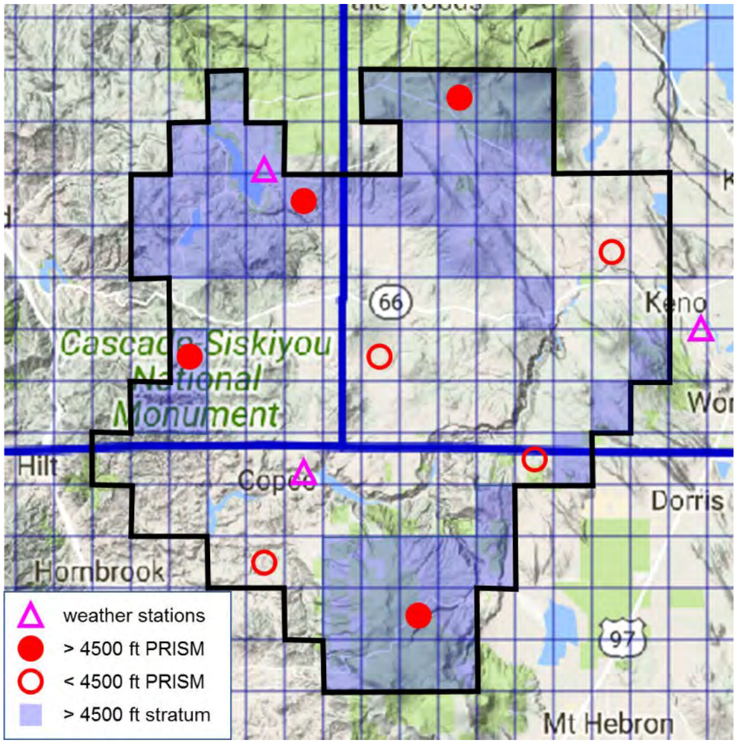

Figure A.4.3.3.6.1.1. PRISM grids and sampled grids, weather stations, and elevation strata in the KIG catchment.

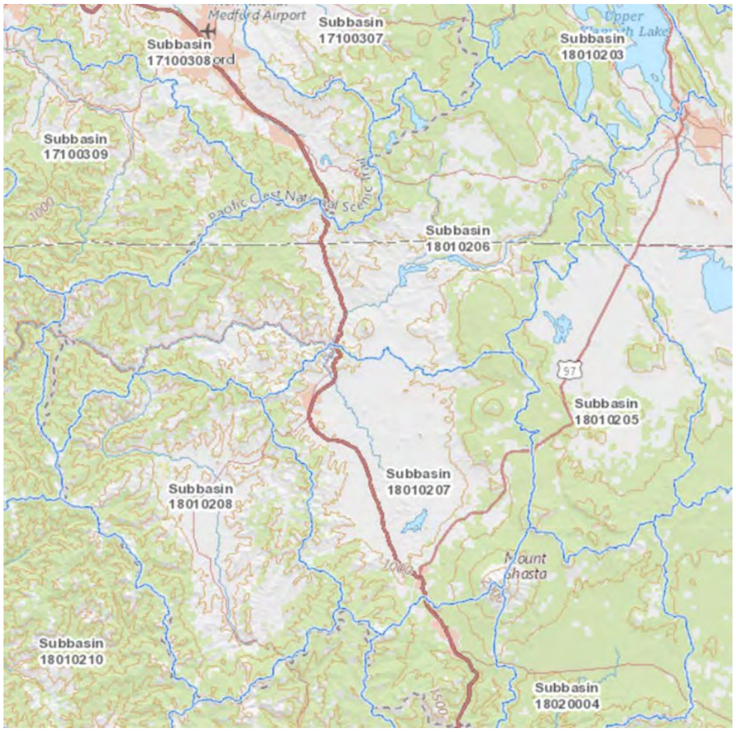

Figure A.4.3.3.6.1.2. Sub-basins encompassing the KIG and mid-Klamath (MK) reaches of the Klamath River. From the USGS National Map: https://viewer.nationalmap.gov/basic/?basemap=b1&category=nhd&title=NHD%20View

Treatment of temperature and precipitation for the mid-Klamath (MK) reach was nearly identical to that of the KIG reach, except that different PRISM grids and weather stations were used, and sampled grids were separated by at least 5 grids (Figure A.4.3.3.6.1.3a). That portion of sub-basin 18010206 contributing runoff to the Klamath River downstream of the IGD gauge, and all of sub-basins 18010208 (Scott River) and 1801207 (Shasta River) were included in the catchment for the MK reach (Figures A.4.3.3.6.1.2 and A.4.3.3.6.1.3a), hereafter called the MK catchment. Weather stations used to disaggregate monthly data to daily time steps for the MK catchment included: Callahan, CA (USC00041316); Yreka, CA (USC00049866); and Big Red Mountain, OR (USS0022G21S). Removing the Scott and Shasta river catchment area from the MK catchment leaves the ungauged MK catchment (Figure A.4.3.3.6.1.3b), for which accretions are also estimated.

After assembling the daily time series of precipitation and average temperature for each sampled PRISM grid, variables were computed that summarized these climate data in various ways. Daily (i = day) averages were computed for two of the catchments: $kippt_i$ and $kitavg_i$ for the KIG catchment; and $mkppt_i$ and $mktavg_i$ for the MK catchment. Daily averages weighted by the proportion of the total number of PRISM grids in a catchment below or above 4,500 ft were computed for each catchment: $kipptwa_i$ and $kitavgwa_i$ for the KIG catchment; and $mkpptwa_i$ and $mktavgwa_i$ for the MK catchment. Daily averages of the PRISM grids within each elevation stratum in each catchment were computed: $lekippt_i$, $hekippt_i$, $lekitavg_i$, and $hekitavg_i$ for the KIG catchment; and $lemkppt_i$, $hemkppt_i$, $lemktavg_i$, and $hemktavg_i$ for the MK catchment.

Temperature and precipitation variables were transformed, rescaled, and stationarized (Van den Berg et al., 2006; Montgomery et al., 2015) by first applying a ln(x_i + c) transformation (note that the *tavg* variables were not ln transformed), where x_i is the daily variable and c is a constant added to increase the minimum x_i above 1. Then, the ln transformed variables were seasonally adjusted (rescaled), and then the first difference was taken. Seasonal adjustment consisted of centering each ln(x_i + c) by subtracting from it the mean for the corresponding day of the water year across the POR. The centered variable was then divided by the standard deviation of the transformed variable for the corresponding day of the water year across the POR. The first difference was then taken as the seasonally adjusted x_i minus the seasonally adjusted x_{i-1}. The prefix *dsaln_* (*d* is for difference, *sa* is for seasonally adjusted, *ln* is for ln transformed, and _ is the c added prior to ln transformation) was appended to each variable name to reflect these manipulations.

Perhaps the greatest utility of the KIG accretion model to water management decision-making is during the late winter and spring seasons, when accretions tend to be largest and most variable, and when use of the accretion forecasts would be involved in decisions whether to trigger releases from UKL for flushing flows. Reasoning that the runoff response to precipitation events would likely be different when the ground is frozen (faster, more variable), a variable was constructed that tracked whether the ground was likely to be frozen or not. Air and soil temperature (2 inches depth) were downloaded for the Beatty, Oregon AgriMet weather station (https://www.usbr.gov/pn/agrimet/webarcread.html) for the period from 10/20/2004 – 12/31/2016). A threshold regression relating the 10-day trailing average of the mean daily air temperature (°F) to the daily soil temperature (°F) at a depth of 2 inches was used to identify the threshold at which this relationship changes (i.e. ground freezing threshold). The results (not shown) indicate that the freezing transition occurred when the 10-day trailing average of the mean daily air temperature was 35.2 (°F). Accordingly, the variables $lekitavg10d_i$ and $hekitavg10d_i$ were computed as the 10-day trailing average of the mean daily air temperature (°F) within the two elevation strata.

Further, because the objective was to develop models forecasting accretions based on recent conditions, precipitation was viewed from the perspective of its availability for immediate (i.e. within days) runoff. Three temperature classes were established to roughly classify this availability for runoff based on some expression of average temperature: ≤28°F was thought to be low availability because it likely fell as snow that did not rapidly melt; >28°F - ≤60°F was thought to be moderate to high availability because it likely fell as rain (or as snow that rapidly melted) and evapotranspiration was low to moderate; >60°F was thought to be low availability because evapotranspiration was moderate to high.

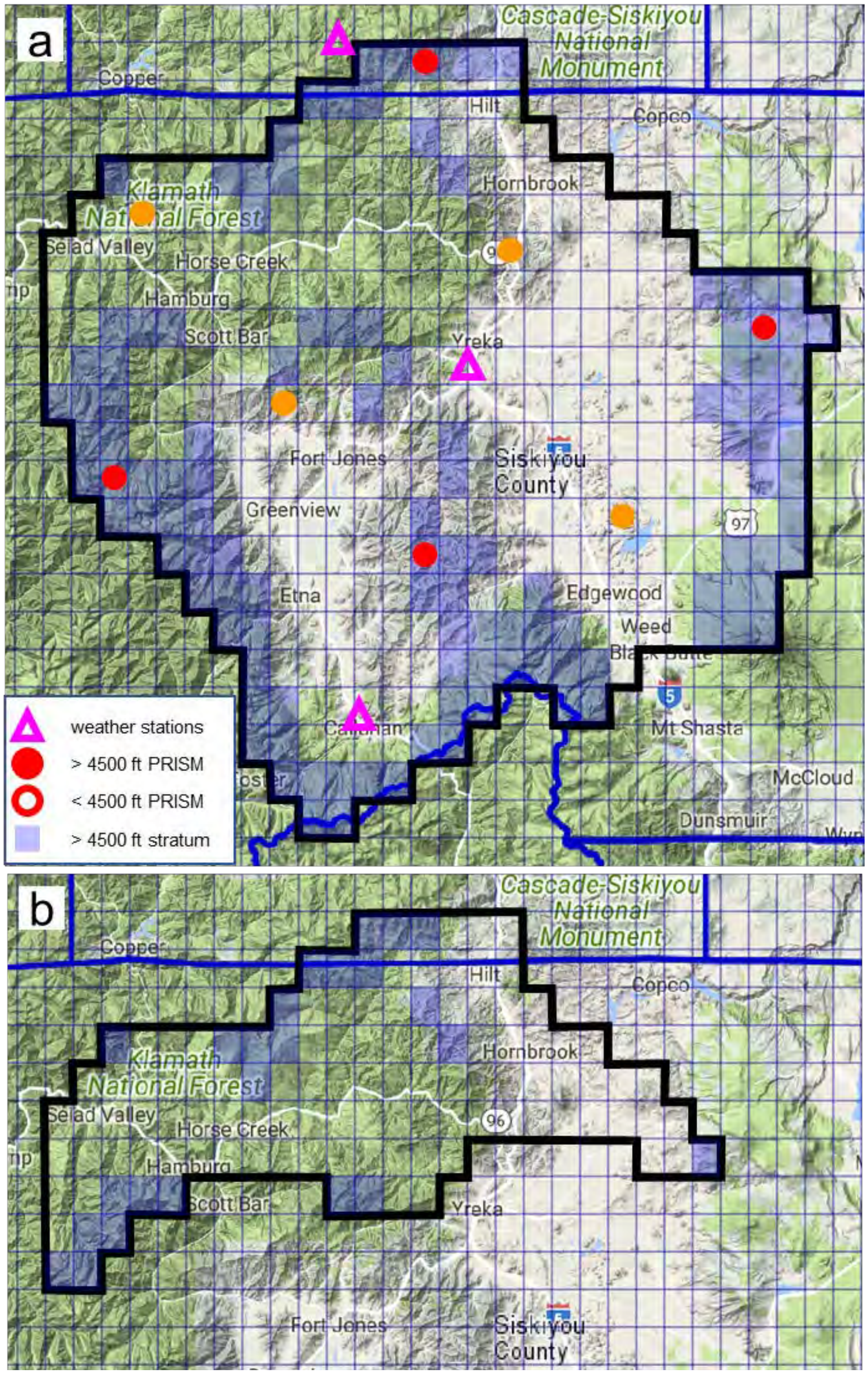

Figure A.4.3.3.6.1.3. PRISM grids and sampled grids, weather stations, and elevation strata in the MK reach used to construct climate variables appropriate to the MK catchment (a). The ungauged MK catchment (b) is the remaining area within the MK catchment after removing the Scott and Shasta river catchments.

To capture potential dynamics associated with interactions among elevation, temperature, precipitation, ground status (frozen/unfrozen), and subsequent runoff, the following series of variables were developed:

$$coldkippt_i = \begin{cases} dsaln1kipptwa_i & if\ kitavgwa_i \leq 28\text{°F} \\ 0 & if\ kitavgwa_i > 28\text{°F} \end{cases}$$

$$coolkippt_i = \begin{cases} dsaln1kipptwa_i & if\ kitavgwa_i > 28\text{°F}\ and\ \leq 60\text{°F} \\ 0 & if\ kitavgwa_i \leq 28\text{°F}\ \ or\ \ > 60\text{°F} \end{cases}$$

$$warmkippt_i = \begin{cases} dsaln1kipptwa_i & if\ kitavgwa_i > 60\text{°F} \\ 0 & if\ kitavgwa_i \leq 60\text{°F} \end{cases}$$

$$coldhekippt_i = \begin{cases} dsaln1hekippt_i & if\ hekitavg_i \leq 28\text{°F} \\ 0 & if\ hekitavg_i > 28\text{°F} \end{cases}$$

$$coolhekippt_i = \begin{cases} dsaln1hekippt_i & if\ hekitavg_i > 28\text{°F}\ and\ \leq 60\text{°F} \\ 0 & if\ hekitavg_i \leq 28\text{°F}\ \ or\ \ > 60\text{°F} \end{cases}$$

$$warmhekippt_i = \begin{cases} dsaln1hekippt_i & if\ hekitavg_i > 60\text{°F} \\ 0 & if\ hekitavg_i \leq 60\text{°F} \end{cases}$$

$$coldlekippt_i = \begin{cases} dsaln1lekippt_i & if\ lekitavg_i \leq 28\text{°F} \\ 0 & if\ lekitavg_i > 28\text{°F} \end{cases}$$

$$coollekippt_i = \begin{cases} dsaln1lekippt_i & if\ lekitavg_i > 28\text{°F}\ and\ \leq 60\text{°F} \\ 0 & if\ lekitavg_i \leq 28\text{°F}\ \ or\ \ > 60\text{°F} \end{cases}$$

$$warmlekippt_i = \begin{cases} dsaln1lekippt_i & if\ lekitavg_i > 60\text{°F} \\ 0 & if\ lekitavg_i \leq 60\text{°F} \end{cases}$$

$$coollekiint_i = coollekippt_i \times dsalekitavg_i$$

$$coolkiint_i = coolkippt_i \times dsalekitavg_i$$

$$kippttavgint_i = dsaln1kipptwa_i \times dsakitavgwa_i$$

$$soilfrzheppt_i = \begin{cases} dsaln1hekippt_i & if\ hekitavg10d_i \leq 35.2\ \text{°F} \\ 0 & if\ hekitavg10d_i > 35.2\ \text{°F} \end{cases}$$

$$soilfrzleppt_i = \begin{cases} dsaln1lekippt_i & if\ lekitavg10d_i \leq 35.2\ \text{°F} \\ 0 & if\ lekitavg10d_i > 35.2\ \text{°F} \end{cases}$$

$$soilthwheppt_i = \begin{cases} dsaln1hekippt_i & if\ hekitavg10d_i > 35.2\ \text{°F} \\ 0 & if\ hekitavg10d_i \leq 35.2\ \text{°F} \end{cases}$$

$$soilthwleppt_i = \begin{cases} dsaln1lekippt_i & if\ lekitavg10d_i > 35.2\ °\mathrm{F} \\ 0 & if\ lekitavg10d_i \leq 35.2\ °\mathrm{F} \end{cases}$$

$$thwleint_i = soilthwleppt_i \times dsalekitavg_i$$

In addition to variables summarizing precipitation and temperature in various ways, an attempt was made to use data tracking snowpack dynamics. However, no NRCS SNOTEL sites with an adequate POR were located within the KIG catchment. The nearest SNOTEL site was at Fish Lake (SNOTEL 479; data download: https://wcc.sc.egov.usda.gov/reportGenerator/view_csv/customGroupByMonthReport/daily/479:OR:SNTL%7Cid=%22%22%7Cname/POR_BEGIN,POR_END/WTEQ::value), for which daily snow water equivalent data was acquired. These data were seasonally adjusted and differenced, but no ln transformation was applied; the variable was named $dsadfishswe_i$.

A.4.3.3.6.2. Flow Volume and Accretion Variables

Accretions to the KIG reach were quantified using daily inflow volume (TAF; measured at USGS gauge 11509500 below Keno Dam; variable $kenotaf_i$), outflow volume (TAF; measured at USGS gauge 11516530 below IGD [often referred to as the IGD gauge]; variable $igtaf_i$), change in combined reservoir storage volume ($kigstoretaf_i$), and travel time.

Computing accretions to the MK reach required daily flow volumes (TAF) entering the reach at the IGD gauge ($igtaf_i$) and leaving the reach at the Seiad Valley gauge (USGS 11520500; variable $seiadtaf_i$), and travel time. Isolating the portion of MK accretions from ungauged sources required daily flow volumes (TAF) measured at the Shasta River gauge (USGS 11517500; variable $shastataf_i$) and the Scott River gauge (USGS 11519500; variable $scotttaf_i$).

Travel time of water between gauges was accounted for in the estimates of daily accretions. Hourly flows at the IGD and Seiad Valley gauges were compared, and when the flow pattern at IGD was clearly discernable at Seiad Valley, the corresponding flows were used to compute the travel time in hours (Figure A.4.3.3.6.2.1a). Repeated many times, this process produced 104 measurements of travel time, which were used to develop regression equations predicting travel time based on flows measured at IGD (Figure A.4.3.3.6.2.1b) and at Seiad Valley (Figure A.4.3.3.6.2.1c) gauges. Travel time varied with flow, from about 9 hours at high flows (about 10,000 cfs at IGD; 16,000 cfs at Seiad Valley) to about 16 hours at low flows (about 900 cfs at IGD; about 1,070 cfs at Seiad Valley).

The equation estimating travel time between the IGD and Seiad Valley gauges on day *i* based on daily average flow at the IGD gauge ($igtaf_i$) is:

$$tt\_igsd\_ig_i = e^{-0.24311\ln(igtaf_i) + 2.91288},$$

where *e* is the base of the natural logarithm (2.71828).

The equation estimating travel time over the same distance, but based on the daily average flow at the Seiad Valley gauge ($seiadtaf_i$) is:

$$tt\_igsd\_sd_i = e^{-0.22153\ln(seiadtaf_i)+\ 2.98041}.$$

The average of these two estimates is taken to calculate mean travel time between the two gauges:

$$tt\_igsd_i = \frac{tt\_igsd\_ig_i + tt\_igsd\_sd_i}{2}$$

A similar process was used to estimate travel time between the Scott River gauge and the Seiad Valley gauge (Figure A.4.3.3.6.2.2):

$$tt\_scsd_i = e^{-0.66034\ln(seiadtaf_i)+\ 3.09763}.$$

Travel time between the Shasta River gauge and the Seiad Valley gauge was estimated in a different way. Because the Shasta River gauge is located 0.64 miles upstream of the confluence with the Klamath River, travel time was estimated as tt_igsd_i times the proportion of the distances between gauges:

$$tt\_shsd_i = \frac{49.64}{61.90} tt\_igsd_i$$

where 49.64 miles is the distance between the Shasta River and Seiad Valley gauges, and 61.90 miles is the distance between the IGD and Seiad Valley gauges. Distances were measured using Google Earth Pro.

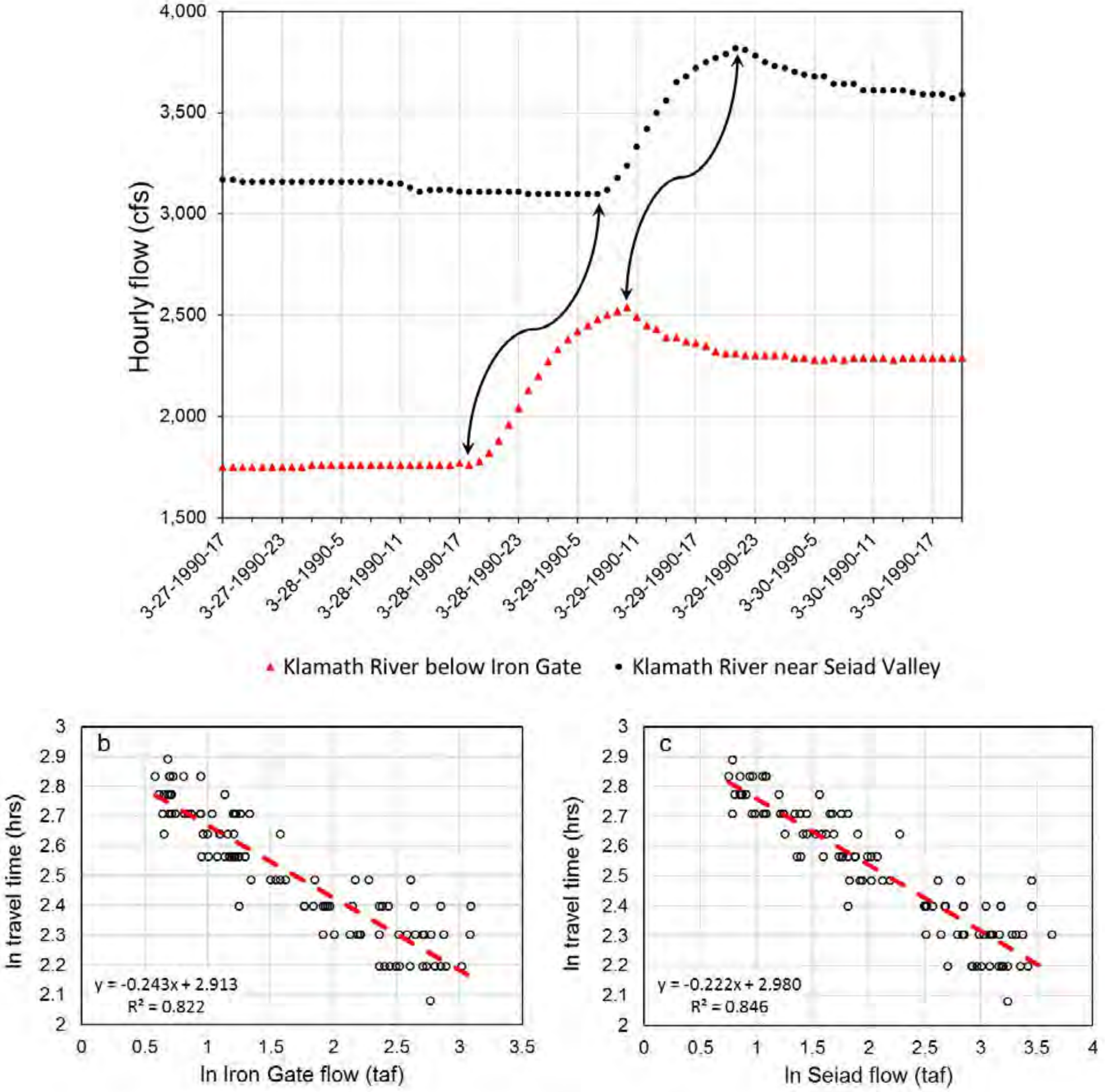

Figure A.4.3.3.6.2.1. Example of estimating travel time between the flow gauges below Iron Gate Dam and near Seiad Valley. In a, each point on a flow time series is an hourly flow measurement at one of the gauges. When the pattern of flow change at Iron Gate was clearly identifiable at Seiad Valley (indicated by the arrows), the travel time in hours was calculated. For reference, ln(9 hrs) = 2.197, and ln(18 hrs) = 2.890. Repeating this process many times (n=104) yields the measured travel times relative to flow at Iron Gate (b) and Seiad Valley (c); all values in b and c are ln transformed. Regressions (equations and dashed lines) provide the means to compute travel time as a function of flow measured at either flow gauge.

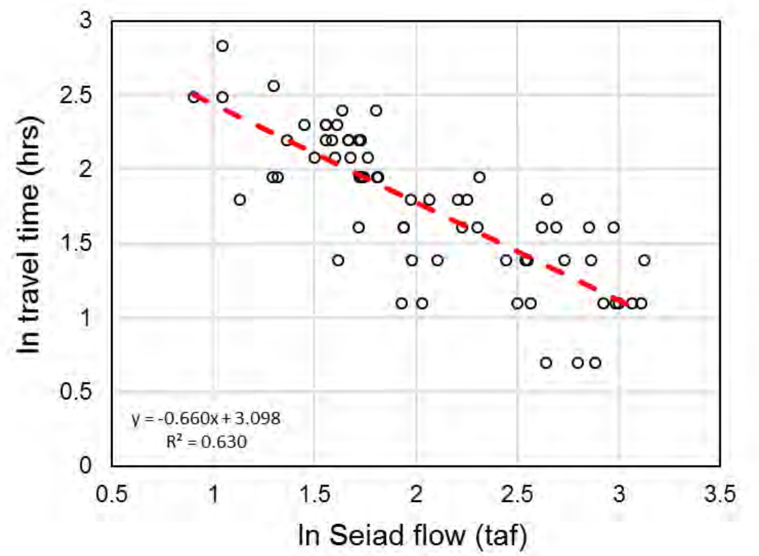

Figure A.4.3.3.6.2.2. Estimating travel time (hours) from the Scott River gauge to the Seiad Valley gauge from n=65 measurements.

Initially the same process used to estimate travel time between the IGD and Seiad Valley gauges was applied to estimate travel time through the KIG reach (between the Keno and IGD gauges). However, this approach did not work, because operations of the hydroelectric project reservoirs obscured or altered the hourly patterns of flow at IGD. Therefore, the travel time estimated between the IGD and Seiad Valley gauges was divided by the distance between them (61.90 miles), and then multiplied by the distance between the gauges at Keno and IGD (42.30 miles) to estimate travel time through the KIG reach:

$$tt\_kenoig_i = \frac{tt\_igsd_i}{61.90} 42.30$$

This approach assumed equivalent rates of travel through the KIG and MK reaches.

Accretions to the MK reach were computed in two ways, one that applies to the entire MK catchment, and the other based solely on the ungauged MK catchment. Accretions to the Klamath River to the MK reach based on the entire MK catchment were computed as:

$$mkawa_i = \left(\left(1 - \frac{tt\_igsd_i}{24}\right) \times (seiadtaf_i - igtaf_i)\right) + \left(\frac{tt\_igsd_i}{24} \times (seiadtaf_i - igtaf_{i-1})\right)$$

Because travel time between the gauges is less than a day (Figure A.4.3.3.6.2.1), accretions were computed as the average flow difference between the Seiad Valley gauge on day *i* and the IGD gauge on days *i* and *i*-1, weighted by travel time (expressed as a fraction of a day).

Accretions from the ungauged MK catchment were computed by subtracting from $mkawa_i$ the accretions from the Shasta and Scott rivers, which were computed as averages weighted by travel time in a manner similar to that for $mkawa_i$:

$$ugmkawa_i = mkawa_i - \left(\left(1 - \frac{tt\_shsd_i}{24}\right) shastataf_i + \frac{tt\_shsd_i}{24} shastataf_{i-1}\right) - \left(\left(1 - \frac{tt\_scsd_i}{24}\right) scotttaf_i + \frac{tt\_scsd_i}{24} scotttaf_{i-1}\right)$$

Computation of accretions to the KIG reach ($kigaccwa_i$) involved accounting for the daily change in storage of the combined hydroelectric reservoirs, $kigstoretaf_i$ (after gaps had been filled in that record):

$$kigacc_i = (igtaf_i - kenotaf_i) + (kigstoretaf_i - kigstoretaf_{i-1})$$

$$kigaccwa_i = \left(1 - \frac{tt\_kenoig_i}{24}\right) kigacc_i + \frac{tt\_kenoig_i}{24} kigacc_{i-1}$$

The time-series for $kigaccwa_i$ is used in the KBPM as the inflow arc I15, the daily accretions to the reach of the Klamath River between Keno Dam and IGD.

One final variable, an expression of KIG accretions that does not account for daily change in storage, was prepared for use as a predictor:

$$kiqdfwa_i = \left(\left(1 - \frac{tt\_kenoig_i}{24}\right) \times (igtaf_i - kenotaf_i)\right) + \left(\frac{tt\_kenoig_i}{24} \times (igtaf_i - kenotaf_{i-1})\right)$$

As with many of the variables previously described, the flow volume and accretion variables were also transformed with ln($x_i + c$), seasonally adjusted, and differenced, yielding the following variables: $dsalnkenotaf_i$, $dsalnigtaf_i$ (note that c=0 for the flow volume variables), $dsaln3mkawa_i$, $dsaln6ugmkawa_i$, $dsaln1kigaccwa_i$, and $dsaln3kiqdfwa_i$. Daily combined storage of the hydro reservoirs was not ln transformed ($dsakigstoretaf_i$).

A.4.3.3.6.3. Filling Gaps in the Reservoir Storage Record

Daily change in combined storage of hydroelectric reservoirs was quantified using reservoir storage data provided to Reclamation and the US Fish and Wildlife Service (USFWS) by PacifiCorp under a Non-disclosure Agreement. Certain aspects of the following analyses were not reported here in keeping with the terms of the Non-disclosure Agreement. After summing the daily storage of JC Boyle, Copco, and Iron Gate reservoirs into a single variable ($kigstoretaf_i$) used to compute KIG accretions, gaps in the record were apparent. Out of the 13,210 days in the period-of-record used in this analysis (10/1/1980 – 11/30/2016), 662 days were missing. The initial task was to develop a model to fill these gaps in the $kigstoretaf_i$ time series, so that daily change in total reservoir storage could be calculated, subsequently enabling computation of daily KIG accretion.

In addition to the gaps caused by the absence of data, during some time periods $kigstoretaf_i$ patterns reflected reservoir management for reasons other than typical operations (e.g. maintenance events, emergency outages, federal agency “borrowing”, etc.). Periods of atypical management were identified by reviewing re-licensing documents in the FERC eLibrary (https://www.ferc.gov/docs-filing/elibrary.asp; project P-2082) and consulting with water operations personnel at Reclamation. These periods were removed from the data (n=649) used to develop a model for filling gaps in $kigstoretaf_i$, but were retained in the final data set used to compute KIG accretions.

Methodological details were the same as for those reported in the sub-section addressing development of the KIG accretion model, so many are deferred to that description. In brief summary, 7 time-series regression models with ARMA (Autoregressive Moving Average) disturbances were developed using Stata 15 (StataCorp, 2017a; Hyndman and Athanasopoulos, 2014; Montgomery et al., 2015; Table A.4.3.3.6.3.1). Predictive performance of each was assessed using 10-fold cross-validation (James et al. 2013); the model with the smallest mean square error (error = actual $kigstoretaf_i$ – predicted $kigstoretaf_i$) averaged across the 10 folds was used to fill the gaps in $kigstoretaf_i$ series. Overall, this approach appeared to do a reasonably good job of filling the gaps. Further details of the analysis are not presented, in keeping with the Non-disclosure Agreement with PacifiCorp.

Table A.4.3.3.6.3.1. Models evaluated for use in filling gaps in the $kigstoretaf_i$ series. The dependent variable in all models was $dsakigstoretaf_i$. Variables included in models include autoregressive (ar) and moving average (ma) terms for errors from the structural equation. Entries show the lags of each variable used in each model. For example, 0/2 indicates use of lags *i*-0, *i*-1, and *i*-2 (*i* = day). The model that yielded the smallest average mean square error (MSE) from 10-fold cross-validation was model 3.

	Model number						
Variables	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Dsalnigtaf				0/5	0/5	0/5	0/5
Dsalnkenotaf				0/5	0/5	0/5	0/5
dsaln1kipptwa	0/5	0/5	0/4	0/5	0/5	0/3	0/3
dsaln3kiqdfwa	0/5	0/5	0/5				
Dsakitavgwa	0/2	0/2	0/1	0/2	0/2	0	0
dsaln3mkawa			0/5			0/4	0/4
dsaln1kipptwa x dsakitavgwa		0					
dsaln1kipptwa x dsaln3kiqdfwa		0					
dsalnigtaf x dsaln1kipptwa					0		0
Ar	1/3	1/3	1/3	1/2	1/2	1/3	1/3
Ma	1/2	1/2	½	1/2	1/3	1/4	¼
average MSE	0.1394	0.1395	0.1330	0.1442	0.1446	0.1411	0.1398

A.4.3.3.6.4. Modeling Accretions Between Keno and Iron Gate Dams

KIG accretions were modeled using time-series regression models with ARMA (Autoregressive Moving-average) disturbances using Stata 15 (StataCorp, 2017a; Hyndman and Athanasopoulos, 2014; Montgomery et al., 2015). This approach fitted the model:

$$y_i = \mathbf{x}_i \boldsymbol{\beta} + \mu_i \qquad \text{(structural equation)}$$

$$\mu_i = \sum_{h=1}^{p} \rho_h \mu_{i-h} + \sum_{j=1}^{q} \theta_j \epsilon_{i-j} + \epsilon_i \qquad \text{(disturbance equation)}$$

where

y_i is the dependent variable at time *i*;
$\mathbf{x}_i$ is the matrix of regressors;
$\boldsymbol{\beta}$ is the vector of regressor coefficients;
μ_i is the error associated with the structural equation;
ρ_h is the autocorrelation parameter of order h from 1 to *p*;
θ_j is the moving-average parameter of order *j* from 1 to *q*;
ϵ_i is the error associated with the disturbance equation, assumed to be a white-noise process.

All variables were transformed with ln($x + c$) as appropriate, seasonally adjusted, and differenced (see prior sections detailing construction of variables). The dependent variable for each model was $dsaln1kigaccwa_i$. The eigenvalue stability condition of each model was checked, confirming the required invertibility condition of the MA process, and confirming the process to be covariance stationary (StataCorp, 2017a). Stationarity of *dsaln1kigaccwa* in each model was confirmed by the rejection of the null hypothesis that the variable followed a unit-root process, using the augmented Dickey-Fuller test (StataCorp, 2017a). Bartlett's white noise test on residuals from each model failed to reject the null hypothesis (95% confidence level) that they came from a white noise process of uncorrelated random variables having a constant mean and a constant variance (StataCorp, 2017a). Residuals were not normally distributed but were symmetric, so the Huber/White sandwich estimator was used to compute standard errors that are robust to symmetric non-normality in the disturbances (StataCorp, 2017a).

Predictive performance of each was assessed using 10-fold cross-validation (James et al., 2013; Hyndman and Athanasopoulos, 2014). In this approach, the model was fitted to the data for water years 1981-1986, which was then used to predict $dsaln1kigaccwa_i$ for water years 1987-1989 (fold $k = 1$). Predicted values were converted back to the original scale of the data, and the mean square error (MSE_k) was computed for fold 1. Then the model was fitted to water years 1981-1989, used to predict $dsaln1kigaccwa_i$ for fold $k = 2$ (the next 3 water years, 1990-1992), and the MSE_k was computed (on original data scale) for fold 2. This process was repeated through fold $k = 10$ (2014-2016), and then the average MSE was computed across all 10 folds. This average MSE was used as the best estimate of the error and predictive capability of each model.

Using these techniques, 23 models were developed (Table A.4.3.3.6.4.1). Note that lags of 0 were commonly used for temperature and precipitation variables and related interactions. This indicates the expected reliance on forecasts of these variables based on products currently available from the California-Nevada River Forecast Center (https://www.cnrfc.noaa.gov/). Attempts were made to obtain historical time-series of forecasts for these variables across the POR used for the modeling, but such data were unavailable. Therefore, historical values of temperature and precipitation were used when forecasting accretions for days 0-3. Use of perfect foresight in this way produced models that do not exhibit the same error characteristics that will be encountered when using forecasted temperature and precipitation to make daily operational decisions. Operational error will be larger than that shown in Table 2 and will need to be quantified through operational use of these models.

Model 21 had the lowest average MSE (0.077) from the cross-validation (Table A.4.3.3.6.4.1, Figure A.4.3.3.6.4.1), and was subsequently used to forecast dsaln1kigaccwai (day 0). The day 0 forecast predicts the accretion for the current day and is intended for use in making a final decision as to whether a flushing flow should be implemented on a given day. Forecasts were also needed for days i+1 (day 1) through i+3 (day 3), when forecasts would be used to guide actions that would necessarily precede release of a flushing flow (e.g. adjusting reservoir elevations to permit spill operations). However, because Model 21 included *dsaln6ugmkawa* for lags of i-1 and i-2, for which no forecasts were available, a different model had to be used for the days beyond day 0. Model 20 was selected for this purpose, because it did not include any regressors for which forecasts were unavailable, its average MSE from cross-validation was very similar to the other candidate models, and the regressor variables were very similar to those in Model 21 (Table A.4.3.3.6.4.1), which would minimize the additional effort necessary to operate using 2 models.

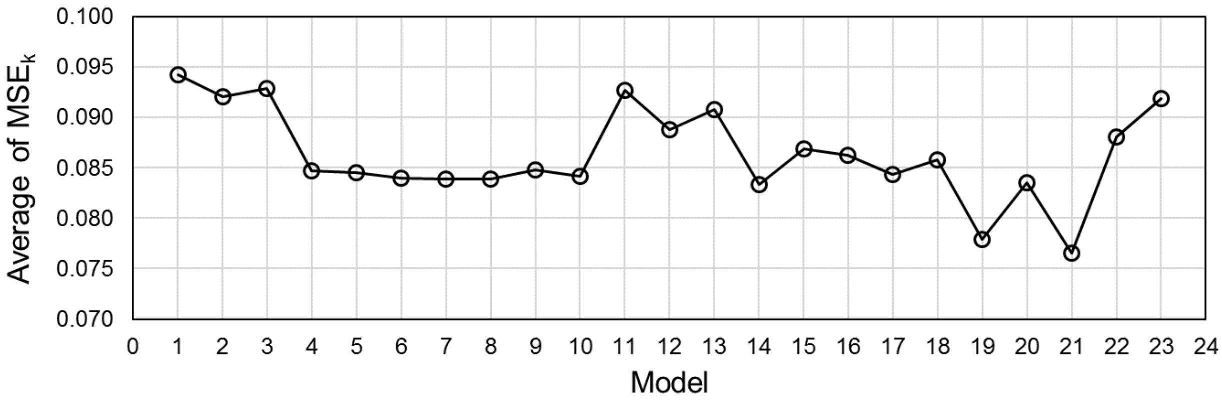

Figure A.4.3.3.6.4.1. Average of the mean square error (error = actual $kigaccwa_i$ – predicted $kigaccwa_i$) across the k=10 folds in the 10-fold cross-validation. Model 21 minimized this MSE$_k$, and was therefore selected as the final model.

Table A.4.3.3.6.4.1. Models evaluated for predicting KIG accretions. The dependent variable in all models was $dsaln1kigaccwa_i$. Variables included in models include autoregressive (ar) and moving average (ma) terms for errors from the structural equation. Entries show the lags of each variable used in each model. For example, 0/2 indicates use of lags *i*-0, *i*-1, and *i*-2, whereas 0 2 indicates use of lags *i*-0 and *i*-2 only (*i* = day). The model that yielded the smallest average mean square error (MSE) from 10-fold cross-validation was model 3.

	Model number																						
Variables	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
dsadfishswe			2/5		3		3										2/5	3	3				
dsaln3kiqdfwa		2																					
dsaln1kipptwa	0/7	0/7	0/7	0/7	0/7	0/7	0/7	0/7	0/7	0/7	0/7				0/7	0/7	0/7		0/7				
dsakitavgwa	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1			0/1 3	0/1 3	0/1 3		0/1				0/3
dsaln3mkawa				1/3	1/3	1/3	1/3	1/3															
dsaln1mkpptwa						0/1	0/1																
dsaln6ugmkawa									1/2	1/2				1/2					1/2		1/2		
dsahekitavg													0/3	0/3				0/3		0/3	0/3	0/3	
dsalekitavg													0/3	0/3				0/3		0/3	0/3	0/3	
dsaln1kipptwa x dsakitavgwa										0 2													
coolhekippt												5 7											
warmhekippt												6											
coldlekippt											0	0/4	0/1	0/1								0/1 4	
coollekippt											0	0/6	0/4	0/1								0/7	
warmlekippt												0/5	0/5	0/1								0/5	
soilfrzheppt															0/1	0/1	0/1	0/1	0/1	0/1	0/1		
soilfrzleppt															0/1	0/1	0/1	0/1	0/1	0/3	0/1		
kippttavgint																0 3	0/1 3		0				
soilthwheppt																		6/7		6/7	6/7		
soilthwleppt																		0/5		0/5	0/5		
thwleint																				1 3	0 2		
coollekiint																						0/3	
coldkippt																							0/1 3/4
coolkippt																							0/7
warmkippt																							0/1 3/7
coolkiint																							0/3
ma	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3
average MSE	.094	.092	.093	.085	.084	.084	.084	.084	.085	.084	.093	.089	.091	.083	.087	.086	.084	.086	.078	.084	.077	.088	.092

The model 21 equation used to forecast $dsaln1kigaccwa_i$ on day 0 was (Table A.4.3.3.6.4.2):

$$
\begin{aligned}
dsaln\widehat{1kig}accwa_i = {} & \beta_{1,i}dsahekitavg_i + \beta_{1,i-1}dsahekitavg_{i-1} + \beta_{1,i-2}dsahekitavg_{i-2} + \\
& \beta_{1,i-3}dsahekitavg_{i-3} + \beta_{2,i}dsalekitavg_i + \beta_{2,i-1}dsalekitavg_{i-1} + \\
& \beta_{2,i-2}dsalekitavg_{i-2} + \beta_{2,i-3}dsalekitavg_{i-3} + \beta_{3,i}soilfrzheppt_i + \\
& \beta_{3,i-1}soilfrzheppt_{i-1} + \beta_{4,i}soilfrzleppt_i + \beta_{4,i-1}soilfrzleppt_{i-1} + \\
& \beta_{5,i-1}dsaln6ugmkawa_{i-1} + \beta_{5,i-2}dsaln6ugmkawa_{i-2} + \beta_{6,i-6}soilthwheppt_{i-6} + \\
& \beta_{6,i-7}soilthwheppt_{i-7} + \beta_{7,i}soilthwleppt_i + \beta_{7,i-1}soilthwleppt_{i-1} + \\
& \beta_{7,i-2}soilthwleppt_{i-2} + \beta_{7,i-3}soilthwleppt_{i-3} + \beta_{7,i-4}soilthwleppt_{i-4} + \\
& \beta_{7,i-5}soilthwleppt_{i-5} + \beta_{8,i}thwleint_i + \beta_{8,i-2}thwleint_{i-2} + \\
& \theta_1(dsaln1kigaccwa_{i-1} - dsaln\widehat{1kig}accwa_{i-1}) + \theta_2(dsaln1kigaccwa_{i-2} - \\
& dsaln\widehat{1kig}accwa_{i-2}) + \theta_3(dsaln1kigaccwa_{i-3} - dsaln\widehat{1kig}accwa_{i-3})
\end{aligned}
$$

The model 20 equation used to forecast $dsaln1kigaccwa_i$ on days 1-3, where *i* = the day being forecasted, was (Table A.4.3.3.6.4.2):

$$
\begin{aligned}
dsaln\widehat{1kig}accwa_i = {} & \beta_{1,i}dsahekitavg_i + \beta_{1,i-1}dsahekitavg_{i-1} + \beta_{1,i-2}dsahekitavg_{i-2} + \\
& \beta_{1,i-3}dsahekitavg_{i-3} + \beta_{2,i}dsalekitavg_i + \beta_{2,i-1}dsalekitavg_{i-1} + \\
& \beta_{2,i-2}dsalekitavg_{i-2} + \beta_{2,i-3}dsalekitavg_{i-3} + \beta_{3,i}soilfrzheppt_i + \\
& \beta_{3,i-1}soilfrzheppt_{i-1} + \beta_{4,i}soilfrzleppt_i + \beta_{4,i-1}soilfrzleppt_{i-1} + \\
& \beta_{4,i-2}soilfrzleppt_{i-2} + \beta_{4,i-3}soilfrzleppt_{i-3} + \beta_{6,i-6}soilthwheppt_{i-6} + \\
& \beta_{6,i-7}soilthwheppt_{i-7} + \beta_{7,i}soilthwleppt_i + \beta_{7,i-1}soilthwleppt_{i-1} + \\
& \beta_{7,i-2}soilthwleppt_{i-2} + \beta_{7,i-3}soilthwleppt_{i-3} + \beta_{7,i-4}soilthwleppt_{i-4} + \\
& \beta_{7,i-5}soilthwleppt_{i-5} + \beta_{8,i-1}thwleint_{i-1} + \beta_{8,i-3}thwleint_{i-3} + \\
& \theta_1(dsaln1kigaccwa_{i-1} - dsaln\widehat{1kig}accwa_{i-1}) + \theta_2(dsaln1kigaccwa_{i-2} - \\
& dsaln\widehat{1kig}accwa_{i-2}) + \theta_3(dsaln1kigaccwa_{i-3} - dsaln\widehat{1kig}accwa_{i-3})
\end{aligned}
$$

Forecasts were restored to the original measurement scale using:

$$
ki\widehat{gacc}wa_i = e^{\left(sd\_ln1kigaccwa_{dowy}\left(dsaln\widehat{1kig}accwa_i + saln1kigaccwa_{i-1}\right)\right) + mn\_ln1kigaccwa_{dowy}} - 1
$$

where

$sd\_ln1kigaccwa_{dowy}$ is the standard deviation of $ln1kigaccwa$ across the POR for day of water year *dowy*;

$mn\_ln1kigaccwa_{dowy}$ is the mean of $ln1kigaccwa$ across the POR for day of water year *dowy*;

e is the base of the natural logarithm (2.71828).

Table A.4.3.3.6.4.2. Coefficients and lags associated with each variable in model 21, used for day 0 forecasts of *dsaln1kigaccwa*, and model 20, used for day 1-3 forecasts of *dsaln1kigaccwa*. In the variables column, *ma* stands for the moving average component of the disturbance equation; all other variables are components of the structural equation.

		Model 21		**Model 20**	
Variables	β	**Lag**	**Coefficient**	**Lag**	**Coefficient**
dsahekitavg	$\beta_{1,i}$	0	-0.084751935	0	-0.079570007
	$\beta_{1,i-1}$	1	-0.131145783	1	-0.135250777
	$\beta_{1,i-2}$	2	-0.09675344	2	-0.12393146
	$\beta_{1,i-3}$	3	-0.07496754	3	-0.108007704
dsalekitavg	$\beta_{2,i}$	0	0.162509412	0	0.159638178
	$\beta_{2,i-1}$	1	0.166952852	1	0.180184281
	$\beta_{2,i-2}$	2	0.084205439	2	0.121336316
	$\beta_{2,i-3}$	3	0.076453299	3	0.114166256
soilfrzheppt	$\beta_{3,i}$	0	0.052230518	0	0.056741619
	$\beta_{3,i-1}$	1	0.038355313	1	0.043526354
soilfrzleppt	$\beta_{4,i}$	0	0.167098975	0	0.160364016
	$\beta_{4,i-1}$	1	0.126016131	1	0.138847704
	$\beta_{4,i-2}$			2	0.052549174
	$\beta_{4,i-3}$			3	0.038833972
dsaln6ugmkawa	$\beta_{5,i-1}$	1	0.104267816		
	$\beta_{5,i-2}$	2	0.12480171		
soilthwheppt	$\beta_{6,i-6}$	6	0.029347092	6	0.035972385
	$\beta_{6,i-7}$	7	0.01785531	7	0.021610083
soilthwleppt	$\beta_{7,i}$	0	0.113246571	0	0.106772664
	$\beta_{7,i-1}$	1	0.081135696	1	0.103718791
	$\beta_{7,i-2}$	2	0.021968845	2	0.056118604
	$\beta_{7,i-3}$	3	0.027132767	3	0.041983045
	$\beta_{7,i-4}$	4	0.01865496	4	0.034074352
	$\beta_{7,i-5}$	5	0.018046125	5	0.02754767
thwleint	$\beta_{8,i}$	0	0.02233405		
	$\beta_{8,i-1}$			1	0.022579397
	$\beta_{8,i-2}$	2	-0.019003767		
	$\beta_{8,i-3}$			3	-0.020293628
ma	θ_1	1	-0.354124765	1	-0.338305637
	θ_2	2	-0.569710264	2	-0.562316149
	θ_3	3	0.086079682	3	0.079656475

Day 0 forecasts made with model 21 performed well in the cross-validation process (Figures A.4.3.3.6.4.2 - A.4.3.3.6.4.11). While there was a tendency to under-predict higher accretions and over-predict lower accretions, model 21 captures the pattern of accretions very well. False positives (i.e. predicting peaks that do not appear) were rare. Use of model 21 to inform final decisions triggering implementation of surface flushing flows appears likely to enhance the efficient use of stored water in UKL by piggybacking on KIG accretion events.

Day 1-3 forecasts made with model 20 do not perform as well (Figures A.4.3.3.6.4.12 - A.4.3.3.6.4.17). The tendency to under-estimate peaks and over-estimate troughs is more pronounced, and many peaks and troughs are missed entirely. This arises in part because as forecasts are made further into the future, the disturbance components of the predictive equation for which the actual accretion is unavailable (because it has not yet happened) are assumed to be zero. When forecasting day 1, $dsaln1kigaccwa_{i-1}$ is not available, and so the quantity $\theta_1(dsaln1kigaccwa_{i-1} - dsaln\widehat{1kig}accwa_{i-1})$ is assumed to be zero. Forecasts made for day 3 assume that all 3 *ma* components of the disturbance equation are zero, and the forecasts reduce to those from the structural equation alone. Despite the lower quality of these forecasts, simulations with the KBPM have demonstrated their worth in informing preliminary decisions regarding preparation for triggering surface flushing flows. Nonetheless, future efforts to improve these forecasts could significantly enhance their utility.

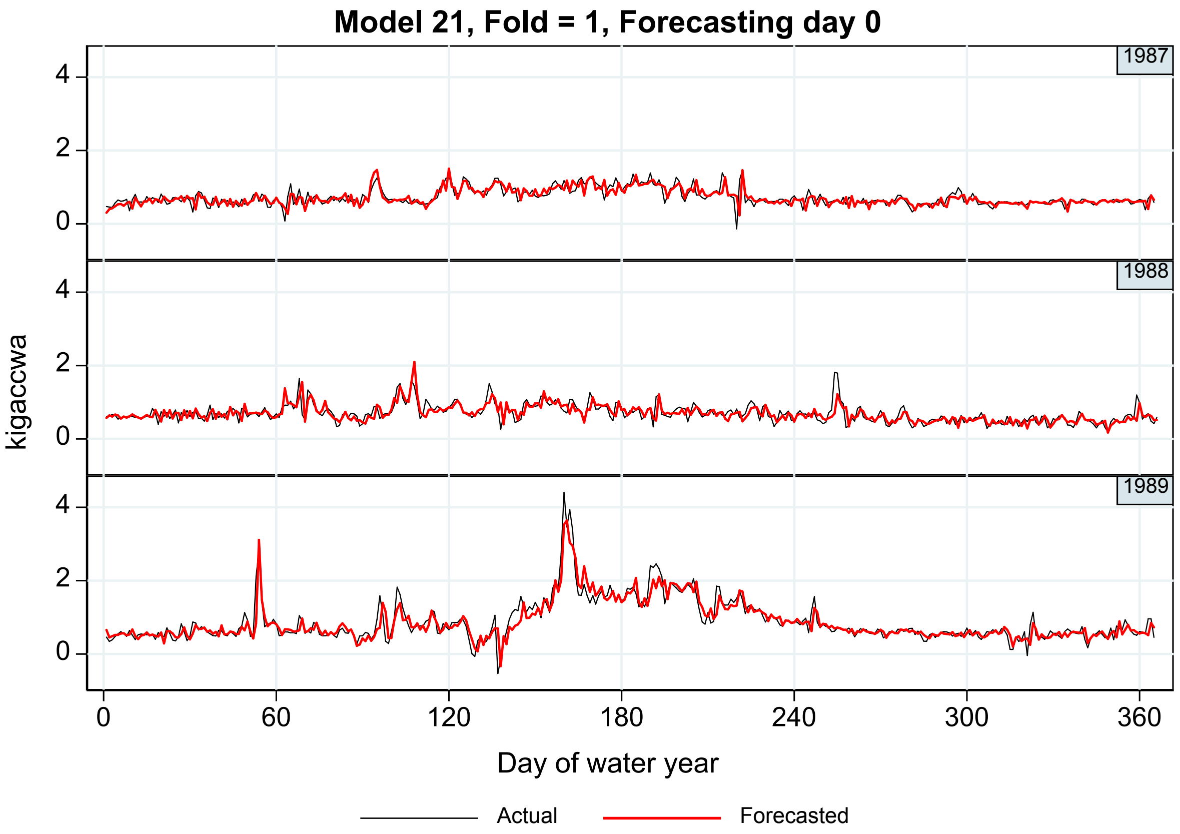

Figure A.4.3.3.6.4.2. Forecasted and actual KIG accretions for day 0 (*kigaccwa*$_i$) for fold 1 from the 10-fold cross-validation process. The model was trained on water years 1981-1986, then used to forecast water years 1987-1989.

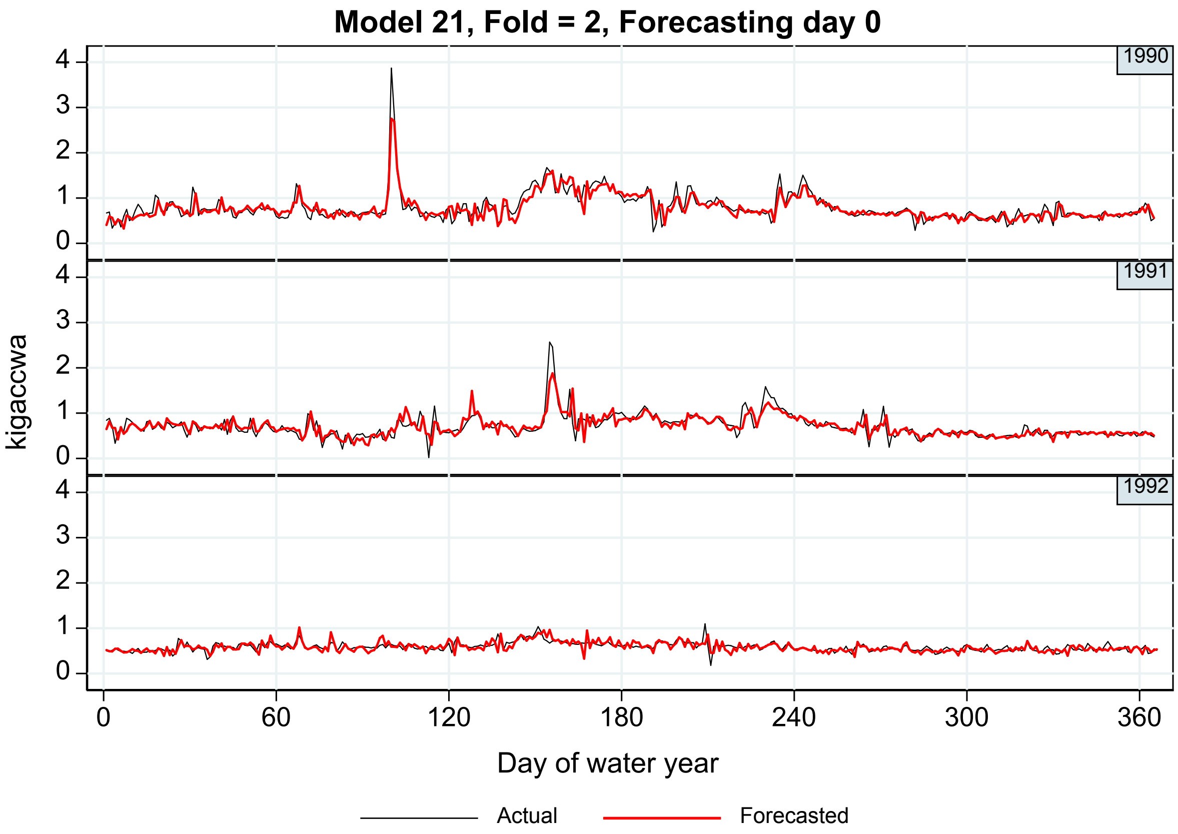

Figure A.4.3.3.6.4.3. Forecasted and actual KIG accretions for day 0 (*kigaccwa*$_i$) for fold 2 from the 10-fold cross-validation process. The model was trained on water years 1981-1989, then used to forecast water years 1990-1992.

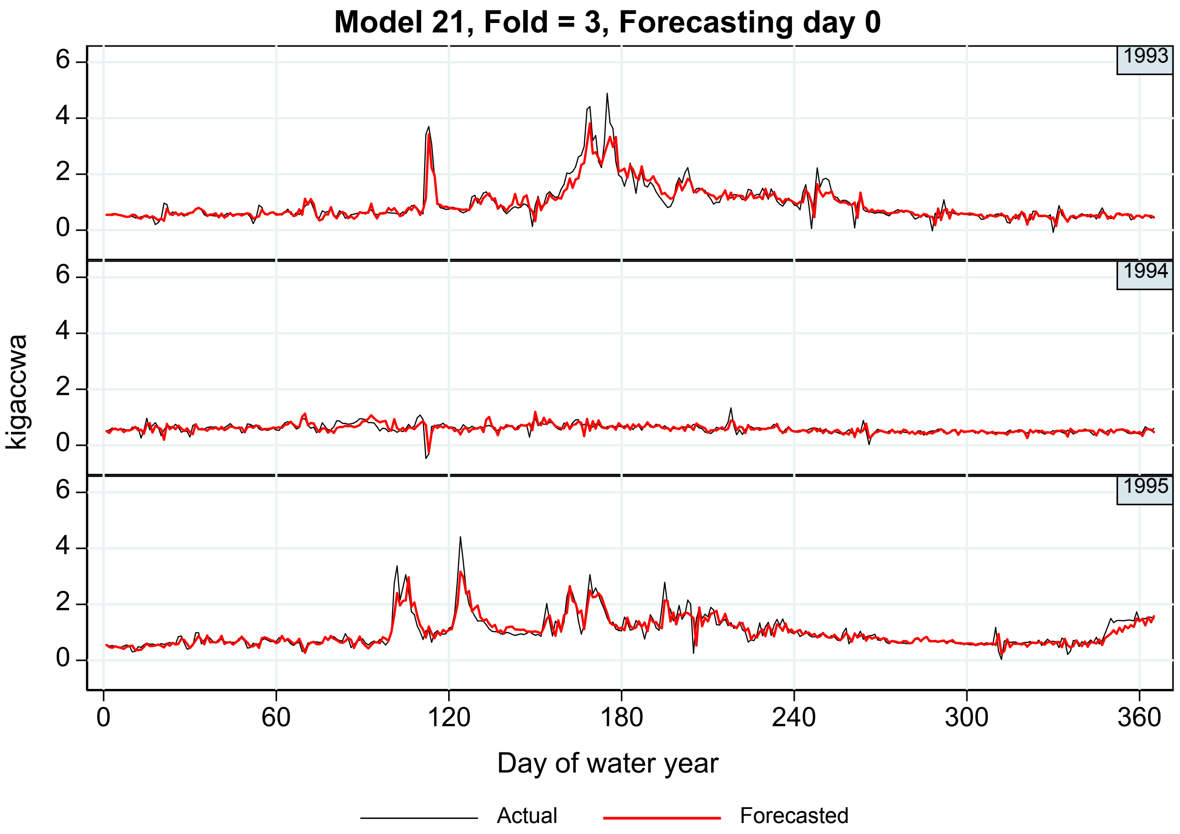

Figure A.4.3.3.6.4.4. Forecasted and actual KIG accretions for day 0 (*kigaccwa*$_i$) for fold 3 from the 10-fold cross-validation process. The model was trained on water years 1981-1992, then used to forecast water years 1993-1995.

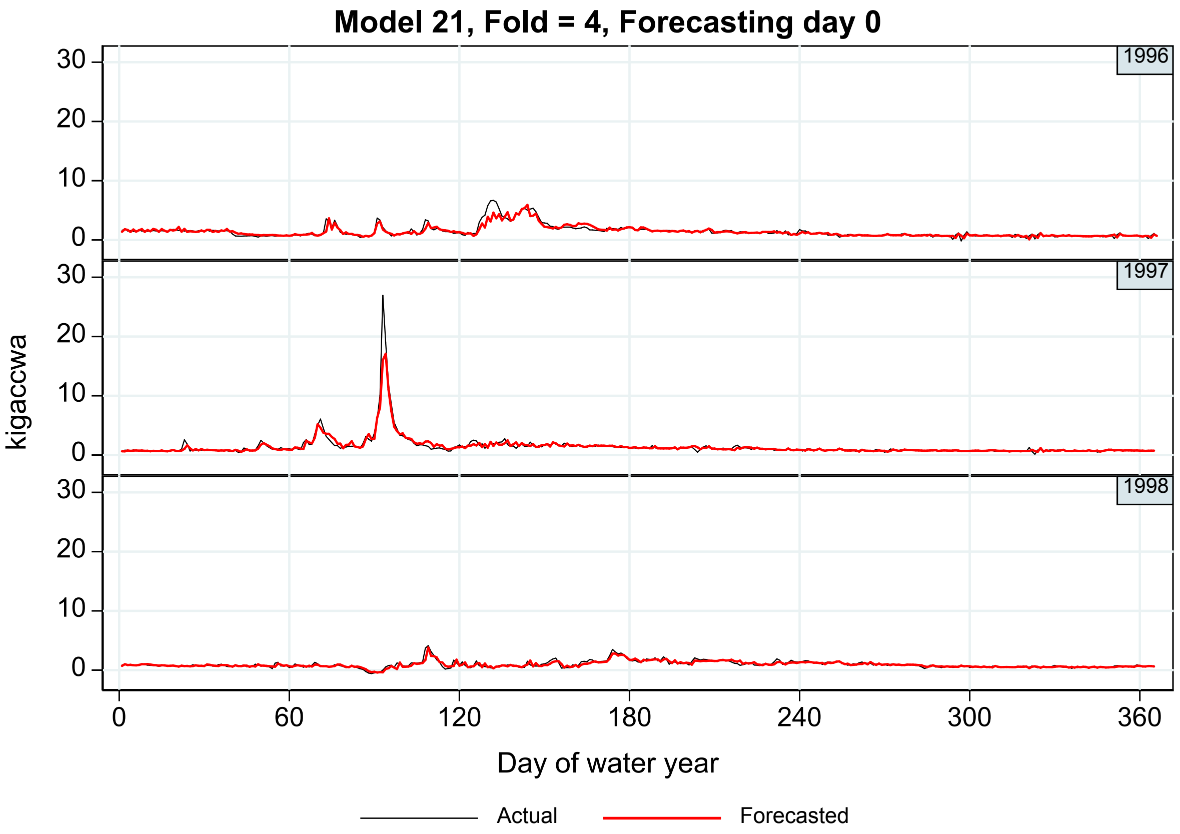

Figure A.4.3.3.6.4.5. Forecasted and actual KIG accretions for day 0 (*kigaccwa*$_i$) for fold 4 from the 10-fold cross-validation process. The model was trained on water years 1981-1995, then used to forecast water years 1996-1998.

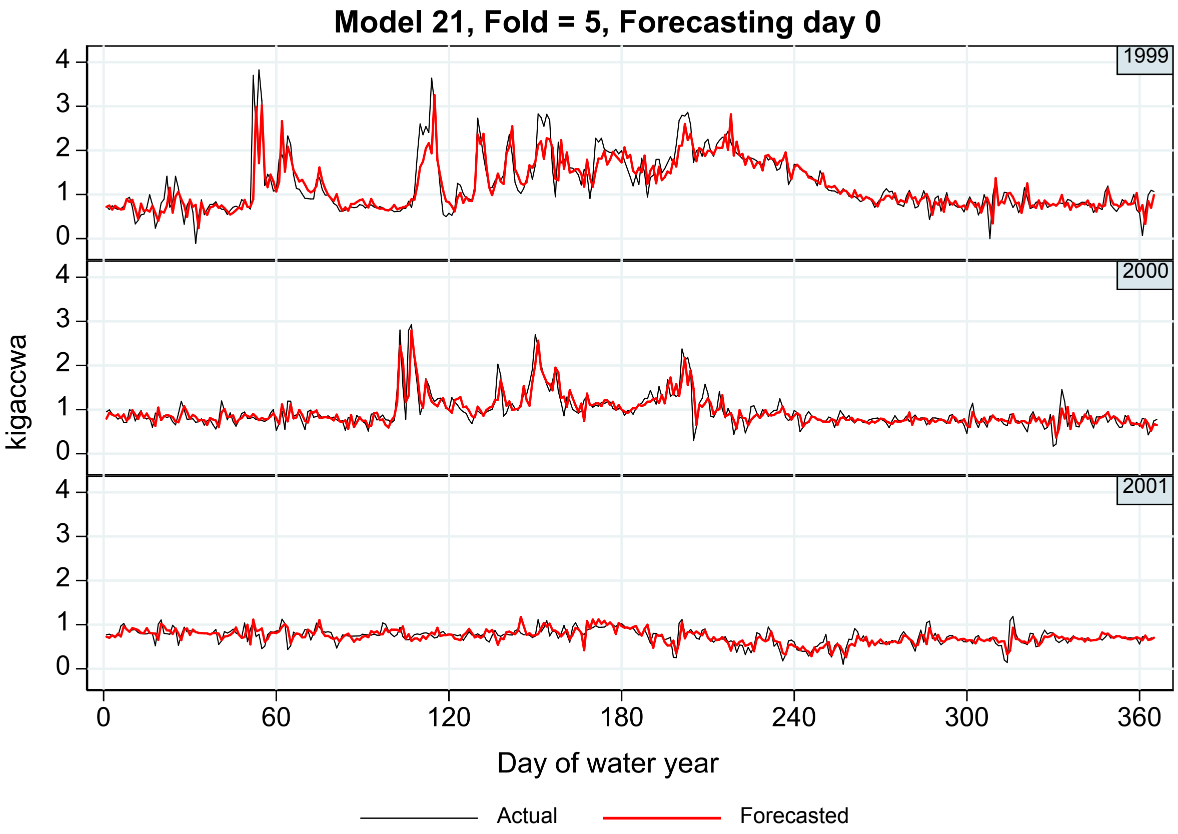

Figure A.4.3.3.6.4.6. Forecasted and actual KIG accretions for day 0 (*kigaccwa*$_i$) for fold 5 from the 10-fold cross-validation process. The model was trained on water years 1981-1998, then used to forecast water years 1999-2001.

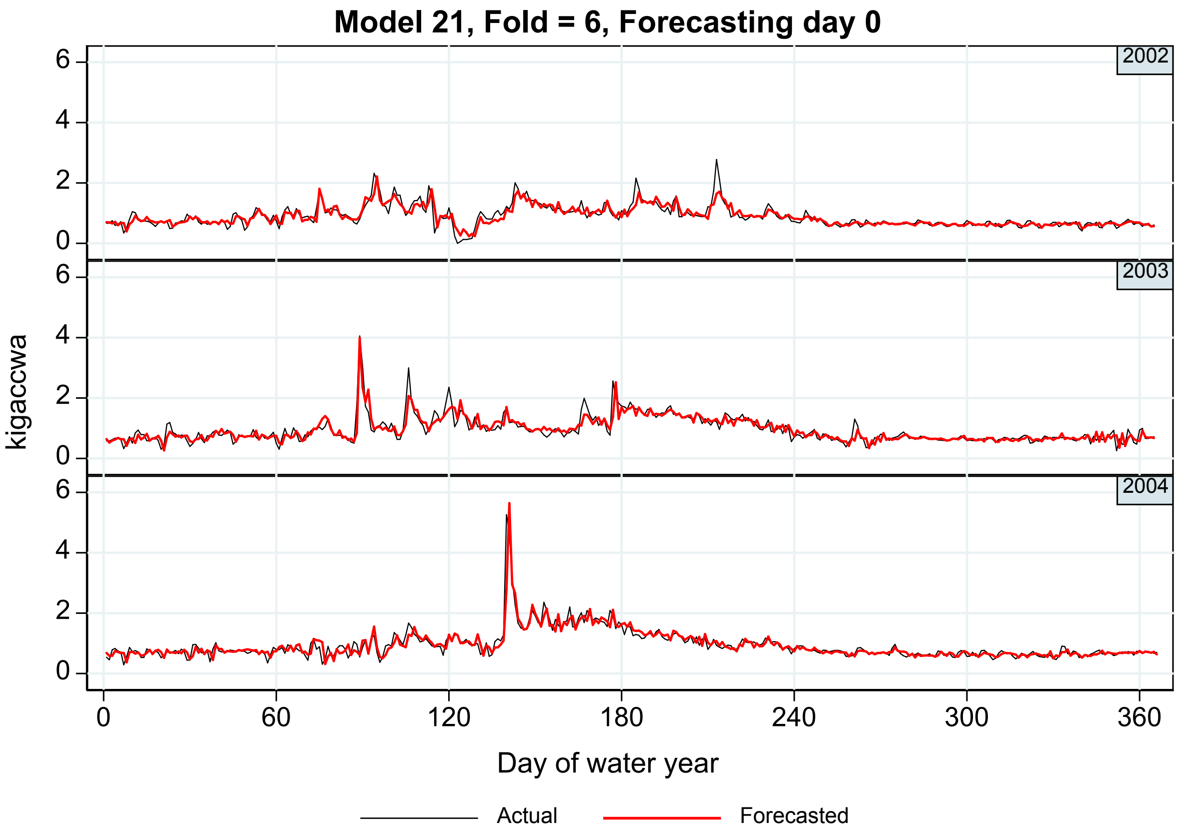

Figure A.4.3.3.6.4.7. Forecasted and actual KIG accretions for day 0 (*kigaccwa*$_i$) for fold 6 from the 10-fold cross-validation process. The model was trained on water years 1981-2001, then used to forecast water years 2002-2004.

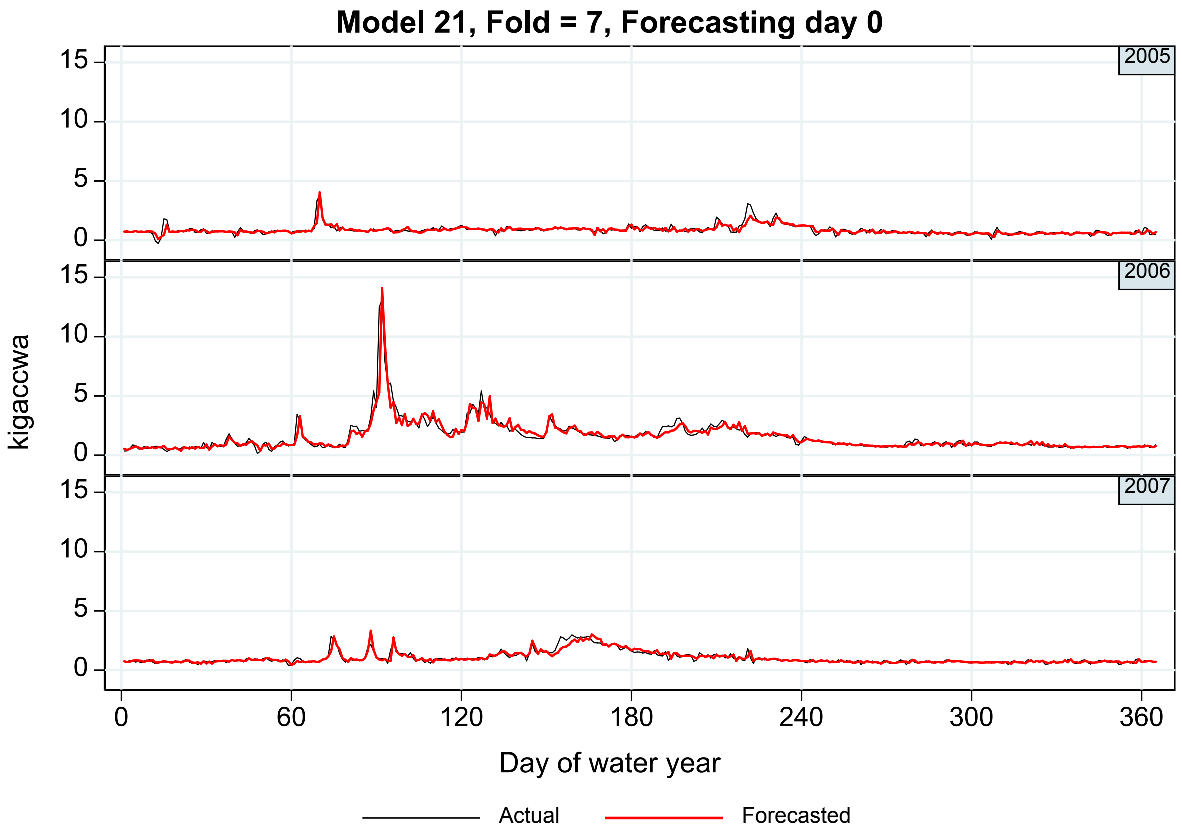

Figure A.4.3.3.6.4.8. Forecasted and actual KIG accretions for day 0 (*kigaccwa*$_i$) for fold 7 from the 10-fold cross-validation process. The model was trained on water years 1981-2004, then used to forecast water years 2005-2007.

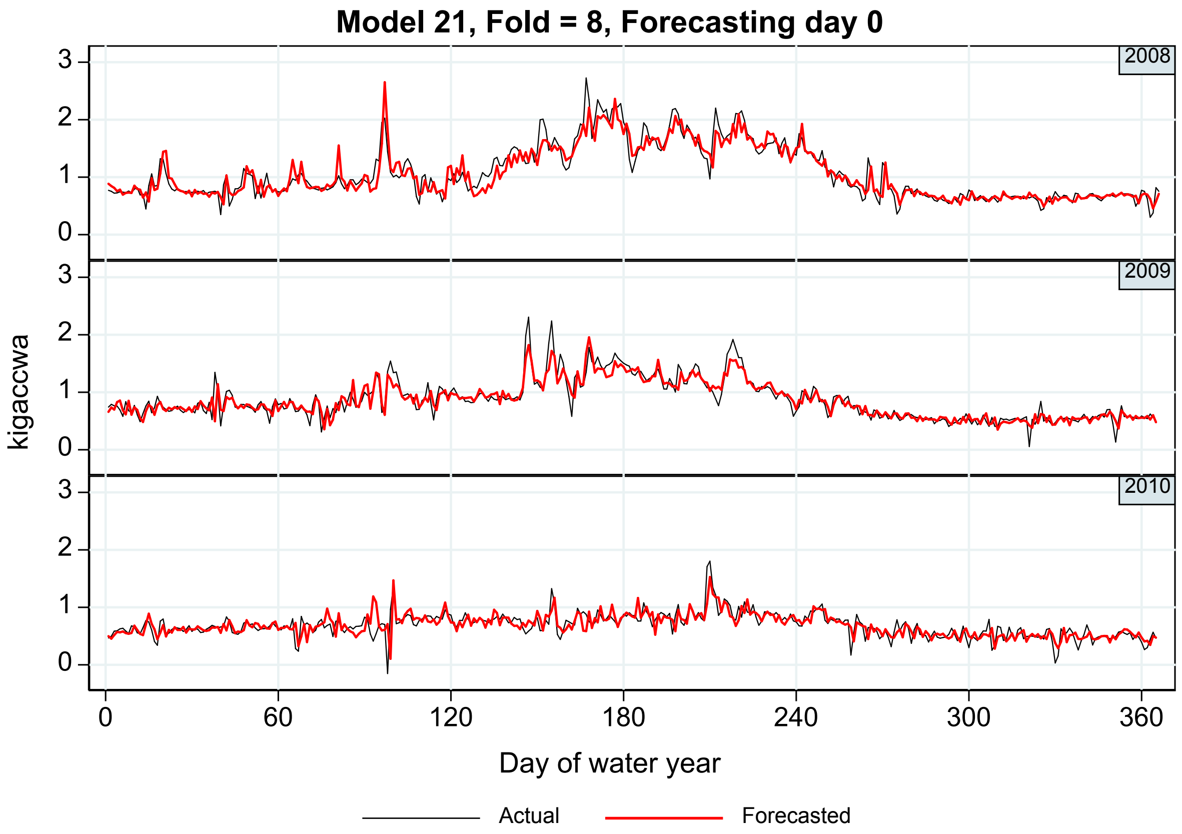

Figure A.4.3.3.6.4.9. Forecasted and actual KIG accretions for day 0 (*kigaccwa*$_i$) for fold 8 from the 10-fold cross-validation process. The model was trained on water years 1981-2007, then used to forecast water years 2008-2010.

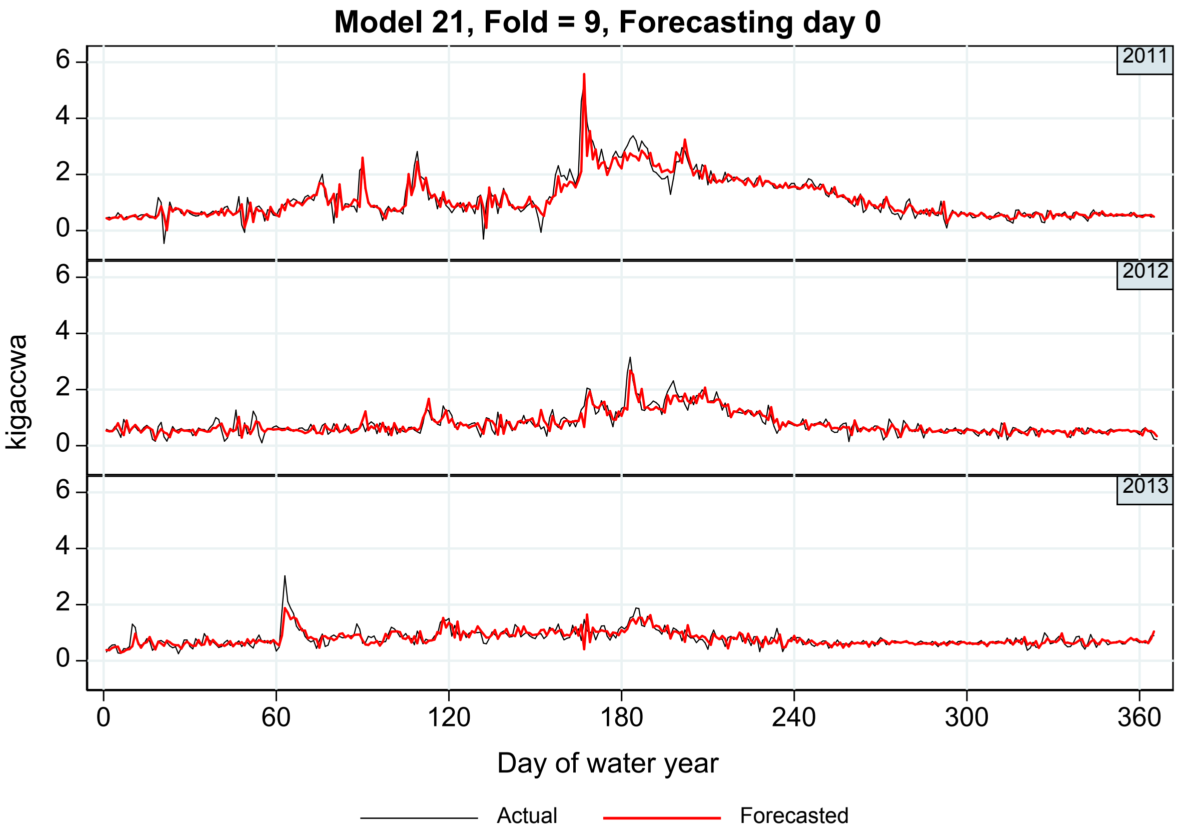

Figure A.4.3.3.6.4.10. Forecasted and actual KIG accretions for day 0 (*kigaccwa*$_i$) for fold 9 from the 10-fold cross-validation process. The model was trained on water years 1981-2010, then used to forecast water years 2011-2013.

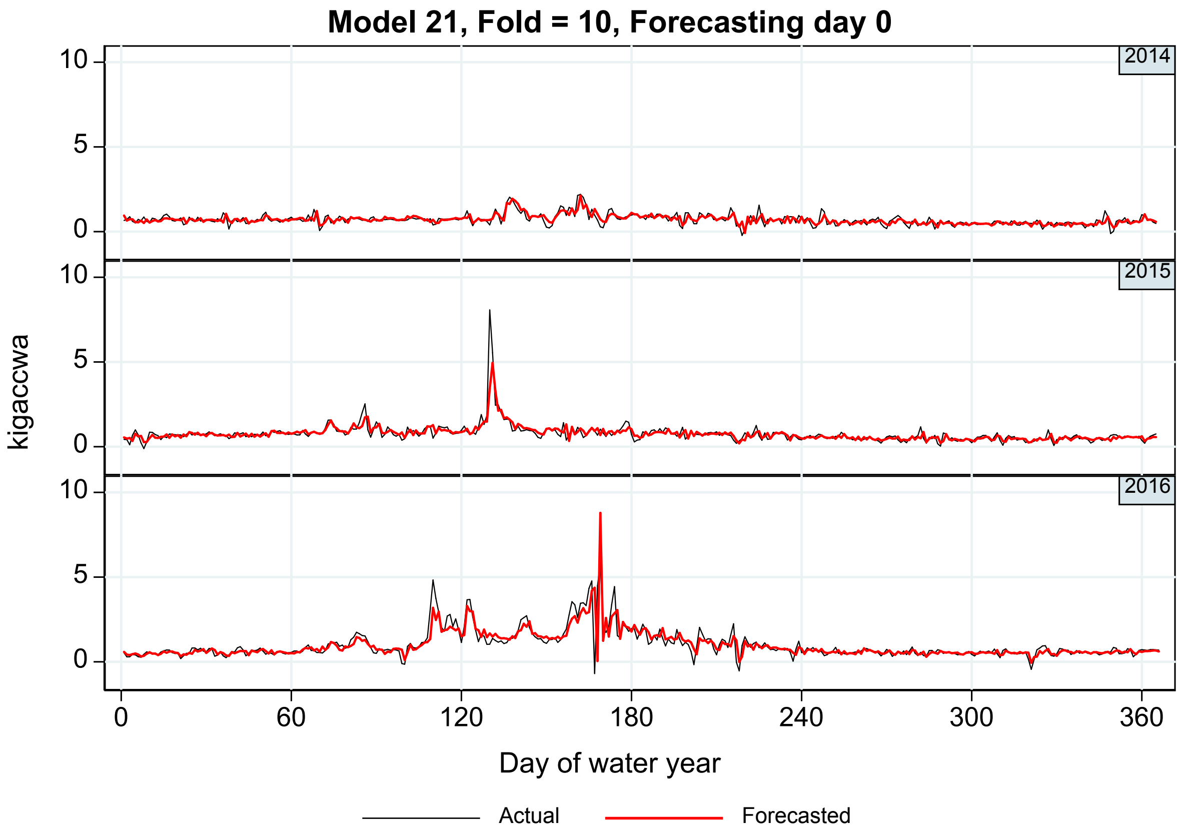

Figure A.4.3.3.6.4.11. Forecasted and actual KIG accretions for day 0 (*kigaccwa*$_i$) for fold 10 from the 10-fold cross-validation process. The model was trained on water years 1981-2013, then used to forecast water years 2014-2016.

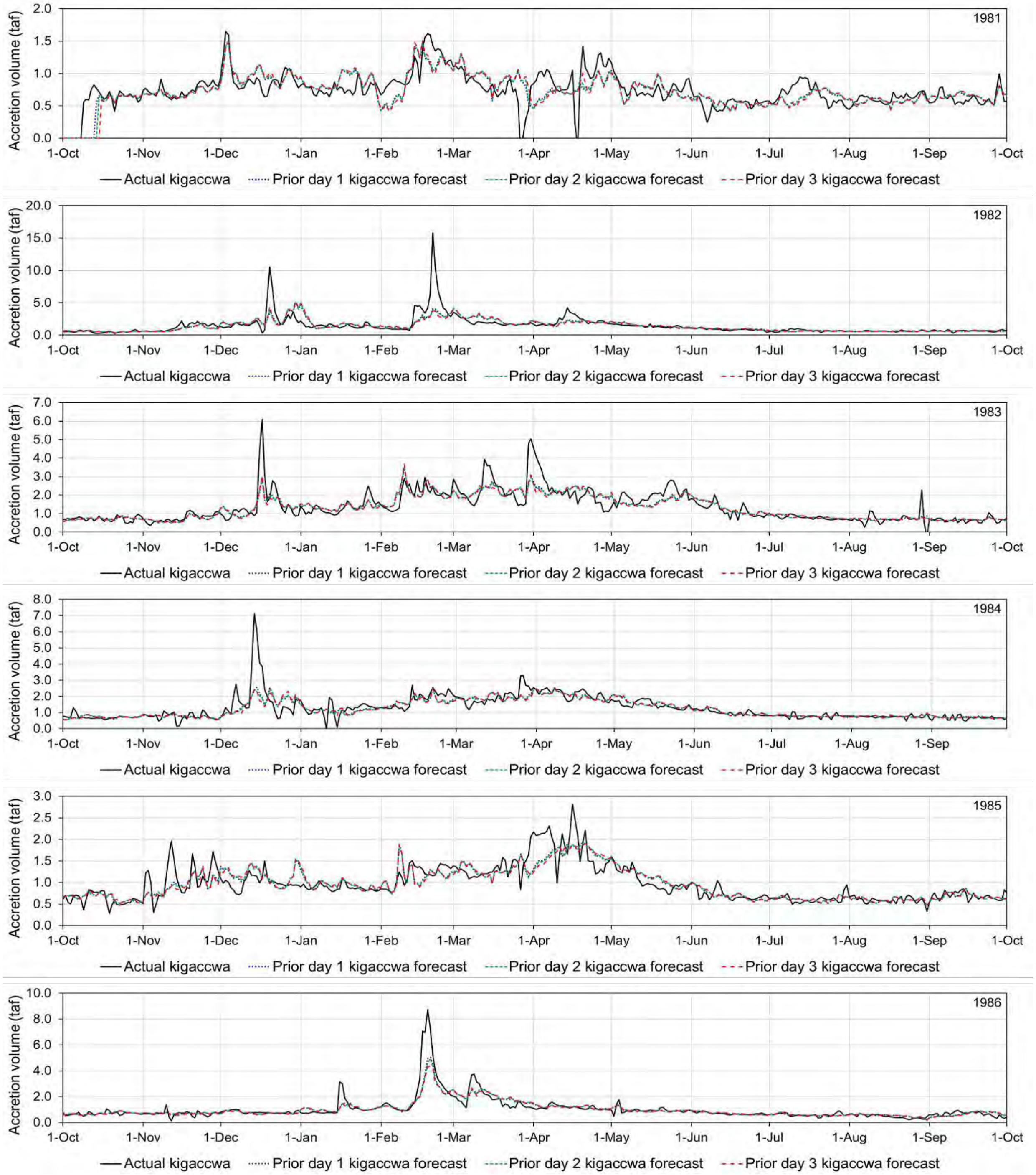

Figure A.4.3.3.6.4.12. Prior KIG accretion forecasts for water years 1981-1986 (based on model 20 fitted across all water years) compared to the actual accretions on those days.

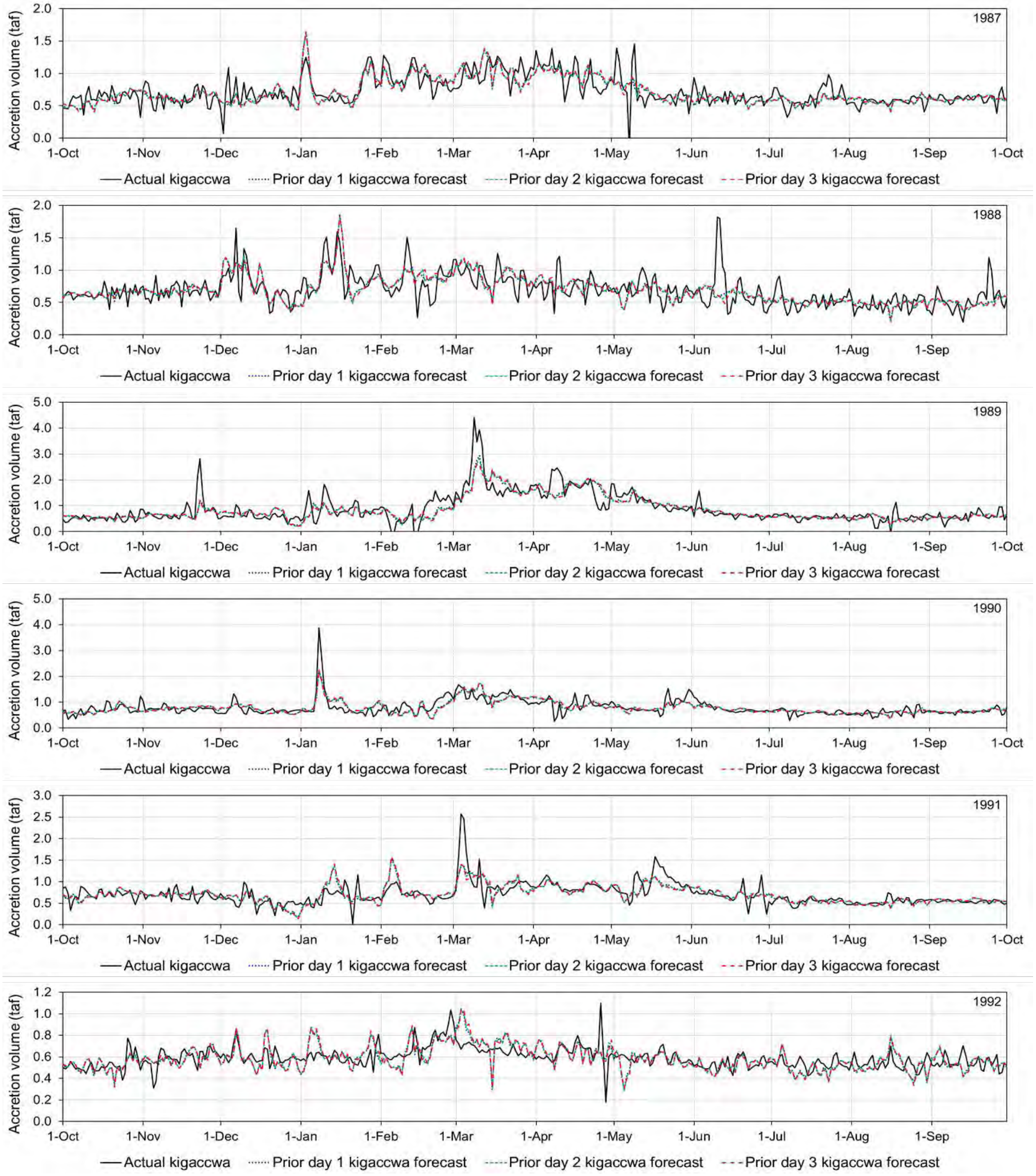

Figure A.4.3.3.6.4.13. Prior KIG accretion forecasts for water years 1987-1992 (based on model 20 fitted across all water years) compared to the actual accretions on those days.

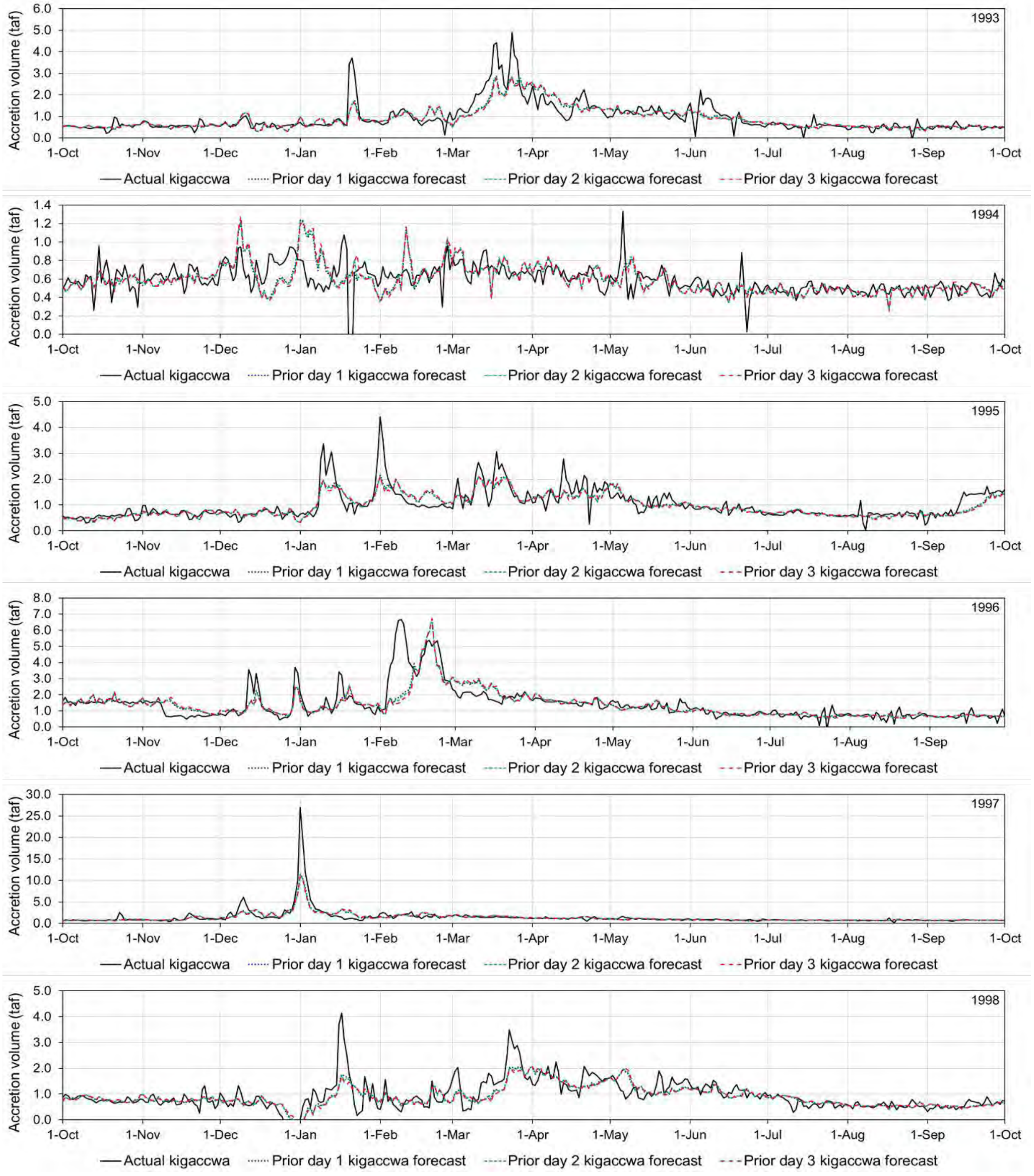

Figure A.4.3.3.6.4.14. Prior KIG accretion forecasts for water years 1993-1998 (based on model 20 fitted across all water years) compared to the actual accretions on those days.

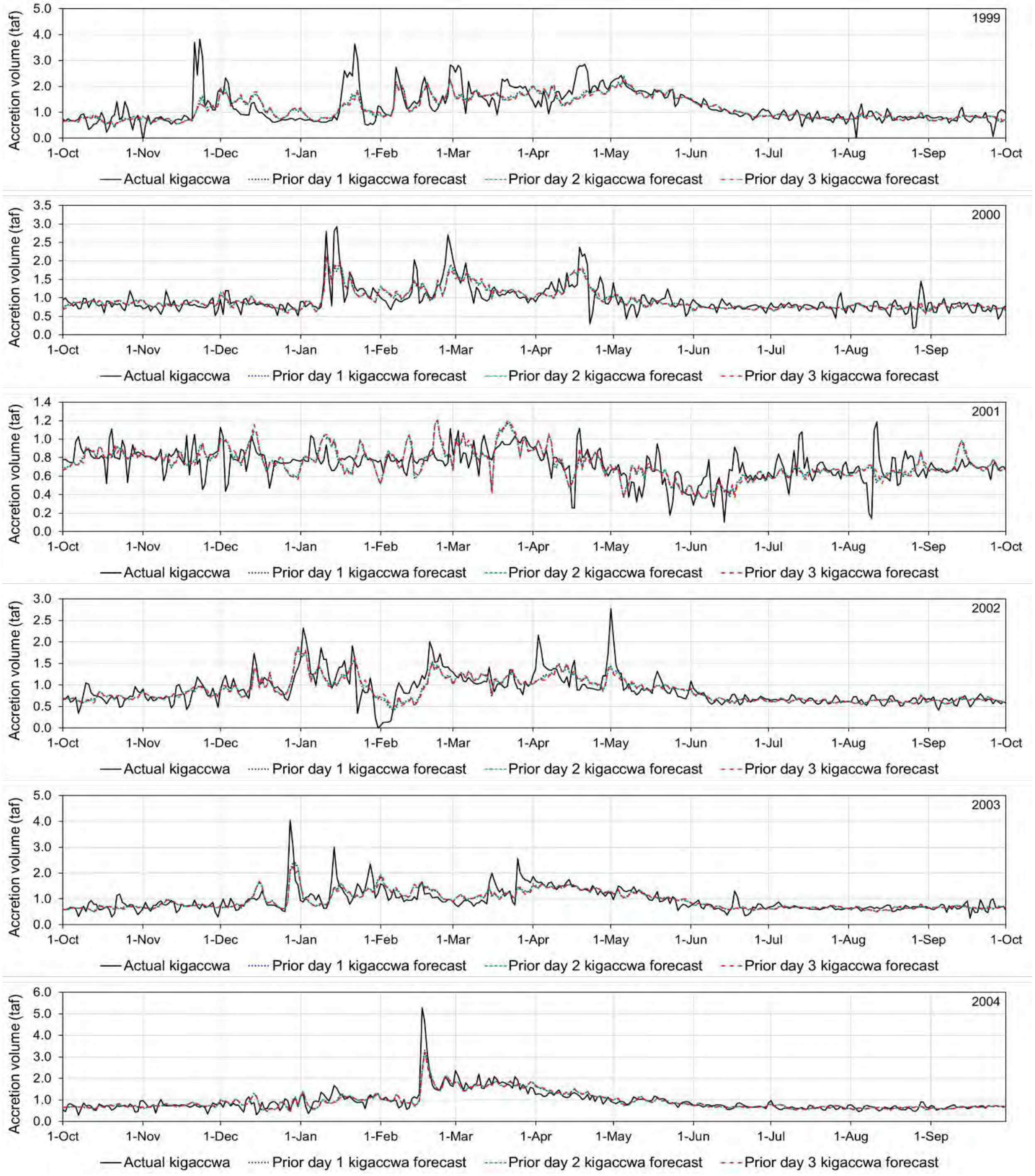

Figure A.4.3.3.6.4.15. Prior KIG accretion forecasts for water years 1999-2004 (based on model 20 fitted across all water years) compared to the actual accretions on those days.

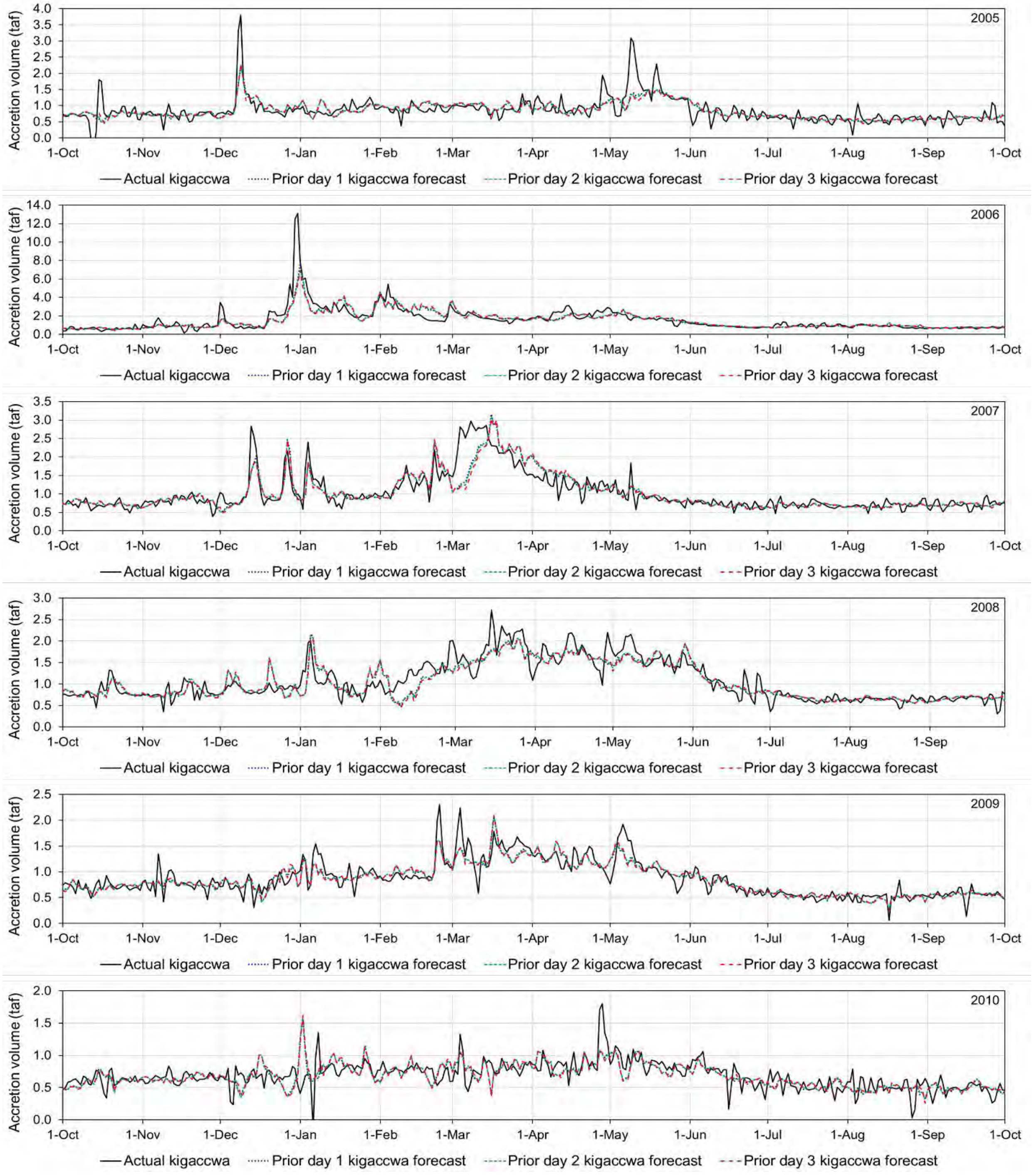

Figure A.4.3.3.6.4.16. Prior KIG accretion forecasts for water years 2005-2010 (based on model 20 fitted across all water years) compared to the actual accretions on those days.

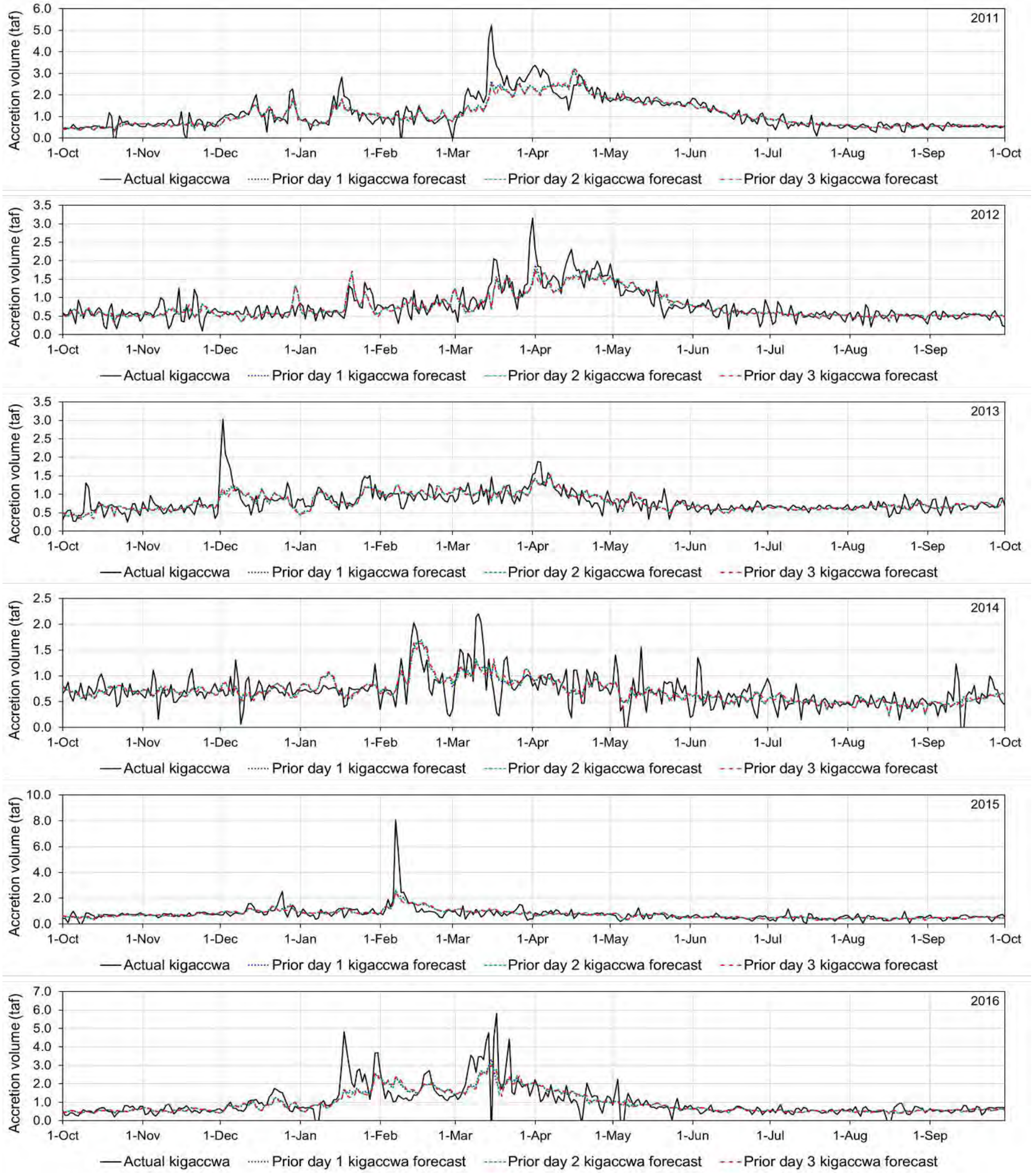

Figure A.4.3.3.6.4.17. Prior KIG accretion forecasts for water years 2011-2016 (based on model 20 fitted across all water years) compared to the actual accretions on those days.

A.4.3.3.7 Lost River Diversion Channel Inflow From Lost River

A mixture of runoff from the Lost River catchment and return flows (primarily from A Canal diversions) is diverted into the LRDC at the Lost River Diversion Dam. Data for these return flows are included in the QA/QC'ed **Daily_Project_Diversions_Final_Dec2016_corrected_Jun2017.xlsx** dataset.

A.4.3.3.8 Area 2 Winter Runoff

The Area A2 Winter Runoff data input is an error closure term for return flows from the Area A2 to the Klamath River. Essentially, this term accounts for water that was introduced to or deducted from the KSD beyond that which would have been expected as a result of agriculture or LKNWR activities, or winter and spring precipitation events that may create runoff that also drains into the KSD. In addition, gage errors, changes in pumping efficiency, changes in canal dimensions and increased or decreased efficiency in area A2 water use could all contribute to this balancing term. Area A2 Winter Runoff is a state variable, meaning that these data are static and unaffected by model adjustment of A2 deliveries or F/FF pumping. It is a timeseries calculated based on the difference between measured F/FF discharge to the Klamath River and simulated return flows from KDD and Area K using the historical gauged deliveries through North and Ady canals. The model assumes no return flow from LKNWR.

These data, as well as data and formulae related to the calculation of these data, are contained in the spreadsheet named: **KDD return flow analysis 18Sep2018 version 4 FINAL.xlsx**. More detail is provided in Section A.4.4.5. In KBPM, Area A2 Winter Runoff data are contained in the file: **PA_4Jan2017_newBathy_I1ExpSm1x_SV.dss**.

A.4.3.3.9 Natural Resources Conservation Service Forecasts

The NRCS provided reconstructed UKL net inflow forecasts for water years 1981 through 2016 using the revised UKL net inflow data (Dunsmoor 2017b). The most recent reconstructed forecasts were completed by NRCS in October 2017.

The KBPM utilizes the 50th percentage of exceedance forecast for UKL inflow for the months of January through June. Operationally, forecasts are provided by NRCS on the first of each month, and forecasts used in the model reflect this constraint. The March through September forecast is used on January 1, February 1, and March 1. Thereafter, forecasts for the forecast month through September are used (e.g. April – September on April 1). Spring/summer forecasted UKL net inflow is calculated in-season using the following formula:

Forecasted UKL Net Inflow = Previous month measured net inflow + Current month inflow forecast through September

The final forecast is issued and used on June 1. Further detail on use of these forecasts is discussed in Section A.4.4.

NRCS forecast reconstructions are contained in the spreadsheet: **Klamath_forecast_reconstructions_new_flow_data 13Oct2017.xlsx**. In KBPM, NRCS forecast data are contained in the file: **forecasts50pct.table**.

A.4.3.4 Model Variables

In many cases, the actual variables used in the model code have names which are not clearly descriptive of their definition. This is a function of multiple model developers, changing intentions and strategies, and general model adaptation. In order to connect the actual model code to the operations described below, please refer to Table A.4.3.4.1, which defines WRIMS variables used in the modelling of the Proposed Action with a common name (as referenced in the operations sections below) and location within the model files. Due to size, this table is located in Section A found at the end of this document.

A.4.4 Simulated Operations

A.4.4.1 Important Annual Operations

A.4.4.1.1 Upper Klamath Lake Control Logic

One of the greatest challenges identified in previous proposed actions was how to manage UKL elevations in such a way that the needs of endangered suckers in UKL are met while also providing a sure water supply to meet the needs of both threatened coho in the Klamath River and Project irrigators. While many approaches were explored, modelers ultimately created model logic that would allow flexibility in managing lake elevations while also discouraging overuse of the finite hydrologic resource, both within years and inter-annually. The UKL control logic was added to KBPM in order to control releases from UKL to the river and the Project based on UKL elevation relative to a hydrologically-dependent central tendency.

The central tendency is based on user-defined end-of-month UKL elevations which are subsequently interpolated to daily values; note that the generic central tendency end-of-month UKL elevations were arrived at through the iterative modeling process and are not intended to change during operations under this PA. This results in a generic annual hydrograph that accounts for seasonal needs of suckers, seasonal water demand for the Klamath River and Project, and end-of-season elevations that create conditions likely to result in storage volumes appropriate to meet the next year's demands on UKL. This generic hydrograph is then adjusted daily, based on a normalized 60-day trailing average of net inflow to UKL.

The adjusted central tendency relies on this smoothed 60-day trailing average net inflow to UKL because raw daily data for net UKL inflow, denoted in the KBPM as I1_Raw, exhibits a great deal of variability due primarily to the effects of wind on UKL elevations, which is used in determining the change in storage. In the 2013 Biological Opinion, a 3-day moving average of UKL net inflow was used to minimize the effects of this daily variability. However, during development of the current PA, modelers felt that the 3-day moving average could be improved upon utilizing a statistical smoothing technique. Initially, a locally estimated scatterplot smoothing (LOESS) was applied to produce daily values for UKL net inflow. This method relies upon a subset of inflow values near the day upon which an inflow value was being estimated. While this technique produced a smooth representation of net inflow, the reliance on inflow data from both before and after the date being estimated was deemed operationally infeasible.
In order to produce an operationally feasible prediction of daily net UKL inflow that was similar to the desirable LOESS curve, a simple exponential smoothing technique is used. The difference between yesterday's observed inflow and yesterday's predicted inflow is multiplied by a smoothing parameter (α). This smoothing parameter is optimized by minimizing the error in observed values (i.e. the difference between observed and predicted). However, because the LOESS curve values were the desired curve to approximate, error was determined using the LOESS curve values. Once the appropriate smoothing parameter is obtained and applied to the difference between observed and predicted inflows, this is added to yesterday's predicted value to determine today's forecasted net inflow. The equation is as follows:

UKL net inflow = predicted inflow (-1) + (α* (observed inflow(-1) – predicted inflow(-1))

where: (-1) indicates yesterday's value

The magnitude of the daily adjustment in UKL central tendency is bounded by user-defined limits which have been tailored to meet the needs outlined above. The final result is a central tendency line that both accounts for hydrologic needs (ESA and irrigation) and accounts for the impact of seasonal hydrology in any given year. Table 4.4.1.1.1 and the equations following provide information on the generic hydrograph and the manner in which adjustments are made.

Table 4.4.1.1.1 End-of-month UKL elevations associated with the generic (i.e., unadjusted) central tendency and the lower and upper bounds within which the tendency can be adjusted, by month. The lower and upper bounds represent the limits of adjustment that can be made to the central tendency in response to hydrology.

Month	Central Tendency Base UKL Elevation (ft.)	Central Tendency Lower Bound UKL Elevation (ft.)	Central Tendency Upper Bound UKL Elevation (ft.)
October	4139.1	4138.7	4139.5
November	4139.6	4139.2	4140.0
December	4140.6	4140.2	4141.0
January	4141.6	4141.2	4142.0
February	4142.4	4142.1	4142.7
March	4142.8	4142.6	4143.0
April	4142.8	4142.6	4143.0
May	4142.4	4142.1	4142.7
June	4141.1	4140.7	4141.5
July	4140.1	4139.7	4140.5
August	4139.4	4139.0	4139.8
September	4139.1	4138.7	4139.5

Normalized 60-day average of net inflow to UKL:

Norm_uklinf_60avg = (uklinf_60avg – uklinf_min(-1)) / (uklinf_max(-1) – uklinf_min(-1))

where: uklinf_60avg = today's average of UKL net inflow for the past 60 days
uklinf_min(-1) = yesterday's minimum UKL net inflow for that day of the water year (dowy) across the POR
uklinf_max(-1) = yesterday's maximum UKL net inflow for that dowy across the POR

Adjustment of UKL central tendency:

Adj_uklcentral = ukltraj_central + (norm_uklinf_60avg – 0.5)

where: ukltraj_central = daily interpolated value for the central tendency
norm_uklinf_60avg = normalized 60-day average of net UKL inflow

The adjusted central tendency is used to signal the need for, and to quantify the magnitude of reduction in, releases from UKL. On any given day, if lake elevations are above the adjusted central tendency, then releases to the river or to the Project proceed unchanged from the delivery rules in the model. However, when UKL elevations are below the adjusted central tendency, Klamath River and Project (when applicable) releases are reduced by a magnitude commensurate with how far UKL is below the adjusted central tendency, which facilitates but does not force the return of UKL to a trajectory in line with the adjusted central tendency.

Release reductions occur based on a storage difference ratio. This ratio determines the magnitude of required reduction based on how far below the adjusted central tendency UKL sits; the further below the adjusted central tendency, the greater the percentage by which releases may be reduced. The storage difference ratio is updated every 5 days, meaning that an action taken on reduction (e.g., no reduction, reduction of 10%) will remain in effect for 5 days from the date of implementation. This was done to maintain operational feasibility of this approach. There are two different storage difference ratios in the model, one that is applied to Klamath River releases and one that is applied to Project releases.

LRD releases may be reduced by up to 80% from the daily calculated release and may be reduced at any time of the year; IGD minima for the Klamath River (as defined in the 2013 Biological Opinion) are still in effect and river flows cannot go below these values. Project releases may be reduced by up to 80% and these reductions can only occur to Project releases for fall/winter water deliveries, November through February, and releases to LKNWR in December through February. This reduction does not apply to the LKNWR transferred water right described in Section A.4.4.9 (additionally, see Section A.4.4.9 and in the Biological Assessment, Section 4.3.2.2.2.2 for additional information about delivery of Project Supply to LKNWR). Both storage difference ratios have an upper bound of 0, meaning that modeled releases will not increase if UKL elevations are above the adjusted central tendency. The lower bounds are -0.8 for LRD and fall/winter Project/LKNWR deliveries. The first step in calculating the storage difference ratio is to determine the volumetric difference between the current UKL elevation and the adjusted central tendency. This is done taking into account the UKL credit that has been accumulated, since this water is intended to remain in UKL (see Section A.4.4.1.2). Once this volumetric difference is determined, the ratio is created by dividing that volume by a volumetric “envelope” on UKL within which UKL may fluctuate. This envelope varies slightly throughout the year, from 20,000 AF to 60,000 AF, with intermediary values linearly interpolated. The broadest envelope (i.e., highest values) is allowed in the spring (Table 4.4.1.2.1.2), when demands on UKL are highest. As this value is used in the denominator of the storage difference ratio calculation (see below), the size of the envelope will dictate the increment by which the storage difference ratio may be applied to releases. A larger envelope value results in a more gradual implementation of adjustment before maximum adjustment is achieved; a smaller envelope value results more rapid increase in adjustment percentage as UKL elevations drop below the central tendency. Table 4.4.1.1.2 and the following equations define the storage difference ratio:

Storage difference pre-adjustment:

Stor_diff_preadj = S1(-1) – prj_UKL_credit – adj_uklcentral_storage

where: S1(-1) = yesterday’s UKL storage volume
prj_UKL_credit = accumulated credit volume in UKL (see Section A.4.4.1.2)

adj_uklcentral_storage = storage volume associated with today’s adjusted central tendency

Table 4.4.1.1.2 UKL adjustment width for each day of the water year; values for intermediate days are linearly interpolated within KBPM.

Day of Water Year	UKL Adjustment Width (TAF)
1	20
124	20
152	60
212	60
227	20
366	20

Storage difference ratio:
Stor_diff_ratio = min (u_bound, max (l_bound, stor_diff_preadj / UKL_adj_width))

where: u_bound = upper bound of storage difference ratio
l_bound = lower bound of storage difference ratio
stor_diff_preadj = unadjusted storage difference ratio
UKL_adj_width = the UKL elevation "envelope" described above

It is important to note that the UKL control logic is not designed to utilize the adjusted central tendency line as a management target. Rather, it is part of an overall management scheme to ensure that needs of the UKL, Klamath River, and the Project are met in the majority of water years. The adjusted central tendency is one step in the process of setting spring/summer and fall/winter releases to the Klamath River from UKL and fall/winter releases to the Project from UKL. The other steps in this process are described in Sections A.4.4.2 and A.4.4.3.

A.4.4.1.2 Upper Klamath Lake Credit

In the 2013 BiOp, both LRDC accretions in excess of Project diversions and F/FF discharge to the Klamath River were included in the formulated IGD flow target. The current proposed action has removed the IGD flow target reliance on these accretions and return flows during the irrigation season; to compensate for this, EWA will have a higher share of UKL Supply to provide IGD flows that were previously met by excess LRDC flow and F/FF pumping. These accretions and return flows will be shared between Project irrigators and UKL for mutual benefit. Irrigators can directly divert Lost River flow to the LRDC or F/FF discharge and it does not count as a diversion of Project Supply. The LRDC flows and F/FF pumping in excess of direct diversion supports controlled IGD flow in lieu of LRD releases. This reduction in LRD release results in higher UKL storage, and the increment of higher storage is termed an Upper Klamath Lake Credit (UKL Credit).

A UKL Credit may be accrued only from March through September, while the EWA is in effect and releases at LRD and IGD are managed (i.e., not in flood operations). Flows from LRDC and F/FF must be in excess of concurrent agricultural diversions, meaning that those flows are potential irrigation water that is instead going to support IGD releases. High rainfall runoff events from the Lost River do not contribute to the UKL Credit. If UKL experiences flood spill during this time period, further UKL Credit cannot be accrued during spill; additionally, during flood control operations, UKL Credit will be considered the first UKL storage spilled.

The purpose of the UKL Credit is to hold water in UKL to facilitate the ability to establish a minimum Project Supply on April 1 with no later reduction, and the possibility of increase in subsequent May 1 and June 1 allocations. Accrual of UKL Credit ensures that there is a volume of water in UKL that can be drawn upon in the case of an early season over-forecast of seasonal inflow to UKL. However, any UKL Credit accrued in UKL above and beyond that necessary to ensure full delivery of Project Supply will remain in UKL to facilitate refill of the lake in the ensuing fall/winter period. There is no carryover of accrued UKL Credit from season to season.

UKL credit calculation:

Prj_UKL_credit = prj_UKL_credit(-1) + (C91_F_IG(-1) + C131_IG(-1) – C15_EXC(-1)) – D1(-1) – C1_AG(-1)

where: prj_UKL_credit(-1) = yesterday’s UKL Credit amount
C91_F_IG(-1) = yesterday’s LRDC contribution to IGD release
C131_IG(-1) = yesterday’s F/FF contribution to IGD release
C15_EXC(-1) = yesterday’s IGD flood release
D1(-1) = yesterday’s A Canal diversion
C1_AG(-1) = yesterday’s LRD release for agricultural diversion

EWA use includes the LRDC flow and F/FF discharge that goes downstream to support IGD releases in controlled flow situations.

A.4.4.2 Fall/Winter Operations

The fall/winter Project operational procedure distributes the available fall/winter UKL inflows between the following:

1. UKL
    a. Increase UKL elevation to meet ESA-listed habitat needs throughout the fall/winter period and the following spring/summer period and increase storage for spring/summer EWA releases and irrigation deliveries.
    b. This is achieved through the UKL control logic.

2. Klamath River
    a. Release sufficient flow from IGD to meet ESA-listed species needs in the Klamath River downstream of IGD; this includes flows to support salmon spawning from October 1 – November 15.
    b. This is achieved through the formulaic approach to calculating IGD targets.

3. Project:
    a. Klamath Drainage District (Area A2 – serviced by North Canal and Ady Canal)
    b. Lease Lands in Area K (within Area A2 – serviced by Ady Canal)
    c. LKNWR (serviced by Ady Canal)

Additionally, sufficient flood pool capacity must be maintained in UKL to protect the surrounding lake levees.

The fall/winter operations period begins on November 1 and ends on February 28/29. Note that there is often overlap between the spring/summer (see Section A.4.4.3 for details) and fall/winter operations in October and November because Area A1 and the LKNWR will likely divert a portion of the spring/summer Project Supply during these months, while EWA accounting ends on October 1. Spring/summer and fall/winter diversion accounts must be kept separate during the overlap period.

During the fall/winter season, the primary goal of operations is to refill UKL in order to support high demands on UKL in early spring, including the possibility of disease prevention/mitigation flows for the Klamath River, ensuring adequate spawning habitat for shoreline spring spawning suckers, and supporting the beginning of Project deliveries. To this end, a premium is placed on the fill rate needed to achieve a UKL elevation of 4,143 feet by the end of February. Note that this target elevation is utilized to calculate a refill trajectory that effectively refills UKL; flood control elevations will prevent UKL from reaching this elevation at the end of February (see Section A.4.4.10). In addition, KDD is provided a reserve supply of up to 28,910 AF between November 1 and February 28/29 via a state water right, and LKNWR is provided maintenance flows of up to 62 cfs/day, with a cap of 11,000 AF in total delivery volume from December through February. Both of these deliveries are subject to the UKL control logic, and so may be reduced based on hydrologic conditions. The remaining inflow to UKL is released to support Klamath River flows at IGD. IGD releases are heavily affected by the accretions downstream of Keno Reservoir. In wetter hydrologic patterns, or during periods immediately following lower-basin storms, the downstream accretions can account for a substantial portion of the flows downstream of IGD.

Following are instructions for implementing fall/winter operations.

Fall/winter releases from UKL for IGD flows are intended to support salmon spawning in October through November 15, and are determined by UKL net inflow and the fill trajectory of UKL thereafter. All KDD and LKNWR deliveries are calculated as shown below and subject the UKL control logic. No UKL credit can be accrued during the fall/winter season. Key model variables referenced throughout this document can be defined in Table A.4.3.4.1 found in Section A at the end of this document.

1. Lookup **Link_min**, which is the minimum flow release from LRD from Oct-Feb. Link River minima are only for modeling purposes and lower Link River flows may be observed in real-time operations. Note that it is operationally possible to reduce LRD flows below these flow minimums, but this requires Reclamation to conduct a fish stranding assessment below LRD (and possibly below Keno Dam). This requires additional personnel and other resources. Given these concerns, it is necessary to weigh the benefit of flows below LRD minimums against personnel and resource requirements for stranding assessments. See the Biological Assessment, section 4.3.2.2.1 for additional details.

Table A.4.4.2.1 Link River Dam minimum flow release; these discharges refer to cfs at Link River Dam, rather than the USGS gauge downstream.

Month	Link_min (cfs)
October	400
November	400
December	300
January	300
February	300

2. Determine IGD flow for the October – November 15 salmon spawning period, **IG_spawn_flow**. This flow determination begins with the lookup of **IG_spawn** flow value based on the normalized 60-day trailing average of net UKL inflow; this value is linearly interpolated between a minimum of 1000 cfs and a maximum 1200 cfs. To this base value, an additional 0 – 125 cfs may be added at intervals of about 10 days based on the 60-day trailing average of UKL net inflow and the date between October 1 and November 15; this is the **IG_spawn_inc**. On any given day during the time period:
   IG_spawn_flow = IG_spawn + IG_spawn_inc

3. Calculate **Needed_fill_rate**, which is the average daily fill rate from yesterday's UKL level to attain 4143 ft. on February 28.

   Needed fill rate = (fill_target_approx_vol – S1(-1)) / (105 – (daynumDV(-1) – 47))

   where: fill_target_approx_vol = volume associated with an UKL elevation of 4143 ft. (534,502 AF);
   S1(-1) = yesterday's storage volume in UKL;
   daynumDV = the current day of the water year, numbered since October 1.

   Note: 105 is the number of days between November 16 and February 28 and 47 is the number of days from October 1 to November 16. This allows for a daily calculation of how much volume should be added to UKL between November 16 and February 28 if 4143 ft. in elevation is to be achieved.

4. Calculate **Link_release_FW**, which is the amount of water that should be released from LRD between October 1 and February 28/29 based on UKL net inflow, UKL filling trajectory, and accretions between LRD and IGD.

   a. First, **Link_release_FW_prep** is calculated, which is a release from LRD that is unadjusted by interaction with the UKL control logic. Flow releases in October – November 15 depend on the IG_spawn_flow, which is implemented in the calculation of C15_target (see below), and so this period is omitted here. From November 16 through February, UKL net inflow is adjusted by 1.5 times the Needed_fill_rate.

      November 16 – February 28/29:
      Link_release_FW_prep = I1(-1) – (1.5 * Needed_fill_rate)

      where: I1(-1) = yesterday's UKL net inflow

   b. Then, Link_release_FW_prep is adjusted by an appropriate daily storage difference ratio, resulting in:
      Link_release_FW = Link_release_FW_prep + (stor_diff_ratio5d * Link_release_FW_prep)

5. Establish **Link_max**, the maximum release possible from LRD, based on the UKL elevation. This is done by selecting the appropriate maximum release based on the associated UKL elevation from the lookup table **Link_max.table**. This value will limit how much water can possibly be released from UKL to support Klamath River, KDD, and LKNWR flows on any given day. Maximum possible releases range from a high of 8,600 cfs when UKL level is 4143.3 ft, to a low of 900 cfs when UKL level is 4137.0 ft.

6. Determine the **Link_WF_target**, which is the maximum value of either Link_min or Link_release_FW.

7. Determine volumes of water needed to meet needs for KDD and LKNWR winter needs.

   a. KDD has a winter water right for a volume of up to 28,910 AF. KDD daily deliveries are subject to UKL control logic and can be reduced by an appropriate percentage on a daily basis as dictated by the UKL control logic. KDD daily deliveries (in cfs) are determined as follows:

      D11_fw_calc_no_UKL_ctrl = min (200 cfs, KDDReserve) * pctNorth
      D12A_fw_calc_no_UKL_ctrl = min (200 cfs, KDDReserve) * pctAdy

      where: KDDReserve = remaining amount of unused state water right, converted to cfs in this calculation
      pctNorth = percentage of delivery to be put down North Canal, based on water year type
      pctAdy = percentage of delivery to be put down Ady Canal, based on water year type

      D11_fw_calc_no_UKL_ctrl and D12A_fw_calc_no_UKL_ctrl are both subject to an appropriate UKL control adjustment.

   b. LKNWR can receive up to 62 cfs/day via Ady Canal from December 1 through February, up to a total volume of 11,000 AF. These deliveries are also subject to UKL control logic and can be reduced by an appropriate percentage on a daily basis.

8. Lookup **IGmin**, which is the minimum flow at the gauge below IGD (minima for other months not shown here):

Table A.4.4.2.2 Minimum Flow Below Iron Gate Dam, October to February

Month	IG_MIF (cfs)
October	1000
November	1000

December	950
January	950
February	950

9. Set **C1forC15**, the LRD release to support IGD flows. For the fall/winter period, this is equal to Link_WF_target.

10. Calculate **C15_target**, which is the targeted release at IGD. From October 1 through November 15, this target is IG_spawn_flow + stor_diff_ratio5d * IG_spawn_flow. This calculation relies upon operational values from 3 days prior (the operational delay accounted for in the model) and a forecast of accretions from 3 days prior. Operationally, IGD releases may vary from those calculated here due to real-time accretion values, flood control operations, and/or other facility operational emergencies and malfunctions.

    C15_target = C1forC15 + I10(-3) + I15_forecast2(-3) + (C131(-3) + max (C91_F(-3) – D11_ss_LRDC(-3) – D12A_ss_LRDC(-3) – D12B_LRDC(-3), 0))

    where: I10 = Link River Dam to Keno Dam accretions;
    I15_forecast2 = forecasted Keno Dam to Iron Gate Dam accretions;
    C131 = F/FF discharge;
    C91_F = LRDC flows toward the Klamath River;
    D11_ss_LRDC = North Canal diversion of LRDC return flow;
    D12A_ss_LRDC = Ady Canal diversion of LRDC return flow to ag;
    D12B_LRDC = Ady Canal diversion of LRDC return flow to LKNWR;
(-3) = operational lag of three days assumed in the model.

A.4.4.3 Spring/Summer Operations

The Project irrigation season runs from March 1 through October 31, although irrigation can continue through November 15 in areas served by D91. The previous section described the fall/winter operations which are the first half of each water year. This section describes the second half of each water year, which covers the irrigation season. The irrigation season operations are controlled by defining the available UKL Supply (WRIMS variable name UKLSupply), which is computed from storage in UKL, forecasted March-September inflow, and target carryover storage. Division of this supply between the Klamath River (EWA_river) and Project (PrjSupply) is dependent on the size of UKL Supply (described below). Any UKL inflow that is not delivered or released for flow will remain in UKL as storage. All water which leaves UKL through either LRD or the A Canal is accounted for against one of these two identified volumes; this includes flood control releases with the exception of spill of UKL credit. LKNWR can receive a portion of the Project Supply or other delivery from UKL. Details for these operations are included in the sections below.

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Both volumes are calculated on March 1 and April 1 with updates on May 1 and June 1. The March and April processes divide up the UKL Supply to help the irrigators and river managers plan out the spring/summer operational period. The May and June processes manage the change in supply by adjusting the volumes. The steps for determining the Project Supply and the EWA are below. Key model variables referenced throughout this section can be found in Table A.4.3.4.1 at the end of this Appendix 4-1.

1. Calculate **UKLSupply** - The UKL supply is updated on the 1st of each month March through June using the most current forecasted net inflow, the end of February storage and the end of September target. This formula is as follows (all values in TAF):

   UKLSupply = [End of February UKL Storage] + [50% exceedance forecast UKL inflow for March through September] – [End of September UKL Storage Target]

   a. The end of February UKL storage is simply the storage in UKL as determined on the last day of February. This is determined using the UKL weighted mean average elevation as determined by USGS for that date along with the elevation-storage table included as Table A.4.4.3.1 found at the end of this Appendix.

   b. The forecasted UKL net inflow for March through September changes each month from March through June. The formulas used for this variable (called **Mar50vol** in the model code) are as follows:
      i. March = [March 1st 50% exceedance probability forecast for UKL net inflows for March through September]
      ii. April = [April 1st 50% exceedance probability forecast for UKL net inflows for April through September] + [Actual net inflows that occurred in March]
      iii. May = [May 1st 50% exceedance probability forecast for UKL net inflows for May through September] + [Actual net inflows that occurred in March] + [Actual net inflows that occurred in April]
      iv. June = [June 1st 50% exceedance probability forecast for UKL net inflows for June through September] + [Actual net inflows that occurred in March] + [Actual net inflows that occurred in April] + [Actual net inflows that occurred in May]

   c. The **End of September UKL Storage Target** is determined each month, March through June, and is dependent on the end of September UKL central tendency (4139.1 ft), the end of September high and low central tendency increments (0.4 ft), and Mar50vol as defined above. The lowest end of September storage target is 4138.7 ft (central tendency minus the low increment) and the highest end of September storage target is 4139.5 ft (the central tendency plus the high increment). The end of September storage target equals the low target (4138.7 ft) if Mar50vol is equal to or less than the lowest Mar50vol in the simulated period of record (160,000 AF). The end of September storage target equals the high target (4139.5 ft) if Mar50vol is equal to or greater than the highest Mar50vol in the simulated period of record (1,316,258 AF). For any Mar50vol in between 160,000 AF and 1,316,258 AF, the end of September storage target is linearly interpolated as follows:

i. Target = 4138.7 + 0.8*(Mar50vol – 160)/1156.258 when Mar50vol > 160,000 AF and Mar50vol < 1,316,258 AF
ii. The elevation target is converted to TAF for use in the UKL supply formula with the elevation-storage table included as Table A.4.4.3.1 found at the end of this Appendix.

2. Calculate **EWA_River** as a portion of UKLSupply. When UKLSupply is less than 670,000 AF, EWA_river is at the EWA minimum of 400,000 AF. When UKLSupply is greater than 1,035,000 AF, EWA_River includes all UKLSupply above the project supply maximum (UKLSupply – 350,000). For UKLSupply between 670,000 AF and 1,035,000 AF, EWA_River is calculated as follows:

   $$\text{EWA\_River} = 0.00029127 * \text{UKLSupply}^2 + 0.29190568 * \text{UKLSupply} + 73.17532589$$

   In even years (e.g., 2020, 2022), EWA_River is further increased by 7,000 AF to cover releases for the Yurok Boat Dance ceremony.

3. Calculate the **Project Supply.**

   a. The maximum Project Supply (PrjSupply) is 350,000 AF. Maximum Project Supply occurs when UKLSupply is greater than 1,035,000 AF.

   b. When UKLSupply is less than 1,035,000 AF, Project Supply = UKLSupply – EWA_River.

   c. In May and June, Project Supply cannot be reduced below the April 1 allocation.

   d. In June, if UKLSupply had decreased relative to the May determination, the Project Supply can be reduced, but to no lower than the April value.

The final determination for Project Supply is made in June and is then fixed through the end of September.

A.4.4.4. Agricultural Water Delivery Sub-model

A.4.4.4.1. Methods

Delivery of irrigation water to agriculture during the spring/summer operational period was simulated using methods that produced realistic patterns of water delivery. Diversion data for the POR from March 1, 1980 through November 15, 2016 (Dunsmoor 2017a) was used to develop the agricultural delivery sub-model. During this time frame, the Project experienced a wide variety of conditions, including periods of essentially unconstrained diversion, periods of moderate to severe diversion constraints, and wet or dry conditions in single years and over sequences of multiple years. Of particular note are years in which regulatory actions changed irrigation patterns so substantially that the historical data was deemed to be unusable for sub-model development. Included in this category are the years 2001 (irrigation shutoff until July), 2010 (extremely late start, irrigation started in mid-May), and 2014-2015 (Ady Canal shutoff for significant portions of both summer irrigation seasons). Accordingly, these years were excluded from the data sets used to develop the sub-model. In addition, 3 test years (1991, 1998, and 2003) were randomly selected, excluded from model derivation, and reserved for evaluating the predictive capability of the final sub-model (James et al. 2013).

The sub-model was structured around 5-day periods within an irrigation water year, which extends from March 1 through the end of February and is comprised of 73 five-day periods (period 73 has 6 days in leap years; Table A.4.4.4.1.1). Period 49 ends on October 31, encompassing the season-of-use for D1, and the summer season-of-use for D11 and D12A. Period 52 ends on November 15, encompassing the season-of-use for D91.

Summing historical delivery volumes (in TAF) across the season-of-use for all 4 diversion arcs yielded what is called Total A, which represents the total water volume diverted during the spring/summer operational period from all surface water sources. In the development of these sub-models, Total A was the sum of deliveries from UKL and deliveries made from the inflow measured at the LRDC headworks at Lost River Diversion Dam.

Historical daily diversion data for years that were not excluded from model development were divided by Total A diversions for each year. The resulting proportions were multiplied by 100, and these percentages were summed within each 5-day period across periods 1-49 for diversion arcs D1, D11, and D12A, and periods 1-52 for diversion arc D91. For each diversion arc, models were fitted to these percentages of Total A diversions, which were subsequently used in the KBPM to estimate the percentage of Total A diversions to be delivered in each timestep (i.e. the irrigation pattern).

Irrigation patterns in any given 5-day period were deemed likely to be influenced by a number of factors, including precipitation, temperature, crop type and distribution, overall water availability, and prior irrigation. Crop type and distribution were eliminated from further consideration because insufficient data were available across the POR. The remaining variables were prepared for use in the sub-model development as follows.

Table A.4.4.4.1.1. Beginning and ending days of 5-day periods within the irrigation water year.

5-day period	First day	Last day		5 day period	First day	Last day		5 day period	First day	Last day
1	1-Mar	5-Mar		26	4-Jul	8-Jul		51	6-Nov	10-Nov
2	6-Mar	10-Mar		27	9-Jul	13-Jul		52	11-Nov	15-Nov
3	11-Mar	15-Mar		28	14-Jul	18-Jul		53	16-Nov	20-Nov
4	16-Mar	20-Mar		29	19-Jul	23-Jul		54	21-Nov	25-Nov
5	21-Mar	25-Mar		30	24-Jul	28-Jul		55	26-Nov	30-Nov
6	26-Mar	30-Mar		31	29-Jul	2-Aug		56	1-Dec	5-Dec
7	31-Mar	4-Apr		32	3-Aug	7-Aug		57	6-Dec	10-Dec
8	5-Apr	9-Apr		33	8-Aug	12-Aug		58	11-Dec	15-Dec
9	10-Apr	14-Apr		34	13-Aug	17-Aug		59	16-Dec	20-Dec
10	15-Apr	19-Apr		35	18-Aug	22-Aug		60	21-Dec	25-Dec
11	20-Apr	24-Apr		36	23-Aug	27-Aug		61	26-Dec	30-Dec
12	25-Apr	29-Apr		37	28-Aug	1-Sep		62	31-Dec	4-Jan
13	30-Apr	4-May		38	2-Sep	6-Sep		63	5-Jan	9-Jan
14	5-May	9-May		39	7-Sep	11-Sep		64	10-Jan	14-Jan
15	10-May	14-May		40	12-Sep	16-Sep		65	15-Jan	19-Jan
16	15-May	19-May		41	17-Sep	21-Sep		66	20-Jan	24-Jan
17	20-May	24-May		42	22-Sep	26-Sep		67	25-Jan	29-Jan
18	25-May	29-May		43	27-Sep	1-Oct		68	30-Jan	3-Feb
19	30-May	3-Jun		44	2-Oct	6-Oct		69	4-Feb	8-Feb
20	4-Jun	8-Jun		45	7-Oct	11-Oct		70	9-Feb	13-Feb
21	9-Jun	13-Jun		46	12-Oct	16-Oct		71	14-Feb	18-Feb
22	14-Jun	18-Jun		47	17-Oct	21-Oct		72	19-Feb	23-Feb
23	19-Jun	23-Jun		48	22-Oct	26-Oct		73	24-Feb	29-Feb
24	24-Jun	28-Jun		49	27-Oct	31-Oct				
25	29-Jun	3-Jul		50	1-Nov	5-Nov				

Precipitation and temperature variables were developed from data obtained from the PRISM Climate Group. PRISM (Parameter-elevation Relationships on Independent Slopes Model) is an interpolation method that estimates precipitation and temperature variables at gridded locations across the conterminous United States based on measurements from a large network of meteorological stations (Daly et al., 2008). Daily time series of maximum temperature (°F) and precipitation (inches) were downloaded (http://prism.oregonstate.edu/explorer/) for 9 randomly selected 4-kilometer grids (Figure A.4.4.4.1.1) for the period from 1/1/1981-11/30/2016. Daily data for the same variables for the period from 3/1/1980-12/31/1980 were downloaded from the National Climatic Data Center, Climate Data Online (https://www.ncdc.noaa.gov/cdo-web/) for three stations (Figure A.4.4.4.1.1): Tulelake, CA (Station USC00049053), Malin 5 E, OR (Station USC00355174), and Klamath Falls 2SSW (Station USC00354506). Mean daily maximum temperature and precipitation were computed for the Project area across either 9 PRISM grids or 3 meteorological stations for the time spans described above. Then total precipitation and average maximum temperature were computed for each 5-day period in each irrigation water year; these variables were named ppt_p and $tmax_p$, where p is the 5-day period.

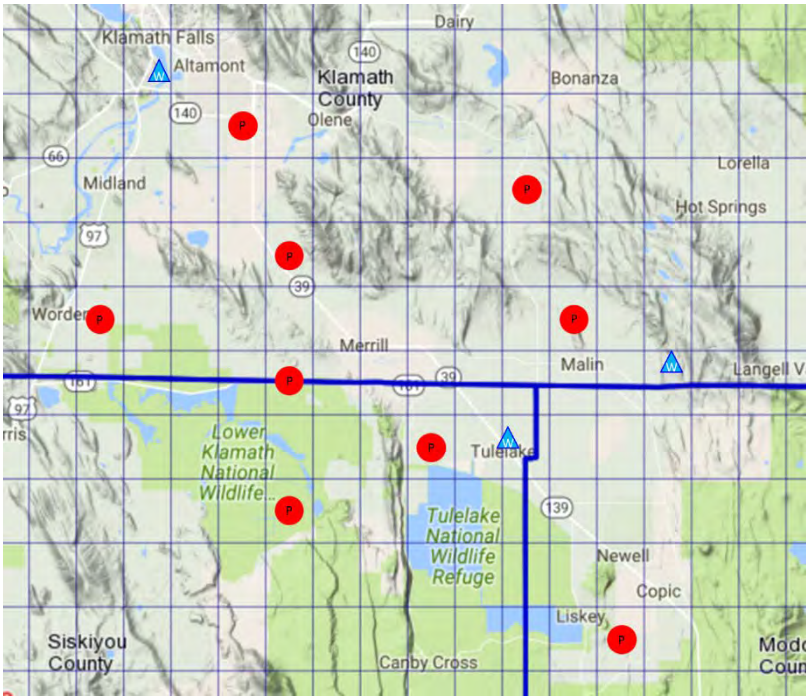

Figure A.4.4.4.1.1. PRISM grid (circles) and weather station (triangles) locations used to compute Project area precipitation and temperature variables.

In addition to using precipitation and maximum temperature variables individually, they were also combined into a single variable. Each was normalized (re-scaled to range between 0 and 1), based on the values of these variables over the period-of-record used in this analysis. For each variable, $x_{p_{norm}}$ was computed as:

$$x_{p_{norm}} = \frac{x_p - x_{p_{min}}}{x_{p_{max}} - x_{p_{min}}}$$

where p is the 5-day period, and p_{min} (p_{max}) is the minimum (maximum) value of the variable for period p across the period-of-record.

Then the normalized maximum temperature $tmax_{p_{norm}}$ was subtracted from 1, so that it ranged from warmest (0) to coolest (1) in a manner complementary to normalized precipitation $ppt_{p_{norm}}$, which ranged from driest (0) to wettest (1). These two normalized variables were combined into one, called the $ptdayindex_p$:

$$ptdayindex_p = ppt_{p_{norm}} + \left(1 - tmax_{p_{norm}}\right)$$

The $ptdayindex_p$ can range from 0 (warm and dry) to 2 (cool and wet).

Variables that summarized winter precipitation and water deliveries were also developed. Total precipitation (inches) and total water deliveries (TAF) through D11 and D12A arcs over the period from December – February preceding each irrigation water year ($cumpptwint_{y-1}$, $cumd11wint_{y-1}$, and $cumd12awint_{y-1}$, respectively) captured the influence of winter precipitation and delivery on the pattern of early season diversions. For use in models for the D11 and D12A diversion arcs, these variables were also normalized (see above; across irrigation water years instead of periods) and combined into $pdindexd11_{y-1}$ and $pdindexd12a_{y-1}$:

$$pdindexd\_{}_{y-1} = cumpptwint_{y-1_{norm}} + cumd\_wint_{y-1_{norm}}$$

where y-1 is the previous irrigation water year, and $d\_$ denotes either delivery arc D11 or D12A. Finally, the variable d_taf_p is the volume (TAF) of deliveries made in each 5-day period, where $d\_$ denotes either delivery arc D11 or D12A.

Anticipated differences in pattern of water use in years with restricted supplies were captured by classifying such years as being water-short, and using a dummy variable (water-short = 1, not water-short = 0) to represent this effect in the models. For model development, data on snow-water-equivalent and Total A diversions was used to classify irrigation water year-type. Daily snow-water-equivalent (SWE; inches) data was downloaded from the NRCS Report Generator site (https://wcc.sc.egov.usda.gov/reportGenerator/) for the following sites: Fish Lake, Billie Creek Divide, Fourmile Lake, Cold Springs Camp, Sevenmile Marsh, Diamond Lake, Chemult Alternative, Silver Creek, Taylor Butte, Summer Rim, Quartz Mountain, and Strawberry. The daily average SWE at these sites was computed, from which the maximum SWE for the March-April period was computed for each year. An irrigation water year was classified as water-short if the maximum SWE for March-April was less than the median of that variable for the period from 1981-2016, and if the Total A diversion was less than the median for that same time period. Irrigation water years designated as being water-short based on these criteria included: 1992, 1995, 2001, 2003, 2005, 2010, 2013, 2014, and 2015.

An information-theoretic approach coupled with model averaging techniques (Burnham and Anderson, 2002; Anderson, 2008) were applied to a sequence of Ordinary Least Squares (OLS) regressions (the model set) predicting the percent delivery of Total A diversions for each 5-day period and delivery arc. In this approach, multiple models were hypothesized *a priori* (the model set), and the OLS results were used to quantify and formally evaluate the relative strength of evidence for each competing hypothesis in the model set. A single, final model for each delivery arc and 5-day period was produced by averaging the model parameters across all models, weighted by the model probabilities.

Model sets were nearly identical for the diversion arcs D1 and D91 (Table A.4.4.4.1.2). Historical D1 deliveries never started before period 6 (Mar 26-30), which is why no models were applied to prior periods for D1, whereas D91 delivery models begin in period 1. D1 delivery models extend through period 49 (through Oct 31), and D91 models extend through period 52 (through Nov 15). Model sets were also nearly identical for the diversion arcs D11 and D12A (Table A.4.4.4.1.3), for which delivery models extend through period 49. Model sets were dissimilar between these pairs of arcs, however, reflecting the differences in how irrigation is managed between the areas served by these arcs.

Table A.4.4.4.1.2. Model sets for the D1 and D91 delivery arcs. In the model notation column, 5-day periods of the irrigation water year are denoted by *p*, and variables lagged to the prior 5-day period are denoted by the subscript *p*-1. Diversion arcs are specified by *d_*, where _ would be either 1 or 91 as appropriate to the delivery arc being modeled. Irrigation water year (March-February) is denoted by *y*, with *y*-1 referring to winter conditions in the prior irrigation water year. OLS regression coefficients are denoted as β.

Model	Model description	Model notation	Periods for D1	Periods for D91
1	delivery %	$\beta_0 + \beta_1 d\_pcta_{p-1}$	7-49	2-52
2	delivery % + precipitation	$\beta_0 + \beta_1 d\_pcta_{p-1} + \beta_2 ppt_{p-1}$	7-49	2-52
3	delivery % + warmth	$\beta_0 + \beta_1 d\_pcta_{p-1} + \beta_3 tmax_{p-1}$	7-49	2-52
4	delivery % + (precipitation & warmth)	$\beta_0 + \beta_1 d\_pcta_{p-1} + \beta_4 ptdayindex_{p-1}$	7-49	2-52
5	delivery % + short supply	$\beta_0 + \beta_1 d\_pcta_{p-1} + \beta_5 shortdum_y$	7-49	2-52
6	delivery % + winter precipitation	$\beta_0 + \beta_1 d\_pcta_{p-1} + \beta_6 cumpptwint_{y-1}$	7-18	2-18
7	winter precipitation + short supply	$\beta_0 + \beta_6 cumpptwint_{y-1} + \beta_5 shortdum_y$	6	1
8	winter precipitation + (precipitation & warmth)	$\beta_0 + \beta_6 cumpptwint_{y-1} + \beta_4 ptdayindex_{p-1}$	6	1
9	winter precipitation + warmth	$\beta_0 + \beta_6 cumpptwint_{y-1} + \beta_3 tmax_{p-1}$	6	1
10	winter precipitation + precipitation	$\beta_0 + \beta_6 cumpptwint_{y-1} + \beta_2 ppt_{p-1}$	6	1

The arcs in Area A1 (D1 and D91) use irrigation water (nearly) exclusively during the growing season, whereas the arcs in Area A2 divert water extensively during the winter, when it is available, as well as during the growing season. Therefore, the variables influencing diversion patterns in the early periods differ between areas. In Area A1, winter precipitation and recent temperature were thought to be the most likely determinants of the delivery pattern, as modified by short supplies in some years, in the earliest period (models 7-10 in Table A.4.4.4.1.2). Similarly, the first period was thought to be influenced by delivery volume in the previous period, as well as by winter diversion volume, winter precipitation totals, or both (models 9-12 in Table A.4.4.4.1.3). Effects of winter precipitation were expected to be influential through period 18 in Area A1 (model 6 in Table A.4.4.4.1.2), and its influence coupled with that of winter diversion volume was expected to affect diversion patterns through period 18 in Area A2 (models 6-8 in Table A.4.4.4.1.3).

For the remainder of the growing season, delivery patterns in Areas A1 and A2 were thought to be influenced by the same variables, namely prior diversion, precipitation, and temperature, as modified by the effects of short supply (models 1-5 in Tables A.4.4.4.1.2 and A.4.4.4.1.3). Period-specific variables used in models were lagged to the prior period, reflecting the potential desire to use the result of this modeling effort in operations. By lagging to previous time periods, no information is used to forecast the percent delivery of Total A diversions in period *p* that would not be available in real-time water management. The sole exception is the reliance in this analysis on the historical percentage of Total A diversion delivered through a diversion arc in the previous time period. While appropriate in terms of using the results of this analysis in the KBPM, which simulates years that have already been experienced, operationally an estimate of Total A diversions would be needed to compute the percentage of Total A diversions delivered in the prior time step. Since in this analysis these percentages were computed from historical data, Total A was known, but operationally Total A would have to be estimated, which would inject more error into the resulting estimates of delivery pattern than is present in this analysis.

Table A.4.4.4.1.3. Model sets for the D11 and D12A delivery arcs. In the model notation column, 5-day periods of the irrigation water year are denoted by *p*, and variables lagged to the prior 5-day period are denoted by the subscript *p*-1. Diversion arcs are specified by *d*_, where _ would be either 1 or 91 as appropriate to the delivery arc being modeled. Irrigation water year (Mar-Feb) is denoted by *y*, with *y*-1 referring to winter conditions in the prior irrigation water year. OLS regression coefficients are denoted as *β*.

Model	**Model description**	**Model notation**	**Periods for D11 and D12A**
1	delivery %	$\beta_0 + \beta_1 d\_pcta_{p-1}$	2-49
2	delivery % + precipitation	$\beta_0 + \beta_1 d\_pcta_{p-1} + \beta_2 ppt_{p-1}$	2-49
3	delivery % + warmth	$\beta_0 + \beta_1 d\_pcta_{p-1} + \beta_3 tmax_{p-1}$	2-49
4	delivery % + (precipitation & warmth)	$\beta_0 + \beta_1 d\_pcta_{p-1}$ $+ \beta_4 ptdayindex_{p-1}$	2-49
5	delivery % + short supply	$\beta_0 + \beta_1 d\_pcta_{p-1} + \beta_5 shortdum_y$	2-49
6	delivery % + winter diversion	$\beta_0 + \beta_1 d\_pcta_{p-1} + \beta_6 cumd\_wint_{y-1}$	2-18
7	delivery % + winter precipitation	$\beta_0 + \beta_1 d\_pcta_{p-1}$ $+ \beta_7 cumpptwint_{y-1}$	2-18
8	delivery % + (winter delivery & precipitation)	$\beta_0 + \beta_1 d\_pcta_{p-1} + \beta_8 pdindexd_{\_y-1}$	2-18
9	delivery volume + winter diversion	$\beta_0 + \beta_9 d\_taf_{p-1} + \beta_6 cumd\_wint_{y-1}$	1
10	delivery volume + winter precipitation	$\beta_0 + \beta_9 d\_taf_{p-1} + \beta_7 cumpptwint_{y-1}$	1
11	delivery volume + (winter delivery & precipitation)	$\beta_0 + \beta_9 d\_taf_{p-1} + \beta_8 pdindexd_{\_y-1}$	1
12	delivery volume	$\beta_0 + \beta_9 d\_taf_{p-1}$	1

OLS regressions were performed using Stata 15 software (StataCorp, 2017b; regress command). Individual regressions were restricted to no more than 2 variables to avoid overfitting (Babyak, 2004). After removing the excluded and test years from the analysis, sample size within each 5-day period was 29 for those models using the variable *cumpptwint* (which was not computed for 1980), and 30 for all other models. Adequacy of OLS regressions was assessed following guidance in StataCorp (2017b), Sheather (2009), and Hyndman and Athanasopoulos (2014). Residual normality was evaluated graphically (Stata commands: qnorm and pnorm); serious deviation from residual normality was rare, confined mostly to the earliest 5-day periods in which 0% deliveries were common. Multicollinearity among predictor variables was evaluated using variance inflation factors (Stata command: estat vif), which never exceeded 2.3 in any of the delivery arcs. Autocorrelation plots and Durbin's alternative test for serial correlation (Stata commands: acf and estat durbinalt, respectively) assessed serial autocorrelation across years within each 5-day period; it was rarely detected. Finally, plots of residuals vs. predicted y and residuals vs. predictors were examined for inappropriate patterns reflecting heteroskedasticity or non-linearity.

Using the equations described in Burnham et al. (2011), and following the admonitions of Anderson and Burnham (2002), the following series of calculations quantified the relative performance of models used to estimate the percentage of Total A deliveries for each diversion arc, culminating in a single model-averaged predictive equation for each diversion arc in each 5-day period. Specifically, for each 5-day period ($p = 1, 2, \dots, P$), and model ($m = 1, 2, \dots, M$), the corrected Akaike Information Criterion $AIC_{c_{p,m}}$ was computed as:

$$AIC_{c_{p,m}} = -2\ln L_{p,m} + 2K_{p,m} + \frac{2K_{p,m}(K_{p,m}+1)}{n_{p,m} - K_{p,m} - 1}$$

where K is the number of estimable parameters, which includes the intercept, slope parameters, and the residual variance, $\ln L$ is the maximized log-likelihood of the model, and n is sample size. Then the $\Delta_{p,m}$ was computed as:

$$\Delta_{p,m} = AIC_{c_{p,m}} - AIC_{c_{p,min}}$$

where $AIC_{c_{p,m}}$ is the AIC_c for model m in 5-day period p, and $AIC_{c_{p,min}}$ is the minimum AIC_c for period p, which is to say it is the best model for that period in that it minimizes the Kullback-Leibler (K-L) information loss (see Burnham and Anderson, 2002 for a complete explanation). $\Delta_{p,m}$ directly quantifies the K-L information loss of model m relative to the best model in the model set, and so provides a valid basis for ranking models and computing Akaike weights, which were calculated as:

$$w_{p,m} = \frac{exp\left(-0.5\Delta_{p,m}\right)}{\sum_{m=1}^{M} exp\left(-0.5\Delta_{p,m}\right)}$$

Once the Akaike weights were obtained, they were used to compute weighted averages of the OLS coefficients for each variable in the model set using:

$$\hat{\hat{\beta}}_p = \sum_{m=1}^{M} w_{p,m}\hat{\beta}_{p,m}$$

where $\hat{\hat{\beta}}_p$ is the model averaged coefficient, and $\hat{\beta}_{p,m}$ is the coefficient estimated by OLS for the mth model in period p.

To make the model-averaged prediction for each period, the Akaike weights were used to compute weighted averages of the OLS predictions of the percentage of Total A delivery for the models within each period:

$$\hat{\hat{Y}}_p = \sum_{m=1}^{M} w_{p,m}\hat{Y}_{p,m}$$

where $\hat{\hat{Y}}_p$ is the model-averaged prediction, and $\hat{Y}_{p,m}$ is the OLS estimate of y.

Finally, the Akaike weights were used to compute the unconditional (that is, not conditioned on any single model) standard error of the model-averaged predictions for each period using:

$$SE\left(\hat{\hat{Y}}_p\right) = \sqrt{\sum_{m=1}^{M} w_{p,m}\left(var\left(\hat{Y}_{p,m}\right) + \left(\hat{Y}_{p,m} - \hat{\hat{Y}}_p\right)^2\right)}$$

where $SE\left(\hat{\hat{Y}}_p\right)$ is the unconditional standard error of the model-averaged predictions for period p, $var\left(\hat{Y}_{p,m}\right)$ is the variance of the OLS estimate for model m in period p, and $\hat{Y}_{p,m}$ is the OLS estimate for model m in period p.

A.4.4.4.2. Results and Discussion

Based on model ranking and error analysis procedures, details of which are provided after the results below, a final model-averaged equation predicting the percent of Total A (the total water volume diverted during the spring/summer operational period from all surface water sources) to be delivered in any given period was developed for each diversion arc:

$$\begin{aligned} d\widehat{1pcta}_p = {} & \hat{\hat{\beta}}_{0,p} + \hat{\hat{\beta}}_{1,p} d1pcta_{p-1} + \hat{\hat{\beta}}_{2,p} ppt_{p-1} + \hat{\hat{\beta}}_{3,p} tmax_{p-1} + \hat{\hat{\beta}}_{4,p} ptdayindex_{p-1} \\ & + \hat{\hat{\beta}}_{5,p} shortdum_y + \hat{\hat{\beta}}_{6,p} cumpptwint_y \end{aligned}$$

$$\begin{aligned} d9\widehat{1pcta}_p = {} & \hat{\hat{\beta}}_{0,p} + \hat{\hat{\beta}}_{1,p} d91pcta_{p-1} + \hat{\hat{\beta}}_{2,p} ppt_{p-1} + \hat{\hat{\beta}}_{3,p} tmax_{p-1} + \hat{\hat{\beta}}_{4,p} ptdayindex_{p-1} \\ & + \hat{\hat{\beta}}_{5,p} shortdum_y + \hat{\hat{\beta}}_{6,p} cumpptwint_y \end{aligned}$$

$$\begin{aligned} d1\widehat{1pcta}_p = {} & \hat{\hat{\beta}}_{0,p} + \hat{\hat{\beta}}_{1,p} d11pcta_{p-1} + \hat{\hat{\beta}}_{2,p} ppt_{p-1} + \hat{\hat{\beta}}_{3,p} tmax_{p-1} + \hat{\hat{\beta}}_{4,p} ptdayindex_{p-1} \\ & + \hat{\hat{\beta}}_{5,p} shortdum_y + \hat{\hat{\beta}}_{6,p} cumd11wint_{y-1} + \hat{\hat{\beta}}_{7,p} cumpptwint_y \\ & + \hat{\hat{\beta}}_{8,p} pdindexd11_{y-1} + \hat{\hat{\beta}}_{9,p} d11taf_{p-1} \end{aligned}$$

$$\begin{aligned} d1\widehat{2apcta}_p = {} & \hat{\hat{\beta}}_{0,p} + \hat{\hat{\beta}}_{1,p} d12apcta_{p-1} + \hat{\hat{\beta}}_{2,p} ppt_{p-1} + \hat{\hat{\beta}}_{3,p} tmax_{p-1} + \hat{\hat{\beta}}_{4,p} ptdayindex_{p-1} \\ & + \hat{\hat{\beta}}_{5,p} shortdum_y + \hat{\hat{\beta}}_{6,p} cumd12awint_{y-1} + \hat{\hat{\beta}}_{7,p} cumpptwint_y \\ & + \hat{\hat{\beta}}_{8,p} pdindexd12a_{y-1} + \hat{\hat{\beta}}_{9,p} d12ataf_{p-1} \end{aligned}$$

Predicted values from these equations in the years used to fit the models are plotted against the historical values in Figures A.4.4.4.2.1 through A.4.4.4.2.4. The results from the model-averaged equations reproduced diversion patterns reasonably well. In Figures A.4.4.4.2.5 through A.4.4.4.2.8, the model-averaged equations were used to forecast diversion patterns in the test years, illustrating how the model-averaged equations would perform if used operationally. Again, historical diversion patterns were depicted reasonably well by the models. Summary statistics of forecast errors in the test years (Table A.4.4.4.2.1) provided further insight into potential errors associated with operational use of these models. However, the small sample size (n=3 per period) used to compute these summary statistics did not provide a comprehensive view of the forecast error structure. If used operationally, more work could be done to more thoroughly quantify likely error of these forecasts.

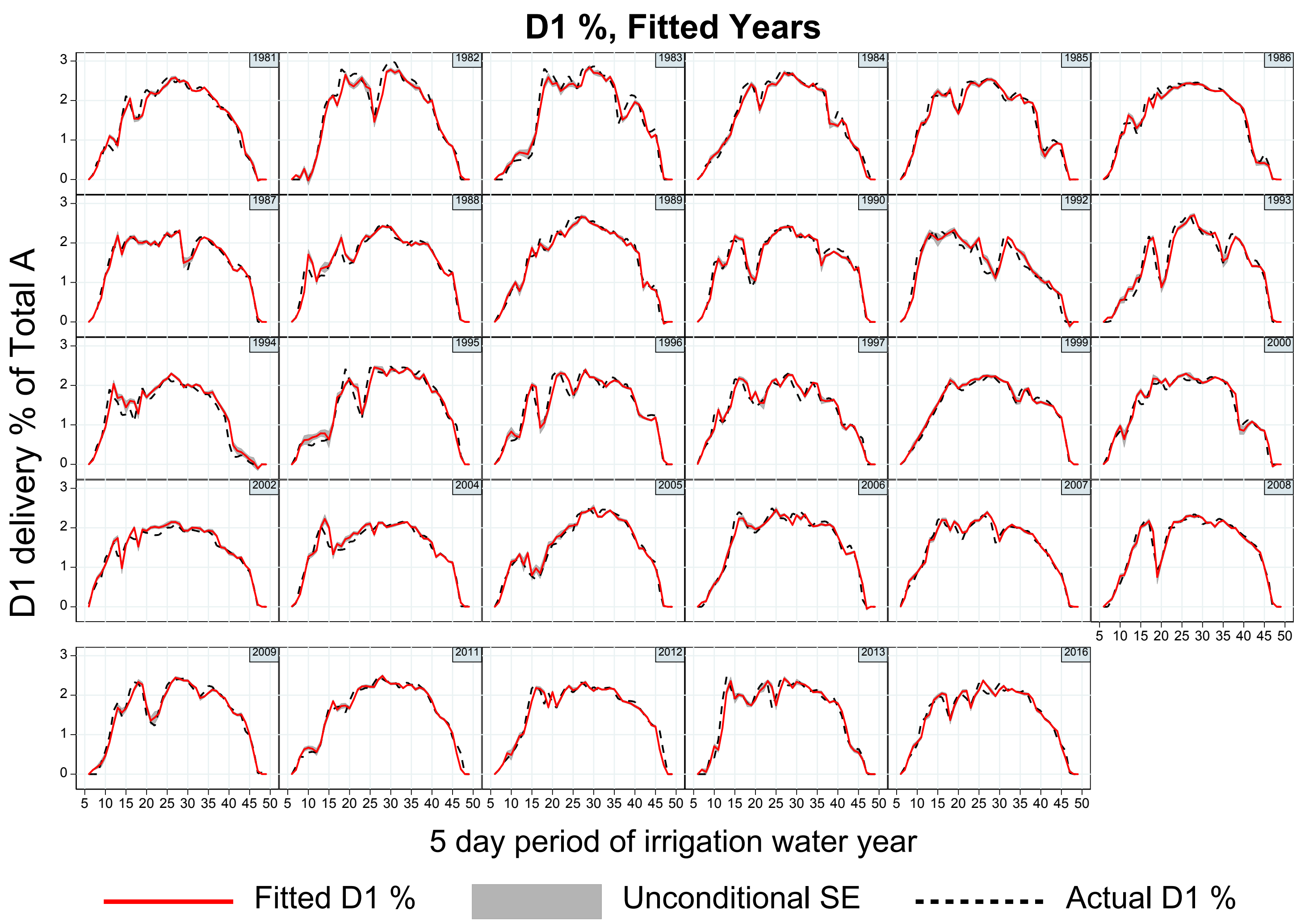

Figure A.4.4.4.2.1. Actual percent delivery of Total A diversions through diversion arc D1 compared to that predicted by the model-averaged predictive equation.

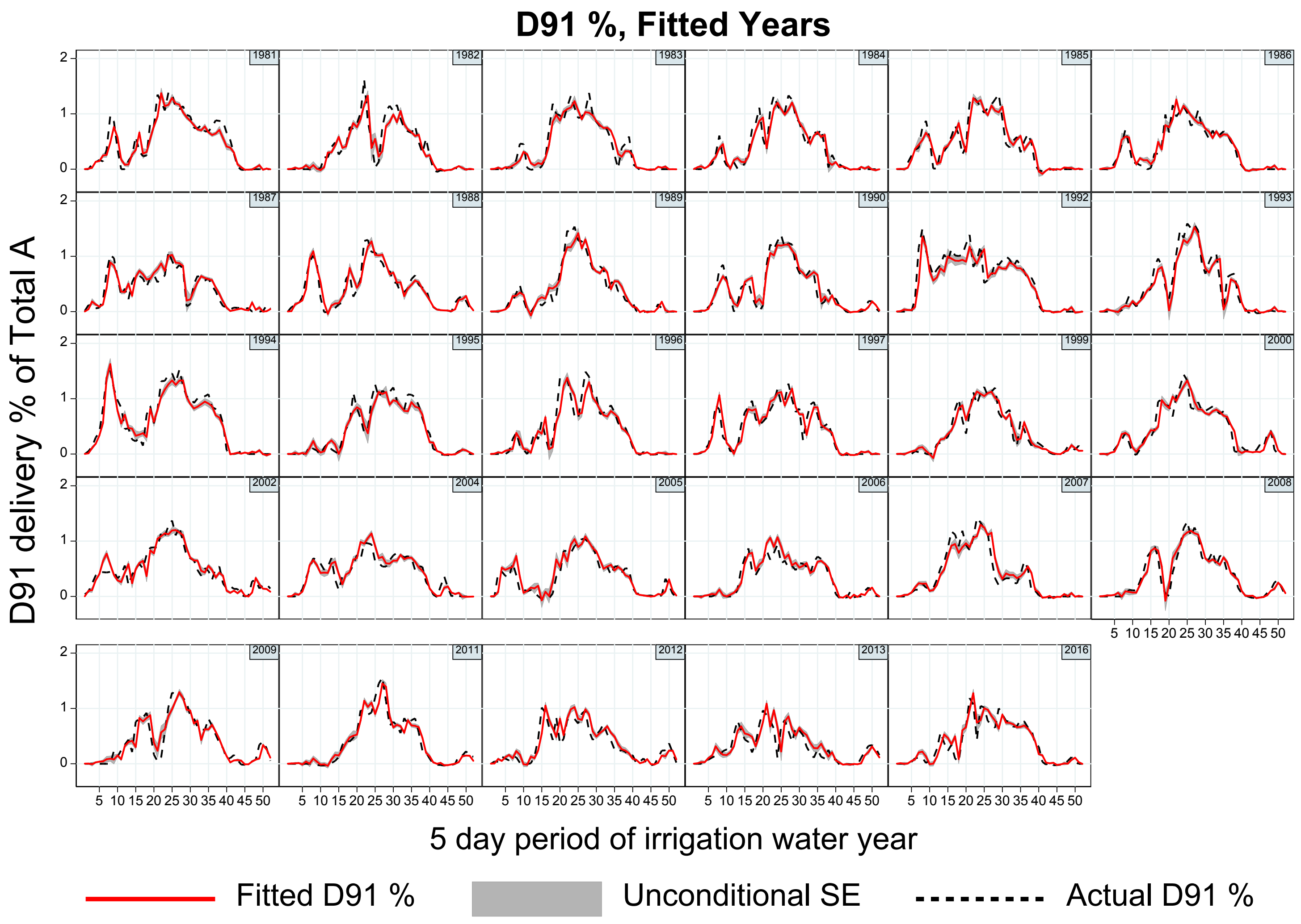

Figure A.4.4.4.2.2. Actual percent delivery of Total A diversions through diversion arc D91 compared to that predicted by the model-averaged predictive equation.

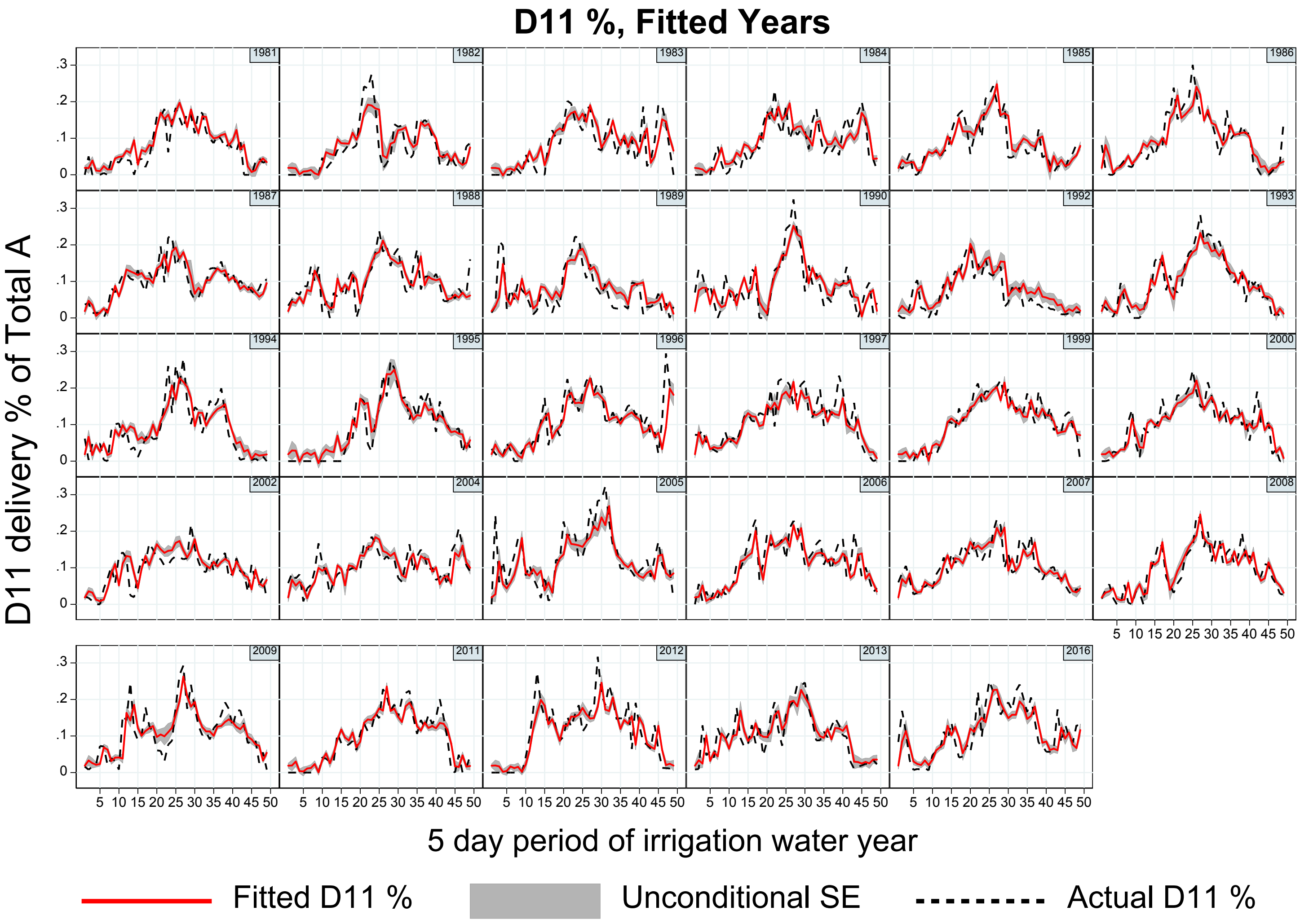

Figure A.4.4.4.4.2.3. Actual percent delivery of Total A diversions through diversion arc D11 compared to that predicted by the model-averaged predictive equation.

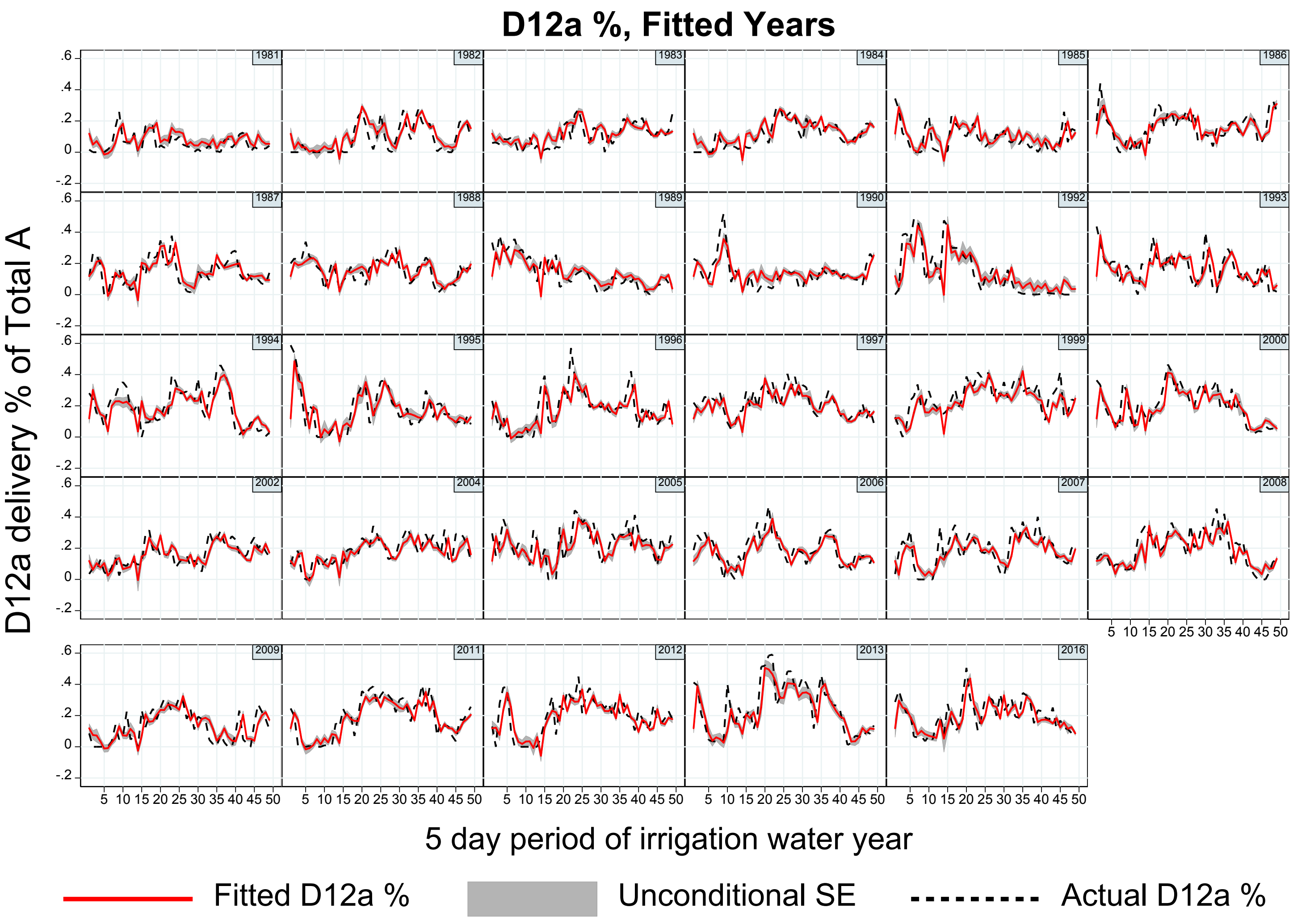

Figure A.4.4.4.2.4. Actual percent delivery of Total A diversions through diversion arc D12A compared to that predicted by the model-averaged predictive equation.

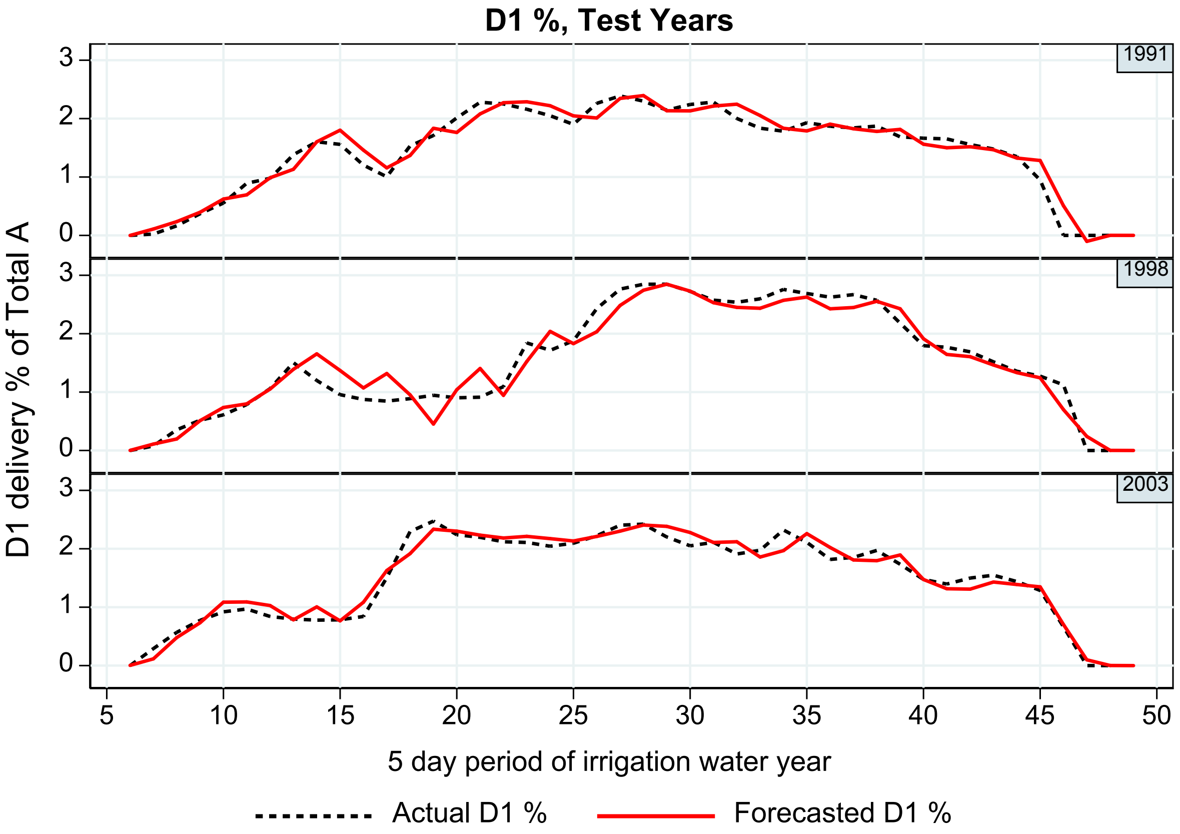

Figure A.4.4.4.2.5. Actual percent delivery of Total A diversions through diversion arc D1 compared to that forecasted by the model-averaged predictive equation in the test years.

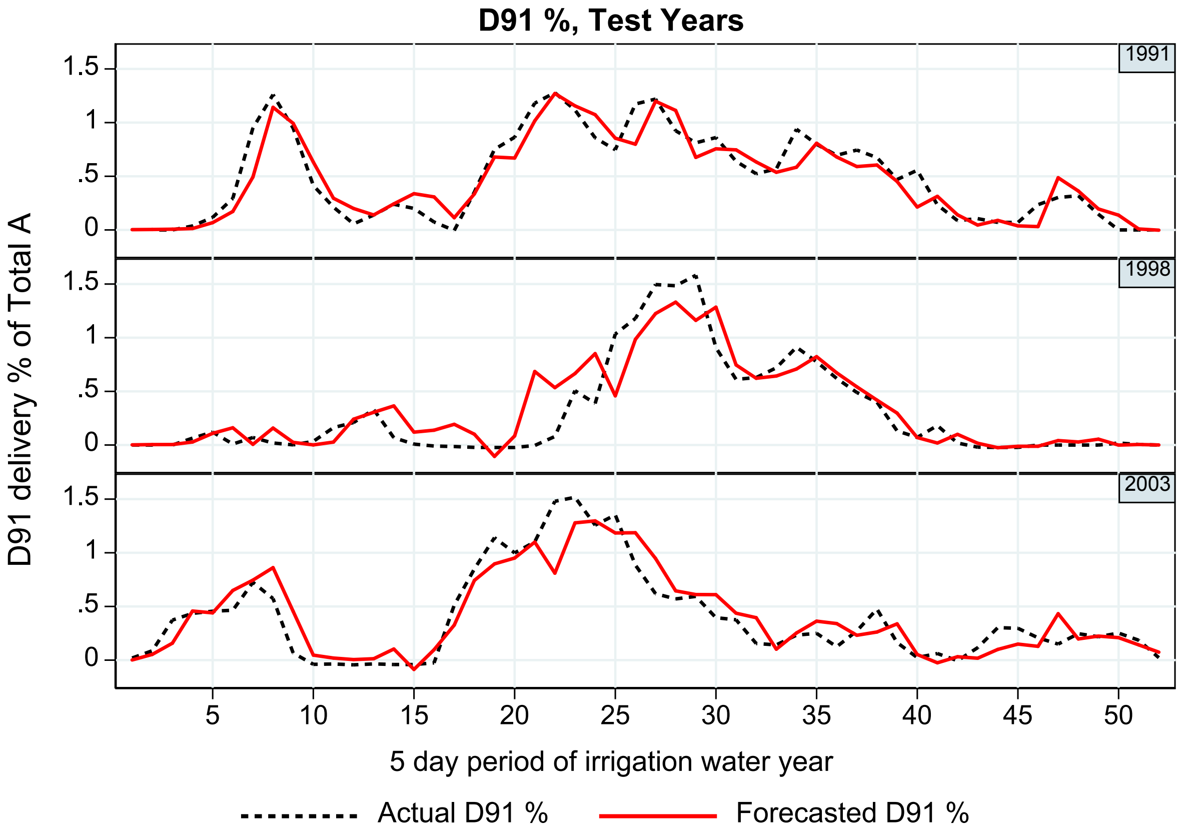

Figure A.4.4.4.2.6. Actual percent delivery of Total A diversions through diversion arc D91 compared to that forecasted by the model-averaged predictive equation in the test years.

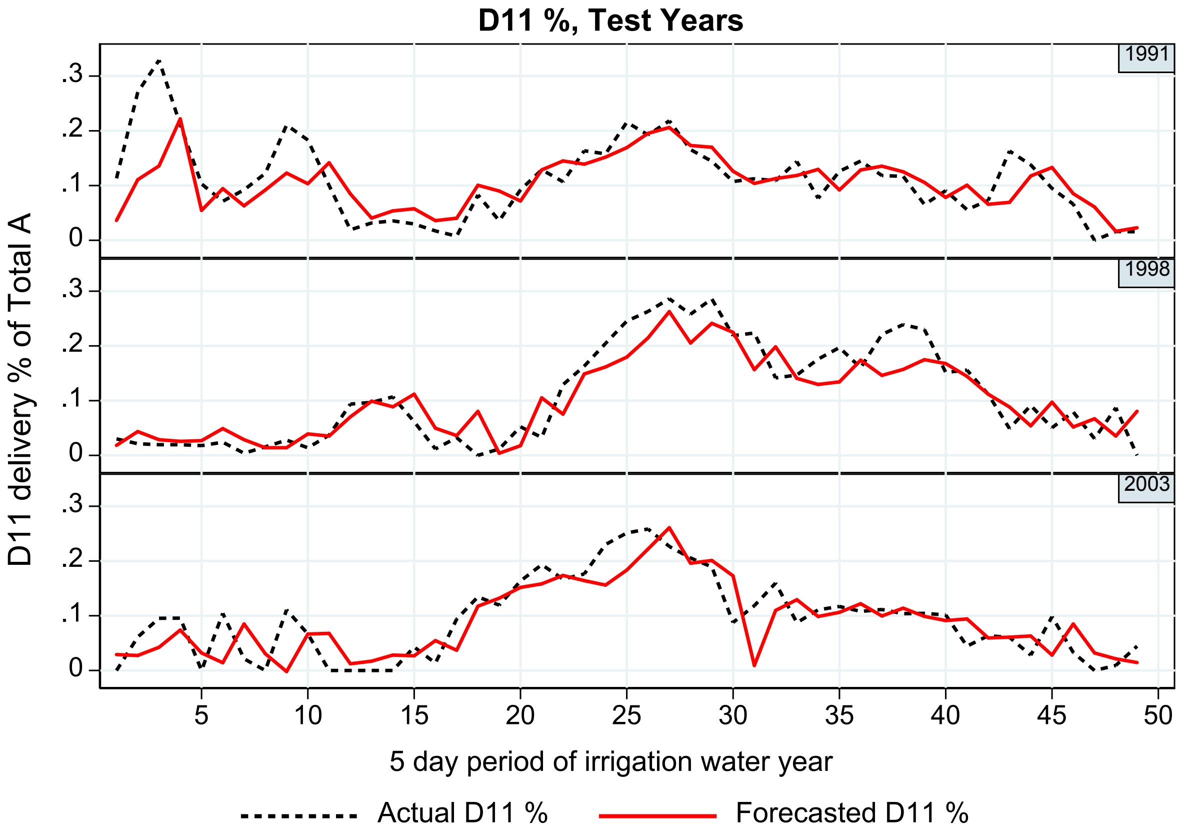

Figure A.4.4.4.2.7. Actual percent delivery of Total A diversions through diversion arc D11 compared to that forecasted by the model-averaged predictive equation in the test years.

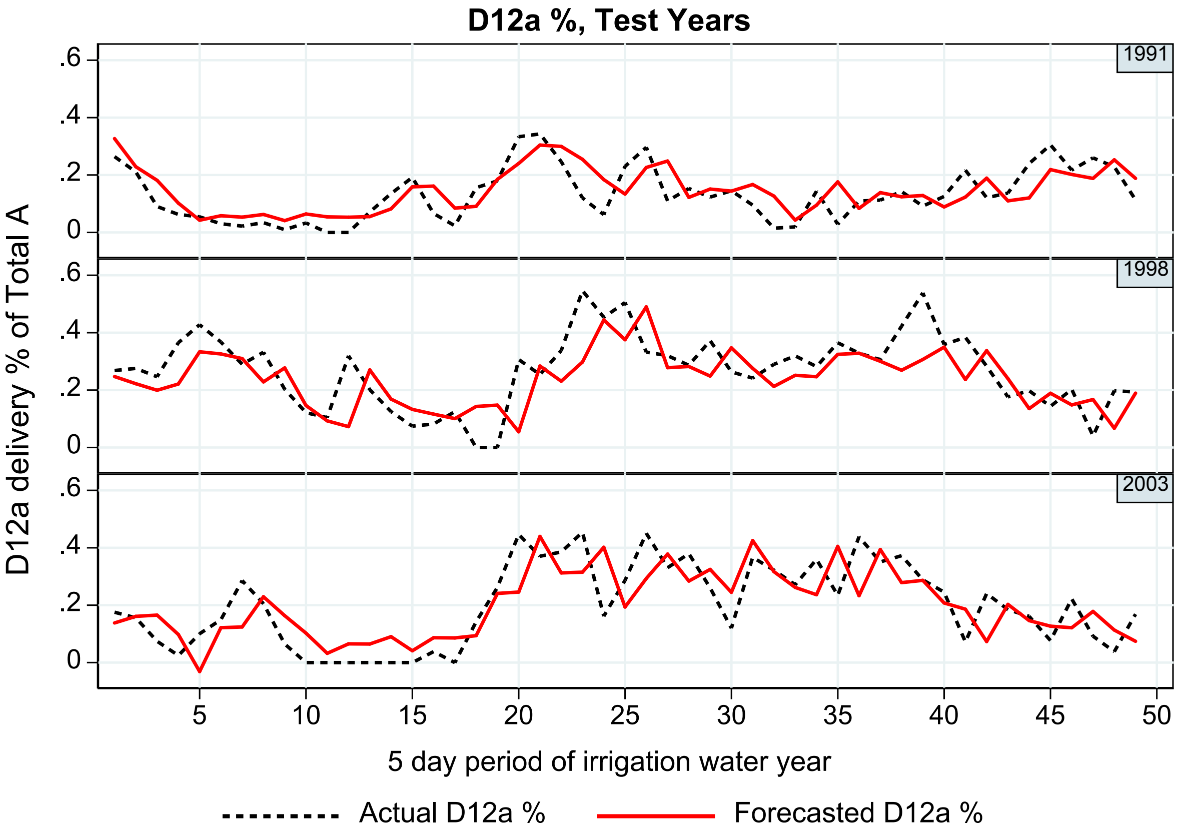

Figure A.4.4.4.2.8. Actual percent delivery of Total A diversions through diversion arc D12A compared to that forecasted by the model-averaged predictive equation in the test years.

Table A.4.4.4.2.1. Error statistics for forecasts of the percent of Total A delivery for each diversion arc in the test years (1991, 1998, and 2003). These one-step-ahead forecasts were generated using the model-averaged equations, using the historic percent of Total A diversion from the prior period as the β_1 predictor. Mean and standard deviation (sd) of forecast errors (actual delivery % - forecasted delivery %) were calculated for each 5-day period of the irrigation water year (Period). Sample size was 3 per period.

	d1pcta			d91pcta			d11pcta			d12apcta	
Period	**mean**	**Sd**		**Mean**	**sd**		**mean**	**sd**		**mean**	**sd**
1				0.004	0.012		0.020	0.053		-0.001	0.054
2				0.008	0.022		0.057	0.093		0.010	0.038
3				0.068	0.128		0.079	0.104		-0.045	0.080
4				0.013	0.031		0.002	0.018		0.010	0.117
5				0.026	0.020		0.002	0.041		0.079	0.061
6	-0.002	0.002		-0.071	0.168		0.014	0.066		0.014	0.037
7	0.019	0.138		0.167	0.255		-0.020	0.047		0.037	0.108
8	0.058	0.118		-0.103	0.206		0.001	0.030		0.017	0.075
9	0.008	0.034		-0.152	0.204		0.071	0.051		-0.068	0.034
10	-0.120	0.049		-0.090	0.125		0.018	0.055		-0.053	0.043
11	0.022	0.162		-0.001	0.118		-0.036	0.035		-0.025	0.033
12	-0.063	0.108		-0.075	0.060		-0.018	0.045		0.043	0.177
13	0.125	0.119		-0.008	0.037		-0.009	0.007		-0.039	0.048
14	-0.228	0.228		-0.148	0.146		-0.009	0.024		-0.027	0.073
15	-0.213	0.218		-0.068	0.099		-0.021	0.034		-0.022	0.049
16	-0.232	0.031		-0.168	0.059		-0.033	0.012		-0.059	0.032
17	-0.249	0.194		-0.047	0.206		0.007	0.046		-0.041	0.058
18	0.159	0.222		0.001	0.116		-0.027	0.049		-0.010	0.115
19	0.169	0.309		0.133	0.096		-0.020	0.032		-0.044	0.091
20	0.017	0.206		0.045	0.151		0.022	0.012		0.182	0.081
21	-0.110	0.351		-0.174	0.454		-0.012	0.055		-0.020	0.055
22	0.022	0.113		0.074	0.565		0.003	0.047		0.042	0.084
23	0.029	0.252		0.013	0.204		0.017	0.007		0.084	0.197
24	-0.209	0.103		-0.240	0.213		0.041	0.034		-0.118	0.125
25	-0.045	0.097		0.212	0.344		0.060	0.012		0.106	0.020
26	0.220	0.194		0.090	0.350		0.027	0.027		0.023	0.163
27	0.141	0.123		-0.013	0.301		0.001	0.031		-0.048	0.090
28	0.008	0.099		-0.037	0.174		0.018	0.031		0.044	0.047
29	-0.058	0.107		0.179	0.222		0.002	0.037		0.010	0.100
30	-0.041	0.172		-0.162	0.245		-0.037	0.042		-0.069	0.064
31	0.038	0.033		-0.101	0.037		0.062	0.051		-0.055	0.019
32	-0.122	0.183		-0.114	0.124		-0.004	0.053		-0.010	0.095
33	0.020	0.206		0.049	0.024		-0.003	0.035		0.018	0.046
34	0.164	0.203		0.179	0.188		0.002	0.050		0.069	0.047
35	0.018	0.150		-0.057	0.052		0.036	0.026		-0.093	0.116
36	-0.014	0.203		-0.084	0.119		-0.004	0.017		0.077	0.112

	d1pcta			**d91pcta**			**d11pcta**			**d12apcta**	
Period	**mean**	**Sd**		**Mean**	**sd**		**mean**	**sd**		**mean**	**sd**
37	0.093	0.112		0.047	0.103		0.023	0.047		-0.021	0.025
38	0.095	0.079		0.088	0.117		0.021	0.053		0.088	0.068
39	-0.178	0.061		-0.107	0.109		0.007	0.048		0.066	0.145
40	-0.005	0.110		0.105	0.206		0.002	0.016		0.028	0.016
41	0.118	0.036		0.056	0.124		-0.028	0.034		0.042	0.138
42	0.104	0.078		-0.057	0.022		0.004	0.004		0.015	0.132
43	0.061	0.053		0.040	0.069		0.018	0.068		-0.018	0.045
44	0.033	0.015		0.063	0.122		0.008	0.038		0.066	0.052
45	-0.121	0.188		0.056	0.081		-0.005	0.065		-0.003	0.077
46	-0.040	0.466		0.098	0.098		-0.015	0.040		0.057	0.043
47	-0.080	0.172		-0.170	0.121		-0.043	0.016		-0.047	0.105
48	-0.002	0.000		-0.008	0.050		0.013	0.034		0.011	0.107
49	0.000	0.001		-0.037	0.027		-0.019	0.056		0.008	0.085
50				-0.025	0.098						
51				0.011	0.028						
52				-0.017	0.030						

The discussion of how the selected formulas were used in the KBPM to simulate Agricultural deliveries is found in Section A.4.4.3 following the several tables below that provide the details of model ranking and error analysis used to select the formulas and coefficients for the four model arcs, D1, D91, D11, and D12a, shown above with the graphed results.

As expected, relative performance of models varied across 5-day periods (Tables A.4.4.4.2.1 and A.4.4.4.2.2), as determined by the relative magnitudes of the $\Delta_m$values. In both tables, results are sorted within each period by the $\Delta_m$values, so that the best performing model (lowest $AICc$) is first and the worst performing model is last. While the results in these tables provide insight into the seasonal influence of climatic and water availability factors, discussion in this regard is deferred to any potential future consideration of modifying this model approach for use in operations. For the present purpose of depicting the pattern of water deliveries in the KBPM, it is useful to note that multimodel-averaging allowed for the weighted (using w_m) influence of different regressors to affect the predicted diversion patterns in a manner that varied across diversion arcs and periods.

The end result of this process was a diversion arc-specific table of model-averaged coefficients for each variable in the model set and for each 5-day period. In any given period, regressors in models with relatively high Akaike weights (that is, w_m near 1) strongly influenced the $\hat{\hat{\beta}}_p$ coefficients in the final averaged model, whereas those with weights near zero had little or no influence on the coefficients (Tables A.4.4.4.2.3 through A.4.4.4.2.7. Each table was used in the KBPM as a lookup table, from which the coefficients corresponding to the appropriate diversion arc, predictor variable, and 5-day period were obtained to compute the percentage of Total A deliveries for each 5-day period.

Table A.4.4.4.2.2. Model ranking and Akaike weights of 5-day period specific for OLS models predicting percent of Total A deliveries through diversion arcs D1 and D91. Within each 5-day period, models are sorted by Δ_m (from “best” to “worst”). In the table below, P = 5-day period of the irrigation water year; M = model number; K = number of estimable parameters of the model; MLL = maximized log-likelihood of the model obtained from OLS output; AIC_c = corrected Akaike Information Criterion; Δ_m = difference between the AIC_c of the model with the minimum AIC_c (the best model) and the AIC_c of model *m*; w_m = Akaike weight for model *m.*

	D1pcta							**D91pcta**					
P	**M**	**K**	**MLL**	**AIC_c**	**Δ_m**	**w_m**		**M**	**K**	**MLL**	**AIC_c**	**Δ_m**	**w_m**
1								7	4	100.22	-190.78	0.00	0.29
1								10	4	100.05	-190.44	0.34	0.25
1								8	4	100.01	-190.35	0.43	0.24
1								9	4	99.97	-190.27	0.51	0.23
2								1	3	69.85	-132.78	0.00	0.31
2								3	4	70.95	-132.29	0.48	0.24
2								4	4	70.79	-131.99	0.79	0.21
2								5	4	70.14	-130.68	2.09	0.11
2								2	4	70.11	-130.62	2.16	0.11
2								6	4	68.78	-127.89	4.89	0.03
3								3	4	36.01	-62.42	0.00	0.41
3								5	4	35.35	-61.10	1.32	0.21
3								4	4	35.34	-61.07	1.35	0.21
3								1	3	33.35	-59.78	2.64	0.11
3								2	4	33.74	-57.88	4.54	0.04
3								6	4	32.20	-54.73	7.69	0.01
4								4	4	53.00	-96.41	0.00	0.30
4								2	4	52.97	-96.35	0.06	0.30
4								1	3	51.25	-95.58	0.83	0.20
4								3	4	51.96	-94.33	2.08	0.11
4								5	4	51.64	-93.68	2.73	0.08
4								6	4	49.97	-90.27	6.14	0.01
5								4	4	52.18	-94.75	0.00	0.48
5								2	4	51.34	-93.09	1.67	0.21
5								3	4	50.93	-92.27	2.48	0.14

	D1pcta							D91pcta					
P	**M**	**K**	**MLL**	**AIC$_c$**	Δ_m	w_m		**M**	**K**	**MLL**	**AIC$_c$**	Δ_m	w_m
5								5	4	50.85	-92.09	2.66	0.13
5								1	3	48.35	-89.79	4.97	0.04
5								6	4	46.34	-83.02	11.74	0.00
6	9	4	83.49	-157.31	0.00	0.36		4	4	27.21	-44.82	0.00	0.40
6	8	4	83.38	-157.10	0.21	0.32		2	4	26.56	-43.51	1.31	0.21
6	10	4	82.72	-155.77	1.54	0.17		1	3	25.02	-43.11	1.70	0.17
6	7	4	82.62	-155.58	1.74	0.15		3	4	26.29	-42.98	1.84	0.16
6								5	4	25.03	-40.45	4.37	0.04
6								6	4	24.55	-39.43	5.39	0.03
7	1	3	35.17	-63.41	0.00	0.43		3	4	12.28	-14.96	0.00	0.67
7	5	4	35.63	-61.65	1.76	0.18		5	4	10.49	-11.38	3.58	0.11
7	3	4	35.22	-60.84	2.57	0.12		1	3	9.04	-11.15	3.80	0.10
7	4	4	35.19	-60.78	2.64	0.12		4	4	10.10	-10.61	4.35	0.08
7	2	4	35.17	-60.74	2.67	0.11		2	4	9.12	-8.64	6.32	0.03
7	6	4	34.18	-58.69	4.72	0.04		6	4	8.65	-7.64	7.32	0.02
8	2	4	26.47	-43.35	0.00	0.53		1	3	11.50	-16.07	0.00	0.38
8	4	4	25.99	-42.39	0.96	0.33		5	4	12.26	-14.92	1.15	0.21
8	1	3	23.01	-39.11	4.24	0.06		4	4	11.72	-13.83	2.24	0.12
8	3	4	23.94	-38.29	5.06	0.04		2	4	11.69	-13.79	2.29	0.12
8	5	4	23.02	-36.44	6.90	0.02		3	4	11.61	-13.63	2.44	0.11
8	6	4	22.62	-35.58	7.77	0.01		6	4	11.03	-12.39	3.68	0.06
9	4	4	11.50	-13.41	0.00	0.39		6	4	14.62	-19.57	0.00	0.37
9	2	4	10.91	-12.22	1.19	0.21		1	3	12.61	-18.31	1.27	0.20
9	3	4	10.61	-11.62	1.79	0.16		3	4	13.68	-17.77	1.81	0.15
9	1	3	9.00	-11.07	2.33	0.12		4	4	13.62	-17.64	1.93	0.14
9	6	4	9.98	-10.29	3.12	0.08		2	4	13.05	-16.50	3.07	0.08
9	5	4	9.28	-8.96	4.44	0.04		5	4	12.84	-16.09	3.48	0.06
10	2	4	9.20	-8.81	0.00	0.54		1	3	24.96	-43.00	0.00	0.29
10	6	4	7.91	-6.15	2.66	0.14		2	4	26.11	-42.63	0.38	0.24

	D1pcta							D91pcta					
P	**M**	**K**	**MLL**	**AIC_c**	**Δ_m**	**w_m**		**M**	**K**	**MLL**	**AIC_c**	**Δ_m**	**w_m**
10	4	4	7.84	-6.08	2.72	0.14		3	4	26.01	-42.41	0.59	0.21
10	1	3	6.26	-5.59	3.21	0.11		5	4	25.72	-41.84	1.17	0.16
10	5	4	6.54	-3.48	5.33	0.04		4	4	24.98	-40.36	2.64	0.08
10	3	4	6.27	-2.95	5.86	0.03		6	4	23.79	-37.91	5.09	0.02
11	2	4	8.70	-7.80	0.00	0.69		3	4	21.05	-32.51	0.00	0.65
11	4	4	7.32	-5.03	2.77	0.17		1	3	18.15	-29.38	3.13	0.14
11	6	4	6.11	-2.55	5.26	0.05		4	4	19.02	-28.45	4.06	0.09
11	1	3	4.63	-2.34	5.47	0.04		5	4	18.88	-28.17	4.34	0.07
11	3	4	5.46	-1.31	6.49	0.03		2	4	18.36	-27.13	5.38	0.04
11	5	4	4.76	0.07	7.88	0.01		6	4	17.14	-24.62	7.89	0.01
12	2	4	5.46	-1.33	0.00	0.79		2	4	24.40	-39.20	0.00	0.90
12	4	4	3.96	1.68	3.01	0.18		4	4	21.46	-33.32	5.89	0.05
12	5	4	1.14	7.32	8.65	0.01		1	3	19.52	-32.11	7.09	0.03
12	1	3	-0.25	7.42	8.75	0.01		5	4	20.05	-30.50	8.71	0.01
12	3	4	0.52	8.57	9.90	0.01		6	4	19.56	-29.46	9.75	0.01
12	6	4	0.04	9.59	10.92	0.00		3	4	19.53	-29.45	9.75	0.01
13	4	4	5.89	-2.18	0.00	0.75		4	4	17.91	-26.21	0.00	0.31
13	2	4	4.51	0.58	2.76	0.19		1	3	16.43	-25.93	0.28	0.27
13	6	4	2.29	5.08	7.26	0.02		2	4	17.31	-25.02	1.19	0.17
13	3	4	2.25	5.09	7.28	0.02		3	4	17.13	-24.67	1.54	0.14
13	1	3	0.55	5.83	8.01	0.01		5	4	16.47	-23.33	2.88	0.07
13	5	4	0.60	8.40	10.58	0.00		6	4	15.56	-21.45	4.76	0.03
14	4	4	2.96	3.68	0.00	0.70		1	3	10.01	-13.09	0.00	0.35
14	2	4	2.07	5.47	1.79	0.29		2	4	10.84	-12.07	1.02	0.21
14	3	4	-1.39	12.39	8.71	0.01		4	4	10.64	-11.69	1.41	0.18
14	1	3	-5.70	18.33	14.65	0.00		3	4	10.20	-10.79	2.30	0.11
14	6	4	-5.13	19.94	16.26	0.00		5	4	10.01	-10.42	2.67	0.09
14	5	4	-5.26	20.11	16.43	0.00		6	4	9.47	-9.27	3.82	0.05
15	5	4	5.84	-2.08	0.00	0.82		5	4	9.68	-9.75	0.00	0.62

	D1pcta							D91pcta					
P	M	K	MLL	AIC_c	Δ_m	w_m		M	K	MLL	AIC_c	Δ_m	w_m
15	2	4	3.97	1.66	3.74	0.13		2	4	8.17	-6.74	3.01	0.14
15	4	4	2.61	4.39	6.47	0.03		1	3	6.71	-6.50	3.25	0.12
15	6	4	1.84	5.99	8.08	0.01		3	4	7.06	-4.52	5.24	0.04
15	1	3	-0.96	8.85	10.93	0.00		4	4	7.01	-4.43	5.33	0.04
15	3	4	-0.85	11.30	13.39	0.00		6	4	6.94	-4.21	5.54	0.04
16	2	4	10.39	-11.18	0.00	0.91		1	3	15.42	-23.92	0.00	0.35
16	4	4	7.84	-6.08	5.11	0.07		2	4	16.37	-23.13	0.78	0.24
16	1	3	4.11	-1.30	9.88	0.01		3	4	15.90	-22.20	1.72	0.15
16	6	4	4.90	-0.13	11.06	0.00		5	4	15.54	-21.48	2.44	0.10
16	5	4	4.85	-0.10	11.09	0.00		4	4	15.47	-21.35	2.57	0.10
16	3	4	4.40	0.81	11.99	0.00		6	4	15.06	-20.46	3.46	0.06
17	2	4	6.18	-2.76	0.00	0.97		2	4	5.79	-1.97	0.00	0.77
17	4	4	2.74	4.11	6.87	0.03		4	4	3.85	1.89	3.87	0.11
17	3	4	-3.32	16.24	19.00	0.00		1	3	1.93	3.05	5.03	0.06
17	6	4	-3.38	16.43	19.18	0.00		6	4	2.20	5.27	7.25	0.02
17	1	3	-5.13	17.19	19.95	0.00		3	4	2.00	5.60	7.57	0.02
17	5	4	-4.99	19.59	22.34	0.00		5	4	1.96	5.68	7.65	0.02
18	3	4	2.74	4.12	0.00	0.78		3	4	9.47	-9.35	0.00	0.76
18	4	4	1.45	6.70	2.59	0.21		4	4	8.16	-6.71	2.63	0.20
18	2	4	-2.00	13.60	9.48	0.01		2	4	5.74	-1.89	7.46	0.02
18	1	3	-5.05	17.03	12.91	0.00		1	3	4.30	-1.67	7.68	0.02
18	5	4	-4.60	18.80	14.69	0.00		5	4	4.30	0.99	10.34	0.00
18	6	4	-5.25	20.16	16.04	0.00		6	4	4.06	1.54	10.89	0.00
19	2	4	5.91	-2.21	0.00	0.95		2	4	5.53	-1.45	0.00	0.58
19	4	4	3.06	3.49	5.70	0.05		4	4	5.18	-0.76	0.69	0.41
19	3	4	-2.72	15.05	17.26	0.00		3	4	0.95	7.69	9.15	0.01
19	1	3	-5.83	18.59	20.80	0.00		1	3	-1.92	10.77	12.22	0.00
19	5	4	-5.18	19.96	22.17	0.00		5	4	-0.66	10.92	12.37	0.00
20	2	4	9.55	-9.49	0.00	1.00		2	4	6.17	-2.73	0.00	0.91

	D1pcta							**D91pcta**					
P	**M**	**K**	**MLL**	**AIC$_c$**	Δ_m	w_m		**M**	**K**	**MLL**	**AIC$_c$**	Δ_m	w_m
20	4	4	3.33	2.95	12.44	0.00		4	4	3.58	2.44	5.18	0.07
20	1	3	1.25	4.42	13.91	0.00		1	3	0.76	5.39	8.13	0.02
20	3	4	1.34	6.93	16.42	0.00		5	4	1.28	7.04	9.78	0.01
20	5	4	1.27	7.05	16.55	0.00		3	4	0.78	8.03	10.77	0.00
21	2	4	12.84	-16.09	0.00	0.91		2	4	6.83	-4.05	0.00	0.86
21	4	4	10.45	-11.30	4.79	0.08		4	4	5.01	-0.43	3.62	0.14
21	1	3	5.72	-4.52	11.56	0.00		1	3	-0.44	7.81	11.86	0.00
21	3	4	6.82	-4.04	12.05	0.00		3	4	0.70	8.19	12.25	0.00
21	5	4	5.84	-2.09	14.00	0.00		5	4	-0.44	10.49	14.54	0.00
22	2	4	9.29	-8.99	0.00	0.75		5	4	2.75	4.10	0.00	0.97
22	5	4	7.76	-5.92	3.06	0.16		2	4	-1.56	12.72	8.61	0.01
22	4	4	6.63	-3.66	5.33	0.05		1	3	-3.32	13.56	9.46	0.01
22	1	3	4.66	-2.41	6.58	0.03		4	4	-2.99	15.58	11.48	0.00
22	3	4	4.82	-0.04	8.95	0.01		3	4	-3.30	16.19	12.09	0.00
23	2	4	20.32	-31.04	0.00	0.96		2	4	5.33	-1.07	0.00	0.67
23	4	4	17.07	-24.54	6.50	0.04		4	4	4.26	1.08	2.15	0.23
23	3	4	13.58	-17.57	13.47	0.00		1	3	1.35	4.22	5.29	0.05
23	1	3	11.65	-16.38	14.66	0.00		3	4	2.68	4.24	5.31	0.05
23	5	4	12.68	-15.76	15.27	0.00		5	4	1.45	6.71	7.78	0.01
24	2	4	11.87	-14.13	0.00	0.27		2	4	6.28	-2.96	0.00	0.85
24	1	3	10.52	-14.12	0.01	0.27		4	4	4.49	0.62	3.57	0.14
24	5	4	11.61	-13.62	0.52	0.21		1	3	-0.28	7.49	10.45	0.00
24	4	4	11.37	-13.13	1.00	0.17		5	4	1.03	7.55	10.50	0.00
24	3	4	10.63	-11.67	2.47	0.08		3	4	0.25	9.11	12.07	0.00
25	4	4	13.34	-17.09	0.00	0.38		1	3	0.30	6.32	0.00	0.48
25	2	4	13.00	-16.40	0.68	0.27		3	4	0.41	8.77	2.45	0.14
25	3	4	12.63	-15.65	1.43	0.19		4	4	0.35	8.90	2.58	0.13
25	1	3	10.85	-14.78	2.31	0.12		5	4	0.32	8.95	2.64	0.13
25	5	4	10.85	-12.10	4.98	0.03		2	4	0.30	8.99	2.68	0.13

	D1pcta							D91pcta					
P	**M**	**K**	**MLL**	**AIC_c**	**Δ_m**	**w_m**		**M**	**K**	**MLL**	**AIC_c**	**Δ_m**	**w_m**
26	2	4	16.55	-23.50	0.00	0.91		2	4	16.18	-22.77	0.00	0.40
26	4	4	14.25	-18.90	4.60	0.09		1	3	14.63	-22.33	0.44	0.32
26	3	4	10.57	-11.54	11.96	0.00		3	4	14.91	-20.22	2.55	0.11
26	1	3	7.59	-8.26	15.24	0.00		4	4	14.64	-19.68	3.08	0.09
26	5	4	7.65	-5.71	17.79	0.00		5	4	14.63	-19.65	3.11	0.08
27	1	3	14.79	-22.66	0.00	0.41		1	3	7.83	-8.73	0.00	0.36
27	5	4	15.41	-21.22	1.44	0.20		3	4	8.75	-7.90	0.83	0.24
27	2	4	15.21	-20.83	1.83	0.16		5	4	8.36	-7.12	1.61	0.16
27	3	4	14.97	-20.34	2.32	0.13		2	4	8.09	-6.58	2.15	0.12
27	4	4	14.79	-19.98	2.67	0.11		4	4	7.98	-6.35	2.38	0.11
28	1	3	15.92	-24.92	0.00	0.34		1	3	9.20	-11.49	0.00	0.33
28	3	4	17.13	-24.66	0.26	0.30		3	4	10.46	-11.32	0.16	0.30
28	4	4	16.57	-23.55	1.37	0.17		4	4	9.97	-10.33	1.15	0.19
28	2	4	15.99	-22.38	2.54	0.10		5	4	9.27	-8.94	2.55	0.09
28	5	4	15.95	-22.30	2.62	0.09		2	4	9.22	-8.83	2.65	0.09
29	2	4	19.05	-28.49	0.00	1.00		2	4	10.69	-11.77	0.00	0.57
29	4	4	12.72	-15.84	12.65	0.00		4	4	10.29	-10.97	0.80	0.38
29	1	3	8.73	-10.53	17.96	0.00		5	4	7.52	-5.43	6.34	0.02
29	5	4	9.73	-9.85	18.64	0.00		3	4	6.57	-3.55	8.23	0.01
29	3	4	8.84	-8.08	20.42	0.00		1	3	5.19	-3.46	8.31	0.01
30	5	4	22.12	-34.65	0.00	0.64		1	3	25.58	-44.23	0.00	0.38
30	2	4	20.72	-31.84	2.81	0.16		2	4	26.60	-43.61	0.62	0.28
30	1	3	19.04	-31.15	3.50	0.11		4	4	25.81	-42.01	2.22	0.12
30	4	4	19.79	-29.98	4.67	0.06		5	4	25.74	-41.89	2.34	0.12
30	3	4	19.10	-28.59	6.05	0.03		3	4	25.60	-41.61	2.62	0.10
31	3	4	20.04	-30.48	0.00	0.32		3	4	14.41	-19.21	0.00	0.32
31	4	4	20.02	-30.43	0.05	0.31		4	4	14.18	-18.76	0.45	0.26
31	1	3	18.36	-29.79	0.69	0.23		1	3	12.79	-18.66	0.55	0.25
31	5	4	18.77	-27.94	2.54	0.09		2	4	13.24	-16.88	2.33	0.10

	D1pcta							D91pcta					
P	**M**	**K**	**MLL**	**AIC_c**	**Δ_m**	**w_m**		**M**	**K**	**MLL**	**AIC_c**	**Δ_m**	**w_m**
31	2	4	18.36	-27.12	3.36	0.06		5	4	12.91	-16.21	3.00	0.07
32	1	3	29.03	-51.13	0.00	0.39		1	3	19.32	-31.73	0.00	0.35
32	2	4	29.87	-50.14	0.99	0.24		5	4	20.44	-31.28	0.45	0.28
32	3	4	29.37	-49.13	2.00	0.14		4	4	19.71	-29.81	1.91	0.13
32	5	4	29.16	-48.73	2.40	0.12		3	4	19.63	-29.66	2.06	0.12
32	4	4	29.05	-48.50	2.63	0.11		2	4	19.57	-29.53	2.19	0.12
33	2	4	25.20	-40.80	0.00	0.86		2	4	17.65	-25.70	0.00	0.72
33	4	4	22.98	-36.37	4.43	0.09		4	4	16.47	-23.35	2.36	0.22
33	1	3	20.56	-34.19	6.61	0.03		1	3	13.13	-19.33	6.38	0.03
33	3	4	20.78	-31.96	8.85	0.01		3	4	13.82	-18.03	7.67	0.02
33	5	4	20.59	-31.59	9.22	0.01		5	4	13.14	-16.68	9.02	0.01
34	2	4	34.81	-60.02	0.00	0.72		1	3	16.44	-25.95	0.00	0.32
34	1	3	31.85	-56.78	3.24	0.14		2	4	17.77	-25.93	0.02	0.32
34	4	4	32.44	-55.29	4.73	0.07		4	4	17.01	-24.42	1.53	0.15
34	3	4	31.88	-54.16	5.86	0.04		5	4	16.87	-24.14	1.81	0.13
34	5	4	31.88	-54.15	5.87	0.04		3	4	16.47	-23.34	2.61	0.09
35	2	4	22.71	-35.81	0.00	0.80		2	4	14.42	-19.24	0.00	0.96
35	1	3	19.28	-31.64	4.17	0.10		1	3	8.94	-10.97	8.27	0.02
35	3	4	19.82	-30.03	5.78	0.04		4	4	10.08	-10.57	8.67	0.01
35	4	4	19.39	-29.19	6.62	0.03		5	4	9.07	-8.54	10.70	0.00
35	5	4	19.38	-29.15	6.66	0.03		3	4	8.95	-8.29	10.95	0.00
36	2	4	11.39	-13.18	0.00	0.81		2	4	14.53	-19.46	0.00	0.52
36	4	4	9.44	-9.28	3.90	0.12		1	3	12.36	-17.79	1.67	0.22
36	1	3	7.11	-7.30	5.88	0.04		4	4	13.22	-16.84	2.62	0.14
36	3	4	7.53	-5.46	7.72	0.02		5	4	12.38	-15.16	4.30	0.06
36	5	4	7.13	-4.66	8.52	0.01		3	4	12.38	-15.15	4.31	0.06
37	1	3	22.09	-37.26	0.00	0.29		3	4	23.78	-37.97	0.00	0.38
37	4	4	23.29	-36.97	0.28	0.25		4	4	23.56	-37.51	0.46	0.30
37	3	4	23.15	-36.70	0.56	0.22		1	3	21.70	-36.47	1.50	0.18

	D1pcta							**D91pcta**					
P	**M**	**K**	**MLL**	**AIC_c**	**Δ_m**	**w_m**		**M**	**K**	**MLL**	**AIC_c**	**Δ_m**	**w_m**
37	2	4	22.78	-35.96	1.30	0.15		2	4	22.26	-34.92	3.05	0.08
37	5	4	22.19	-34.79	2.47	0.08		5	4	21.71	-33.81	4.15	0.05
38	2	4	20.43	-31.26	0.00	1.00		2	4	17.04	-24.47	0.00	0.63
38	4	4	14.35	-19.09	12.16	0.00		1	3	14.30	-21.68	2.79	0.16
38	1	3	12.07	-17.21	14.04	0.00		5	4	14.97	-20.35	4.12	0.08
38	3	4	12.24	-14.87	16.38	0.00		4	4	14.92	-20.23	4.24	0.08
38	5	4	12.14	-14.67	16.59	0.00		3	4	14.53	-19.46	5.02	0.05
39	2	4	21.48	-33.36	0.00	0.61		1	3	17.06	-27.20	0.00	0.46
39	4	4	20.98	-32.37	0.99	0.37		4	4	17.21	-24.83	2.37	0.14
39	3	4	17.93	-26.27	7.10	0.02		3	4	17.19	-24.79	2.41	0.14
39	1	3	14.56	-22.19	11.17	0.00		2	4	17.18	-24.77	2.43	0.14
39	5	4	14.60	-19.59	13.77	0.00		5	4	17.06	-24.52	2.68	0.12
40	2	4	13.85	-18.10	0.00	0.68		3	4	29.81	-50.01	0.00	0.40
40	4	4	12.75	-15.89	2.20	0.23		4	4	29.29	-48.98	1.04	0.24
40	3	4	11.05	-12.50	5.60	0.04		1	3	27.81	-48.69	1.33	0.20
40	1	3	9.62	-12.31	5.79	0.04		2	4	28.48	-47.36	2.65	0.11
40	5	4	9.62	-9.64	8.46	0.01		5	4	27.86	-46.13	3.89	0.06
41	4	4	20.21	-30.82	0.00	0.49		3	4	43.71	-77.81	0.00	0.35
41	3	4	20.13	-30.66	0.17	0.45		4	4	43.29	-76.98	0.84	0.23
41	2	4	17.72	-25.85	4.97	0.04		1	3	41.83	-76.73	1.09	0.21
41	1	3	15.34	-23.75	7.07	0.01		5	4	42.59	-75.58	2.24	0.12
41	5	4	15.56	-21.53	9.29	0.00		2	4	42.33	-75.07	2.75	0.09
42	2	4	19.10	-28.59	0.00	0.96		3	4	63.29	-116.97	0.00	0.38
42	4	4	15.78	-21.97	6.63	0.03		4	4	62.81	-116.01	0.96	0.23
42	1	3	11.70	-16.47	12.12	0.00		1	3	61.45	-115.98	0.99	0.23
42	3	4	12.57	-15.55	13.05	0.00		2	4	61.94	-114.28	2.69	0.10
42	5	4	12.41	-15.22	13.37	0.00		5	4	61.45	-113.31	3.66	0.06
43	4	4	24.22	-38.83	0.00	0.60		1	3	50.47	-94.01	0.00	0.28
43	2	4	23.63	-37.67	1.17	0.33		4	4	51.56	-93.51	0.50	0.22

	D1pcta							D91pcta					
P	**M**	**K**	**MLL**	**AIC_c**	**Δ_m**	**w_m**		**M**	**K**	**MLL**	**AIC_c**	**Δ_m**	**w_m**
43	3	4	21.94	-34.27	4.56	0.06		3	4	51.52	-93.45	0.57	0.21
43	1	3	18.38	-29.84	9.00	0.01		5	4	51.23	-92.86	1.15	0.16
43	5	4	18.40	-27.20	11.63	0.00		2	4	51.08	-92.57	1.44	0.14
44	2	4	29.85	-50.09	0.00	0.35		1	3	44.09	-81.25	0.00	0.47
44	4	4	29.75	-49.91	0.19	0.32		3	4	44.22	-78.83	2.42	0.14
44	1	3	27.84	-48.77	1.33	0.18		4	4	44.16	-78.73	2.53	0.13
44	3	4	28.56	-47.52	2.58	0.10		5	4	44.11	-78.62	2.63	0.13
44	5	4	28.05	-46.51	3.58	0.06		2	4	44.10	-78.60	2.65	0.13
45	2	4	21.41	-33.21	0.00	0.84		2	4	65.47	-121.34	0.00	0.32
45	4	4	19.57	-29.53	3.68	0.13		1	3	64.08	-121.23	0.11	0.30
45	1	3	15.77	-24.62	8.60	0.01		4	4	65.02	-120.45	0.89	0.20
45	3	4	16.89	-24.18	9.04	0.01		3	4	64.27	-118.94	2.40	0.10
45	5	4	15.77	-21.95	11.27	0.00		5	4	64.08	-118.57	2.77	0.08
46	1	3	6.48	-6.04	0.00	0.41		1	3	75.89	-144.86	0.00	0.41
46	3	4	7.01	-4.42	1.62	0.18		3	4	76.38	-143.15	1.70	0.17
46	4	4	6.96	-4.32	1.72	0.17		5	4	76.34	-143.08	1.77	0.17
46	2	4	6.65	-3.71	2.34	0.13		4	4	76.14	-142.68	2.17	0.14
46	5	4	6.49	-3.39	2.66	0.11		2	4	75.92	-142.23	2.62	0.11
47	1	3	20.77	-34.61	0.00	0.47		1	3	38.76	-70.59	0.00	0.48
47	2	4	20.91	-32.22	2.40	0.14		4	4	38.81	-68.01	2.57	0.13
47	4	4	20.82	-32.03	2.58	0.13		2	4	38.79	-67.99	2.60	0.13
47	5	4	20.81	-32.02	2.60	0.13		3	4	38.78	-67.97	2.62	0.13
47	3	4	20.77	-31.94	2.68	0.12		5	4	38.76	-67.91	2.68	0.13
48	1	3	102.51	-198.10	0.00	0.47		1	3	46.97	-87.02	0.00	0.33
48	5	4	102.69	-195.79	2.31	0.15		4	4	47.90	-86.19	0.83	0.22
48	3	4	102.57	-195.53	2.56	0.13		3	4	47.80	-85.99	1.03	0.19
48	4	4	102.55	-195.51	2.59	0.13		2	4	47.67	-85.74	1.29	0.17
48	2	4	102.53	-195.46	2.64	0.13		5	4	47.05	-84.51	2.52	0.09
49	2	4	146.32	-283.04	0.00	0.70		3	4	28.78	-47.95	0.00	0.37

	D1pcta							D91pcta					
P	**M**	**K**	**MLL**	**AIC$_c$**	Δ_m	w_m		**M**	**K**	**MLL**	**AIC$_c$**	Δ_m	w_m
49	4	4	145.16	-280.71	2.33	0.22		4	4	28.48	-47.36	0.59	0.27
49	3	4	143.59	-277.58	5.46	0.05		1	3	26.46	-46.01	1.95	0.14
49	1	3	141.79	-276.66	6.38	0.03		2	4	27.58	-45.57	2.39	0.11
49	5	4	141.85	-274.09	8.95	0.01		5	4	27.56	-45.52	2.43	0.11
50								1	3	47.02	-87.11	0.00	0.38
50								5	4	47.65	-85.70	1.41	0.19
50								2	4	47.58	-85.56	1.55	0.17
50								4	4	47.45	-85.30	1.82	0.15
50								3	4	47.13	-84.66	2.45	0.11
51								2	4	53.91	-98.22	0.00	0.38
51								4	4	53.60	-97.59	0.63	0.28
51								1	3	51.94	-96.96	1.26	0.20
51								3	4	52.48	-95.35	2.87	0.09
51								5	4	52.02	-94.44	3.77	0.06
52								1	3	66.60	-126.27	0.00	0.47
52								5	4	66.75	-123.90	2.37	0.14
52								3	4	66.67	-123.75	2.52	0.13
52								2	4	66.65	-123.70	2.57	0.13
52								4	4	66.60	-123.60	2.67	0.12

Table A.4.4.4.4.2.3. Model ranking and Akaike weights of 5-day period specific for OLS models predicting percent of Total A deliveries through diversion arcs D11 and D12A. Within each 5-day period, models are sorted by Δ_m (from "best" to "worst"). In the table below, P = 5-day period of the irrigation water year; M = model number; K = number of estimable parameters of the model; MLL = maximized log-likelihood of the model obtained from OLS output; AIC_c = corrected Akaike Information Criterion; Δ_m = difference between the AIC_c of the model with the minimum AIC_c (the best model) and the AIC_c of model *m*; w_m = Akaike weight for model *m*.

	D11pcta							D12Apcta					
P	**M**	**K**	**MLL**	**AIC_c**	**Δ_m**	**w_m**		**M**	**K**	**MLL**	**AIC_c**	**Δ_m**	**w_m**
1	12	3	67.45	-127.98	0.00	0.86		12	3	22.56	-38.20	0.00	0.45
1	9	4	66.60	-123.53	4.45	0.09		9	4	23.31	-36.96	1.24	0.24
1	11	4	65.25	-120.83	7.14	0.02		11	4	23.09	-36.51	1.69	0.19
1	10	4	65.09	-120.50	7.47	0.02		10	4	22.54	-35.41	2.79	0.11
2	1	3	46.37	-85.81	0.00	0.37		3	4	35.46	-61.33	0.00	0.59
2	5	4	47.35	-85.10	0.71	0.26		4	4	34.19	-58.77	2.55	0.17
2	3	4	46.65	-83.71	2.10	0.13		1	3	32.60	-58.27	3.06	0.13
2	4	4	46.44	-83.29	2.53	0.10		5	4	32.89	-56.17	5.15	0.04
2	2	4	46.37	-83.15	2.66	0.10		2	4	32.70	-55.80	5.53	0.04
2	8	4	44.78	-79.89	5.92	0.02		8	4	31.51	-53.36	7.97	0.01
2	6	4	44.59	-79.51	6.30	0.02		7	4	31.49	-53.32	8.01	0.01
2	7	4	44.46	-79.25	6.56	0.01		6	4	31.44	-53.22	8.11	0.01
3	2	4	51.63	-93.67	0.00	0.36		1	3	26.65	-46.38	0.00	0.25
3	1	3	49.88	-92.85	0.82	0.24		5	4	27.98	-46.36	0.01	0.25
3	4	4	51.16	-92.71	0.95	0.22		7	4	27.58	-45.49	0.89	0.16
3	3	4	50.03	-90.46	3.20	0.07		3	4	27.20	-44.80	1.58	0.11
3	5	4	49.96	-90.32	3.34	0.07		2	4	27.01	-44.41	1.96	0.09
3	8	4	48.69	-87.72	5.95	0.02		4	4	26.66	-43.72	2.66	0.07
3	7	4	48.59	-87.51	6.16	0.02		8	4	26.18	-42.69	3.69	0.04
3	6	4	47.96	-86.25	7.42	0.01		6	4	25.79	-41.91	4.46	0.03
4	4	4	71.31	-133.03	0.00	0.34		1	3	39.72	-72.51	0.00	0.39
4	2	4	70.94	-132.29	0.74	0.23		5	4	40.24	-70.89	1.63	0.17
4	1	3	69.46	-132.00	1.03	0.20		2	4	40.04	-70.48	2.03	0.14
4	3	4	70.50	-131.39	1.63	0.15		4	4	39.80	-70.01	2.51	0.11
4	5	4	69.69	-129.77	3.25	0.07		3	4	39.74	-69.88	2.63	0.10

	D11pcta							D12Apcta					
P	**M**	**K**	**MLL**	**AIC$_c$**	Δ_m	w_m		**M**	**K**	**MLL**	**AIC$_c$**	Δ_m	w_m
4	7	4	67.63	-125.60	7.43	0.01		8	4	38.60	-67.53	4.98	0.03
4	6	4	67.13	-124.58	8.44	0.00		6	4	38.49	-67.32	5.20	0.03
4	8	4	66.76	-123.85	9.18	0.00		7	4	38.19	-66.72	5.80	0.02
5	3	4	68.19	-126.79	0.00	0.46		5	4	37.93	-66.26	0.00	0.47
5	4	4	67.38	-125.15	1.64	0.20		1	3	35.72	-64.52	1.74	0.20
5	1	3	65.72	-124.51	2.28	0.15		3	4	36.80	-64.01	2.25	0.15
5	5	4	66.60	-123.60	3.19	0.09		4	4	35.91	-62.22	4.04	0.06
5	2	4	66.11	-122.63	4.16	0.06		2	4	35.82	-62.04	4.22	0.06
5	6	4	65.24	-120.82	5.97	0.02		6	4	35.33	-61.00	5.26	0.03
5	8	4	63.94	-118.21	8.58	0.01		8	4	34.71	-59.75	6.51	0.02
5	7	4	63.37	-117.08	9.71	0.00		7	4	34.28	-58.89	7.38	0.01
6	2	4	71.80	-133.99	0.00	0.61		5	4	33.84	-58.08	0.00	0.26
6	1	3	69.16	-131.40	2.59	0.17		1	3	32.46	-58.00	0.09	0.25
6	3	4	70.01	-130.41	3.58	0.10		6	4	33.80	-57.93	0.15	0.24
6	5	4	69.60	-129.59	4.40	0.07		2	4	32.50	-55.41	2.67	0.07
6	4	4	69.27	-128.94	5.05	0.05		3	4	32.49	-55.37	2.71	0.07
6	8	4	66.62	-123.57	10.43	0.00		4	4	32.46	-55.32	2.76	0.06
6	7	4	66.48	-123.29	10.71	0.00		8	4	31.98	-54.30	3.78	0.04
6	6	4	66.47	-123.28	10.71	0.00		7	4	31.06	-52.46	5.63	0.02
7	1	3	61.12	-115.31	0.00	0.42		4	4	42.89	-76.19	0.00	0.31
7	5	4	61.54	-113.48	1.83	0.17		2	4	42.62	-75.63	0.55	0.23
7	2	4	61.42	-113.24	2.08	0.15		1	3	41.06	-75.19	1.00	0.19
7	4	4	61.24	-112.87	2.44	0.12		3	4	42.33	-75.05	1.13	0.18
7	3	4	61.12	-112.64	2.68	0.11		5	4	41.16	-72.72	3.47	0.05
7	7	4	58.72	-107.76	7.55	0.01		7	4	40.10	-70.54	5.65	0.02
7	6	4	58.68	-107.70	7.61	0.01		6	4	39.54	-69.42	6.76	0.01
7	8	4	58.60	-107.54	7.78	0.01		8	4	39.36	-69.05	7.14	0.01
8	3	4	61.97	-114.34	0.00	0.33		3	4	33.19	-56.78	0.00	0.30
8	4	4	61.66	-113.71	0.63	0.24		4	4	32.93	-56.25	0.53	0.23

	D11pcta							**D12Apcta**					
P	**M**	**K**	**MLL**	**AIC_c**	**Δ_m**	**w_m**		**M**	**K**	**MLL**	**AIC_c**	**Δ_m**	**w_m**
8	1	3	60.19	-113.46	0.88	0.21		1	3	31.51	-56.09	0.69	0.22
8	2	4	60.81	-112.01	2.33	0.10		2	4	32.10	-54.59	2.18	0.10
8	5	4	60.22	-110.84	3.50	0.06		5	4	32.05	-54.50	2.28	0.10
8	7	4	59.91	-110.15	4.19	0.04		7	4	30.41	-51.15	5.63	0.02
8	8	4	58.83	-108.00	6.34	0.01		8	4	30.25	-50.83	5.95	0.02
8	6	4	58.09	-106.51	7.84	0.01		6	4	30.07	-50.48	6.30	0.01
9	1	3	63.92	-120.92	0.00	0.29		1	3	33.81	-60.69	0.00	0.30
9	4	4	64.89	-120.19	0.73	0.20		5	4	34.99	-60.38	0.30	0.26
9	3	4	64.83	-120.05	0.87	0.19		3	4	34.39	-59.18	1.50	0.14
9	5	4	64.74	-119.88	1.04	0.17		4	4	34.29	-58.98	1.71	0.13
9	2	4	64.41	-119.23	1.69	0.12		2	4	33.98	-58.37	2.32	0.09
9	6	4	61.61	-113.55	7.37	0.01		8	4	33.18	-56.70	3.99	0.04
9	7	4	61.53	-113.40	7.52	0.01		7	4	32.71	-55.75	4.94	0.03
9	8	4	61.45	-113.24	7.68	0.01		6	4	32.49	-55.32	5.37	0.02
10	2	4	66.51	-123.42	0.00	0.36		5	4	32.23	-54.87	0.00	0.27
10	1	3	64.82	-122.71	0.71	0.25		1	3	30.76	-54.59	0.28	0.24
10	4	4	65.98	-122.37	1.05	0.21		2	4	32.05	-54.50	0.37	0.23
10	5	4	64.92	-120.24	3.18	0.07		4	4	31.58	-53.55	1.32	0.14
10	3	4	64.89	-120.17	3.25	0.07		3	4	30.78	-51.97	2.90	0.06
10	7	4	62.96	-116.24	7.18	0.01		7	4	29.75	-49.83	5.04	0.02
10	8	4	62.92	-116.17	7.25	0.01		6	4	29.69	-49.72	5.15	0.02
10	6	4	62.49	-115.30	8.12	0.01		8	4	29.45	-49.24	5.63	0.02
11	2	4	61.69	-113.78	0.00	0.41		1	3	39.81	-72.70	0.00	0.26
11	1	3	59.83	-112.74	1.04	0.25		7	4	40.83	-71.99	0.71	0.18
11	8	4	60.15	-110.64	3.14	0.09		2	4	40.67	-71.74	0.95	0.16
11	3	4	60.01	-110.42	3.36	0.08		4	4	40.59	-71.57	1.13	0.15
11	5	4	59.95	-110.31	3.47	0.07		3	4	40.12	-70.65	2.05	0.09
11	4	4	59.95	-110.30	3.48	0.07		5	4	39.81	-70.02	2.68	0.07
11	7	4	58.91	-108.15	5.63	0.02		6	4	39.83	-70.00	2.70	0.07

	D11pcta							D12Apcta					
P	M	K	MLL	AIC_c	Δ_m	w_m		M	K	MLL	AIC_c	Δ_m	w_m
11	6	4	57.72	-105.77	8.01	0.01		8	4	38.18	-66.69	6.01	0.01
12	4	4	63.27	-116.95	0.00	0.61		3	4	37.35	-65.09	0.00	0.64
12	3	4	62.63	-115.66	1.28	0.32		4	4	35.86	-62.13	2.97	0.15
12	2	4	60.77	-111.93	5.01	0.05		1	3	34.18	-61.45	3.65	0.10
12	1	3	58.34	-109.76	7.18	0.02		5	4	34.87	-60.13	4.96	0.05
12	5	4	58.81	-108.01	8.93	0.01		2	4	34.47	-59.35	5.74	0.04
12	8	4	55.92	-102.17	14.78	0.00		7	4	32.90	-56.13	8.96	0.01
12	6	4	55.91	-102.16	14.78	0.00		8	4	32.86	-56.05	9.04	0.01
12	7	4	55.91	-102.16	14.79	0.00		6	4	32.58	-55.50	9.60	0.01
13	1	3	50.45	-93.97	0.00	0.38		7	4	38.80	-67.93	0.00	0.31
13	5	4	50.90	-92.20	1.78	0.16		1	3	37.24	-67.56	0.37	0.26
13	2	4	50.61	-91.62	2.35	0.12		3	4	37.81	-66.01	1.92	0.12
13	4	4	50.61	-91.62	2.35	0.12		4	4	37.58	-65.56	2.37	0.09
13	3	4	50.50	-91.40	2.57	0.11		5	4	37.42	-65.24	2.69	0.08
13	8	4	50.18	-90.69	3.29	0.07		2	4	37.25	-64.91	3.02	0.07
13	7	4	48.90	-88.13	5.84	0.02		6	4	36.87	-64.06	3.87	0.04
13	6	4	48.85	-88.02	5.95	0.02		8	4	36.37	-63.07	4.86	0.03
14	6	4	67.21	-124.76	0.00	0.62		6	4	29.07	-48.47	0.00	0.60
14	5	4	65.90	-122.20	2.56	0.17		1	3	26.16	-45.39	3.08	0.13
14	2	4	64.98	-120.35	4.41	0.07		8	4	26.75	-43.83	4.64	0.06
14	7	4	64.97	-120.26	4.50	0.07		4	4	26.71	-43.83	4.64	0.06
14	1	3	63.01	-119.10	5.66	0.04		2	4	26.63	-43.65	4.82	0.05
14	4	4	63.73	-117.85	6.91	0.02		3	4	26.57	-43.54	4.93	0.05
14	3	4	63.02	-116.44	8.32	0.01		5	4	26.46	-43.33	5.14	0.05
14	8	4	60.75	-111.83	12.94	0.00		7	4	24.99	-40.31	8.16	0.01
15	1	3	60.82	-114.71	0.00	0.41		1	3	32.39	-57.86	0.00	0.32
15	4	4	61.27	-112.94	1.77	0.17		6	4	33.13	-56.59	1.27	0.17
15	3	4	61.16	-112.72	1.99	0.15		2	4	32.97	-56.34	1.52	0.15
15	2	4	60.94	-112.28	2.43	0.12		4	4	32.79	-55.99	1.87	0.13

	D11pcta							D12Apcta					
P	M	K	MLL	AIC$_c$	Δ_m	w$_m$		M	K	MLL	AIC$_c$	Δ_m	w$_m$
15	5	4	60.88	-112.16	2.56	0.11		3	4	32.43	-55.26	2.60	0.09
15	7	4	59.24	-108.82	5.90	0.02		5	4	32.39	-55.19	2.67	0.08
15	8	4	58.77	-107.88	6.83	0.01		7	4	31.72	-53.78	4.08	0.04
15	6	4	58.44	-107.21	7.51	0.01		8	4	31.11	-52.55	5.31	0.02
16	2	4	58.56	-107.51	0.00	0.75		2	4	32.09	-54.57	0.00	0.30
16	4	4	56.54	-103.47	4.04	0.10		5	4	31.81	-54.03	0.54	0.23
16	1	3	55.08	-103.24	4.27	0.09		1	3	30.32	-53.72	0.85	0.20
16	5	4	55.33	-101.07	6.45	0.03		4	4	31.40	-53.19	1.38	0.15
16	3	4	55.08	-100.57	6.95	0.02		3	4	30.43	-51.25	3.32	0.06
16	7	4	53.70	-97.73	9.78	0.01		7	4	29.62	-49.58	5.00	0.02
16	8	4	53.37	-97.07	10.44	0.00		6	4	29.60	-49.54	5.04	0.02
16	6	4	53.10	-96.53	10.99	0.00		8	4	29.10	-48.54	6.03	0.01
17	1	3	61.86	-116.80	0.00	0.44		1	3	37.29	-67.65	0.00	0.26
17	5	4	62.09	-114.58	2.22	0.15		4	4	38.54	-67.49	0.16	0.24
17	3	4	61.98	-114.36	2.44	0.13		2	4	38.29	-66.98	0.68	0.19
17	4	4	61.91	-114.22	2.58	0.12		3	4	38.21	-66.82	0.83	0.17
17	2	4	61.86	-114.13	2.67	0.12		5	4	37.30	-64.99	2.66	0.07
17	7	4	60.05	-110.42	6.37	0.02		6	4	36.43	-63.19	4.46	0.03
17	8	4	59.70	-109.74	7.06	0.01		7	4	36.01	-62.35	5.30	0.02
17	6	4	59.58	-109.50	7.30	0.01		8	4	35.73	-61.80	5.85	0.01
18	2	4	57.22	-104.83	0.00	0.59		1	3	36.43	-65.95	0.00	0.36
18	4	4	56.55	-103.51	1.32	0.31		5	4	36.84	-64.08	1.86	0.14
18	3	4	54.56	-99.52	5.31	0.04		3	4	36.59	-63.59	2.36	0.11
18	1	3	53.18	-99.45	5.38	0.04		4	4	36.47	-63.33	2.61	0.10
18	5	4	53.47	-97.35	7.48	0.01		2	4	36.44	-63.28	2.67	0.09
18	7	4	52.20	-94.74	10.09	0.00		8	4	36.46	-63.25	2.70	0.09
18	8	4	51.62	-93.58	11.25	0.00		6	4	36.24	-62.81	3.13	0.08
18	6	4	51.20	-92.74	12.09	0.00		7	4	35.16	-60.66	5.29	0.03
19	4	4	58.66	-107.72	0.00	0.54		5	4	26.89	-44.19	0.00	0.57

	D11pcta							**D12Apcta**					
P	**M**	**K**	**MLL**	**AIC_c**	**Δ_m**	**w_m**		**M**	**K**	**MLL**	**AIC_c**	**Δ_m**	**w_m**
19	3	4	58.07	-106.55	1.17	0.30		1	3	24.70	-42.47	1.71	0.24
19	2	4	56.98	-104.37	3.36	0.10		2	4	24.75	-39.90	4.29	0.07
19	1	3	54.59	-102.27	5.46	0.04		3	4	24.72	-39.84	4.35	0.06
19	5	4	55.05	-100.50	7.22	0.01		4	4	24.70	-39.80	4.39	0.06
20	2	4	55.85	-102.10	0.00	0.76		5	4	36.20	-62.80	0.00	0.78
20	4	4	54.51	-99.43	2.67	0.20		1	3	33.01	-59.09	3.71	0.12
20	1	3	50.96	-95.01	7.09	0.02		2	4	33.05	-56.49	6.31	0.03
20	3	4	51.69	-93.77	8.32	0.01		4	4	33.02	-56.45	6.35	0.03
20	5	4	51.47	-93.34	8.75	0.01		3	4	33.01	-56.42	6.38	0.03
21	5	4	56.15	-102.69	0.00	0.43		5	4	37.60	-65.61	0.00	0.61
21	1	3	54.15	-101.38	1.31	0.22		1	3	35.14	-63.35	2.26	0.20
21	4	4	54.97	-100.34	2.36	0.13		2	4	35.60	-61.60	4.01	0.08
21	2	4	54.81	-100.02	2.67	0.11		4	4	35.28	-60.96	4.65	0.06
21	3	4	54.74	-99.89	2.80	0.11		3	4	35.14	-60.68	4.93	0.05
22	1	3	49.77	-92.61	0.00	0.37		1	3	27.45	-47.98	0.00	0.46
22	2	4	50.84	-92.07	0.54	0.28		5	4	27.79	-45.98	2.00	0.17
22	4	4	50.22	-90.83	1.78	0.15		3	4	27.54	-45.48	2.50	0.13
22	3	4	49.81	-90.02	2.59	0.10		4	4	27.51	-45.41	2.57	0.13
22	5	4	49.77	-89.94	2.67	0.10		2	4	27.45	-45.31	2.68	0.12
23	2	4	47.94	-86.28	0.00	0.29		1	3	27.71	-48.49	0.00	0.35
23	4	4	47.78	-85.96	0.33	0.24		2	4	28.81	-48.02	0.48	0.28
23	1	3	46.31	-85.70	0.59	0.21		5	4	28.19	-46.78	1.71	0.15
23	3	4	47.24	-84.88	1.41	0.14		4	4	28.06	-46.51	1.98	0.13
23	5	4	47.05	-84.50	1.78	0.12		3	4	27.72	-45.83	2.66	0.09
24	4	4	62.26	-114.93	0.00	0.57		4	4	42.17	-74.74	0.00	0.55
24	3	4	61.08	-112.56	2.37	0.18		3	4	41.70	-73.79	0.94	0.34
24	5	4	60.87	-112.13	2.79	0.14		5	4	39.65	-69.70	5.03	0.04
24	2	4	59.98	-110.35	4.57	0.06		1	3	37.93	-68.93	5.81	0.03
24	1	3	58.53	-110.14	4.79	0.05		2	4	39.21	-68.81	5.93	0.03

	D11pcta							D12Apcta					
P	**M**	**K**	**MLL**	**AIC$_c$**	**Δ_m**	**w_m**		**M**	**K**	**MLL**	**AIC$_c$**	**Δ_m**	**w_m**
25	1	3	45.99	-85.05	0.00	0.37		1	3	36.51	-66.09	0.00	0.32
25	5	4	46.84	-84.09	0.97	0.23		2	4	37.42	-65.24	0.85	0.21
25	4	4	46.37	-83.14	1.91	0.14		5	4	37.40	-65.20	0.89	0.21
25	3	4	46.33	-83.05	2.00	0.14		4	4	37.15	-64.71	1.38	0.16
25	2	4	46.27	-82.95	2.10	0.13		3	4	36.71	-63.83	2.26	0.10
26	2	4	52.37	-95.15	0.00	0.50		4	4	37.68	-65.76	0.00	0.31
26	4	4	51.98	-94.35	0.80	0.34		2	4	37.32	-65.03	0.73	0.22
26	3	4	50.49	-91.39	3.76	0.08		1	3	35.89	-64.85	0.91	0.20
26	1	3	48.97	-91.01	4.14	0.06		3	4	37.21	-64.82	0.94	0.20
26	5	4	48.97	-88.33	6.82	0.02		5	4	36.21	-62.82	2.93	0.07
27	1	3	56.51	-106.09	0.00	0.32		1	3	42.66	-78.39	0.00	0.46
27	2	4	57.47	-105.35	0.74	0.22		5	4	42.97	-76.35	2.04	0.17
27	4	4	57.39	-105.18	0.91	0.21		2	4	42.71	-75.83	2.56	0.13
27	3	4	57.02	-104.44	1.65	0.14		4	4	42.67	-75.73	2.66	0.12
27	5	4	56.72	-103.85	2.25	0.11		3	4	42.66	-75.71	2.68	0.12
28	2	4	60.24	-110.89	0.00	0.60		1	3	37.80	-68.68	0.00	0.35
28	5	4	59.74	-109.88	1.00	0.36		2	4	38.62	-67.64	1.04	0.21
28	1	3	55.39	-103.85	7.03	0.02		5	4	38.49	-67.37	1.31	0.18
28	4	4	56.18	-102.76	8.13	0.01		4	4	38.30	-67.00	1.68	0.15
28	3	4	55.47	-101.33	9.56	0.01		3	4	38.08	-66.55	2.13	0.12
29	1	3	44.30	-81.68	0.00	0.40		1	3	40.35	-73.78	0.00	0.41
29	2	4	45.14	-80.68	1.00	0.24		3	4	41.05	-72.50	1.28	0.22
29	4	4	44.50	-79.39	2.28	0.13		4	4	40.70	-71.81	1.98	0.15
29	5	4	44.46	-79.33	2.35	0.12		5	4	40.42	-71.24	2.55	0.11
29	3	4	44.32	-79.03	2.65	0.11		2	4	40.36	-71.11	2.67	0.11
30	5	4	53.74	-97.88	0.00	0.40		4	4	33.24	-56.88	0.00	0.25
30	1	3	52.11	-97.31	0.58	0.30		1	3	31.89	-56.85	0.03	0.25
30	2	4	52.52	-95.43	2.45	0.12		2	4	33.19	-56.78	0.10	0.24
30	4	4	52.38	-95.16	2.72	0.10		3	4	32.79	-55.98	0.91	0.16

	D11pcta							D12Apcta					
P	**M**	**K**	**MLL**	**AIC$_c$**	Δ_m	w_m		**M**	**K**	**MLL**	**AIC$_c$**	Δ_m	w_m
30	3	4	52.20	-94.80	3.09	0.08		5	4	32.25	-54.90	1.98	0.09
31	2	4	56.74	-103.88	0.00	0.32		2	4	40.40	-71.21	0.00	0.50
31	1	3	55.08	-103.23	0.64	0.23		1	3	38.23	-69.54	1.67	0.22
31	3	4	56.22	-102.84	1.04	0.19		3	4	38.97	-68.35	2.86	0.12
31	4	4	55.91	-102.22	1.66	0.14		4	4	38.71	-67.81	3.40	0.09
31	5	4	55.81	-102.02	1.85	0.13		5	4	38.54	-67.47	3.73	0.08
32	1	3	55.55	-104.17	0.00	0.40		1	3	34.36	-61.79	0.00	0.36
32	5	4	56.49	-103.38	0.80	0.27		2	4	35.18	-60.76	1.04	0.21
32	3	4	55.59	-101.57	2.60	0.11		4	4	35.09	-60.59	1.21	0.20
32	4	4	55.55	-101.51	2.66	0.11		3	4	34.70	-59.80	1.99	0.13
32	2	4	55.55	-101.50	2.67	0.11		5	4	34.36	-59.12	2.67	0.09
33	5	4	60.96	-112.33	0.00	0.61		5	4	33.58	-57.56	0.00	0.38
33	1	3	58.55	-110.18	2.15	0.21		1	3	31.99	-57.05	0.51	0.30
33	2	4	58.78	-107.95	4.38	0.07		2	4	32.41	-55.22	2.33	0.12
33	4	4	58.69	-107.77	4.56	0.06		4	4	32.37	-55.13	2.42	0.11
33	3	4	58.57	-107.53	4.80	0.06		3	4	32.10	-54.60	2.96	0.09
34	1	3	56.42	-105.92	0.00	0.44		4	4	40.39	-71.17	0.00	0.33
34	3	4	56.83	-104.07	1.85	0.17		1	3	38.73	-70.55	0.63	0.24
34	5	4	56.59	-103.57	2.35	0.14		3	4	39.85	-70.09	1.08	0.19
34	4	4	56.58	-103.56	2.36	0.13		2	4	39.66	-69.73	1.45	0.16
34	2	4	56.43	-103.26	2.66	0.12		5	4	38.91	-68.22	2.96	0.08
35	1	3	58.19	-109.46	0.00	0.40		1	3	35.79	-64.65	0.00	0.47
35	3	4	58.93	-108.26	1.20	0.22		3	4	35.97	-62.33	2.32	0.15
35	4	4	58.59	-107.58	1.88	0.15		2	4	35.86	-62.13	2.52	0.13
35	5	4	58.38	-107.16	2.30	0.13		4	4	35.81	-62.02	2.63	0.13
35	2	4	58.20	-106.80	2.66	0.10		5	4	35.79	-61.98	2.66	0.12
36	1	3	63.04	-119.16	0.00	0.47		1	3	43.92	-80.92	0.00	0.41
36	3	4	63.24	-116.88	2.28	0.15		3	4	44.49	-79.39	1.53	0.19
36	2	4	63.07	-116.53	2.62	0.13		4	4	44.28	-78.97	1.95	0.15

	D11pcta							D12Apcta					
P	M	K	MLL	AIC$_c$	Δ_m	w$_m$		M	K	MLL	AIC$_c$	Δ_m	w$_m$
36	4	4	63.06	-116.52	2.63	0.13		5	4	44.12	-78.63	2.29	0.13
36	5	4	63.06	-116.52	2.63	0.13		2	4	44.03	-78.47	2.45	0.12
37	4	4	64.03	-118.46	0.00	0.28		1	3	37.41	-67.90	0.00	0.41
37	1	3	62.51	-118.10	0.36	0.24		5	4	38.32	-67.04	0.86	0.27
37	2	4	63.84	-118.08	0.37	0.24		2	4	37.43	-65.26	2.63	0.11
37	3	4	63.54	-117.48	0.98	0.17		3	4	37.43	-65.26	2.64	0.11
37	5	4	62.59	-115.57	2.88	0.07		4	4	37.41	-65.22	2.68	0.11
38	1	3	55.98	-105.04	0.00	0.38		5	4	41.85	-74.11	0.00	0.40
38	3	4	57.03	-104.46	0.58	0.28		1	3	40.28	-73.64	0.47	0.32
38	4	4	56.21	-102.81	2.22	0.12		3	4	40.61	-71.61	2.50	0.11
38	5	4	56.16	-102.72	2.32	0.12		4	4	40.34	-71.07	3.03	0.09
38	2	4	56.02	-102.43	2.60	0.10		2	4	40.31	-71.01	3.10	0.08
39	1	3	53.49	-100.06	0.00	0.44		1	3	31.19	-55.45	0.00	0.31
39	3	4	54.07	-98.54	1.52	0.20		3	4	32.52	-55.44	0.01	0.31
39	4	4	53.59	-97.57	2.49	0.13		4	4	31.92	-54.25	1.21	0.17
39	2	4	53.52	-97.43	2.63	0.12		5	4	31.55	-53.50	1.95	0.12
39	5	4	53.50	-97.40	2.66	0.12		2	4	31.39	-53.19	2.27	0.10
40	3	4	69.55	-129.50	0.00	0.35		1	3	38.97	-71.02	0.00	0.47
40	1	3	67.90	-128.87	0.63	0.25		5	4	39.24	-68.88	2.14	0.16
40	5	4	68.85	-128.09	1.41	0.17		3	4	39.01	-68.43	2.59	0.13
40	4	4	68.74	-127.88	1.62	0.15		2	4	38.98	-68.37	2.65	0.12
40	2	4	68.06	-126.52	2.98	0.08		4	4	38.97	-68.35	2.67	0.12
41	3	4	53.71	-97.83	0.00	0.88		1	3	40.27	-73.61	0.00	0.42
41	4	4	51.52	-93.45	4.38	0.10		2	4	40.72	-71.83	1.77	0.17
41	1	3	47.92	-88.92	8.90	0.01		5	4	40.60	-71.59	2.01	0.15
41	2	4	48.71	-87.82	10.01	0.01		4	4	40.47	-71.35	2.26	0.14
41	5	4	47.95	-86.31	11.52	0.00		3	4	40.28	-70.97	2.64	0.11
42	1	3	55.25	-103.59	0.00	0.46		1	3	36.04	-65.15	0.00	0.42
42	2	4	55.45	-101.29	2.29	0.15		3	4	36.35	-63.09	2.06	0.15

	D11pcta							**D12Apcta**					
P	**M**	**K**	**MLL**	**AIC_c**	**Δ_m**	**w_m**		**M**	**K**	**MLL**	**AIC_c**	**Δ_m**	**w_m**
42	4	4	55.39	-101.19	2.40	0.14		4	4	36.34	-63.09	2.06	0.15
42	3	4	55.30	-100.99	2.59	0.13		5	4	36.27	-62.93	2.22	0.14
42	5	4	55.26	-100.92	2.66	0.12		2	4	36.22	-62.84	2.31	0.13
43	1	3	52.64	-98.36	0.00	0.39		1	3	49.92	-92.92	0.00	0.44
43	2	4	53.31	-97.01	1.34	0.20		2	4	50.36	-91.12	1.80	0.18
43	5	4	53.06	-96.51	1.84	0.15		4	4	50.17	-90.75	2.17	0.15
43	4	4	53.02	-96.43	1.92	0.15		3	4	49.98	-90.37	2.55	0.12
43	3	4	52.74	-95.88	2.48	0.11		5	4	49.92	-90.25	2.67	0.12
44	1	3	56.89	-106.86	0.00	0.44		1	3	41.85	-76.78	0.00	0.33
44	3	4	57.29	-104.98	1.89	0.17		3	4	42.86	-76.13	0.65	0.24
44	4	4	57.16	-104.72	2.14	0.15		4	4	42.65	-75.70	1.08	0.19
44	2	4	56.96	-104.32	2.54	0.12		2	4	42.14	-74.69	2.09	0.12
44	5	4	56.90	-104.20	2.66	0.12		5	4	42.12	-74.64	2.14	0.11
45	3	4	58.05	-106.51	0.00	0.38		5	4	42.39	-75.19	0.00	0.51
45	1	3	56.56	-106.21	0.30	0.32		1	3	40.18	-73.44	1.75	0.21
45	2	4	56.91	-104.21	2.29	0.12		2	4	40.87	-72.14	3.04	0.11
45	4	4	56.68	-103.77	2.74	0.10		3	4	40.79	-71.98	3.21	0.10
45	5	4	56.56	-103.53	2.98	0.08		4	4	40.18	-70.77	4.42	0.06
46	1	3	58.11	-109.30	0.00	0.45		1	3	36.01	-65.10	0.00	0.45
46	3	4	58.36	-107.12	2.17	0.15		3	4	36.42	-63.23	1.87	0.18
46	4	4	58.35	-107.09	2.20	0.15		4	4	36.11	-62.61	2.49	0.13
46	2	4	58.21	-106.82	2.47	0.13		5	4	36.07	-62.53	2.57	0.12
46	5	4	58.19	-106.78	2.51	0.13		2	4	36.02	-62.45	2.66	0.12
47	1	3	51.31	-95.70	0.00	0.44		1	3	38.14	-69.36	0.00	0.40
47	5	4	51.63	-93.65	2.05	0.16		4	4	38.68	-67.77	1.60	0.18
47	4	4	51.48	-93.36	2.34	0.14		3	4	38.67	-67.74	1.63	0.18
47	2	4	51.45	-93.31	2.40	0.13		2	4	38.39	-67.19	2.18	0.13
47	3	4	51.40	-93.20	2.50	0.13		5	4	38.16	-66.73	2.63	0.11
48	1	3	65.04	-123.15	0.00	0.40		1	3	48.88	-90.83	0.00	0.44

	D11pcta							D12Apcta					
P	M	K	MLL	AIC$_c$	Δ_m	w_m		M	K	MLL	AIC$_c$	Δ_m	w_m
48	5	4	65.96	-122.31	0.84	0.26		3	4	49.33	-89.05	1.78	0.18
48	2	4	65.16	-120.71	2.44	0.12		2	4	49.03	-88.46	2.37	0.14
48	4	4	65.07	-120.55	2.61	0.11		5	4	48.92	-88.23	2.60	0.12
48	3	4	65.04	-120.48	2.68	0.11		4	4	48.90	-88.20	2.63	0.12
49	1	3	51.70	-96.47	0.00	0.47		3	4	50.02	-90.44	0.00	0.46
49	2	4	51.86	-94.12	2.36	0.14		4	4	49.71	-89.83	0.61	0.34
49	4	4	51.77	-93.94	2.54	0.13		2	4	48.41	-87.23	3.21	0.09
49	5	4	51.73	-93.86	2.62	0.13		1	3	46.61	-86.30	4.14	0.06
49	3	4	51.71	-93.83	2.65	0.13		5	4	47.80	-85.99	4.45	0.05

Table A.4.4.4.4.2.4. Model-averaged coefficients for predicting the percent of Total A diversion through arc D1 specific to each 5-day period of the irrigation water year.

Period	$\hat{\hat{\beta}}_{1,p}$ ***d1pcta***	$\hat{\hat{\beta}}_{2,p}$ ***ppt***	$\hat{\hat{\beta}}_{3,p}$ ***tmax***	$\hat{\hat{\beta}}_{4,p}$ ***ptdayindex***	$\hat{\hat{\beta}}_{5,p}$ ***shortdum***	$\hat{\hat{\beta}}_{6,p}$ ***cumpptwint***	$\hat{\hat{\beta}}_{0,p}$ ***constant***
6	0.00000	-0.00840	0.00021	-0.00316	-0.00069	0.00129	-0.00534
7	4.89474	0.00307	-0.00008	0.00071	0.00629	-0.00104	0.11349
8	1.25829	-0.67129	0.00015	-0.03989	0.00011	-0.00017	0.21523
9	0.78117	-0.41206	0.00107	-0.05936	0.00276	-0.01330	0.31869
10	1.31826	-1.48578	0.00003	-0.02144	-0.00273	-0.03078	0.15832
11	0.97914	-1.46711	0.00016	-0.03756	0.00070	-0.01120	0.25354
12	0.92898	-2.33513	0.00004	-0.04945	0.00206	-0.00060	0.36677
13	0.78099	-0.48028	0.00023	-0.32691	0.00015	0.00371	0.67261
14	0.56899	-0.93787	0.00023	-0.33477	-0.00003	0.00003	1.03871
15	0.82889	-0.28926	0.00000	-0.01456	-0.33369	0.00265	0.48421
16	0.62921	-3.75767	0.00001	-0.01883	-0.00046	-0.00029	0.81728
17	0.39790	-3.72180	0.00000	-0.01684	0.00000	0.00000	1.30555
18	0.60348	-0.02061	0.02166	-0.08892	0.00007	0.00001	-0.63705
19	0.64032	-4.47995	0.00000	-0.02919	0.00000	0.00000	0.87154
20	0.54326	-3.11626	0.00000	-0.00052	-0.00001	0.00000	0.95772
21	0.59650	-1.98105	0.00001	-0.01891	-0.00004	0.00000	0.89645
22	0.58738	-2.87929	0.00003	-0.01288	-0.03887	0.00000	0.93399
23	0.66797	-1.96561	0.00001	-0.00813	-0.00006	0.00000	0.79649
24	0.58102	-0.44357	0.00019	-0.01942	-0.02756	0.00000	0.97929
25	0.58799	-0.45708	0.00164	-0.06563	-0.00014	0.00000	0.83622
26	0.71910	-2.22443	0.00003	-0.02665	0.00000	0.00000	0.71222
27	0.79748	-0.24014	-0.00041	-0.00047	-0.01612	0.00000	0.57915
28	0.92376	-0.06480	-0.00178	0.01646	0.00162	0.00000	0.33011
29	1.09140	-2.19888	0.00000	-0.00052	0.00001	0.00000	-0.25928
30	0.85001	-0.20516	0.00004	-0.00472	0.09506	0.00000	0.30853
31	0.69106	-0.00190	-0.00276	0.04956	0.00519	0.00000	0.87585
32	0.73936	-0.20258	-0.00041	-0.00096	0.00285	0.00000	0.59554
33	0.69968	-2.95382	0.00003	-0.01589	-0.00014	0.00000	0.65606
34	0.96808	-0.81213	-0.00002	-0.00336	0.00034	0.00000	0.06084
35	0.84424	-1.21464	-0.00018	-0.00091	-0.00079	0.00000	0.31498
36	0.65902	-2.04784	0.00010	-0.02271	0.00021	0.00000	0.65816
37	0.82121	0.18396	-0.00125	0.02239	0.00220	0.00000	0.38635
38	0.92944	-1.85082	0.00000	-0.00051	0.00001	0.00000	0.07401
39	0.83461	-1.45973	0.00020	-0.11440	-0.00001	0.00000	0.26141
40	0.89172	-1.11728	0.00039	-0.05463	-0.00003	0.00000	0.04650
41	0.82994	-0.07436	0.00461	-0.09573	0.00023	0.00000	-0.21816
42	0.80064	-1.64988	0.00001	-0.00689	-0.00011	0.00000	0.19455
43	0.85920	-0.74590	0.00045	-0.10845	-0.00002	0.00000	0.10719
44	0.84725	-0.46204	0.00027	-0.02957	0.00176	0.00000	0.05451

Period	$\hat{\hat{\beta}}_{1,p}$ d1pcta	$\hat{\hat{\beta}}_{2,p}$ ppt	$\hat{\hat{\beta}}_{3,p}$ tmax	$\hat{\hat{\beta}}_{4,p}$ ptdayindex	$\hat{\hat{\beta}}_{5,p}$ shortdum	$\hat{\hat{\beta}}_{6,p}$ cumpptwint	$\hat{\hat{\beta}}_{0,p}$ constant
45	0.95137	-2.44737	0.00004	-0.02037	-0.00001	0.00000	-0.00353
46	0.51954	0.07166	-0.00082	0.01570	0.00141	0.00000	0.07901
47	0.30723	-0.03814	0.00000	-0.00264	-0.00218	0.00000	-0.10126
48	-0.00078	0.00057	-0.00001	0.00014	-0.00035	0.00000	0.00247
49	0.06254	0.01281	0.00000	0.00048	0.00000	0.00000	-0.00018

Within the KBPM, these estimated percentages were multiplied by an estimate of Total A diversions to compute the diversion volume for that 5-day period, which was then divided by 5 to compute the delivery volume for each day.

Table A.4.4.4.2.5. Model-averaged coefficients for predicting the percent of Total A diversion through arc D91 specific to each 5-day period of the irrigation water year.

Period	$\hat{\hat{\beta}}_{1,p}$ d91pcta	$\hat{\hat{\beta}}_{2,p}$ ppt	$\hat{\hat{\beta}}_{3,p}$ tmax	$\hat{\hat{\beta}}_{4,p}$ ptdayindex	$\hat{\hat{\beta}}_{5,p}$ shortdum	$\hat{\hat{\beta}}_{6,p}$ cumpptwint	$\hat{\hat{\beta}}_{0,p}$ constant
1	0.00000	-0.00558	0.00000	-0.00023	-0.00089	-0.00088	0.00336
2	2.36408	-0.00503	0.00027	-0.00363	-0.00096	-0.00057	-0.00163
3	1.33396	-0.00836	0.00205	-0.01564	0.01639	-0.00033	-0.07046
4	1.16868	-0.07956	0.00015	-0.00965	-0.00150	-0.00041	0.02298
5	0.99620	-0.09775	0.00037	-0.02320	-0.00653	-0.00001	0.03511
6	1.30424	-0.18141	0.00075	-0.04323	0.00029	-0.00096	0.05140
7	1.41305	-0.01239	0.00858	-0.00890	0.01628	-0.00109	-0.35941
8	1.10001	-0.05376	0.00020	-0.00583	-0.02111	-0.00378	0.08997
9	0.72463	-0.06870	0.00071	-0.01239	-0.00340	-0.07185	0.08912
10	0.66532	-0.23661	-0.00087	-0.00072	0.01005	-0.00075	0.04811
11	0.66183	-0.01409	-0.00486	0.00728	0.00574	-0.00030	0.26158
12	0.72896	-1.32435	0.00000	-0.00512	0.00075	0.00028	0.14230
13	0.83767	-0.12658	0.00064	-0.04411	-0.00142	0.00118	0.10402
14	0.66323	-0.14848	0.00038	-0.01514	-0.00036	-0.00248	0.14170
15	1.00616	-0.14127	-0.00023	-0.00493	-0.13642	-0.00009	0.11575
16	0.88618	-0.30872	-0.00054	-0.00249	-0.00364	-0.00071	0.18861
17	0.50472	-1.49939	0.00005	-0.02642	-0.00043	-0.00013	0.35678
18	0.44408	-0.03101	0.01581	-0.05887	0.00005	0.00026	-0.68761
19	0.28014	-2.06896	0.00009	-0.19401	0.00024	0.00000	0.69524
20	0.44183	-2.38322	0.00001	-0.02340	0.00081	0.00000	0.45237
21	0.35624	-2.42354	0.00002	-0.04712	0.00000	0.00000	0.74503
22	0.61450	-0.04327	0.00000	-0.00043	-0.41196	0.00000	0.54564
23	0.41989	-1.37446	0.00050	-0.05152	-0.00074	0.00000	0.62263
24	0.34829	-4.21112	0.00002	-0.06080	-0.00088	0.00000	0.81751
25	0.84271	0.00580	-0.00049	0.00549	0.00331	0.00000	0.15713
26	0.62309	-0.49588	-0.00033	-0.00122	0.00011	0.00000	0.37114
27	0.88094	-0.18408	-0.00214	0.00709	-0.01550	0.00000	0.35742
28	0.77504	-0.03044	-0.00233	0.02417	0.00300	0.00000	0.35344

Period	$\hat{\hat{\beta}}_{1,p}$ ***d91pcta***	$\hat{\hat{\beta}}_{2,p}$ ***ppt***	$\hat{\hat{\beta}}_{3,p}$ ***tmax***	$\hat{\hat{\beta}}_{4,p}$ ***ptdayindex***	$\hat{\hat{\beta}}_{5,p}$ ***shortdum***	$\hat{\hat{\beta}}_{6,p}$ ***cumpptwint***	$\hat{\hat{\beta}}_{0,p}$ ***constant***
29	0.59289	-1.11812	0.00010	-0.13675	0.00507	0.00000	0.30315
30	0.68944	-0.24293	-0.00007	-0.00444	0.00346	0.00000	0.20350
31	0.56705	-1.20224	-0.00338	0.04650	-0.00273	0.00000	0.52813
32	0.79052	0.07667	-0.00047	0.00745	-0.02537	0.00000	0.16817
33	0.73847	-3.12125	0.00011	-0.05552	-0.00011	0.00000	0.16800
34	0.79208	-0.41364	0.00010	-0.01248	0.00826	0.00000	0.13431
35	0.67852	-2.41290	0.00000	-0.00171	0.00020	0.00000	0.20559
36	0.61753	-0.83238	0.00007	-0.01502	0.00102	0.00000	0.19564
37	0.68822	0.10934	-0.00297	0.03617	0.00042	0.00000	0.34565
38	0.74442	-0.69261	-0.00021	-0.00857	0.00685	0.00000	0.07278
39	0.57384	-0.04460	0.00027	-0.00629	-0.00003	0.00000	0.04300
40	0.42344	-0.03909	0.00215	-0.02054	-0.00093	0.00000	-0.14205
41	0.61921	-0.03202	0.00098	-0.01080	-0.00416	0.00000	-0.10590
42	0.56841	-0.00952	0.00050	-0.00559	0.00002	0.00000	-0.03554
43	0.27155	-0.03828	0.00030	-0.00627	-0.00423	0.00000	-0.00237
44	0.89970	-0.00687	0.00009	-0.00118	0.00078	0.00000	-0.01265
45	0.48782	-0.09624	0.00004	-0.00332	-0.00013	0.00000	0.00068
46	0.44229	-0.00243	0.00007	-0.00086	-0.00151	0.00000	-0.00546
47	1.87684	-0.01012	0.00005	-0.00152	0.00003	0.00000	0.04007
48	1.09058	-0.02965	0.00031	-0.00702	0.00093	0.00000	0.01186
49	0.55530	-0.05143	0.00178	-0.02231	0.00778	0.00000	-0.04411
50	0.98108	-0.03629	0.00007	-0.00316	-0.00523	0.00000	-0.00300
51	0.62378	-0.11767	0.00014	-0.00875	-0.00048	0.00000	0.00340
52	0.40152	-0.00234	-0.00004	0.00016	0.00102	0.00000	0.00036

Table A.4.4.4.2.6. Model-averaged coefficients for predicting the percent of Total A diversion through arc D11 specific to each 5-day period of the irrigation water year.

Period	$\hat{\hat{\beta}}_{1,p}$ **d11pcta**	$\hat{\hat{\beta}}_{2,p}$ **ppt**	$\hat{\hat{\beta}}_{3,p}$ **tmax**	$\hat{\hat{\beta}}_{4,p}$ **ptdayindex**	$\hat{\hat{\beta}}_{5,p}$ **shortdum**	$\hat{\hat{\beta}}_{9,p}$ **d11taf**	$\hat{\hat{\beta}}_{6,p}$ **cumd11wint**	$\hat{\hat{\beta}}_{7,p}$ **cumpptwint**	$\hat{\hat{\beta}}_{8,p}$ **pdindexd11**	$\hat{\hat{\beta}}_{0,p}$ **constant**
1	0.00000	0.00000	0.00000	0.00000	0.00000	0.07301	-0.00034	0.00023	-0.00054	0.01869
2	0.81156	-0.00174	-0.00017	0.00116	0.00932	0.00000	-0.00004	-0.00012	-0.00072	0.02610
3	0.43019	0.08239	-0.00005	0.00771	-0.00059	0.00000	-0.00001	-0.00042	-0.00086	0.01621
4	0.66484	-0.03242	0.00013	-0.00603	0.00052	0.00000	0.00001	-0.00013	-0.00003	0.00668
5	0.19510	-0.00585	0.00073	-0.00399	0.00164	0.00000	0.00010	-0.00004	0.00019	-0.01749
6	0.74089	0.15853	0.00009	0.00029	0.00076	0.00000	0.00000	0.00001	0.00004	0.00484
7	0.68091	-0.02076	0.00000	-0.00080	0.00248	0.00000	0.00001	-0.00007	-0.00001	0.01494
8	0.75170	-0.01502	0.00041	-0.00515	-0.00023	0.00000	0.00001	-0.00125	-0.00047	0.00235
9	1.00361	-0.02075	0.00015	-0.00325	-0.00311	0.00000	-0.00001	0.00004	-0.00002	-0.00228
10	0.32083	-0.11076	0.00002	-0.00414	-0.00046	0.00000	0.00000	-0.00014	-0.00021	0.03806
11	0.63233	-0.09542	-0.00003	-0.00055	-0.00059	0.00000	-0.00001	-0.00072	-0.00533	0.03604
12	0.65594	-0.01430	0.00085	-0.02756	0.00011	0.00000	0.00000	0.00000	0.00000	-0.00164
13	0.79517	-0.01189	0.00004	-0.00166	-0.00329	0.00000	-0.00006	-0.00048	-0.00533	0.02879
14	0.44772	-0.01209	0.00000	-0.00028	-0.00579	0.00000	-0.00468	0.00284	-0.00002	0.07476
15	0.82228	-0.00626	0.00009	-0.00311	0.00066	0.00000	-0.00001	0.00045	0.00035	0.02490
16	0.47569	-0.42237	0.00000	-0.00293	-0.00041	0.00000	0.00000	-0.00012	-0.00010	0.06104
17	0.83949	-0.00093	0.00006	-0.00065	-0.00152	0.00000	-0.00001	0.00028	0.00020	0.02379
18	0.06452	-0.29755	0.00008	-0.01389	0.00022	0.00000	0.00000	-0.00011	-0.00007	0.10816
19	0.41162	-0.03275	0.00066	-0.02807	0.00027	0.00000	0.00000	0.00000	0.00000	0.03074
20	0.72065	-0.32597	0.00002	-0.01170	0.00021	0.00000	0.00000	0.00000	0.00000	0.06758
21	0.60006	-0.01591	0.00009	-0.00247	-0.01668	0.00000	0.00000	0.00000	0.00000	0.06917
22	0.44099	-0.12259	0.00004	-0.00380	0.00011	0.00000	0.00000	0.00000	0.00000	0.08588
23	0.33793	-0.08527	0.00027	-0.00852	-0.00357	0.00000	0.00000	0.00000	0.00000	0.09005
24	0.33401	-0.02003	0.00038	-0.02713	-0.00509	0.00000	0.00000	0.00000	0.00000	0.09773
25	0.23845	-0.02368	0.00016	-0.00288	-0.00829	0.00000	0.00000	0.00000	0.00000	0.12582
26	0.40076	-0.22377	0.00017	-0.01903	-0.00002	0.00000	0.00000	0.00000	0.00000	0.11464
27	0.85083	-0.12250	0.00017	-0.00589	0.00126	0.00000	0.00000	0.00000	0.00000	0.02723

Period	$\hat{\hat{\beta}}_{1,p}$ ***d11pcta***	$\hat{\hat{\beta}}_{2,p}$ ***ppt***	$\hat{\hat{\beta}}_{3,p}$ ***tmax***	$\hat{\hat{\beta}}_{4,p}$ ***ptdayindex***	$\hat{\hat{\beta}}_{5,p}$ ***shortdum***	$\hat{\hat{\beta}}_{9,p}$ ***d11taf***	$\hat{\hat{\beta}}_{6,p}$ ***cumd11wint***	$\hat{\hat{\beta}}_{7,p}$ ***cumpptwint***	$\hat{\hat{\beta}}_{8,p}$ ***pdindexd11***	$\hat{\hat{\beta}}_{0,p}$ ***constant***
28	0.47245	0.85496	0.00000	0.00030	0.01878	0.00000	0.00000	0.00000	0.00000	0.07014
29	0.72650	-0.05503	-0.00003	-0.00270	-0.00205	0.00000	0.00000	0.00000	0.00000	0.05750
30	0.69444	-0.02431	0.00004	-0.00150	0.01467	0.00000	0.00000	0.00000	0.00000	0.02297
31	0.58760	-1.75888	-0.00041	0.00480	0.00298	0.00000	0.00000	0.00000	0.00000	0.08048
32	0.77070	-0.00247	-0.00004	0.00023	-0.00731	0.00000	0.00000	0.00000	0.00000	0.02995
33	0.66535	-0.01554	0.00001	-0.00073	-0.02172	0.00000	0.00000	0.00000	0.00000	0.04518
34	0.53705	-0.00340	-0.00019	0.00148	-0.00144	0.00000	0.00000	0.00000	0.00000	0.06634
35	0.45320	0.00214	-0.00027	0.00239	-0.00134	0.00000	0.00000	0.00000	0.00000	0.07921
36	0.65755	0.00440	0.00010	-0.00041	-0.00038	0.00000	0.00000	0.00000	0.00000	0.03655
37	0.73441	-0.09679	0.00023	-0.00667	-0.00039	0.00000	0.00000	0.00000	0.00000	0.01212
38	0.42220	-0.00349	-0.00064	0.00229	-0.00131	0.00000	0.00000	0.00000	0.00000	0.12308
39	0.54685	0.00488	0.00024	-0.00128	-0.00029	0.00000	0.00000	0.00000	0.00000	0.02126
40	0.54022	-0.00384	0.00048	-0.00279	-0.00287	0.00000	0.00000	0.00000	0.00000	0.00782
41	0.47370	-0.00237	0.00302	-0.00550	-0.00002	0.00000	0.00000	0.00000	0.00000	-0.18044
42	0.47340	-0.01208	0.00003	-0.00144	0.00027	0.00000	0.00000	0.00000	0.00000	0.03649
43	0.62588	-0.05757	0.00005	-0.00244	-0.00288	0.00000	0.00000	0.00000	0.00000	0.02007
44	0.54080	-0.01005	0.00013	-0.00174	0.00027	0.00000	0.00000	0.00000	0.00000	0.01941
45	0.98573	-0.02386	-0.00048	0.00070	-0.00002	0.00000	0.00000	0.00000	0.00000	0.03722
46	0.70021	-0.00987	0.00008	-0.00163	-0.00088	0.00000	0.00000	0.00000	0.00000	0.01247
47	0.71077	-0.01267	0.00006	-0.00186	-0.00269	0.00000	0.00000	0.00000	0.00000	0.00892
48	0.61525	0.00468	0.00000	0.00039	0.00486	0.00000	0.00000	0.00000	0.00000	0.01640
49	0.82883	0.01144	-0.00002	0.00092	-0.00066	0.00000	0.00000	0.00000	0.00000	0.00889

Table A.4.4.4.2.7. Model-averaged coefficients for predicting the percent of Total A diversion through arc D12A specific to each 5-day period of the irrigation water year.

Per-iod	$\hat{\hat{\beta}}_{1,p}$ ***d12apcta***	$\hat{\hat{\beta}}_{2,p}$ ***ppt***	$\hat{\hat{\beta}}_{3,p}$ ***tmax***	$\hat{\hat{\beta}}_{4,p}$ ***ptdayindex***	$\hat{\hat{\beta}}_{5,p}$ ***shortdum***	$\hat{\hat{\beta}}_{9,p}$ ***d12ataf***	$\hat{\hat{\beta}}_{6,p}$ ***cumd12awint***	$\hat{\hat{\beta}}_{7,p}$ ***cumpptwint***	$\hat{\hat{\beta}}_{8,p}$ ***pdindexd12a***	$\hat{\hat{\beta}}_{0,p}$ ***constant***
1	0.00000	0.00000	0.00000	0.00000	0.00000	0.18305	-0.00128	-0.00062	-0.01744	0.11927
2	0.81802	-0.00416	0.00356	-0.01294	-0.00141	0.00000	0.00000	0.00015	0.00026	-0.13215
3	0.50800	0.02508	0.00034	-0.00047	0.01952	0.00000	0.00007	-0.01538	-0.00328	0.06648
4	0.74563	-0.02448	-0.00004	-0.00113	0.00581	0.00000	0.00006	0.00026	0.00154	0.03679
5	0.94796	0.00776	0.00041	-0.00108	-0.03660	0.00000	-0.00014	0.00009	-0.00095	-0.03227
6	0.70165	0.00825	0.00004	0.00006	0.01693	0.00000	0.00171	-0.00029	0.00346	-0.01036
7	0.83783	-0.14322	0.00045	-0.01472	-0.00078	0.00000	0.00002	-0.00074	-0.00020	0.01350
8	0.71768	-0.03803	0.00096	-0.01296	-0.00424	0.00000	0.00000	-0.00065	-0.00060	-0.00151
9	0.81116	-0.02466	0.00025	-0.00375	-0.01483	0.00000	-0.00005	-0.00103	-0.00336	0.01049
10	0.47693	-0.19870	0.00003	-0.00749	0.01970	0.00000	0.00005	-0.00077	-0.00008	0.06323
11	0.52394	-0.05049	0.00011	-0.00569	0.00006	0.00000	0.00031	-0.01372	-0.00025	0.03948
12	0.53874	0.00830	-0.00306	0.00861	0.00237	0.00000	0.00000	-0.00027	-0.00032	0.21843
13	0.58993	-0.00289	0.00021	-0.00290	-0.00169	0.00000	-0.00015	0.02536	0.00115	0.04005
14	0.54369	-0.01630	0.00013	-0.00254	0.00176	0.00000	0.00622	-0.00014	0.00830	-0.06316
15	0.77568	-0.04073	0.00005	-0.00561	-0.00025	0.00000	-0.00116	0.00200	-0.00066	0.07246
16	0.36187	-0.28472	0.00006	-0.00882	-0.01675	0.00000	0.00008	-0.00111	-0.00006	0.12564
17	0.69767	-0.05804	0.00040	-0.01241	-0.00033	0.00000	0.00009	-0.00051	0.00020	0.04328
18	0.47018	0.00286	0.00011	-0.00074	0.00456	0.00000	0.00034	0.00058	0.00862	0.06206
19	0.22942	-0.00854	-0.00003	-0.00010	0.05956	0.00000	0.00000	0.00000	0.00000	0.15117
20	1.03382	0.00251	0.00000	0.00023	-0.07933	0.00000	0.00000	0.00000	0.00000	0.05434
21	0.76818	-0.01832	-0.00001	-0.00091	0.04779	0.00000	0.00000	0.00000	0.00000	0.04952
22	0.70908	-0.00292	0.00016	-0.00232	-0.00672	0.00000	0.00000	0.00000	0.00000	0.04407
23	0.46171	-0.12922	0.00003	-0.00435	-0.00685	0.00000	0.00000	0.00000	0.00000	0.14161
24	0.67594	0.02001	-0.00181	0.05507	0.00271	0.00000	0.00000	0.00000	0.00000	0.17308
25	0.61014	0.08799	-0.00014	0.00581	0.00959	0.00000	0.00000	0.00000	0.00000	0.09351
26	0.93549	-0.08750	0.00060	-0.01972	0.00215	0.00000	0.00000	0.00000	0.00000	-0.01883
27	0.81487	0.02788	0.00001	0.00063	0.00394	0.00000	0.00000	0.00000	0.00000	0.00657

Per-iod	$\widehat{\overline{\beta}}_{1,p}$ ***d12apcta***	$\widehat{\overline{\beta}}_{2,p}$ ***ppt***	$\widehat{\overline{\beta}}_{3,p}$ ***tmax***	$\widehat{\overline{\beta}}_{4,p}$ ***ptdayindex***	$\widehat{\overline{\beta}}_{5,p}$ ***shortdum***	$\widehat{\overline{\beta}}_{9,p}$ ***d12ataf***	$\widehat{\overline{\beta}}_{6,p}$ ***cumd12awint***	$\widehat{\overline{\beta}}_{7,p}$ ***cumpptwint***	$\widehat{\overline{\beta}}_{8,p}$ ***pdindexd12a***	$\widehat{\overline{\beta}}_{0,p}$ ***constant***
28	0.76392	-0.23708	0.00017	-0.00605	-0.00737	0.00000	0.00000	0.00000	0.00000	0.02694
29	0.81036	-0.00158	-0.00052	0.00501	-0.00129	0.00000	0.00000	0.00000	0.00000	0.06148
30	0.83403	0.18065	-0.00048	0.01650	-0.00327	0.00000	0.00000	0.00000	0.00000	0.07737
31	0.62705	5.46917	0.00036	-0.00409	0.00198	0.00000	0.00000	0.00000	0.00000	0.02542
32	0.68780	-0.14152	0.00032	-0.00844	-0.00024	0.00000	0.00000	0.00000	0.00000	0.03492
33	0.77325	0.09220	-0.00014	0.00541	-0.02715	0.00000	0.00000	0.00000	0.00000	0.04019
34	0.53871	0.08192	-0.00060	0.02100	0.00147	0.00000	0.00000	0.00000	0.00000	0.11879
35	1.06332	0.01770	0.00020	-0.00100	-0.00052	0.00000	0.00000	0.00000	0.00000	0.00698
36	0.74104	-0.01487	0.00038	-0.00345	-0.00222	0.00000	0.00000	0.00000	0.00000	0.02980
37	0.73660	0.01336	0.00005	-0.00005	0.01212	0.00000	0.00000	0.00000	0.00000	0.05461
38	0.72754	0.00388	0.00023	-0.00126	-0.02137	0.00000	0.00000	0.00000	0.00000	0.02525
39	0.67850	0.02486	-0.00115	0.01003	0.00418	0.00000	0.00000	0.00000	0.00000	0.12946
40	0.58512	-0.00461	-0.00007	0.00036	0.00380	0.00000	0.00000	0.00000	0.00000	0.04039
41	0.48806	0.06198	-0.00003	0.00252	0.00390	0.00000	0.00000	0.00000	0.00000	0.06385
42	0.85842	0.01809	-0.00018	0.00385	0.00344	0.00000	0.00000	0.00000	0.00000	0.01941
43	0.77617	0.04323	-0.00004	0.00211	0.00025	0.00000	0.00000	0.00000	0.00000	0.01957
44	0.54905	-0.03201	0.00044	-0.00596	-0.00250	0.00000	0.00000	0.00000	0.00000	0.01051
45	0.76631	-0.05339	-0.00015	-0.00012	-0.03242	0.00000	0.00000	0.00000	0.00000	0.04758
46	0.36573	-0.00601	-0.00025	0.00186	-0.00149	0.00000	0.00000	0.00000	0.00000	0.11049
47	0.50002	-0.02650	0.00032	-0.00677	-0.00074	0.00000	0.00000	0.00000	0.00000	0.05247
48	0.83936	0.01029	0.00020	-0.00061	0.00080	0.00000	0.00000	0.00000	0.00000	0.02084
49	0.84612	-0.02674	0.00136	-0.01716	0.00189	0.00000	0.00000	0.00000	0.00000	-0.05438

A.4.4.4.3. Implementing the Agricultural Water Delivery Sub-model in the KBPM

In the KBPM, the sub-model described in preceding sections has been fully implemented. For each 5-day period of the spring/summer irrigation season, the sub-model predicts the percent of Total A diversions to be delivered through each diversion arc. Several additional steps were taken within the KBPM to calculate the daily flow to be delivered through each diversion arc.

An estimate of Total A diversions was necessary in order to compute the daily diversions. Predicated on the assumption that the Project Supply will be fully used in each year, KBPM runs were iterated to obtain estimates of two variables used to estimate Total A diversions. Total seasonal diversion of return flow from the LRDC and pumps F/FF for all diversion arcs (dir_div_acc_est) was calculated from KBPM output. Also, the predicted percentages of Total A diversions from KBPM output were summed across diversion arcs for each irrigation water year, and a simple proportional adjustment (Pct_tota_adjust) was developed to correct for departures of these sums from 100%. Then the estimated Total A diversion (esttota) was calculated as:

esttota = PrjSupply_irr + dir_div_acc_est + Pct_tota_adjust * PrjSupply_irr

where PrjSupply_irr = PrjSupply - RefugeFallSupply

Daily diversions were then computed for each diversion arc by multiplying esttota by the predicted percent of Total A diversion for the appropriate 5-day period, dividing the product by 5 days, and converting the volume to cfs. D1 diversions always were comprised solely of UKL water. The other diversion arcs were split into arcs accounting for diversion of UKL water (Project Supply) as opposed to diversion of return flow.

A.4.4.5. Project Return Flows

Project return flow results from delivered water which could not be fully consumed by the Project land to which it was applied. At some times of year, return flows from irrigation are frequently mixed with runoff from precipitation or snowmelt. Return flows are considered separately for the three different irrigation areas of A1, A2 and the LKNWR (see Figure A.4.3.1.1).

Area A1 returns flow to the Lost River downstream of Harpold Dam. This return flow is accounted for through the time-series input (i.e. historical daily flow measured at LRDC headworks) of the Lost River to the Lost River Diversion Channel, or I91 in the model. Because the area between Harpold Dam and the LRDC headworks is served by D1 (A Canal) diversions, the inflows in the I91 arc were adjusted either up or down to reflect changes in A Canal diversion from what occurred historically. For example, historical I91 flow was zero for extended periods during the irrigation shutoff in 2001, whereas the KBPM simulates substantial A Canal diversion throughout 2001 under the Proposed Action. In this case, I91 flows had to be adjusted upwards to reflect the likely outcome of the Proposed Action in such a year. Conversely, simulated A Canal diversion in 1992 under the Proposed Action were much smaller than the actual diversions in that year, requiring a downward adjustment of I91 flow in the simulation.

Adjustments to LRDC inflow reflecting changed (relative to historical) A Canal diversions were made by first subtracting each 5-day period sum of simulated D1 deliveries from the historical

D1 deliveries. Multiplying this difference by 0.2, subtracting the result from I91, dividing this result by 5 days, and converting the resulting daily volume to cfs completed the adjustment. The 0.2, essentially the expected proportion of A Canal diversion expected to appear as return flow at the LRDC headworks, was selected because it produced simulated LRDC inflows of a reasonable magnitude relative to the base flow periods of other years. As a result of this process, the LRDC inflows now respond dynamically to changes in D1 diversions.

Total Area A2 return flows from the Project and Refuge lands (LKNWR and Area K) through the KSD are represented as C131 in the KBPM. Variable C131 can be further divided into return flows from the Project (return flow arc R131a) and LKNWR (return flow arc R131b), along with local runoff from the surrounding area. The Proposed Action assumes R131b to be zero, a conservative assumption reflecting the likely result of LKNWR supply reductions from the historical condition.

Agricultural return flows in R131a were simulated dynamically by a series of simple models estimating non-Refuge return flows from the F/FF pumps for different time periods throughout the year. Different models were required for different periods because of the manner with which water is managed. In Area A2, the agricultural lands are typically flooded over the winter months, pumped off in the late winter or early spring, and then irrigated through the summer and fall months. More extensive winter flood-up can be expected to incrementally reduce the irrigation demand (and the associated return flow) during the following spring and summer, and vice versa. Winter precipitation contributes to the extent of the winter flood-up, as well as the return flow volume pumped off.

All analyses were done using the 5-day periods of the irrigation water year described in Section 4.4.4.1. The irrigation water year was split into two seasons for the purpose of developing variables for use in modeling F&FF return flows. Periods 50-14 encompass the winter and spring periods when flood-up and pump-off activities are prevalent in Area A2. Periods 15-49 encompass the late spring through early fall period comprising the bulk of the growing season. Average daily precipitation (inches) and average daily maximum temperature (°F) for Area A2 were a subset of those used for the agricultural water delivery sub-model development (see section 4.4.4.1); that is, these data were from the PRISM grids in Area A2 in Figure A.4.4.4.1.1. In order to combine precipitation with diversions, average precipitation depth was converted to precipitation volume (TAF) by multiplying it by the approximate irrigated acreage within KDD (27,000 acres).

Historical daily D11 and D12A diversions into Area A2 were summed and used to quantify daily irrigation diversions into A2. Total agricultural diversion plus precipitation volume was computed for each period (variable cum_KDD_in_5d). Cumulative agricultural diversion plus precipitation volume was computed for periods 50-14 (variable cum_KDD_in_p50to14) and 15-49 (variable cum_KDD_in_p15to49); values for these two variables were held constant after the end period until the next starting period was encountered. These three variables were rescaled to be between 0 and 1 (normalized; see formula in Section A.4.4.4.1), and the prefix "norm_" was appended to each of their variable names.

Historical daily returns from the LKNWR measured at KSD at Stateline Road were subtracted from the historical daily volume pumped into the Klamath River at pumps F/FF, assuming a 1-day travel time within the KSD. These historical daily return flows absent the LKNWR returns were summed by 5-day period (variable FFFagout) and used as the dependent variable in developing the simple models used to simulate R131a in the KBPM.

Various expressions of agricultural return flow in the current period relative to combined ag diversion and precipitation as of the end of the previous period (indicated by the prefix “lag_”) were calculated:

cum_KDD_in_5d_prop = (FFFagout + 1) / (lag_cum_KDD_in_5d + 1)

cum_KDD_in_p50to14_prop = (FFFagout + 1) / (lag_cum_KDD_in_p50to14 + 1)

cum_KDD_in_p15to49_prop = (FFFagout + 1) / (lag_cum_KDD_in_p15to49 + 1)

Averages by 5-day period across irrigation water year were calculated for each of these variables, denoted by the prefix “avg_”.

A series of potential models estimating FFFagout was developed and evaluated based on error characteristics. For each model, error (simulated FFFagout – actual FFFagout) was summarized by 5-day period as mean error (ME), mean square error (MSE), and mean absolute error (MAE). Only the models selected for use in the KBPM are presented here. The models are:

Model_9 = max(0, avg_cum_KDD_in_5d_prop * (lag_cum_KDD_in_5d + 1) - 1)

Model_10 = max(0, model_9 + (-1 * lag_norm_cum_KDD_in_5d * model_9))

Model_11 = max(0, avg_cum_KDD_in_p50to14_prop * (lag_cum_KDD_in_p50to14 + 1) - 1)

Model_12 = max(0, model_11 + (-1 * lag_norm_cum_KDD_in_p50to14 * model_11))

Model_13 = max(0, avg_cum_KDD_in_p15to49_prop * (lag_cum_KDD_in_p15to49 + 1) - 1)

Model_14 = max(0, model_13 + (-1 * lag_norm_cum_KDD_in_p15to49 * model_13))

Model_17 = (model_11 + model_12) / 2

Model_19 = (model_9 + model_11) / 2

Model_20 = (model_9 + model_10 + model_11 + model_12) / 4

Model_22 = (model_9 + model_10 + model_11 + model_12 + model_13 + model_14) / 6

In the KBPM, R131a is computed using:
Model_11 for periods 1-9 and 62-73;

Model_19 for periods 10-32;
Model_20 for periods 33-50;
Model_22 for periods 51-55; and
Model_17 for periods 56-61.

Daily estimates of R131a were obtained by dividing each model result by the number of days in the period and converting from volume to cfs. Implementation of this logic in the KBPM makes R131a dynamically responsive to past irrigation diversions and precipitation.

Errors associated with simulating R131a (Table A.4.4.5.1) tend to be larger during the winter and early spring, tend towards overestimation during the first half of the irrigation water year, but tend towards underestimation during the last half. Note that this model structure was intended only for use in the KBPM. Real-time operational forecasts of R131a are possible and could be developed if deemed useful to operations.

Table A.4.4.5.1. Error characteristics associated with the models used to simulate R131a in the KBPM. Period is 5-day period of the irrigation water year, which begins on March 1. Error is computed as simulated minus actual FFFagout (units are TAF). ME is mean error; MSE is mean square error; and MAE is mean absolute error.

Period	ME	MSE	MAE		Period	ME	MSE	MAE
1	0.016	1.123	0.850		38	-0.151	0.121	0.285
2	0.039	1.146	0.922		39	-0.150	0.152	0.323
3	0.012	1.039	0.823		40	-0.134	0.097	0.237
4	0.010	1.531	1.008		41	-0.129	0.137	0.291
5	0.029	1.443	0.988		42	-0.089	0.087	0.232
6	0.008	1.047	0.782		43	-0.101	0.119	0.269
7	0.025	0.893	0.709		44	-0.063	0.073	0.196
8	0.015	0.960	0.765		45	-0.066	0.052	0.178
9	0.014	0.464	0.525		46	-0.046	0.031	0.129
10	0.050	0.175	0.322		47	-0.030	0.045	0.170
11	0.074	0.184	0.306		48	-0.028	0.070	0.192
12	0.068	0.211	0.334		49	-0.002	0.040	0.142
13	0.088	0.193	0.301		50	-0.069	0.042	0.141
14	0.072	0.110	0.249		51	-0.024	0.074	0.196
15	0.107	0.253	0.321		52	0.039	0.120	0.255
16	0.066	0.095	0.250		53	-0.032	0.070	0.218
17	0.093	0.160	0.287		54	-0.019	0.077	0.216
18	0.081	0.132	0.295		55	-0.031	0.117	0.220
19	0.066	0.134	0.285		56	-0.057	0.072	0.212
20	0.068	0.124	0.277		57	-0.066	0.093	0.241
21	0.079	0.163	0.332		58	-0.102	0.089	0.220
22	0.069	0.159	0.301		59	-0.096	0.122	0.260
23	0.067	0.154	0.327		60	-0.104	0.100	0.230
24	0.056	0.150	0.318		61	-0.135	0.119	0.263
25	0.050	0.164	0.334		62	0.074	0.179	0.330
26	0.059	0.142	0.291		63	0.048	0.328	0.400
27	0.077	0.154	0.311		64	0.067	0.237	0.361
28	0.075	0.153	0.311		65	0.009	0.224	0.335
29	0.066	0.104	0.262		66	-0.024	0.487	0.467
30	0.063	0.090	0.238		67	-0.021	0.581	0.537
31	0.078	0.187	0.352		68	-0.033	0.494	0.511
32	0.085	0.127	0.297		69	-0.034	0.650	0.637
33	-0.143	0.102	0.246		70	-0.028	0.846	0.735
34	-0.102	0.095	0.215		71	-0.008	0.955	0.766
35	-0.120	0.115	0.270		72	-0.006	1.140	0.886
36	-0.177	0.144	0.281		73	0.006	1.249	0.867
37	-0.199	0.119	0.281					

In past versions of the KBPM (including the original spreadsheet model, KPSIM) a variable called A2 Winter Runoff was included in determining the C131 flow. In reality, this term had little to do with runoff – it has always been an error closure term. In the present KBPM, the name A2 Winter Runoff has been dropped, although the error closure term has been retained. This error closure term, I131, is input to the KBPM as an inflow arc, though it is comprised of both positive and negative terms. It was derived by using the model structure described above to simulate the historical FFFagout, and then subtracting the simulated FFFagout from the historical.

A.4.4.6. EWA Use in Model

The EWA is accounted for through releases for the Klamath River through LRD and releases for flood protection. The flood control releases are further described in Sections A.4.4.8 and A.4.4.10. Regardless of the intent of the release, all LRD releases that are not diverted to the Project or LKNWR are counted against the EWA. Furthermore, during IGD controlled flow conditions (e.g., minimum required flows, IGD targeted flows, ramping flows), contributions to IGD flow from LRDC and F/FF pumping are counted as EWA releases when they result in an equivalent reduction in LRD releases to support Klamath River flows. This does not happen when UKL is in flood control.

Targeted flows from March to September are the sum of a formulated LRD release, Keno Reservoir accretions, and Keno to IGD accretions. These flow targets control IGD operations when they are greater than the required minimum flows. There are two LRD release formulas for EWA use: one that applies March to June, and one that applies July to September. EWA releases in service of IGD flow targets are subject to reduction under the UKL control logic (reduction applies to LRD specifically, as described below). EWA releases in service of disease mitigation/habitat flows (as defined in Section A.4.4.7 and BA, Section 4.3.2.2.2.4), minimum required IGD flows, and IGD ramping flows are not subject to reduction under UKL control logic.

The spring/summer LRD release formulation is based on EWA allocation and UKL control logic from March 1 – September 30, and additionally accounts for UKL net inflow and forecasted March-September UKL net inflow from March 1 – June 30 (but not from July 1 – September 30, as described below). From March 1 – June 30 there is also a correction applied that accelerates EWA release if there was under-release in previous days (e.g., due to UKL control) and decelerates EWA release if there was an over-release in previous days (e.g., due to flood control or surface flushing flows). The following steps are taken to calculate the LRD Release:

1. Calculate **in_pct_Mar50vol**, used to ensure that LRD releases for IGD flows properly reflect both the UKL net inflow from the previous day and an appropriate adjustment to account for NRCS forecast error experienced through the current day. This release adjustment is calculated March through June, relying upon the Mar50vol (March 1 – June 1 monthly NRCS forecast of UKL net inflow, combined with actual net inflow since March 1). Experienced forecast error is added to the Mar50vol in order to ensure that releases are increased or decreased to account for deviations from prior UKL net inflow forecasts. In addition, a further release correction, in the form of a UKLSupply dependent quadratic equation developed from model output, is made to avoid substantial over or underspending of calculated EWA across the season. The in_pct_Mar50vol variable is calculated as follows:

$$\begin{aligned}\text{In\_pct\_Mar50vol} = {} & \max(0, \text{I1}(-1) / (\text{Mar50vol} +\_\text{fcst\_error}) * (1 - 0.000000029263 * \\ & \text{UKLSupply}^2 - 0.000107692714 * \text{UKLSupply} + 0.082201089297))\end{aligned}$$

where: I1(-1) = yesterday's UKL net inflow
Mar50vol = NRCS forecast of inflow to UKL, March through September
fcst_error = 0 in March; otherwise, from April to June
[Last month's 50% exceedance UKL net inflow forecast] –

[Last month's actual UKL net inflow] –
[This month's 50% exceedance UKL net inflow forecast]
UKLSupply = calculated UKL Supply as described in section A.4.4.3

2. Determine **Link_release_ss_diff**, which is the cumulative difference between what was actually released from LRD to support IGD flows yesterday and what was expected to be released to support yesterday's IGD flow target. This variable ensures that actual LRD releases remain in line with what is calculated so that seasonal expenditure of EWA remains on track to utilize the full EWA. Link_release_ss_diff serves as a correction for previous over or under release. The calculation is as follows:

   Link_release_ss_diff = C1_River(-1) – prj_credit_spill_forEWA + prj_acc_addition_to_EWA – Link_release_SS_prep(-1) + Link_release_ss_diff(-1)

   where: C1_River(-1) = yesterday's actual LRD release yesterday's actual LRD release that flows out of IGD
   prj_credit_spill_forEWA = spill of the UKL credit due to flood releases
   prj_acc_addition_to_EWA = Project return flows that supported EWA release, and, therefore, count as EWA release
   Link_release_SS_prep(-1) = yesterday's calculated LRD release for IGD flow
   Link_release_ss_diff(-1) = yesterday's computation of this same variable

4. Calculate the **Link_release_SS_prep**, which is the release of UKL water at LRD to support IGD flows. As mentioned above, this flow is calculated differently through the summer. In March through June, EWA releases are predicated on UKL net inflow and are adjusted to ensure that as much EWA water is being released as is practicable while keeping EWA expenditure on track to avoid substantial over or underspending by the end of the season. This is accomplished using the in_pct_Mar50vol and Link_release_ss_diff variables described above, as well as by reserving an amount of EWA for July through September IGD flows. This reserved volume is approximately the quantity of water needed to be released from LRD to the river from July to September to meet IGD minimum flows when Keno Reservoir and Keno Dam to IGD accretions are at their historical medians (i.e., 130,000 AF). The March through June formulation is as follows:

   Link_release_ss_prep = in_pct_Mar50vol * (EWA_River – 130 TAF – Link_release_ss_diff)

   where: in_pct_Mar50vol = UKL net inflow release adjustment
   EWA_River = calculated EWA allocation
   Link_release_ss_diff = cumulative difference between actual and calculated LRD release for IGD flow

   For July through September, it is no longer necessary to make the adjustments needed in the March through June period. There is a known volume of EWA remaining, and it is all intended to be expended. If more UKL water is needed to support EWA minima in the July through September period than is remaining in the EWA, UKL supports the over expenditure of EWA to ensure minima are met. The July through September formula is as follows:

Link_release_ss_prep = EWA_remain_JulSep / daysinmonth

where: EWA_remain_JulSep = EWA volume remaining, adjusted for each month; July receives 35% of the remaining volume for July – September, August receives 44% of the remaining volume for August – September, and September receives what remains on September 1.
daysinmonth = the number of days in the current month

5. Determine **Link_release_SS** by adjusting Link_release_ss_prep by the appropriate storage difference ratio (UKL control logic).

6. If the formulated LRD release exceeds the maximum possible LRD release (variable Link_max is the maximum LRD release that varies with UKL surface elevation), then the maximum possible release will be made but the actual IGD flows can fall short of the target. Maximum possible releases range from a high of 8,600 cfs when UKL level is 4143.3 ft., to a low of 900 cfs when UKL level is 4137.0 ft.

7. Lookup **IGmin**, which is the minimum flow at the gauge below IGD (minima for other months not shown here). If the IGD flow target is less than the minimum flow required, then the minimum required flow is released at IGD.

Table A.4.4.6.1. Minimum flow below Iron Gate Dam, March through September

Month	IG_MIF (cfs)
March	1000
April	1325
May	1175
June	1025
July	900
August	900
September	1000

8. Set **C1forC15**, the LRD release to support IGD flows. For the spring/summer period, this is equal to Link_release_SS.

9. Calculate **C15_target**, which is the targeted release at IGD. This calculation relies upon operational values from 3 days prior, the operational delay accounted for in the model, and a forecast of accretions from 3 days prior. Operationally, IGD releases may vary from those calculated here due to real-time accretion values and flood control operations. Releases are not allowed to exceed a specified maximum (IG_max) during the July-September period. Values for IG_max vary with EWA_River, ranging from 1000-1500 cfs in July, 1050-1250 cfs in August, and 1100-1350 cfs in September.

C15_target = min(IG_max, C1forC15 + I10(-3) + I15_forecast2(-3))

where: I10 = LRD to Keno Dam (Keno Reservoir) accretions;
I15_forecast2 = forecasted Keno Dam to IGD accretions;
(-3) = operational lag of three days assumed in the model.

A.4.4.7. Surface Flushing Flows

In addition to normal UKL releases to support IGD flows during the spring/summer period, the PA implements a surface flushing flow between March 1 to April 15 based on criteria outlined below. See the Biological Assessment, Section 4.3.2.2.2.4 for additional context regarding Reclamation's proposed implementation of approximately 50,000 AF of EWA in dry years and considerations for real-time operations.

Spring/summer IGD flow targets are determined as described in Section A.4.4.6 on a daily basis. However, between March 1 and April 15, a surface flushing flow may replace the daily formula for a three-day period under certain conditions. Surface flushing flows are forced by the model in years in which calculated EWA on March 1 or April 1 is less than 575,000 AF and certain hydrologic conditions are met. If hydrologic conditions supporting a 6,030 cfs surface flushing flow do not occur in these forced flow years, the model will produce maximum releases from Link River Dam for three days beginning on April 15. In years in which the calculated EWA on March 1 or April 1 is greater than or equal to the 575,000 AF threshold, a surface flushing flow may occur on an opportunistic basis if favorable hydrologic conditions exist. Implemented surface flushing flows are subject to ramping rates (see A.4.4.11). Flows which meet the KBPM criteria of a surface flushing flow, but happen outside of the March 1 to April 15 window, will not satisfy model requirements of a surface flushing flow. All surface flushing flow releases are counted against the EWA.

Model conditions on a surface flushing flow are described below. These releases replace normal IGD minimum flows when they are triggered, effectively forcing the model to produce a three-day, 6,030 cfs flow at IGD with attendant releases from LRD. At the end of the three-day period, normal calculation of Link River release resumes.

1. Determine **Link_max_DG1**, which is a conservative estimate of the maximum release from LRD in the months of March and April. The flow estimate is made conservative via a reduction in yesterday's UKL elevation by 0.3 ft., which has the effect of lowering the maximum assumed release. This is to ensure that there is sufficient head to meet the required flow even as UKL levels are dropping over the three-day release. The reduced UKL elevation is used to select a release value from the table **Link_max.table** in KBPM. Intermediary values are linearly interpolated.

2. Calculate **I15_proj_3day**, an average of forecasted Keno Dam to IGD accretions for the next three days. These accretion values are based on the accretion forecast model described in Section A.4.3.3.6. This variable, along with Link_max_DG1, will be used to determine if hydrologic conditions will exist for the next three-day period that would support a surface flushing flow.

   I15_proj_3day = (I15_forecast0 + I15_forecast1 + I15_forecast2) / 3

where: I15_forecast0 = Keno Dam to IGD accretion forecast for today
I15_forecast1 = Keno Dam to IGD accretion forecast for tomorrow
I15_forecast2 = Keno Dam to IGD accretion forecast for 2 days from today

3. Set **DG1_daycount**, a counter that will begin when a surface flushing flow is triggered and ensure that the flow does not exceed the three-day period prescribed in the model.

4. Determine **DG1_supply**, which is a variable that will replace the IG_min if a flushing flow is triggered. The value of this variable is 6,030 cfs, except in the case of a forced flushing flow in which conditions do not allow for release of this magnitude. In this case, maximum LRD releases will be made to create the highest possible IGD flows achievable for three days. Conditions which trigger a flushing flow are as follows:

    a. Forced flushing flow will be implemented if:
        i. Date is between March 1 and April 15;
        ii. EWA < 575,000 AF;
        iii. Link_max_DG1 + I15_proj_3day > 6030 cfs; and
        iv. S1yestelev (yesterday's UKL elevation) > 4142.4 ft.

    b. Opportunistic flushing flow will be implemented if:
        i. Date is between March 1 and April 15;
        ii. EWA ≥ 575,000 AF;
        iii. Link_max_DG1 + I15_proj_3day > 6030 cfs;
        iv. S1yestelev (yesterday's UKL elevation) > 4142.4 ft.; and
        v. C15(-1) [yesterday's Iron Gate Dam flow] > 3999 cfs.

    c. If March/April 1 EWA is less than 575,000 AF and no flushing flow has been implemented by April 15, a flushing flow (maximum possible, up to 6,030 cfs, release for 72 hours) is attempted regardless of UKL elevation, maximum LRD capacity, or IGD flow.

5. Once a surface flushing flow has been triggered during the March 1 to April 15 time period in a given water year, the model will not try to produce the surface flushing flow again in that water year.

A.4.4.8. EWA and Flood Control Releases

Flood control releases occur any time UKL elevation exceeds the allowable flood control elevation under normal operations criteria (discussed further in Section A.4.4.10). During the irrigation season, these releases typically occur March through May in average to wet years, but can occur at any time of year depending on the rate of snow melt, fall and winter inflow, and carry over storage in UKL.

When releases are made for flood control, they are counted against the EWA and factored into future EWA releases. In some cases, the flood control releases can be so large that the remaining EWA volume would not be considered adequate to provide acceptable Klamath River fish habitat for the remainder of the spring/summer period.

In order to protect against this scenario, a measure was added to ensure that the remaining EWA was enough to accommodate the minimum fish needs. This protection is considered whenever the total flood control releases have exceeded 22% of EWA_River by June 1. This measure ensures a certain volume of remaining EWA each month according to the following criteria:

1. If the total flood control releases that have occurred by June 1 exceed 22% of the EWA on June 1, then the remaining EWA is reset to 25% of the total June 1st EWA.

2. If the total flood control releases that have occurred by July 1 exceed 22% of the EWA (as calculated on June 1), then the remaining EWA is reset to 18% of the total EWA.

3. If the total flood control releases that have occurred by August 1 exceed 22% of the EWA (as calculated on June 1), then the remaining EWA is reset to 13% of the total EWA.

4. If the total flood control releases that have occurred by September 1 exceed 22% of the EWA (as calculated on June 1), then the remaining EWA is reset to 7% of the total EWA.

It is unlikely that spills will continue after June, however the potential for this does occur in very wet years where UKL remains full throughout the spring. The model results show that, when following this management plan, flood control releases do not occur in any year in the period of record after June.

A.4.4.9. LKNWR Operations

Water delivery to LKNWR is modeled in the KBPM in four distinct time periods: April through September delivery of a water right transferred from Upper Klamath National Wildlife Refuge (UKNWR; see the Biological Assessment, Section 4.3.2.2.8 for additional details); June through July delivery of UKL water; August through November delivery of Project Supply (see the Biological Assessment, Section 4.3.2.2.2.2 for additional details); and December through February delivery of winter maintenance flow. Reclamation, USFWS, and Project irrigators are currently undertaking a process to develop a shortage sharing agreement (per the 2017 memo from Deputy Secretary of the Interior Connor) to distribute a portion of Project Supply to LKNWR; as this process is on-going, this Biological Assessment will not include specific information regarding LKNWR deliveries from Project Supply between August and November. See the Biological Assessment, Section 4.3.2.2.2.2 for additional context and details regarding this process.

There is no provision for delivery to LKNWR in the month of March. All modeled delivery of water to LKNWR occurs through the Ady Canal. Additional water may be made available to LKNWR from the D Plant pumps, but this water is not modelled in the KBPM nor considered within the scope of this action. However, it is Reclamation’s assumption that D Plant water, if and when delivered, will be utilized on LKNWR, unless the water is necessary to meet other legal obligations of the Project.

1. Delivery of the transferred water right occurs from April 1 through September 30. This water right, transferred from its original place of use at UKNWR, is for a daily flow of up to 30.3 cfs, which is the determined consumptive use volume of the transferred right. This flow is delivered on a daily basis in the model and is not subject to reduction via the UKL control logic. Delivery of this transferred water right is only available if Sevenmile Creek is not regulated to a senior water right (i.e., the Project); the portion of the original UKNWR water right on the Wood River was not considered here given that the Wood River is often regulated to the Klamath Tribes' Time Immemorial water right and therefore not available for transfer. See the Biological Assessment, Section 4.3.2.2.8 for additional details regarding this transferred water right.

2. Delivery of UKL water to LKNWR in the June 1 through July 31 period is conditioned on the following:

    a. The refuge has no target delivery in June through July if Project Supply is less than 350 TAF, which is considered a full supply in this Proposed Action.

    b. In June through July, if the Project has a full supply and if UKL elevation is above the threshold level denoted in Table A.4.4.9.1, then LKNWR can receive a daily delivery equal to the monthly demand, also in Table A.4.4.9.1, converted to cubic feet/second and divided by the number of days in the month. These deliveries are conditioned on UKL elevation remaining above the threshold for the month; if UKL drops below this threshold, deliveries will cease. Deliveries in these months of UKL water do not count against Project Supply nor do they affect delivery of the aforementioned transferred water right.

Table A.4.4.9.1. Monthly LKNWR demand and UKL elevation threshold which condition LKNWR deliveries.

Month	Refuge Demand (TAF)	UKL Threshold (ft)
June	5.94	4142.5
July	6.93	4141.5

3. The details regarding delivery of Project Supply to LKNWR have not yet been established. As mentioned above, Reclamation, USFWS, and Project irrigators are currently undertaking a process to determine what portion of Project Supply is appropriate for delivery to LKNWR between August 1 and November 30; those details are not yet available. See the Biological Assessment, Section 4.3.2.2.2.2 for additional details regarding this process.

4. A maintenance flow is made available to LKNWR in the months of December through February. This flow is intended to allow LKNWR managers to receive water during a time of decreased demand from other users in order to manage their resources for the Spring-Summer season when demand from other users is highest and less water is made available to the refuge. Flows during this time period are capped at 62 cfs/day, or a total of up to 11,000 AF for the December through February period. These flows are subject to reduction via UKL control logic on a daily basis.

A.4.4.10. Flood Control Operations

Flood control operations are implemented in order to protect the infrastructure surrounding UKL. The modeled flood control operations were developed to mimic realistic flood control operations; however real-time management (i.e., professional judgement) will also be used in order to ensure safety and appropriate water management within UKL. The modeled operations manage the water during winter and early spring in a manner that prevents UKL from filling too early and remaining at or near full pool for several months in wetter years. The modeled flood control operations attempt to balance liability risk with risks associated with diminished water supplies for the Project, LKNWR, and the Klamath River. Actual flood control releases will be made at the discretion of Reclamation and PacifiCorp (the operator of LRD) in coordination with USFWS and National Marine Fisheries Service.

Outline of Flood Control Operations

The general process of flood control consists of spilling water from UKL when necessary to prevent elevations from increasing above flood pool elevations, which change throughout the year in response to inflow forecasts and experienced hydrology. Flood pool elevation is calculated each day to create a smooth UKL operation, allowing UKL to fill by the end of March in drier years and by the end of April in wetter years.

The flood control elevations (termed “threshold” by the model language included below) are determined through the following process:

1. The UKL flood control elevation is set at 4141.4 ft. in September and October and then is steadily increased from 4141.4 ft. to 4141.8 ft. from November 1 through December 31. In most years, there are no flood control releases during these months.

2. From January 1 through April 30, the UKL flood control elevations are determined based on the forecasted inflow and the day of the month. The NRCS UKL net inflow forecast is used to determine the end of month flood control elevation each month (using Table A.4.4.10.1 below) and the daily flood control elevation is linearly interpolated between the current end of month elevation and the previous month’s end of month flood control elevation.

    a. The distinction between wet conditions and dry conditions in Table A.4.4.10.1 is made based on the NRCS March through September 50% exceedance probability forecast for UKL net inflow volume issued in January, February and March. The forecast issued in March is used for both March and April. If the forecasted March through September net UKL inflow is greater than 710,000 AF, the year is considered wet; the water year is considered dry if the forecasted net inflow is equal to or less than 710,000 AF.

    b. The daily flood control elevation is calculated using the equation below:

Current Threshold = [Yesterday's threshold value] + ([This month's threshold] – [Last month's threshold]) / [Number of days in the month]
Note: The threshold will not decrease from day to day.

3. The UKL flood control elevations remain at the April 30 level from May 1 through August 31.

Table A.4.4.10.1. UKL flood control elevations for the last day of each month under relatively dry or wet conditions.

Month	Dry Condition Elevation (ft) (Forecast ≤ 710 TAF)	Wet Condition Elevation (ft) (Forecast > 710 TAF)
October	4141.4	4141.4
November	4141.6	4141.6
December	4141.8	4141.8
January	4142.3	4142.0
February	4142.7	4142.4
March	4143.1	4142.8
April	4143.3	4143.3

A.4.4.11. Flow Ramping

Flow ramping at IGD

The target ramp down rates at IGD are as follows:

- When IGD flows are greater than 4,600 cfs: decreases in flows of no more than 2,000 cfs per 24-hour period, and no more than 500 cfs per six-hour period.
- When IGD flows are greater than 3,600 cfs but equal to or less than 4,600 cfs: decreases in flows of 1,000 cfs or less per 24-hour period, and no more than 250 cfs per six-hour period.
- When IGD flows are greater than 3,000 cfs but equal to or less than 3,600 cfs: decreases in flows of 600 cfs or less per 24-hour period, and no more than 150 cfs per six-hour period.
- When IGD flows are above 1,750 cfs but equal to or less than 3,000 cfs: decreases in flows of 300 cfs or less per 24-hour period, and no more than 125 cfs per four-hour period.
- When IGD flows are 1,750 cfs or less: decreases in flows of 150 cfs or less per 24-hour period and no more than 50 cfs per two-hour period.

Upward ramping is not restricted.

The KBPM includes only the very crude representation of PacifiCorp reservoir storage and operations necessary to implement the operations described in this appendix. Therefore, the model is only able to adjust LRD releases to attempt to comply with the ramping rate restrictions assumed. In addition, LRD releases cannot necessarily be adjusted to comply with the ramping rate restrictions if unregulated flows (i.e., flood releases) are present at LRD or IGD.

Table A.4.4.3.1 Elevation storage-area for Upper Klamath Lake

Active Storage (TAF)	Elevation (ft.)	Area (acres)
0.000	4136.0	66,109
6.610	4136.1	66,321
13.255	4136.2	66,461
19.914	4136.3	66,579
26.585	4136.4	66,701
33.255	4136.5	66,824
39.929	4136.6	66,927
46.633	4136.7	67,007
53.344	4136.8	67,082
60.062	4136.9	67,155
66.775	4137.0	67,228
73.488	4137.1	67,299
80.228	4137.2	67,371
86.975	4137.3	67,443
93.730	4137.4	67,514
100.478	4137.5	67,584
107.227	4137.6	67,654
114.002	4137.7	67,725
120.785	4137.8	67,798
127.576	4137.9	67,880
134.367	4138.0	68,080
141.175	4138.1	68,349
148.023	4138.2	68,467
154.882	4138.3	68,572
161.751	4138.4	68,674
168.616	4138.5	68,775
175.486	4138.6	68,877
182.385	4138.7	68,979

Active Storage (TAF)	Elevation (ft.)	Area (acres)
189.295	4138.8	69,083
196.215	4138.9	69,187
203.133	4139.0	69,294
210.054	4139.1	69,404
217.007	4139.2	69,516
223.971	4139.3	69,635
230.998	4139.4	70,809
238.182	4139.5	72,984
245.526	4139.6	74,049
252.971	4139.7	74,672
260.471	4139.8	75,180
268.021	4139.9	75,668
275.608	4140.0	76,225
283.247	4140.1	76,843
290.968	4140.2	77,454
298.756	4140.3	78,156
306.618	4140.4	78,963
314.552	4140.5	79,878
322.574	4140.6	80,890
330.725	4140.7	81,982
338.987	4140.8	83,098
347.359	4140.9	84,174
355.819	4141.0	85,167
364.364	4141.1	86,055
373.018	4141.2	86,839
381.746	4141.3	87,519
390.535	4141.4	88,088
399.359	4141.5	88,549
408.216	4141.6	88,921

Active Storage (TAF)	Elevation (ft.)	Area (acres)
417.133	4141.7	89,231
426.078	4141.8	89,491
435.047	4141.9	89,705
444.018	4142.0	89,880
452.996	4142.1	90,031
462.015	4142.2	90,166
471.047	4142.3	90,292
480.090	4142.4	90,405
489.127	4142.5	90,508
498.165	4142.6	90,607
507.240	4142.7	90,703
516.324	4142.8	90,798
525.417	4142.9	90,891
534.502	4143.0	90,982
543.587	4143.1	91,071
552.707	4143.2	91,164
561.838	4143.3	91,265
570.974	4143.4	91,376
580.110	4143.5	91,486

Section A: Model Variables

Table A.4.3.4.1. Model Variables (note that *cfs_taf or *taf_cfs in a formula denotes conversion to new units; (-1) in formula refers to yesterday's value for a given variable; "Total A" refers to sum of delivery volumes for arcs D1, D11, D12A, and D91 or A Canal, North Canal, Ady Canal for agriculture, and Miller Hill/Station 48, respectively).

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
A2FW	Winter water right for A2 diversions	Winter water right for A2 diversions, set to 28.910 taf.	-	Definitions.wresl
adj_endhi	Variable used to compute adj_uklcentral	Set to 0.5. Used to compute adj_uklcentral.	-	UKLThresholds.wresl
adj_endlow	Variable used to compute adj_uklcentral	Set to -0.5. Used to compute adj_uklcentral.	-	UKLThresholds.wresl
adj_intercept	Variable used to compute adj_uklcentral	Computed as: adj_endhi - norm_inf_hi * adj_slope	adj_intercept_	UKLThresholds.wresl
adj_slope	Variable used to compute adj_uklcentral	Computed as: (adj_endhi - adj_endlow) / (norm_inf_hi - norm_inf_low)	adj_slope_	UKLThresholds.wresl
Apr50	April NRCS forecast	April NRCS 50% exceedence forecast for total April-September UKL net inflow.	-	Definitions.wresl
avg_cum_KDD_in_5d_prop	Average cum_KDD_in_5d_prop	Average cum_KDD_in_5d_prop by 5-day period across irrigation water years.	avg_cum_KDD_in_5d_prop_	AgRefOps.wresl
avg_cum_KDD_in_p15to49_prop	Average cum_KDD_in_p15to49_prop	Average cum_KDD_in_p15to49_prop by 5-day period across irrigation water years.	avg_cum_KDD_in_p15to49_prop_	AgRefOps.wresl
avg_cum_KDD_in_p50to14_prop	Average cum_KDD_in_p50to14_prop	Average cum_KDD_in_p50to14_prop by 5-day period across irrigation water years.	avg_cum_KDD_in_p50to14_prop_	AgRefOps.wresl
C1	Link River Dam Release	Total Link River flow released out of Link River Dam from Upper Klamath Lake.	C1	Channel-table.wresl
C1_AG	Link Ag release	Link release to support Ag and refuge diversions at Station 48, Miller Hill, North Canal and Ady Canal	C1_AG	Channel-table.wresl
C1_EXC	Link excess release	Link release in excess of minimum flow requirement and needs of Ag and refuge diversions. Likely due to UKL flood control spill or Iron Gate flow requirements.	C1_EXC	Channel-table.wresl
c1_EXCcumdv	Cumulative C1_EXC releases	Cumulative volume released through the C1_EXC arc beginning on March 1.	c1_EXCcumdv	SeasonalSupply.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
C1_MIF	Link MIF requirement	Portion of Link release made to support the Link minimum instream flow requirement.	C1_MIF	Channel-table.wresl
C1_River	Link river release	Portion of Link release that flows out of Iron Gate Dam. This is accounted for as an EWA release from March to September.	C1_River	Channel-table.wresl
C13	Keno Dam Release	Release at Keno Dam on the Klamath River.	C13	Channel-table.wresl
C131	Klamath Straits Drain flow (or Pumping Plant F/FF)	Return flows and runoff from the A2 area and LKNWR that are pumped through pumping plant F/FF.	C131	Channel-table.wresl
C131_IG	F/FF pumping to Iron Gate	F/FF pumping that flows out Iron Gate. This is accounted for as an EWA release from March to September when Iron Gate is under controlled flow (minimum, target, or ramping).	C131_IG	Channel-table.wresl
C131_PRJ	F/FF pumping to project	F/FF pumping that is re-diverted by the project at Station 48, Miller Hill, North Canal or Ady Canal.	C131_PRJ	Channel-table.wresl
C15	Iron Gate Dam flow	Flow downstream of Iron Gate Reservoir on the Klamath River.	C15	Channel-table.wresl
C15_EXC	Iron Gate excess flow	Flow in excess of all requirements (MIF, TARG, and RAMP) caused by UKL and/or Iron Gate reservoir flood spill.	C15_EXC	Channel-table.wresl
C15_MIF	Iron Gate MIF requirement	Portion of Iron Gate flow needed to meet minimum instream flow requirement.	C15_MIF	Channel-table.wresl
C15_RAMP	Iron Gate ramping flow	Increment of Iron Gate flow above MIF and TARG needed to support flow ramping requirements.	C15_RAMP	Channel-table.wresl
C15_TARG	Iron Gate target flow	Increment of Iron Gate flow above minimum required needed to meet Iron Gate target flow.	C15_TARG	Channel-table.wresl
C15target	Daily Iron Gate flow target	Daily Iron Gate flow target.	C15target_	UKLReleases.wresl
C15target_prep1	Variable used to determine whether Iron Gate Reservoir should be filled to spillway	This is a C15 target used to determine whether Iron Gate must be filled to spillway elevation to hit a flow target above 1700 cfs. Computed as: C1forC15dv(-1) + I10(-1) + I15_forecast1(-1).	C15target_prep1_	UKLReleases.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
C15target_prep2	Variable used to determine whether Iron Gate Reservoir should be filled to spillway	This is a C15 target used to determine whether Iron Gate must be filled to spillway elevation to hit a flow target above 1700 cfs. Computed as: C1forC15dv(-2) + I10(-2) + I15_forecast2(-2).	C15target_prep2_	UKLReleases.wresl
C1forC15	Daily target releases from UKL for setting Iron Gate targets	Daily target releases from UKL for setting Iron Gate targets. During October-February, set equal to Link_WF_target. During March-September, set equal to Link_release_SS.	C1forC15dv	UKLReleases.wresl
C91	Lost River Diversion Channel	LRDC flow to the Klamath River (+) or from the Klamath River (-).	C91	Channel-table.wresl
cum_KDD_in_5d_	Total KDD_indv volume by 5-day period	KDD_indv volume summed within each 5-day period of the irrigation water year.	cum_KDD_in_5d_	AgRefOps.wresl
cum_KDD_in_p15to 49_	Cumulative volume input to KDD for periods 15 through 49	Cumulative volume input (diversion and precipitation) to KDD for periods 15 (May 10) through 49 (October 31).	cum_KDD_in_p15to 49_	AgRefOps.wresl
cum_KDD_in_p50to 14_	Cumulative volume input to KDD for periods 50 through 14	Cumulative volume input (diversion and precipitation) to KDD for periods 50 (November 1) through 14 (May 9).	cum_KDD_in_p50to 14_	AgRefOps.wresl
Cum_Ppt	Cumulative daily Project-area precipitation	Cumulative daily precipitation (in) since March 1 through each 5 day period of the irrigation water year for the Project area	Cum_Ppt_	AgForecast.wresl
Cum_Tmax	Cumulative daily Project-area maximum temperature	Cumulative daily maximum air temperature (°F) since March 1 through each 5 day period of the irrigation water year for the Project area	Cum_Tmax_	AgForecast.wresl
CumAg_ss_Del	Cumulative spring-summer ag diversions from UKL	Cumulative volume of surface water diverted for ag use under spring-summer operations from UKL from March through November.	CumAg_ss_DelDV	SeasonalSupply.wresl
CumAg_ss_Div	Cumulative spring-summer ag diversions from all surface water sources	Cumulative volume of surface water diverted for ag use under spring-summer operations from March through November, including diversion of water from UKL, non-UKL water from LRDC, and F/FF return flow.	CumAg_ss_DivDV	SeasonalSupply.wresl
CumAgLRDC_ss_D el	Cumulative spring-summer ag diversion from LRDC and F/FF returns	Cumulative volume of surface water diverted for ag use under spring-summer operations from March through November, including diversion of non-UKL water from LRDC, and F/FF return flow.	CumAgLRDC_ss_ DelDV	SeasonalSupply.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
cumd11wint	Prior winter D11 diversions	Cumulative total D11 diversions within each irrigation water year from period 56 (December 1) through period 73 (the end of February).	cumd11wint_	AgForecast.wresl
cumd12awint	Prior winter D12A diversions	Cumulative total D12A diversions within each irrigation water year from period 56 (December 1) through period 73 (the end of February).	cumd12awint_	AgForecast.wresl
cumI15	Cumulative volume of Keno-to-Iron Gate accretions	Cumulative volume (taf) of accretions to the Keno-to-Iron Gate reach of the Klamath River beginning Oct 1.	cumI15_	FallWinterRiverOps. wresl
cumpptwint	Cumulative winter precipitation	Cumulative Prj_Ppt within each irrigation water year from period 56 (December 1) through period 73 (the end of February).	cumpptwint_	AgForecast.wresl
CumRefDeliv_fw_DV	Cumulative fall-winter deliveries to the Refuge from UKL	Cumulative delivery of UKL water through D12B to the Refuge from December-February.	CumRefDeliv_fw_DV	SeasonalSupply.wresl
CumRefDeliv_ss_DV	Cumulative spring-summer deliveries to the Refuge from UKL	Cumulative delivery of UKL water through D12B to the Refuge from March-November.	CumRefDeliv_ss_DV	SeasonalSupply.wresl
D1	A Canal Deliveries	A Canal project deliveries to area A1	D1	Delivery-table.wresl
D1_5d_	Daily simulated D1 volume	Simulated volume diverted into D1 on the current day.	D1_5d_	Definitions.wresl
D1_5d_Cum_	Total simulated D1 volume for five_day_period	Total simulated volume diverted into D1 in each five_day_period.	D1_5d_Cum_	Definitions.wresl
D1_act_	Daily actual D1 volume	Historic (actual) volume diverted into D1 on the current day.	D1_act_	Definitions.wresl
D1_act_5d_Cum_	Total actual D1 volume for five_day_period	Total historic (actual) volume diverted into D1 in each five_day_period.	D1_act_5d_Cum_	Definitions.wresl
D1_const	Constant for D1 deliveries as percent of Total A	Model-averaged constant for D1 deliveries as percent of Total A.	-	AgForecast.wresl
D1_cumpptwint	Coefficient for cumpptwint influence on D1 deliveries as percent of Total A	Model-averaged coefficient for the influence of cumpptwint on D1 deliveries as percent of Total A.	-	AgForecast.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
D1_l1_d1pcta	Coefficient for D1 deliveries as percent of Total A	Model-averaged coefficient for D1 deliveries as percent of Total A from the previous 5-day period.	-	AgForecast.wresl
D1_l1_ppt	Coefficient for Prj_Ppt influence on D1 deliveries as percent of Total A	Model-averaged coefficient for the influence of Prj_Ppt (lagged to the previous 5-day period) on D1 deliveries as percent of Total A.	-	AgForecast.wresl
D1_l1_ptdayindex	Coefficient for ptdayindex influence on D1 deliveries as percent of Total A	Model-averaged coefficient for the influence of ptdayindex (lagged to the previous 5-day period) on D1 deliveries as percent of Total A.	-	AgForecast.wresl
D1_l1_tmax	Coefficient for Mean_Tmax influence on D1 deliveries as percent of Total A	Model-averaged coefficient for the influence of Mean_Tmax (lagged to the previous 5-day period) on D1 deliveries as percent of Total A.	-	AgForecast.wresl
D1_pcta_reg_	Forecasted D1 delivery percent of Total A	Forecasted D1 delivery percent of Total A for the current 5-day period.	D1_pcta_reg_	AgForecast.wresl
D1_RealPCTA	Historical D1 delivery as percent of Total A	Historical daily D1 diversion volume percentage of Total A deliveries (Mar-Oct) summed within each 5-day period of the irrigation water year.	D1_RealPCTA_	AgForecast.wresl
D1_shortdum	Coefficient for shortdum influence on D1 deliveries as percent of Total A	Model-averaged coefficient for the influence of shortdum on D1 deliveries as percent of Total A.	-	AgForecast.wresl
D1_calc	D1 delivery target from ag delivery sub-model	D1 delivery target from ag delivery sub-model, set equal to D1calc_reg during March - November, otherwise is 0.	D1calcdv	AgRefOps.wresl
D1calc_reg	Forecast of daily D1	Forecast of daily delivery (cfs) through the D1 arc.	D1calc_reg_	AgForecast.wresl
D11	North Canal Deliveries	North Canal Project Deliveries to area A2	D11	Delivery-table.wresl
D11_const	Constant for D11 deliveries as percent of Total A	Model-averaged constant for D11 deliveries as percent of Total A.	-	AgForecast.wresl
D11_cumd11wint	Coefficient for cumd11wint influence on D11 deliveries as percent of Total A	Model-averaged coefficient for the influence of cumd11wint on D11 deliveries as percent of Total A.	-	AgForecast.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
D11_cumpptwint	Coefficient for cumpptwint influence on D11 deliveries as percent of Total A	Model-averaged coefficient for the influence of cumpptwint on D11 deliveries as percent of Total A.	-	AgForecast.wresl
D11_fw_calc	Fall-winter component of D11calc	D11calc for November-February, otherwise 0.	D11_fw_calcdv	AgRefOps.wresl
D11_fw_calc_no_ UKL_ctrl	D11 winter release calculation without UKL control	D11 winter release calculation without UKL control, computed as the minimum of either (200 cfs or KDDReserve * taf_cfs) * pctNorth.	D11_fw_calc_no_ UKL_ctrldv	AgRefOps.wresl
D11_l1_d11pcta	Coefficient for D11 deliveries as percent of Total A	Model-averaged coefficient for D11 deliveries as percent of Total A from the previous 5-day period.	-	AgForecast.wresl
D11_l1_d11taf	Coefficient for prior period D11 delivery volume influence on D11 deliveries as percent of Total A	Model-averaged coefficient for the influence of prior period D11 delivery volume on D11 deliveries as percent of Total A.	-	AgForecast.wresl
D11_l1_ppt	Coefficient for Prj_Ppt influence on D11 deliveries as percent of Total A	Model-averaged coefficient for the influence of Prj_Ppt (lagged to the previous 5-day period) on D11 deliveries as percent of Total A.	-	AgForecast.wresl
D11_l1_ptdayindex	Coefficient for ptdayindex influence on D11 deliveries as percent of Total A	Model-averaged coefficient for the influence of ptdayindex (lagged to the previous 5-day period) on D11 deliveries as percent of Total A.	-	AgForecast.wresl
D11_l1_tmax	Coefficient for Mean_Tmax influence on D11 deliveries as percent of Total A	Model-averaged coefficient for the influence of Mean_Tmax (lagged to the previous 5-day period) on D11 deliveries as percent of Total A.	-	AgForecast.wresl
D11_pcta_reg_	Forecasted D11 delivery percent of Total A	Forecasted D11 delivery percent of Total A for the current 5-day period.	D11_pcta_reg_	AgForecast.wresl
D11_pdindexd11	Coefficient for pdindexd11 influence on D11 deliveries as percent of Total A	Model-averaged coefficient for the influence of pdindexd11 on D11 deliveries as percent of Total A.	-	AgForecast.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
D11_RealPCTA	Historical D11 delivery as percent of Total A	Historical daily D11 diversion volume percentage of Total A deliveries (Mar-Oct) summed within each 5-day period of the irrigation water year	D11_RealPCTA_	AgForecast.wresl
D11_shortdum	Coefficient for shortdum influence on D11 deliveries as percent of Total A	Model-averaged coefficient for the influence of shortdum on D11 deliveries as percent of Total A.	-	AgForecast.wresl
D11_ss_calc	Spring-summer component of D11calc	D11calc for March-October, otherwise 0.	D11_ss_calcdv	AgRefOps.wresl
D11calc	Diversion target for D11	Diversion target for D11. Set equal to D11calc_reg during March - October. Otherwise computed as: D11_fw_calc_no_UKL_ctrl + stor_diff_ratio5d * D11_fw_calc_no_UKL_ctrl.	D11calcdv	AgRefOps.wresl
D11calc_reg	Forecast of daily D11	Forecast of daily delivery (cfs) through the D11 arc.	D11calc_reg_	AgForecast.wresl
D12	Ady Canal flow	Ady Canal flow to either Area A2 (including the Area K lease lands) or the Lower Klamath National Wildlife Refuge	D12	Delivery-table.wresl
D12A	Ady Canal Ag Flow	Ady Canal flow to project in Area A2	D12A	Delivery-table.wresl
D12a_const	Constant for D12A deliveries as percent of Total A	Model-averaged constant for D12A deliveries as percent of Total A.	-	AgForecast.wresl
D12a_cumd12awint	Coefficient for cumd12awint influence on D12A deliveries as percent of Total A	Model-averaged coefficient for the influence of cumd12awint on D12A deliveries as percent of Total A.	-	AgForecast.wresl
D12a_cumpptwint	Coefficient for cumpptwint influence on D12A deliveries as percent of Total A	Model-averaged coefficient for the influence of cumpptwint on D12A deliveries as percent of Total A.	-	AgForecast.wresl
D12A_fw_calc	Fall-winter component of D12Acalc	D12Acalc for November-February, otherwise 0.	D12a_fw_calcdv	AgRefOps.wresl
D12A_fw_calc_no_UKL_ctrl	D12A winter release calculation without UKL control	D12A winter release calculation without UKL control, computed as the minimum of either (200 cfs or KDDReserve * taf_cfs) * pctAdyag.	D12a_fw_calc_no_UKL_ctrldv	AgRefOps.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
D12a_l1_d12apcta	Coefficient for D12A deliveries as percent of Total A	Model-averaged coefficient for D12A deliveries as percent of Total A from the previous 5-day period.	-	AgForecast.wresl
D12a_l1_d12ataf	Coefficient for prior period D12A delivery volume influence on D12A deliveries as percent of Total A	Model-averaged coefficient for the influence of prior period D12A delivery volume on D12A deliveries as percent of Total A.	-	AgForecast.wresl
D12a_l1_ppt	Coefficient for Prj_Ppt influence on D12A deliveries as percent of Total A	Model-averaged coefficient for the influence of Prj_Ppt (lagged to the previous 5-day period) on D12A deliveries as percent of Total A.	-	AgForecast.wresl
D12a_l1_ptdayindex	Coefficient for ptdayindex influence on D12A deliveries as percent of Total A	Model-averaged coefficient for the influence of ptdayindex (lagged to the previous 5-day period) on D12A deliveries as percent of Total A.	-	AgForecast.wresl
D12a_l1_tmax	Coefficient for Mean_Tmax influence on D12A deliveries as percent of Total A	Model-averaged coefficient for the influence of Mean_Tmax (lagged to the previous 5-day period) on D12A deliveries as percent of Total A.	-	AgForecast.wresl
D12a_pcta_reg_	Forecasted D12A delivery percent of Total A	Forecasted D12A delivery percent of Total A for the current 5-day period.	D12a_pcta_reg_	AgForecast.wresl
D12a_pdindexd12a	Coefficient for pdindexd12a influence on D12A deliveries as percent of Total A	Model-averaged coefficient for the influence of pdindexd12a on D12A deliveries as percent of Total A.	-	AgForecast.wresl
D12a_RealPCTA	Historical D12A delivery as percent of Total A	Historical daily D12A diversion volume percentage of Total A deliveries (Mar-Oct) summed within each 5-day period of the irrigation water year	D12a_RealPCTA_	AgForecast.wresl
D12a_shortdum	Coefficient for shortdum influence on D12A deliveries as percent of Total A	Model-averaged coefficient for the influence of shortdum on D12A deliveries as percent of Total A.	-	AgForecast.wresl
D12A_ss_calc	Spring-summer component of D12Acalc	D12Acalc for March-October, otherwise 0.	D12a_ss_calcdv	AgRefOps.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
D12Acalc	Diversion target for D12A	Diversion target for D12A. Set equal to D12Acalc_reg during March - October. Otherwise computed as: D12A_fw_calc_no_UKL_ctrl + stor_diff_ratio5d * D12A_fw_calc_no_UKL_ctrl.	D12acalcdv	AgRefOps.wresl
D12acalc_reg	Forecast of daily D12A	Forecast of daily delivery (cfs) through the D12A arc.	D12acalc_reg_	AgForecast.wresl
D12B	Ady Canal Refuge Flow	Ady Canal flow to the Lower Klamath National Wildlife Refuge	D12B	Delivery-table.wresl
D12Bcalc	Delivery target for D12B (LKNWR)	Delivery target for D12B (LKNWR), computed without UKL control.	D12Bcalcdv	AgRefOps.wresl
D12Bcalc_Supply Table	Component of LKNWR delivery computation	Component of LKNWR delivery computation. Computed as Monthly_RemainRefugeFallSupply * RefugeFallRelDist/daysinmonth * taf_cfs.	D12Bcalc_Supply Table_	AgRefOps.wresl
D12Bcalc_UKL	Deliveries to LKNWR from UKL	Delivery target for D12B (LKNWR), computed with UKL control.	D12Bcalc_UKLdv	AgRefOps.wresl
D91	Station 48/Miller Hill Deliveries	Lost River Diversion Channel Project deliveries through the Station 48 diversion and Miller Hill Pumping Plant	D91	Delivery-table.wresl
D91_const	Constant for D91 deliveries as percent of Total A	Model-averaged constant for D91 deliveries as percent of Total A.	-	AgForecast.wresl
D91_cumpptwint	Coefficient for cumpptwint influence on D91 deliveries as percent of Total A	Model-averaged coefficient for the influence of cumpptwint on D91 deliveries as percent of Total A.	-	AgForecast.wresl
D91_l1_d91pcta	Coefficient for D91 deliveries as percent of Total A	Model-averaged coefficient for D91 deliveries as percent of Total A from the previous 5-day period.	-	AgForecast.wresl
D91_l1_ppt	Coefficient for Prj_Ppt influence on D91 deliveries as percent of Total A	Model-averaged coefficient for the influence of Prj_Ppt (lagged to the previous 5-day period) on D91 deliveries as percent of Total A.	-	AgForecast.wresl
D91_l1_ptdayindex	Coefficient for ptdayindex influence on D91 deliveries as percent of Total A	Model-averaged coefficient for the influence of ptdayindex (lagged to the previous 5-day period) on D91 deliveries as percent of Total A.	-	AgForecast.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
D91_I1_tmax	Coefficient for Mean_Tmax influence on D91 deliveries as percent of Total A	Model-averaged coefficient for the influence of Mean_Tmax (lagged to the previous 5-day period) on D91 deliveries as percent of Total A.	-	AgForecast.wresl
D91_pcta_reg_	Forecasted D91 delivery percent of Total A	Forecasted D91 delivery percent of Total A for the current 5-day period.	D91_pcta_reg_	AgForecast.wresl
D91_RealPCTA	Historical D91 delivery as percent of Total A	Historical daily D91 diversion volume percentage of Total A deliveries (Mar-Nov 15) summed within each 5-day period of the irrigation water year.	D91_RealPCTA_	AgForecast.wresl
D91_shortdum	Coefficient for shortdum influence on D91 deliveries as percent of Total A	Model-averaged coefficient for the influence of shortdum on D91 deliveries as percent of Total A.	-	AgForecast.wresl
D91calc	D91 delivery target from ag delivery sub-model	D91 delivery target from ag delivery sub-model, set equal to D91calc_reg during March - November, otherwise is 0.	D91calcdv	AgRefOps.wresl
D91calc_reg	Forecast of daily D91	Forecast of daily delivery (cfs) through the D91 arc.	D91calc_reg_	AgForecast.wresl
daynum	Day of water year	Day 1 is October 1, incremented by 1 each day thereafter.	daynumDV	Definitions.wresl
daysinprevmo	Days in previous month	Number of days in the previous month.	-	Definitions.wresl
dg1_compliance	Surface flushing flow compliance	Set to a value of 1 within a year once a surface flushing flow has been implemented and achieved; otherwise set to 0.	dg1_compliance_	Definitions.wresl
DG1_compliance_ threshold	Surface flushing flow compliance threshold	Minimum flow threshold for determination if a surface flushing flow has already occurred during December to April. Set at 5,000 cfs. This is not the flow target for a forced surface flushing flow.	-	Operations_Switches. wresl
DG1_supply	Minimum flow target below Iron Gate Dam to implement surface flushing flow	Minimum flow target below Iron Gate Dam to implement surface flushing flow.	DG1_supply_	FallWinterRiverOps. wresl
DG1_target	Surface flushing flow target	Surface flushing flow target. Set to 6,030 cfs.	-	Operations_Switches. wresl
dir_div_acc_est	Total diversion of return flows	Total seasonal diversion of return flow from the LRDC and pumps F&FF for all diversion arcs.	-	AgForecast.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
dowy	Day of water year	Day of water year: October 1 is day 1, September 30 is day 365 (366 in leap years).	dowy_	FallWinterRiverOps. wresl
DT	Distribution type	Distribution type of year based on Mar-50. Set to: 1 when Mar50 ≤ 420 taf; 2 when Mar50 is between 420-510 taf; 3 when Mar50 is between 510-690 taf; 4 when Mar50 ≥ 690 taf.	-	Definitions.wresl
EOS_hiinc	September increment above unadjusted UKL central tendency	Maximum allowable increment above the unadjusted UKL central tendency for the end of September.	-	Res_Reqs.wresl
EOS_lowinc	September increment below unadjusted UKL central tendency	Maximum allowable increment below the unadjusted UKL central tendency for the end of September.	-	Res_Reqs.wresl
EOScent_lvl	September unadjusted UKL central tendency	Unadjusted UKL central tendency for the end of September.	-	Res_Reqs.wresl
EOStgt_lvl	End-of-September UKL storage target level	End-of-September UKL storage target level.	EOStgt_lvl_	Res_Reqs.wresl
EOStgtsto	End-of-September UKL storage target volume	End-of-September UKL storage target volume. UKL active storage volume associated with EOStgt_lvl.	EOStgtstodv	Res_Reqs.wresl
esttota	Estimated Total A delivery	Estimated Total A delivery for an irrigation water year, including diversions of UKL water and diversions of return flows.	esttota_	AgForecast.wresl
EWA_remain_Jul Sep	EWA volume for release in each summer month	EWA volume to be released in each month from July-September. In July, this volume is 35% of EWAremain on July 1. In August, it is 44% of EWAremain on August 1. In September, it is remaining EWA volume.	EWA_remain_Jul Sep_	UKLReleases.wresl
EWA_River	Environmental water account	Allocation from UKLSupply for use by the Klamath River.	EWA_Riverdv	SeasonalSupply.wresl
EWA_threshold	surface flushing flow EWA threshold	EWA threshold for mandatory surface flushing flow release. Set to 575 TAF. If EWA is less than this threshold, a surface flushing flow must be released sometime between March 1st and April 15th	-	Operations_Switches. wresl
EWAmin	Minimum EWA	Minimum volume for the Environmental Water Account, set to 400 TAF.	EWAmin_	Definitions.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
EWARemain	Remaining EWA	Volume of EWA remaining, computed on the first day of each month (starting March 1) as: max(EWARemainMinimum, EWA_River - EWAUseddv(-1)). Its value remains constant throughout the remainder of each month.	EWARemainDV	SeasonalSupply.wresl
EWARemain Minimum	EWA remain minimum	Minimum EWA volume to retain for use in June-September period to ensure that sufficient EWA volume remains to cover summer period in years when flows through C1_EXC arc are above a specifed proportion of the EWA volume. That is, when c1_EXCcumdv(-1)≥(0.22*EWA_River), EWARemainMinimum is computed each month as: 0.25*EWA_River in June; 0.18*EWA_River in July; 0.13*EWA_River in August; and 0.07*EWA_River in September.	EWARemain Minimumdv	SeasonalSupply.wresl
EWAUseddv	EWA used	Volume of Link River Dam releases accounted for as EWA water. Computed as: March 1: C1_MIF*cfs_taf+C1_EXC*cfs_taf After March 1: EWAUsedDV(-1) + C1_MIF*cfs_taf + C1_EXC*cfs_taf - prj_credit_spill_forEWA*cfs_taf + prj_acc_addition_to_EWA*cfs_taf.	EWAUseddv	SeasonalSupply.wresl
excluded_dum	Dummy variable for excluded years	Set to 1 for years when historical diversions were altered from normal seasonal patterns by regulatory action to an extent warranting their removal from model development. Excluded years were 2001, 2010, 2014, and 2015.	excluded_dum_	AgForecast.wresl
Fcst_error	Forecast error	Tracking the approximate real-time forecast error, computed first day of the month April-June. On April 1: Mar50 - (Apr50 + LastMonthInf). On May 1: Apr50 - (May50 + LastMonthInf). On June 1: May50 - (Jun50 + LastMonthInf).	Fcst_error_	Definitions.wresl
Feb50	February NRCS forecast	February NRCS 50% exceedence forecast for total March-September UKL net inflow.	-	Definitions.wresl
fill_target_approx	UKL fill target	Elevation (ft) targeted for filling UKL by February 28. Set to 4143.0 ft, this is a soft target, the system is not forced to hit the target. Used beginning on November 16.	-	FallWinterRiverOps. wresl
fill_target_approx_ vol	UKL fill target volume	Active storage volume (TAF) at the elevation of the fill_target_approx.	-	FallWinterRiverOps. wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
five_day_period	Five-day period of the irrigation water year	Five-day periods begining March 1, ending at the end of February. Period 73 has 6 days in leap years.	five_day_period_	Definitions.wresl
Flood50fc	UKL net inflow forecasts used in flood operations	NRCS 50% exceedence forecasts for total Mar-Sep UKL net inflow made in Jan-Mar, and total Apr-Sep UKL net inflow forecast made in April.	-	Res_Reqs.wresl
I1	UKL net inflow - smoothed	Net Inflow into Upper Klamath Lake (calculated as the change in storage plus releases through A Canal and Link River Dam). This input timeseries was smoothed to minimize fluctuations due to wind effects on lake levels.	I1_	Inflow-table.wresl
I1_raw	UKL net inflow - raw data	Net Inflow into Upper Klamath Lake (calculated as the change in storage plus releases through A Canal and Link River Dam). This is added as a raw value and does not smooth out significant fluctuations caused by wind effects on lake level.	I1_raw_	Inflow-table.wresl
I10	Lake Ewauna accretions	Lake Ewauna Accretions - difference between historical flows released out of Link River Dam minus known diversions and the measured flow upstream of Keno Reservoir. Diversions include LRDC which may flow into the Klamath River as an inflow.	I10_	Inflow-table.wresl
I131	Area 2 return flow closure term	Input timeseries that is the difference between actual return flows minus modeled return flows based on actual deliveries, precipitation and temperature.	I131_	Inflow-table.wresl
I15	Keno to Iron Gate accretions	Keno to Iron Gate accretion timeseries developed with historical mass balance from Keno Dam to the flow gage below Iron Gate Dam.	I15_	Inflow-table.wresl
I15_d0d3_total	Total 4-day forecasted Keno-to-Iron Gate accretion volume	Forecasted Keno-to-Iron Gate accretion volume summed across forecasts for day 0 (current day) through day 3.	I15_d0d3_total_	FallWinterRiverOps. wresl
I15_FORECAST0	Iron Gate accretion 0 day forecast	Forecast of today's Keno to Iron Gate accretion.	-	Inflow-table.wresl
I15_FORECAST1	Iron Gate accretion 1 day forecast	Forecast of tomorrow's Keno to Iron Gate accretion.	-	Inflow-table.wresl
I15_FORECAST2	Iron Gate accretion 2 day forecast	Forecast of day after tomorrow's Keno to Iron Gate accretion.	-	Inflow-table.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
I15_FORECAST3	Iron Gate accretion 3 day forecast	Forecast of Keno to Iron Gate accretions three days from now.	-	Inflow-table.wresl
I15_proj_3day	Projected 3-day average daily volume of Keno-to-Iron Gate accretions	Average daily Keno-to-Iron Gate accretion volume forecasted for days 0-2.	I15_proj_3day_	FallWinterRiverOps. wresl
I15_wyAvgVol	Water year average Keno-to-Iron Gate accretion volume	Average accretion volume (TAF) to the Keno-to-Iron Gate reach of the Klamath River from October 1 to the current day.	I15_wyAvgVol_	FallWinterRiverOps. wresl
I91	LRDC at Wilson	Flow diverted at Wilson Dam into the Lost River Diversion Channel. The flow is a combination of flow from the Lost River (timeseries input) and return flows from Area 1 (dynamically determined from a return flow model).	I91_	Inflow-table.wresl
I91_D1Adjust	Adjusted I91	Historical I91 adjusted by I91_reduce.	I91_D1Adjust_	Definitions.wresl
I91_HIST	Historical flow measured at LRDC headworks	Historical diversion into the LRDC, measured at the headworks at Wilson Dam.	I91_HIST_	Definitions.wresl
I91_IG	LRDC inflow to Iron Gate Dam flow	Flow into the LRDC from Wilson Dam that contributes to Iron Gate flow (not diverted by the project).	I91_IG	Inflow-table.wresl
I91_PRJ	LRDC inflow diverted by project	Flow into the LRDC from Wilson Dam that is diverted by the Klamath Project at Station 48, Miller Hill, North Canal, or Ady Canal.	I91_PRJ	Inflow-table.wresl
I91_reduce	Adjustment for I91	Volume by which the historical I91 arc needs to be adjusted to account for changes in D1 deliveries.	I91_reduce_	Definitions.wresl
IG_max	Maximum Iron Gate flow July-September	Maximum flow target below Iron Gate Dam in July-September. Used to constrain C15_target. IG_max is interpolated based on EWA_River between 320 taf and 1500 taf (IG_max constant below 320 taf or above 1500 taf). IG_max varies between 1000-1500 cfs in July; 1050-1250 cfs in August; and 1100-1350 cfs in September.	IG_max_	UKLReleases.wresl
IG_ramp_flow	Ramped Iron Gate flow	Computed as C15(-1) - IG_ramp_rate.	IG_ramp_flow_	UKLReleases.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
IG_ramp_rate	Iron Gate ramp rate	Computes down-ramp rates for Iron Gate: If C15(-1) < 1750 cfs + 150 cfs, then IG_ramp_rate = 150 cfs If C15(-1) < 3000 cfs + 300 cfs, then IG_ramp_rate = 300 cfs If C15(-1) < 3600 cfs, then IG_ramp_rate = 600 cfs If C15(-1) ≥ 3600 cfs .and. c15(-1) < 4000, then IG_ramp_rate = c15(-1) - 3000 cfs If C15(-1) ≥ 4000 cfs .and. c15(-1) < 4600, then IG_ramp_rate = 1000 cfs Otherwise IG_ramp_rate = min(2000 cfs, c15(-1) - 3600 cfs)	IG_ramp_rate_	UKLReleases.wresl
IG_spawn	Initial fall spawning flow below Iron Gate Dam	Initial flow specified on Oct 1 for fall spawning flows below Iron Gate Dam. Selected by interpolation between 1000 and 1200 cfs based on norm_uklinf_60avg.	IG_spawn_	FallWinterRiverOps. wresl
IG_spawn_flow	Spawning flow at below Iron Gate Dam	Final flow specified for the fall spawning period (October 1-November 15) below Iron Gate Dam. Computed by adding the appropriate IG_spawn_inc variables to IG_spawn.	IG_spawn_flow_	FallWinterRiverOps. wresl
IG_spawn_inc_ Nov1	Final incremental increase of fall spawning flow at Iron Gate	Flow increment added to fall spawning flows November 1-15 below Iron Gate Dam. Selected by interpolation between 0 and 125 cfs based on norm_uklinf_60avg.	-	FallWinterRiverOps. wresl
IG_spawn_inc_ Oct12	First incremental increase of fall spawning flow at Iron Gate	Flow increment added to fall spawning flows October 12-21 below Iron Gate Dam. Selected by interpolation between 0 and 125 cfs based on norm_uklinf_60avg.	-	FallWinterRiverOps. wresl
IG_spawn_inc_ Oct22	Second incremental increase of fall spawning flow at Iron Gate	Flow increment added to fall spawning flows October 22-31 below Iron Gate Dam. Selected by interpolation between 0 and 125 cfs based on norm_uklinf_60avg.	-	FallWinterRiverOps. wresl
IGmin	Minimum flow below Iron Gate Dam	Establishes the minimum flow required below Iron Gate Dam. When surface flushing flows have been triggered, this is set to the value of the DG1_Supply. When Boat Dance flows have been triggered, this is set to 1700 cfs. Otherwise it is set to the established monthly minimum flows.	IGmin_	FallWinterRiverOps. wresl
in_pct_Mar50vol	UKL net inflow percent of forecasted/realized net inflow	Used to establish Link River Dam release targets during March-June, which are subsequently used to establish targets at Iron Gate.	in_pct_Mar50vol_	UKLReleases.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
intercept_4dTrigger_mult	Variable used to compute stage1_trigger	Variable involved in computation of stage1_trigger. Computed as: upper_4dTrigger_mult - upper_I15_wyAvg_mult * slope_4dTrigger_mult.	intercept_4dTrigger_mult_	FallWinterRiverOps.wresl
irr_WY	Irrigation water year	The irrigation water year extends from March 1 through the end of February. Its value is the same as that for the calendar year for March - December.	-	AgForecast.wresl
Jan50	January NRCS forecast	January NRCS 50% exceedence forecast for total March-September UKL net inflow.	-	Definitions.wresl
Jun50	June NRCS forecast	June NRCS 50% exceedence forecast for total June-September UKL net inflow.	-	Definitions.wresl
KDD_indv	Input of diversion and precipitation volume into KDD	Daily total volume of D11, D12A, and KDD_ppt_acft, combined.	KDD_indv	AgRefOps.wresl
KDD_ppt	Average daily precipitation in Area A2	Average daily precipitation (in) for 3 PRISM grids in Area A2.	-	AgRefOps.wresl
KDD_ppt_acft	Precipitation volume in KDD area	KDD_ppt converted to a volume (taf), assuming 27,000 acres in KDD.	-	AgRefOps.wresl
KDDOctFebDV	Running total of winter deliveries to KDD	Running total of November - February deliveries through D11 and D12A (does not include October, despite the variable name).	KDDOctFebDV	AgRefOps.wresl
KDDReserve	Amount of KDD winter water right remaining unused	Amount of KDD winter water right remaining unused, computed as A2FW - KDDOctFebDV(-1) during November - February.	KDDResDV	AgRefOps.wresl
Keno_min	Minimum Keno Dam release	Minimum release (cfs) from Keno Dam.	Keno_min_	FallWinterRiverOps.wresl
l_bound	Lower bound of stor_diff_ratio	Lower bound of stor_diff_ratio, set to -0.8.	-	UKLThresholds.wresl
L1_D11taf	Simulated D11 delivery volume total for prior 5-day period	Simulated D11 delivery volume total for prior 5-day period.	L1_D11taf_	AgForecast.wresl
L1_D12ataf	Simulated D12A delivery volume total for prior 5-day period	Simulated D12A delivery volume total for prior 5-day period.	L1_D12ataf_	AgForecast.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
lag_norm_cum_ KDD_in_5d	Normalized cum_KDD_in_5d_	Normalized cum_KDD_in_5d_, from the previous 5-day period.	lag_norm_cum_KD D_in_5d_	AgRefOps.wresl
lag_norm_cum_ KDD_in_p15to49	Normalized cum_KDD_in_p15to49_	Normalized cum_KDD_in_p15to49_, from the previous 5-day period.	lag_norm_cum_KD D_in_p15to49_	AgRefOps.wresl
lag_norm_cum_ KDD_in_p50to14	Normalized cum_KDD_in_p50to14_	Normalized cum_KDD_in_p50to14_, from the previous 5-day period.	lag_norm_cum_KD D_in_p50to14_	AgRefOps.wresl
LastMonthInf	Last month's UKL net inflow volume	Total volume of UKL net inflow (taf) for previous month.	LastMonthInfdv	Definitions.wresl
Link_max	Maximum acheivable release from Link River Dam	Maximum achievable release from Link River Dam based on a stage-discharge curve, ranging from 900 cfs when UKL elevation is 4137.0 ft to 8600 cfs when UKL elevation is 4143.3 ft.	Link_max_	FallWinterRiverOps. wresl
Link_max_DG1	Maxmimum Link River Dam release used for DG1_supply calculation	Expression of the maximum Link River Dam release for use in calculating the DG1_supply. Computed as the Link_max associated with yesterday's UKL elevation minus 0.3 ft. This 0.3 ft buffer reduces the likelihood of triggering a surface flushing flow that cannot be attained.	Link_max_DG1_	FallWinterRiverOps. wresl
Link_min	Minimum Link River Dam release	Minimum release (cfs) from Link River Dam.	Link_min_	FallWinterRiverOps. wresl
Link_release_FW	Fall-winter flow release target for Link River Dam	Flow release target for Link River Dam for October-February. Computed as Link_release_FW_prep reduced (when appropriate) by the product of the stor_diff_ratio5d and Link_release_FW_prep.	Link_release_FW_	FallWinterRiverOps. wresl
Link_release_FW_ prep	Calculated release target for Link River Dam	Initial flow release target for Link River Dam for October-February. From October - November 15, computed as IG_spawn_flow minus accretions and measured return flows plus diversions. From November 16 through February, computed as yesterday's UKL net inflow minus the Needed_fill_rate multiplied by 1.5.	Link_release_FW_ prep_	FallWinterRiverOps. wresl
Link_release_SS	Link River Dam release target, with UKL control, during spring-summer	Calculated release of UKL water at Link River Dam for March-September, with UKL control.	Link_release_SSdv	UKLReleases.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
Link_release_ss_diff	Difference between actual and expected Link River Dam releases	Cumulative difference between what was actually released from Link River Dam to support Iron Gate Dam flows yesterday and what was expected to be released to support yesterday's Iron Gate flow target.	Link_release_ss_diff_	UKLReleases.wresl
Link_release_SS_prep	Link River Dam release target, without UKL control, during spring-summer	Calculated release of UKL water at Link River Dam for March-September, without UKL control.	Link_release_SS_prep_	UKLReleases.wresl
Link_WF_target	Target release for Link River Dam during fall-winter period	Link River Dam release target for October - February. Computed as the maximum of either Link_min or Link_release_FW.	Link_WF_target_	FallWinterRiverOps.wresl
LinktoIG_Delay	Iron Gate flow target delay	Delay between scheduling the Iron Gate flow target and implementing the target. Delay is currently set at 3 days.	-	Operations_Switches.wresl
lower_4dTrigger_mult	Variable used to compute stage1_trigger	Variable involved in computation of stage1_trigger. Set to 2.2.	-	FallWinterRiverOps.wresl
lower_I15_wyAvg_mult	Variable used to compute stage1_trigger	Variable involved in computation of stage1_trigger. Set to 0.7.	-	FallWinterRiverOps.wresl
Mar1_EWA_	EWA_River on March 1	EWA_River on March 1.	Mar1_EWA_	UKLThresholds.wresl
Mar50	March NRCS forecast	March NRCS 50% exceedence forecast for total March-September UKL net inflow.	-	Definitions.wresl
Mar50vol	Combined forecasted/experienced UKL net inflow	Always applicable to the March-September period, this is the NRCS 50% exceedence forecast for UKL net inflow looking forward plus the experienced UKL net inflow since March 1.	Mar50voldv	Definitions.wresl
May50	May NRCS forecast	May NRCS 50% exceedence forecast for total May-September UKL net inflow.	-	Definitions.wresl
Mean_Tmax	Mean daily Project area maximum temperature	Mean daily Tmax (°F) for the Project area from nine randomly selected PRISM grids, averaged within iwy 5 day periods of the irrigation water year	Mean_Tmax_	AgForecast.wresl
model_10	KDD return flow model 10	KDD return flow model 10.	model_10_	AgRefOps.wresl
model_11	KDD return flow model 11	KDD return flow model 11. S	model_11_	AgRefOps.wresl
model_12	KDD return flow model 12	KDD return flow model 12.	model_12_	AgRefOps.wresl
model_13	KDD return flow model 13	KDD return flow model 13. S	model_13_	AgRefOps.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
model_14	KDD return flow model 14	KDD return flow model 14.	model_14_	AgRefOps.wresl
model_17	KDD return flow model 17	KDD return flow model 17.	model_17_	AgRefOps.wresl
model_19	KDD return flow model 19	KDD return flow model 19.	model_19_	AgRefOps.wresl
model_20	KDD return flow model 20	KDD return flow model 20. S	model_20_	AgRefOps.wresl
model_22	KDD return flow model 22	KDD return flow model 22.	model_22_	AgRefOps.wresl
model_9	KDD return flow model 9	KDD return flow model 9.	model_9_	AgRefOps.wresl
Monthly_RemainRefugeFallSupply	RemainRefugeFallSupply on first day of the month	During August - November, RemainRefugeFallSupply on the first day of the month.	Monthly_RemainRefugeFallSupply_	AgRefOps.wresl
Needed_fill_rate	Needed UKL fill rate	For any day between November 16 and February 28, this is the average UKL fill rate needed to reach the fill_target_approx elevation (4143.0 ft) by February 28.	Needed_fill_rate_	FallWinterRiverOps.wresl
norm_inf_hi	Variable used to compute adj_uklcentral	Upper end of the norm_uklinf_60avg, set to 1. Used to compute adj_uklcentral.	-	UKLThresholds.wresl
norm_inf_low	Variable used to compute adj_uklcentral	Lower end of the norm_uklinf_60avg, set to 0. Used to compute adj_uklcentral.	-	UKLThresholds.wresl
norm_uklinf_60avg	Normalized 60-day trailing average of UKL net inflow	60-day trailing average of UKL net inflow re-scaled (normalized) to be between 0 and 1.	norm_uklinf_60avgDV	UKLThresholds.wresl
normcumd11	Normalized cumd11wint	Re-scaled cumd11wint (between 0 and 1).	normcumd11_	AgForecast.wresl
normcumd12a	Normalized cumd12awint	Re-scaled cumd12awint (between 0 and 1).	normcumd12a_	AgForecast.wresl
normcumpptwint	Normalized cumpptwint	Re-scaled cumpptwint (between 0 and 1).	normcumpptwint_	AgForecast.wresl
normMar50vol	Normalized Mar50vol	Normalized (re-scaled to be between 0 and 1) Mar50vol across all months and years in the POR.	normMar50vol_	Res_Reqs.wresl
normppt	Normalized Prj_Ppt	Re-scaled Prj_Ppt (between 0 and 1), for use in calculating the ptdayindex.	normppt_	AgForecast.wresl
normpptc	Normalized Cum_Ppt	Re-scaled Cum_Ppt (between 0 and 1), for use in calculating the ptindex.	normpptc_	AgForecast.wresl
normtmax	Normalized Mean_Tmax	Re-scaled Mean_Tmax (between 0 and 1), for use in calculating the ptdayindex. Subtracted from 1 to flip the scale, so that increasingly warm conditions move towards 0.	normtmax_	AgForecast.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
normtmaxc	Normalized Cum_Tmax	Re-scaled Cum_Tmax (between 0 and 1), for use in calculating the ptindex. Subtracted from 1 to flip the scale, so that increasingly warm conditions move towards 0.	normtmaxc_	AgForecast.wresl
Pct_tota_adjust	Proportional adjustment for percentage of Total A	An adjustment factor applied to estimates of percentage of Total A summed across all diversion arcs, to ensure that they sum to 1 for each irrigation water year.	-	AgForecast.wresl
pctAdyAg	Historical D12A as percent of Area A2 diversion	Historical D12A delivery as percentage of Area A2 total delivery. Used to compute D12A deliveries during November-February.	-	AgRefOps.wresl
pctNorth	Historical D11 as percent of Area A2 diversion	Historical D11 delivery as percentage of Area A2 total delivery. Used to compute D11 deliveries during November-February.	-	AgRefOps.wresl
pdindexd11	Index of winter precipitation and winter D11 deliveries	Index combining winter precipitation and winter D11 delivery volume: normcumpptwint + normcumd11.	pdindexd11_	AgForecast.wresl
pdindexd12a	Index of winter precipitation and winter D12a deliveries	Index combining winter precipitation and winter D12a delivery volume: normcumpptwint + normcumd12a.	pdindexd12a_	AgForecast.wresl
prj_acc_addition_to _EWA	Combined LRDC and F/FF EWA release contribution	Calculation of yesterday's LRDC accretions and F/FF pumping that counted as an EWA release and therefore adds to the UKL credit.	prj_acc_addition_to _EWA_	Project_IG_release_ credit.wresl
prj_credit_spill_ forEWA	Spill of UKL credit	Yesterday's spill of accumulated UKL credit. This does not count as an EWA release.	prj_credit_spill_forE WA_	Project_IG_release_ credit.wresl
Prj_Ppt	Average daily Project-area precipitation	Mean daily precipitation in inches for the Project area from nine randomly selected PRISM grids, averaged within 5-day periods of the irrigation water year	Prj_Ppt_	AgForecast.wresl
prj_UKL_credit	UKL credit	Accumulated credit in UKL due to LRDC accretion and F/FF pumping contribution to EWA release	prj_UKL_credit_	Project_IG_release_ credit.wresl
PrjPpt_max	Maximum Prj_Ppt for period of record	Maximum value of Prj_Ppt for a given 5-day period across all irrigation water years in the period of record. Used to re-scale (normalize) Prj_Ppt to be between 0 and 1, for use in calculating the ptdayindex.	PrjPpt_max_	AgForecast.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
PrjPpt_min	Minimum Prj_Ppt for period of record	Minimum value of Prj_Ppt for a given 5-day period across all irrigation water years in the period of record. Used to re-scale (normalize) Prj_Ppt to be between 0 and 1, for use in calculating the ptdayindex.	PrjPpt_min_	AgForecast.wresl
PrjPptCum_max	Maximum Cum_Ppt for period of record	Maximum value of Cum_Ppt for a given 5-day period across all irrigation water years in the period of record. Used to re-scale (normalize) Cum_Ppt to be between 0 and 1, for use in calculating the ptindex.	PrjPptCum_max_	AgForecast.wresl
PrjPptCum_min	Minimum Cum_Ppt for period of record	Minimum value of Cum_Ppt for a given 5-day period across all irrigation water years in the period of record. Used to re-scale (normalize) Cum_Ppt to be between 0 and 1, for use in calculating the ptindex.	PrjPptCum_min_	AgForecast.wresl
PrjSupply	Project supply	Allocation from UKLSupply for use by the Project irrigators.	PrjSupplydv	SeasonalSupply.wresl
PrjSupply_Apr1	Project supply on April 1	Project supply computed on April 1 as min(Projectmax, UKLsupply - EWA_River).	PrjSupply_Apr1_	SeasonalSupply.wresl
PrjSupply_irr	Project supply for irrigation	Allocation from UKLSupply for use by the Project, computed as max(0., PrjSupply - RefugeFallSupply).	PrjSupply_irrdv	SeasonalSupply.wresl
PrjSupply_irr_Apr1 min	Project supply for irrigation on April 1	Allocation from UKLSupply for use by the Project on April 1, computed as max(0., PrjSupply_Apr1 - RefugeFallSupplyApr1min).	PrjSupply_irr_Apr1 mindv	SeasonalSupply.wresl
Proj_full_check	Project full supply check	Set to 1 when Project supply is at its maximum. Set to 1 when either UKLsupply - EWA_River > Projectmax or UKLsupply > 1035; set to zero otherwise.	Proj_full_check_	SeasonalSupply.wresl
projectmax	Maximum allocation of UKL water for Project use	Maximum allocation of UKL water for Project use, set to 350 TAF.	projectmaxdv	Definitions.wresl
ptdayindex	Precipitation-temperature index	The sum of normppt and normtmax for a 5-day period of the irrigation water year. Values near zero indicate warm, dry conditions; values near 1 indicate cool, wet conditions.	ptdayindex_	AgForecast.wresl
ptindex	Cumulative precipitation-temperature index	The sum of normpptc and normtmaxc for a 5-day period of the irrigation water year. Values near zero indicate warm, dry conditions; values near 1 indicate cool, wet conditions.	ptindex_	AgForecast.wresl
R131a	Return flow from KDD	Return flow from KDD.	R131a	Return-table.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
R131b	Return flow from LKNWR	Return flow from LKNWR. Set to 0.	R131b	Return-table.wresl
RefugeFallCumulDist	Component of LKNWR delivery computation	Variable used to compute D12B deliveries. Set to 1.0 in August, 0.84 in September, 0.60 in October, and 0.20 in November.	RefugeFallCumulDist_	AgRefOps.wresl
RefugeFallRelDist	Component of LKNWR delivery computation	Variable used to compute D12B deliveries. Computed as RefugeFallSupplyDist / RefugeFallCumulDist during August - November.	RefugeFallRelDist_	AgRefOps.wresl
RefugeFallSupply	Refuge Fall Supply		RefugeFallSupply_	SeasonalSupply.wresl
RefugeFallSupplyApr1min	Refuge Fall Supply on April 1	Refuge Fall Supply on April 1.	RefugeFallSupplyApr1min_	SeasonalSupply.wresl
RefugeFallSupplyDist	Component of LKNWR delivery computation	Variable used to compute D12B deliveries. Set to 0.16 in August, 0.25 in September, 0.40 in October, and 0.20 in November.	RefugeFallSupplyDist_	AgRefOps.wresl
RemainRefugeFallSupply	Remaining LKNWR fall supply	Remaining LKNWR fall supply. August - November, it is computed as the RefugeFallSupply on August 1, and as max(0., RemainRefugeFallSupply_(-1) - max(0.,D12b(-1)-transfer_diversion)*cfs_taf) thereafter.	RemainRefugeFallSupply_	AgRefOps.wresl
Rfg_month_dem	Monthly demand volume for LKNWR	Monthly demand volume (TAF) for LKNWR.	-	AgRefOps.wresl
Rfg_PrjSupPct	Refuge percentage of Project supply	Percentage of Project Supply set aside for LKNWR use in August – November.	Rfg_PrjSupPct_	SeasonalSupply.wresl
Rfg_PrjSupPctmin	Refuge percentage of Project supply on April 1	The Rfg_PrjSupPct computed based on PrjSupply_Apr1.	Rfg_PrjSupPctmin_	SeasonalSupply.wresl
S1	UKL storage	Storage in UKL as modeled through the mass balance of UKL net inflow, Link releases, and A Canal diversions.	S1	Reservoir-table.wresl
S15	Iron Gate storage	This is a simplistic representation of Iron Gate storage in order to replicate necessary fill to the Iron Gate spillway to make releases greater than 1,700 cfs over the spillway.	S15	Reservoir-table.wresl
S15_proj	Projected storage in Iron Gate Reservoir at end of today	Projected storage in Iron Gate Reservoir at end of today, computed as: min(S15level4, C13_MIF1(-1)*cfs_taf + I15_forecast0*cfs_taf + S15(-1) - max(IGmin, C15target)*cfs_taf).	S15_proj_	UKLReleases.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
S15target	Iron Gate Reservoir storage target	Set to 53 TAF (volume at spillway elevation) when C15target > 1700 cfs or when stage1_trigger_ = 1; otherwise set to 51 TAF. Used to fill Iron Gate Reservoir to spillway elevation before C15target flows requiring spill.	S15target_	UKLReleases.wresl
S1yestelev	UKL elevation	Elevation of UKL water surface measured at the end of yesterday. In the model, this is determined using the calculated storage (S1) in the storage-elevation lookup table.	S1yestelevdv	Reservoir-table.wresl
sb	Step-back	Variable used in lag functions to "step-back", or lag, to the last day of the previous five_day_period.	sb_	Definitions.wresl
shortdum	Water-short-year indicator	Dummy variable used in forecasting models to indicate when water supply is substantially less than irrigation demand. When UKLSupply < 836 TAF, this variable is set to 1, indicating water-short conditions. It is zero otherwise.	shortdum_	AgForecast.wresl
slope_4dTrigger_ mult	Variable used to compute stage1_trigger	Variable involved in computation of stage1_trigger. Computed as: (upper_4dTrigger_mult - lower_4dTrigger_mult) / (upper_I15_wyAvg_mult - lower_I15_wyAvg_mult).	slope_4dTrigger_ mult_	FallWinterRiverOps. wresl
SSdaynum	Day of spring-summer season	Day 1 is March 1, incremented by 1 each day thereafter.	SSdaynumDV	Definitions.wresl
stage1_trigger	Trigger to fill Iron Gate Reservoir to spillway elevation	Triggers the filling of Iron Gate Reservoir to its spillway elevation in anticipation of releases from UKL for a surface flushing flow. It is triggered when (I15_d0d3_total(-1) - (I15_wyAvgVol(-1) * 4.)) ≥ (I15_wyAvgVol(-1) * (slope_4dTrigger_mult * I15_wyAvgVol(-1) + intercept_4dTrigger_mult)	stage1_trigger_	FallWinterRiverOps. wresl
stor_diff_ratio	Daily storage difference ratio	Daily expression of the storage difference ratio, which is used in UKL control logic.	stor_diff_ratio_	UKLThresholds.wresl
stor_diff_ratio5d	Storage difference ratio for 5-day period	5-day period expression of the storage difference ratio, which is used in UKL control logic. For each 5-day period, it is set to the value of stor_diff_ratio on day 1 of the 5-day period.	stor_diff_ratio5d_	UKLThresholds.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
stor_diff_ratio5d_ag	Storage difference ratio for refuge	The storage difference ratio computed for each 5-day period that is applied to D12B (Refuge) diversions. Despite the name, it is not applied to ag diversions. It is the same as stor_diff_ratio5d but is not allowed to drop below -0.5 or to go above 0.	stor_diff_ratio5d_ag_	SeasonalSupply.wresl
switch_acc_AddToTarget	Iron Gate Target augmentation switch	Conditional variable that equals 1 when LRDC accretions and F/FF pumping augment Iron Gate calculated target. Equals 0 when they do not augment Iron Gate calculated target. In current proposed action this variable equals 1 from October to February and 0 from March to September.	-	Project_IG_release_credit.wresl
Tmax_max	Maximum Mean_Tmax for period of record	Maximum value of Mean_Tmax for a given 5-day period across all irrigation water years in the period of record. Used to re-scale (normalize) Mean_Tmax to be between 0 and 1, for use in calculating the ptdayindex.	Tmax_max_	AgForecast.wresl
Tmax_min	Minimum Mean_Tmax for period of record	Minimum value of Mean_Tmax for a given 5-day period across all irrigation water years in the period of record. Used to re-scale (normalize) Mean_Tmax to be between 0 and 1, for use in calculating the ptdayindex.	Tmax_min_	AgForecast.wresl
TmaxCum_max	Maximum Tmax_Cum for period of record	Maximum value of Tmax_Cum for a given 5-day period across all irrigation water years in the period of record. Used to re-scale (normalize) Tmax_Cum to be between 0 and 1, for use in calculating the ptindex.	TmaxCum_max_	AgForecast.wresl
TmaxCum_min	Minimum Tmax_Cum for period of record	Minimum value of Tmax_Cum for a given 5-day period across all irrigation water years in the period of record. Used to re-scale (normalize) Tmax_Cum to be between 0 and 1, for use in calculating the ptindex.	TmaxCum_min_	AgForecast.wresl
transfer_diversion	Refuge transfer	Input of 11 TAF of transfer from UKL refuge to Lower Klamath Lake refuge uniformly distributed on a daily basis from April through September	refuge_transfer	Operations_Switches.wresl
u_bound	Upper bound of stor_diff_ratio	Upper bound of stor_diff_ratio, set to 0.	-	UKLThresholds.wresl
UKL_adj_width	stor_diff_ratio denominator	Specifies the volume in the denominator of the stor_diff_ratio.	-	UKLThresholds.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
UKL_flood_lvl	Maximum UKL monthly level	Maximum allowable UKL level for each month. Set to 4143.1 ft for all months except April (4143.2 ft), and May and June (4143.3 ft).	S1_maxL_dv	Res_Reqs.wresl
UKL_flood_sto	Year-round threshold storage for UKL flood releases	Year-round threshold storage for UKL flood releases, set equal to UKL_release_sto during Oct-Apr, otherwise set to UKL_flood_sto1. This is the final determination of the UKL flood release storage threshold in the KBPM.	S1_maxS_dv	Res_Reqs.wresl
UKL_flood_sto1	Maximum UKL monthly storage volume	Maximum allowable UKL level for each month: active storage volume associated with UKL_flood_lvl.	-	Res_Reqs.wresl
UKL_min_lvl	Minimum UKL monthly level	Minimum allowable UKL level for each month. Set to 4137.0 ft in all months.	S1_minL_dv	Res_Reqs.wresl
UKL_min_sto	Minimum UKL monthly storage volume	Minimum allowable UKL storage volume for each month: active storage volume associated with UKL_min_sto.	S1_minS_dv	Res_Reqs.wresl
UKL_release_level_ som_use	UKL flood release level at start of month	Computed as: max(UKL_release_lvl_som, UKL_release_thresh_(-day)), where (-day) is the last day of the previous month.	UKL_rels_lvl_som_ use_	Res_Reqs.wresl
UKL_release_lvl	Year-round threshold level for UKL flood releases	Year-round threshold storage for UKL flood releases. This is the UKL level associated with UKL_flood_sto, and is the final determination of the UKL flood release threshold level in the KBPM.	UKL_release_lvl_dv	Res_Reqs.wresl
UKL_release_lvl_ eom	UKL flood release level at end of month	UKL flood release level at end of month.	UKL_release_lvl_ eom_	Res_Reqs.wresl
UKL_release_lvl_ som	UKL flood release level at start of month	UKL flood release level at start of month.	UKL_release_lvl_ som_	Res_Reqs.wresl
UKL_release_sto	Oct-Apr threshold storage for UKL flood releases	Threshold storage volume for UKL flood releases during Oct-Apr period, when it is set equal to UKL_release_thresh_sto. It set to zero in other months.	-	Res_Reqs.wresl
UKL_release_thresh	UKL flood release threshold level	UKL level above which flood releases occur.	UKL_release_thresh _	Res_Reqs.wresl
UKL_release_thresh _sto	UKL flood release threshold storage volume	UKL volume above which flood releases occur. This is the UKL active storage volume associated with UKL_release_thresh.	-	Res_Reqs.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
UKL_rfg_up_thresh	UKL refuge upper threshold	During June-July, UKL level thresholds above which the Refuge can receive a daily delivery equal to the monthly demand, if the Project has a full supply. Set to 4142.50 ft in June, and 4141.50 ft in July.	UKL_rfg_up_thresh_	SeasonalSupply.wresl
UKLsupply	UKL supply	Supply identified in UKL as available to meet needs in the river, Refuge, and Project.	UKLSupplydv	SeasonalSupply.wresl
ukltraj_central	UKL central tendency base	Unadjusted UKL central tendency.	ukltraj_central_	UKLThresholds.wresl
ukltraj_high	Upper bound to adjusted UKL central tendency	Upper bound to adjusted UKL central tendency.	ukltraj_high_	UKLThresholds.wresl
ukltraj_low	Lower bound to adjusted UKL central tendency	Lower bound to adjusted UKL central tendency.	ukltraj_low_	UKLThresholds.wresl
upper_4dTrigger_mult	Variable used to compute stage1_trigger	Variable involved in computation of stage1_trigger. Set to 3.	-	FallWinterRiverOps.wresl
upper_I15_wyAvg_mult	Variable used to compute stage1_trigger	Variable involved in computation of stage1_trigger. Set to 1.6.	-	FallWinterRiverOps.wresl

Section B: Proposed Action Model Output Graphs

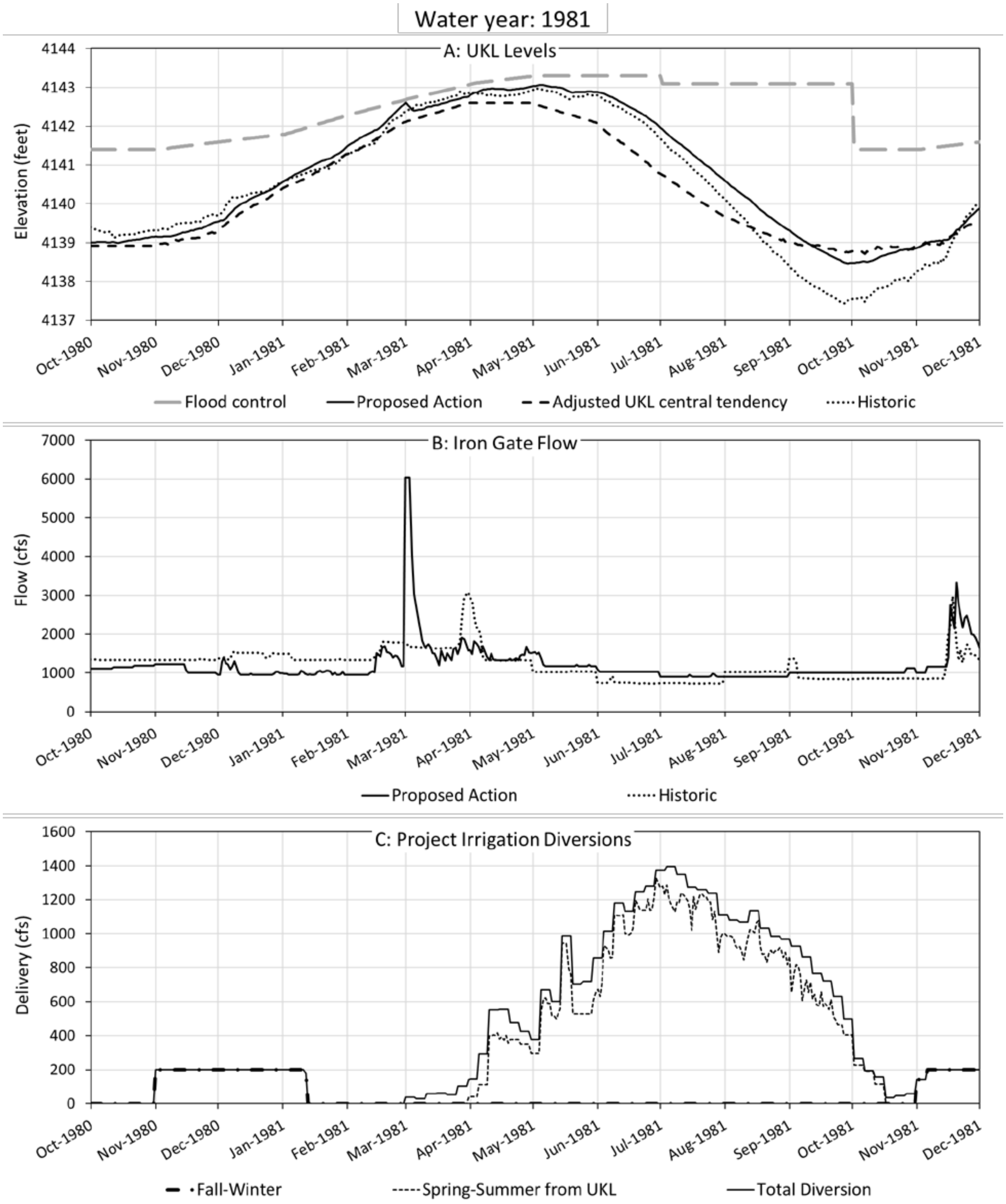

Figure B1. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1981.

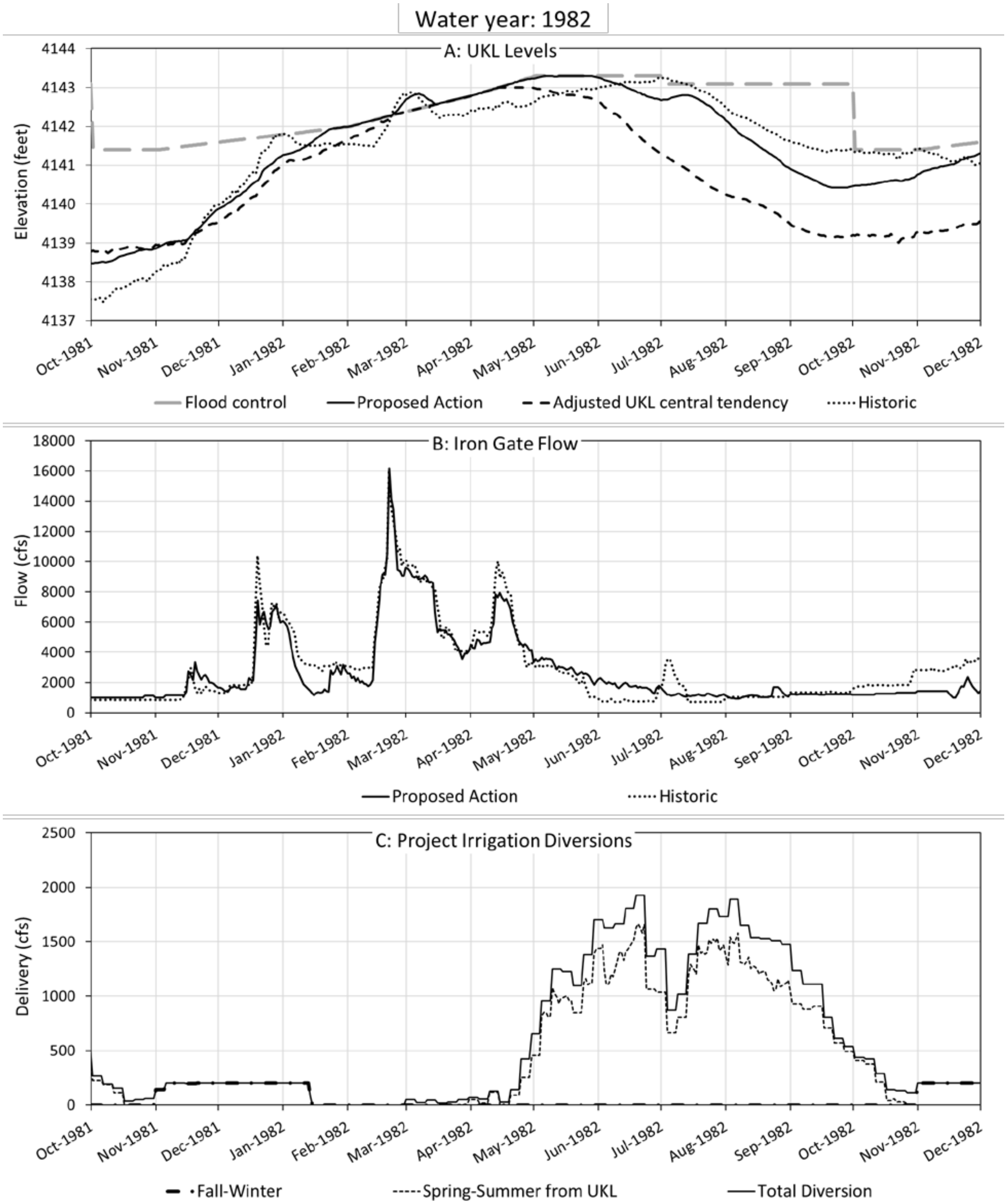

Figure B2. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1982.

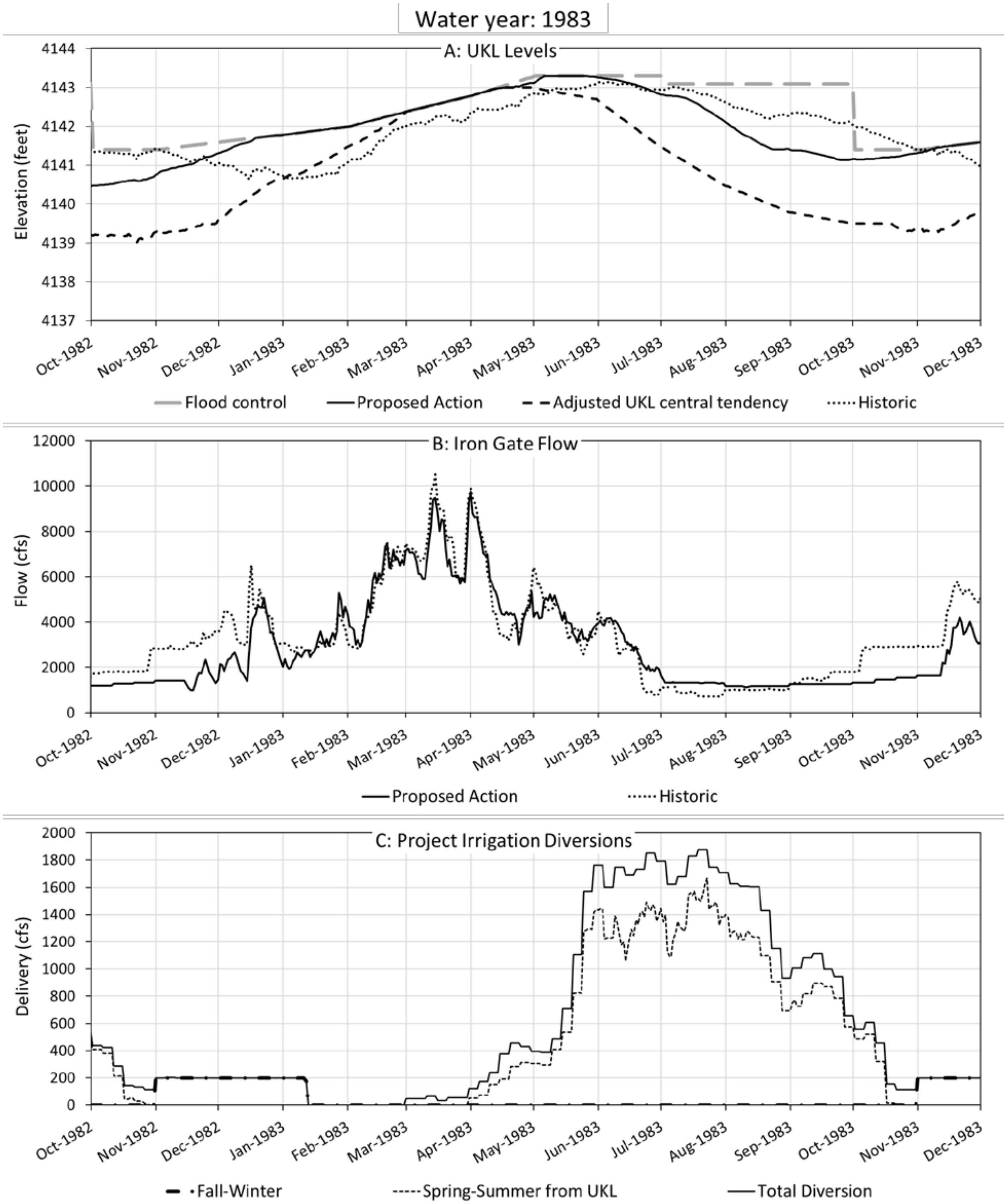

Figure B3. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1983.

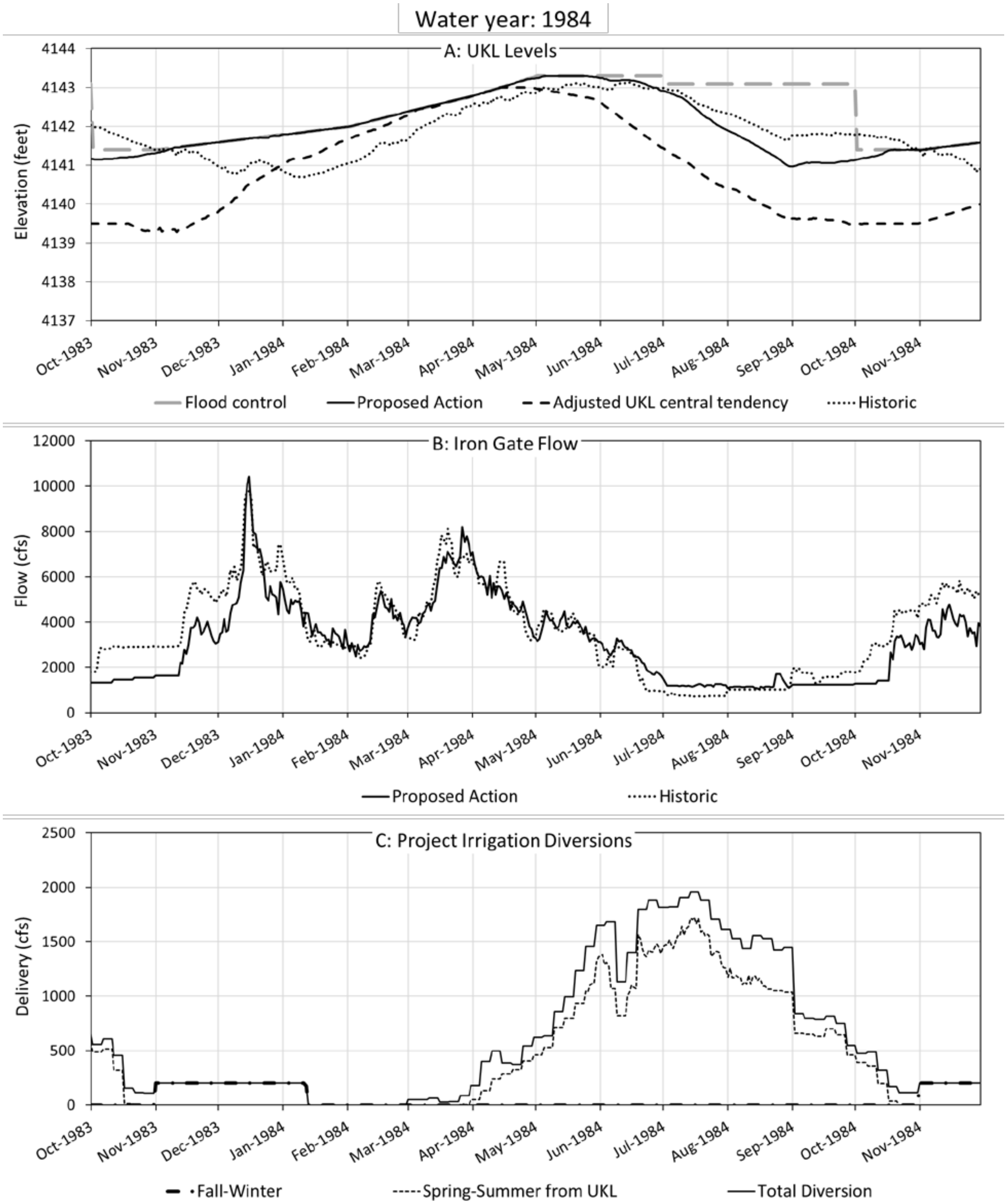

Figure B4. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1984.

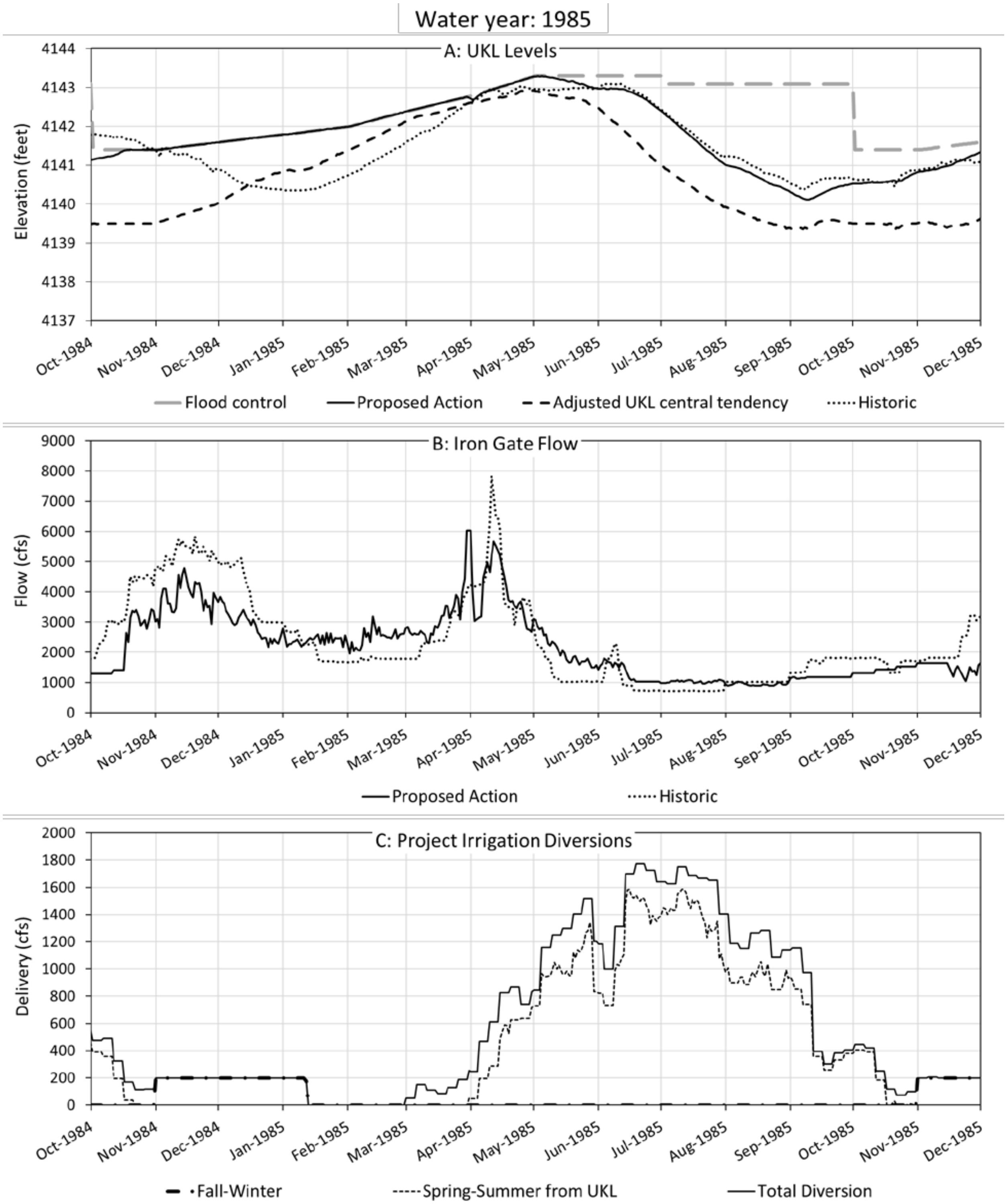

Figure B5. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1985.

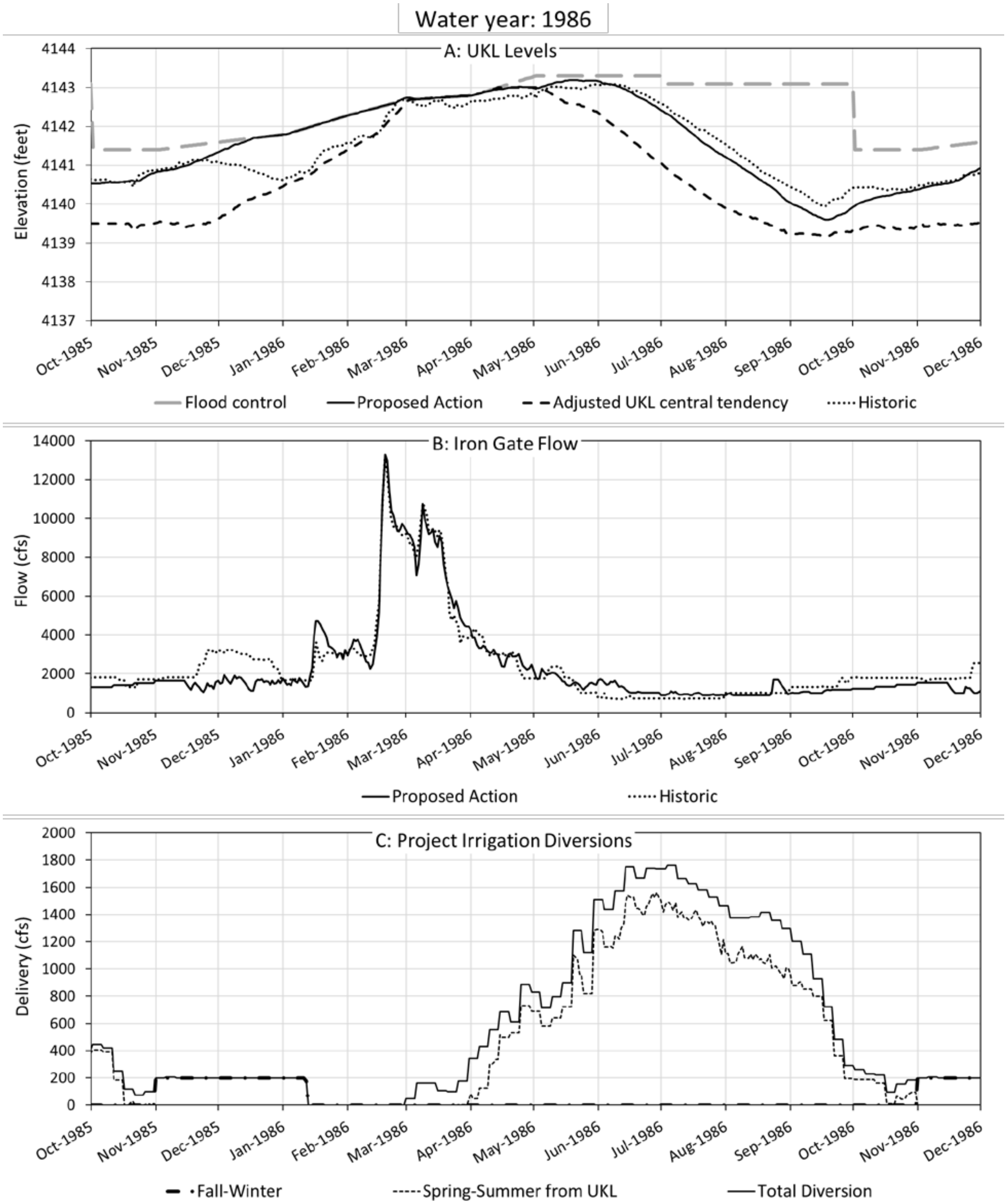

Figure B6. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1986.

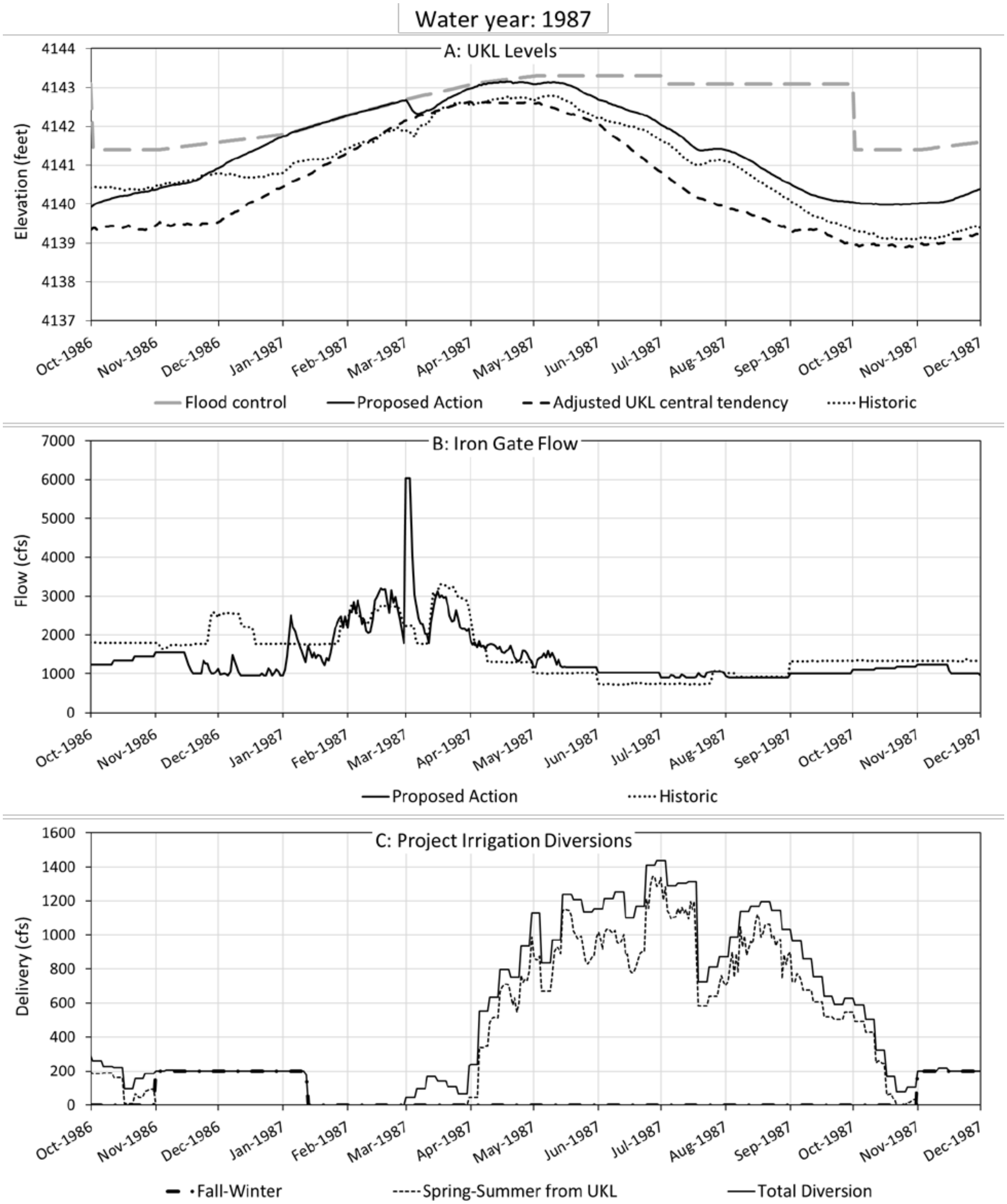

Figure B7. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1987.

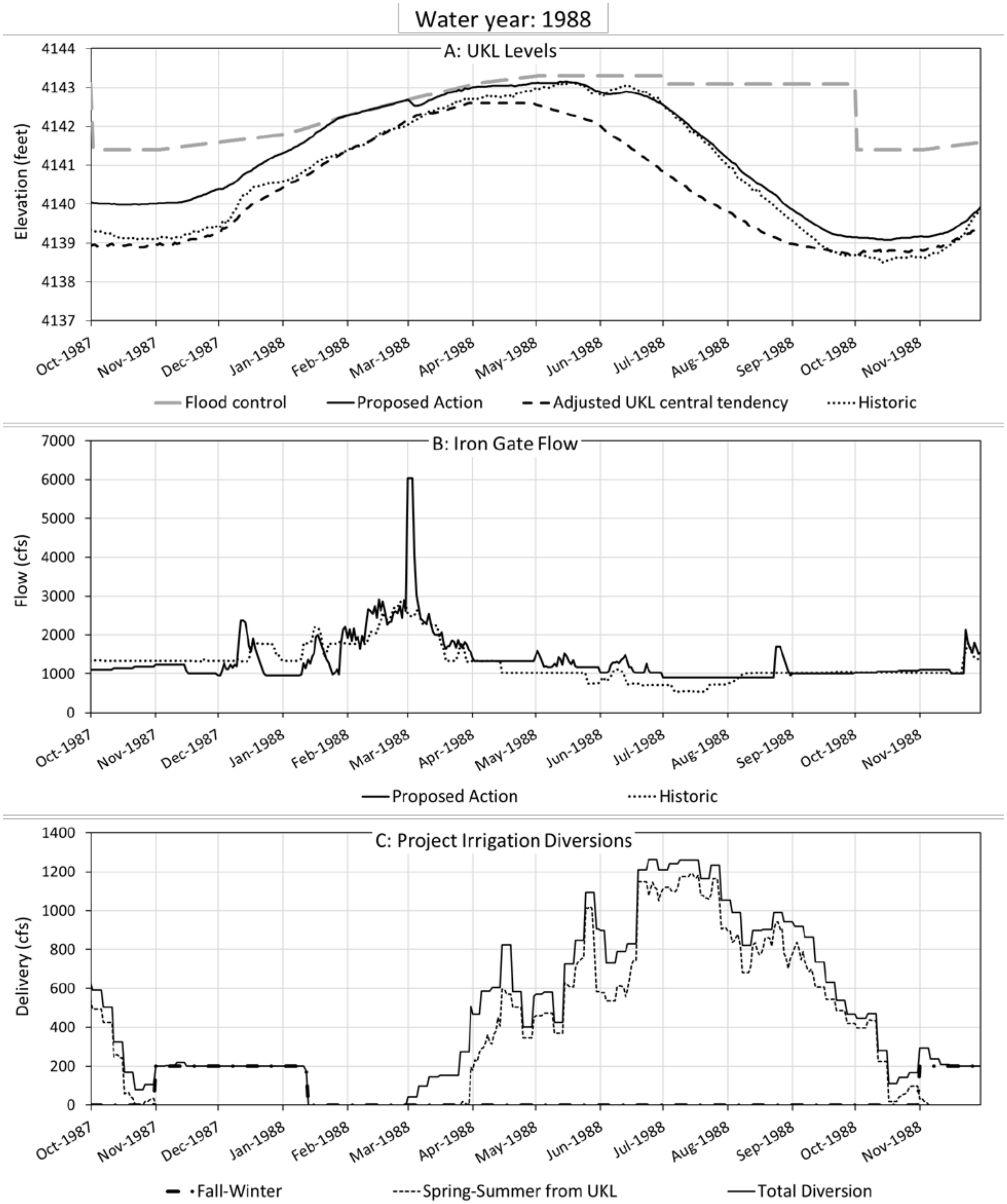

Figure B8. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1988.

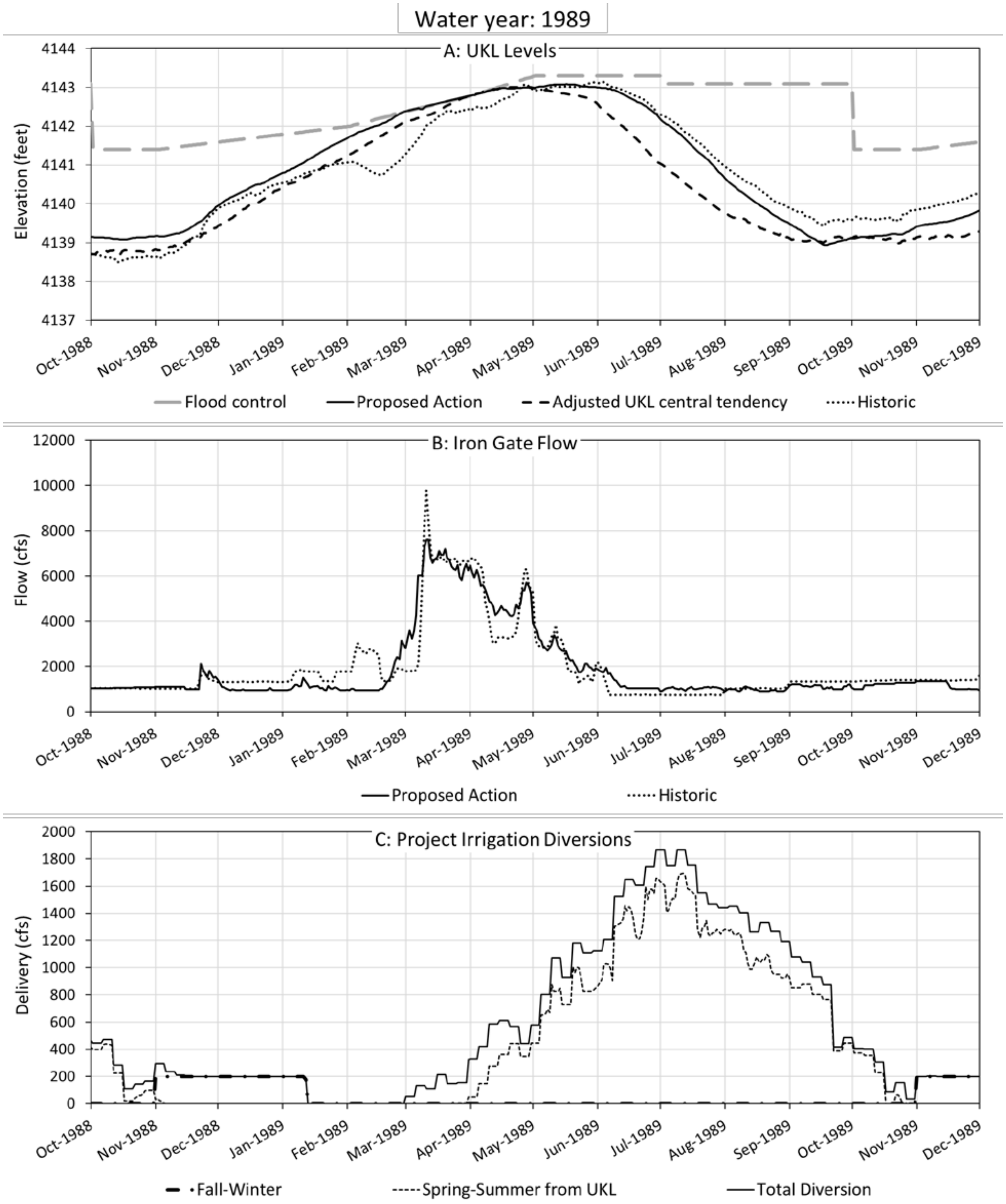

Figure B9. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1989.

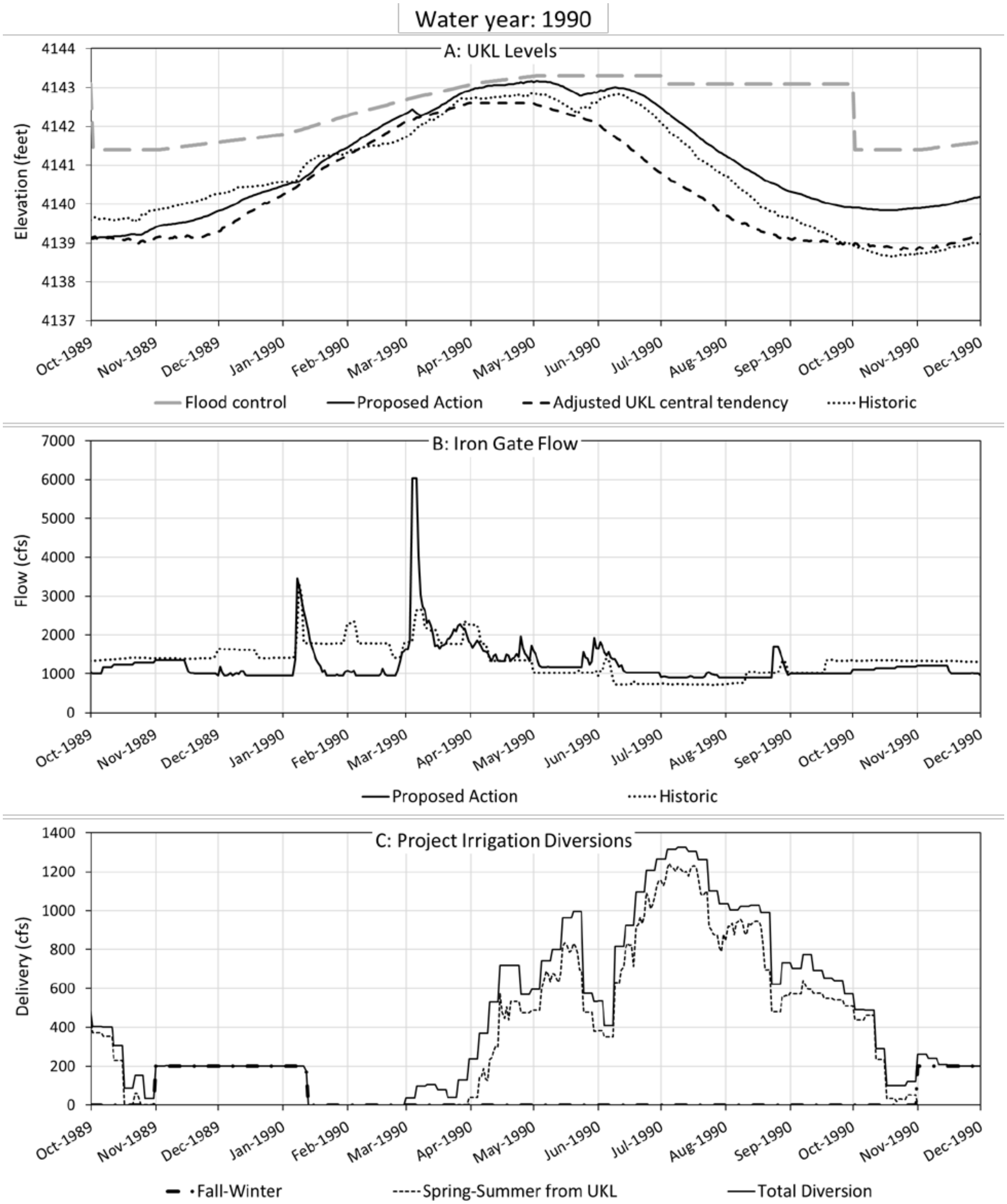

Figure B10. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1990.

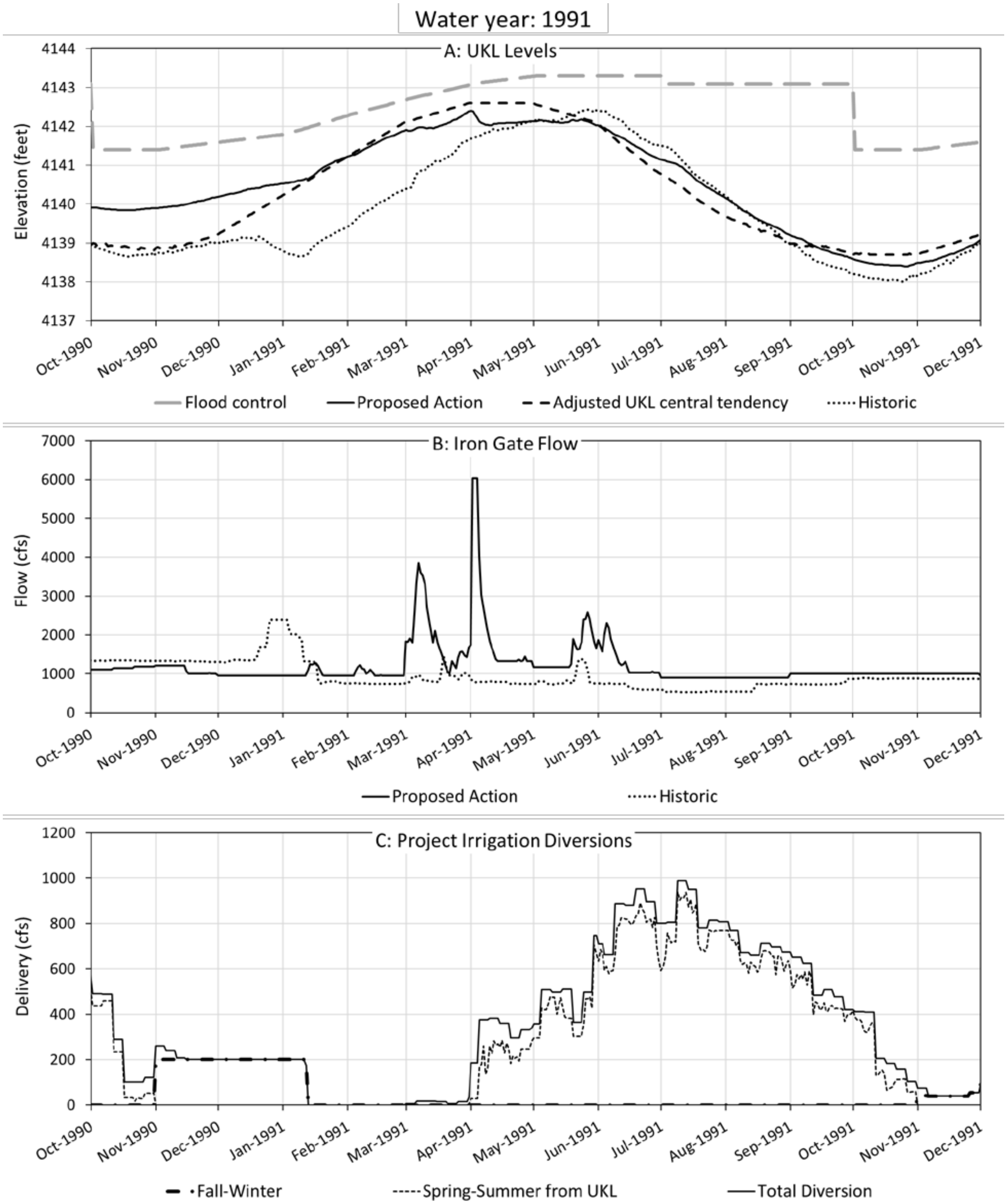

Figure B11. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1991.

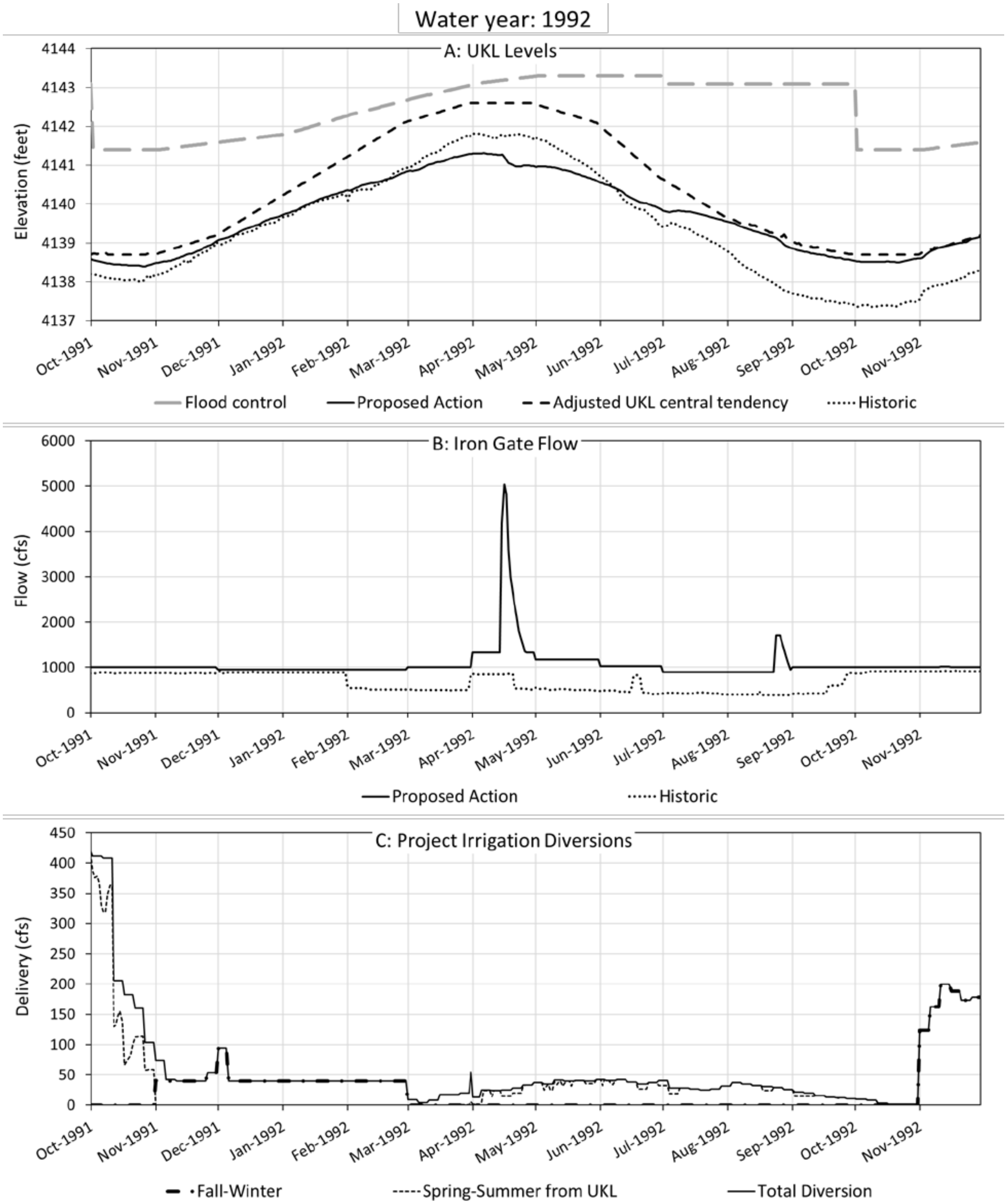

Figure B12. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1992.

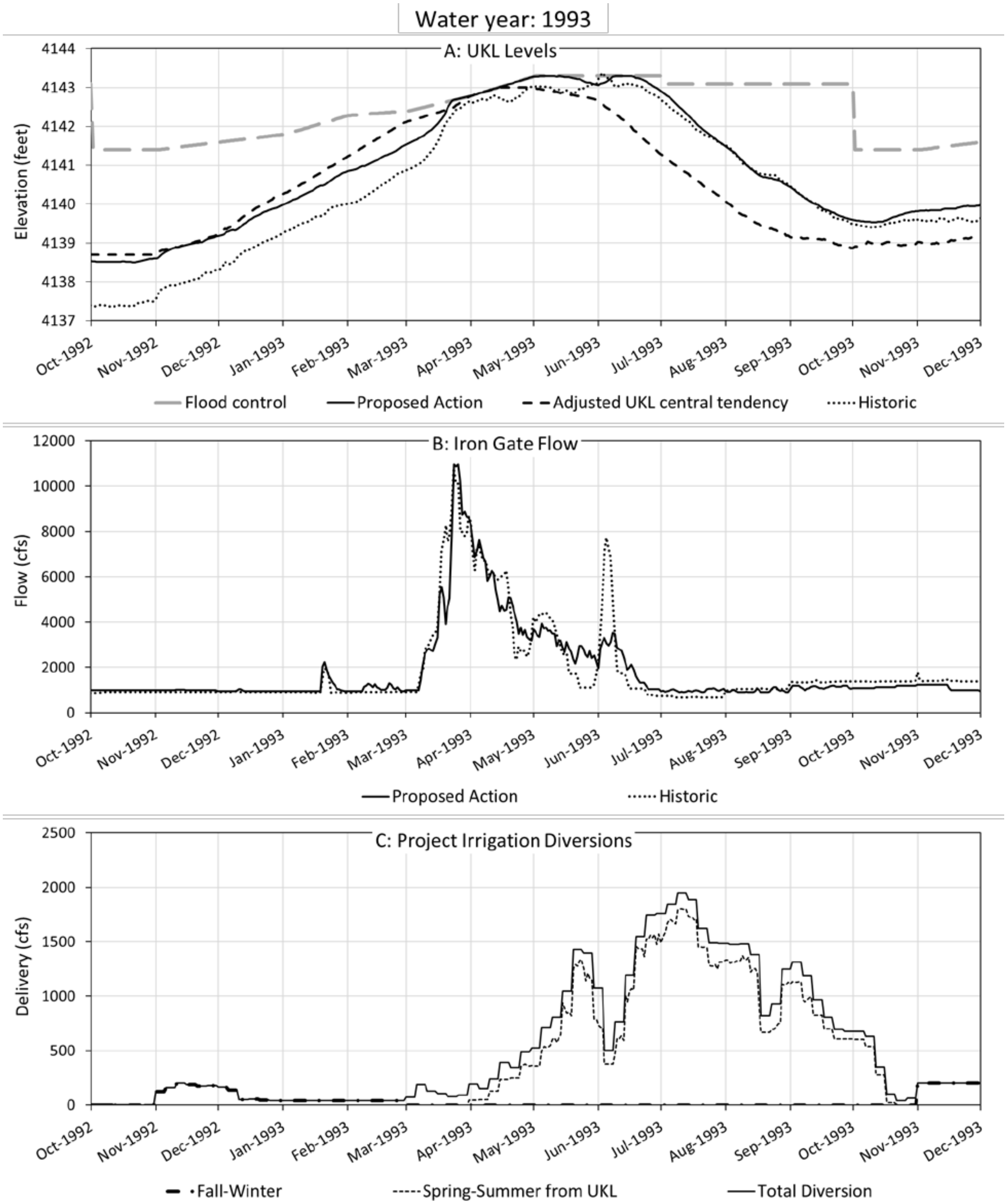

Figure B13. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1993.

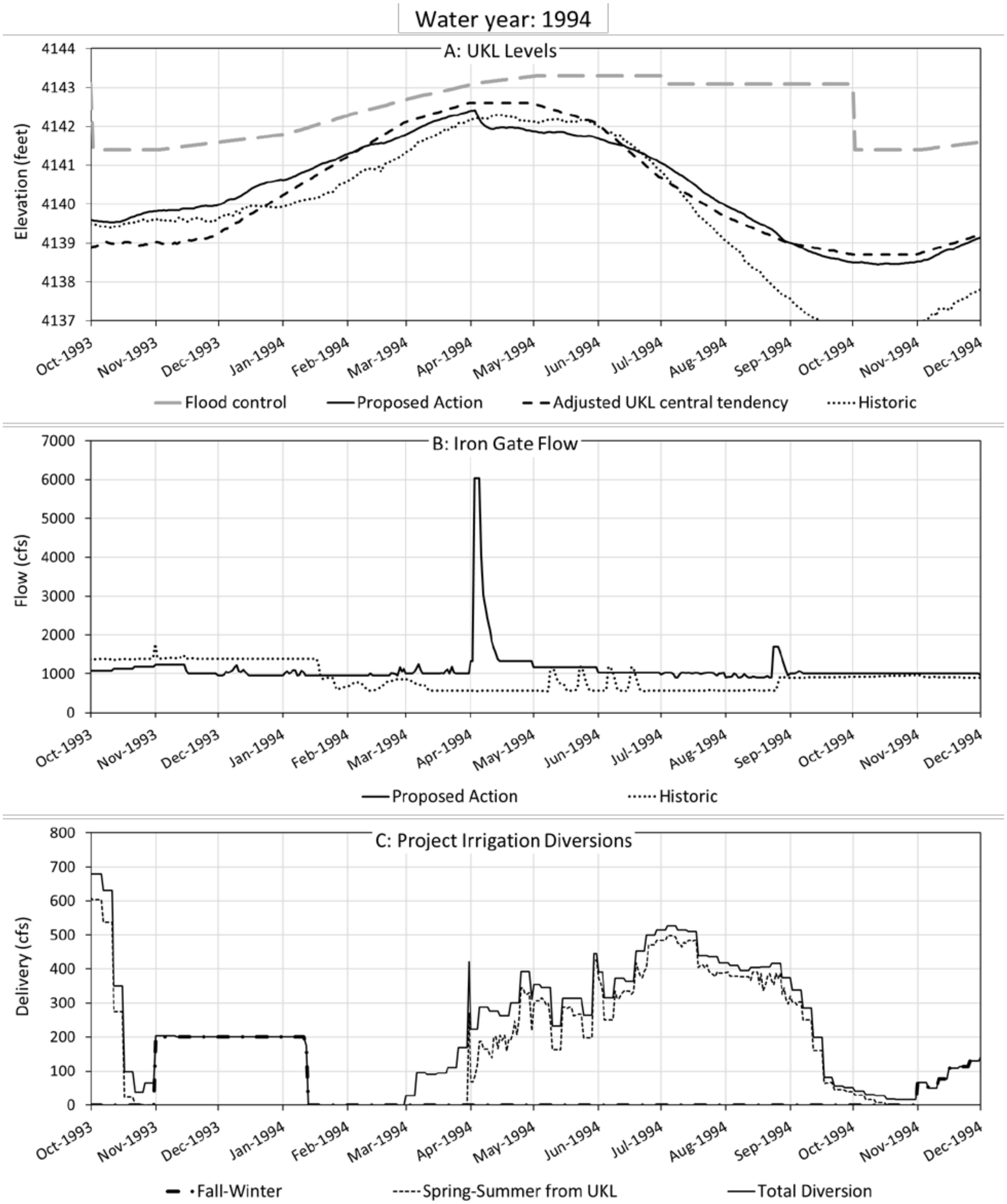

Figure B14. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1994.

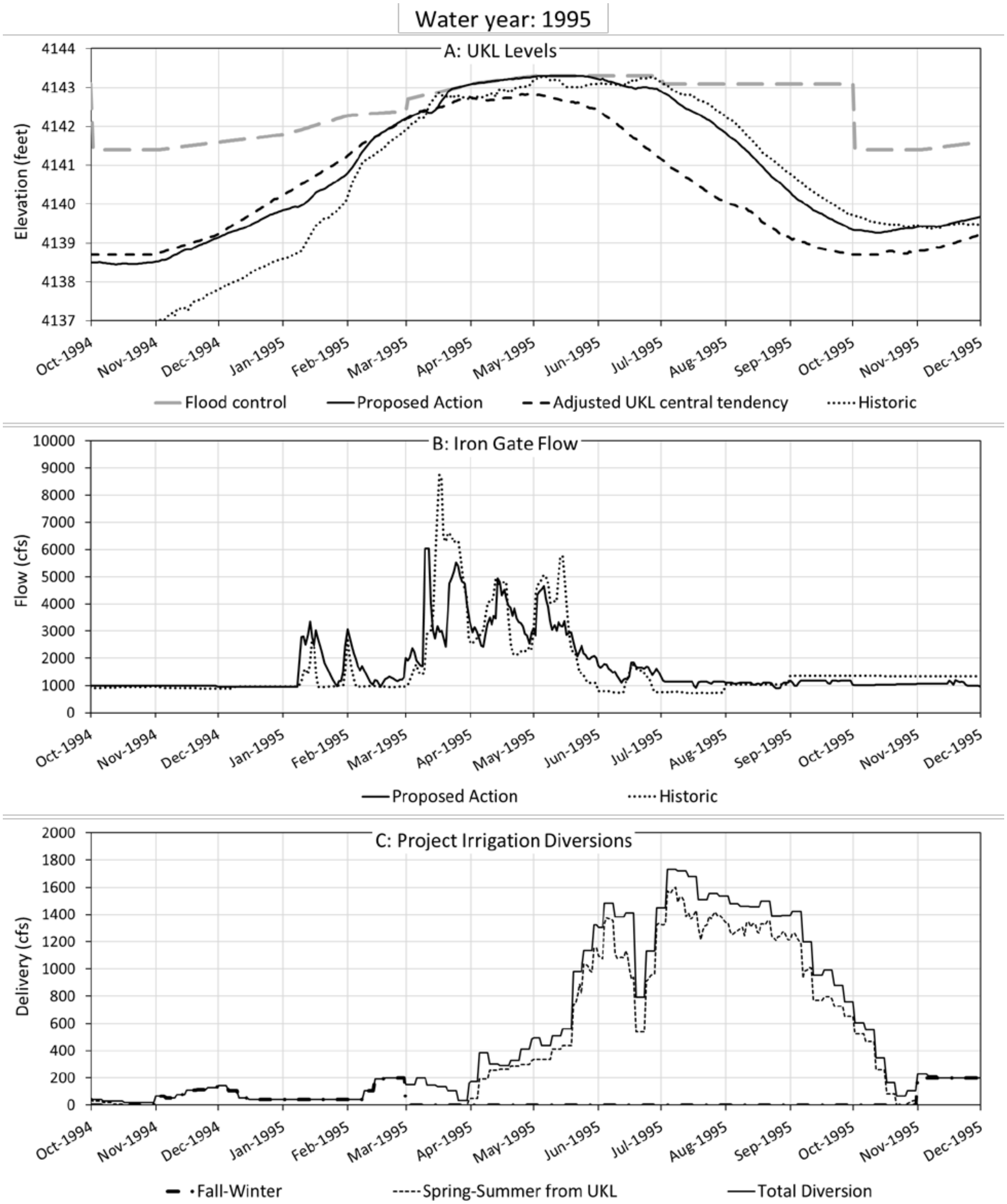

Figure B15. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1995.

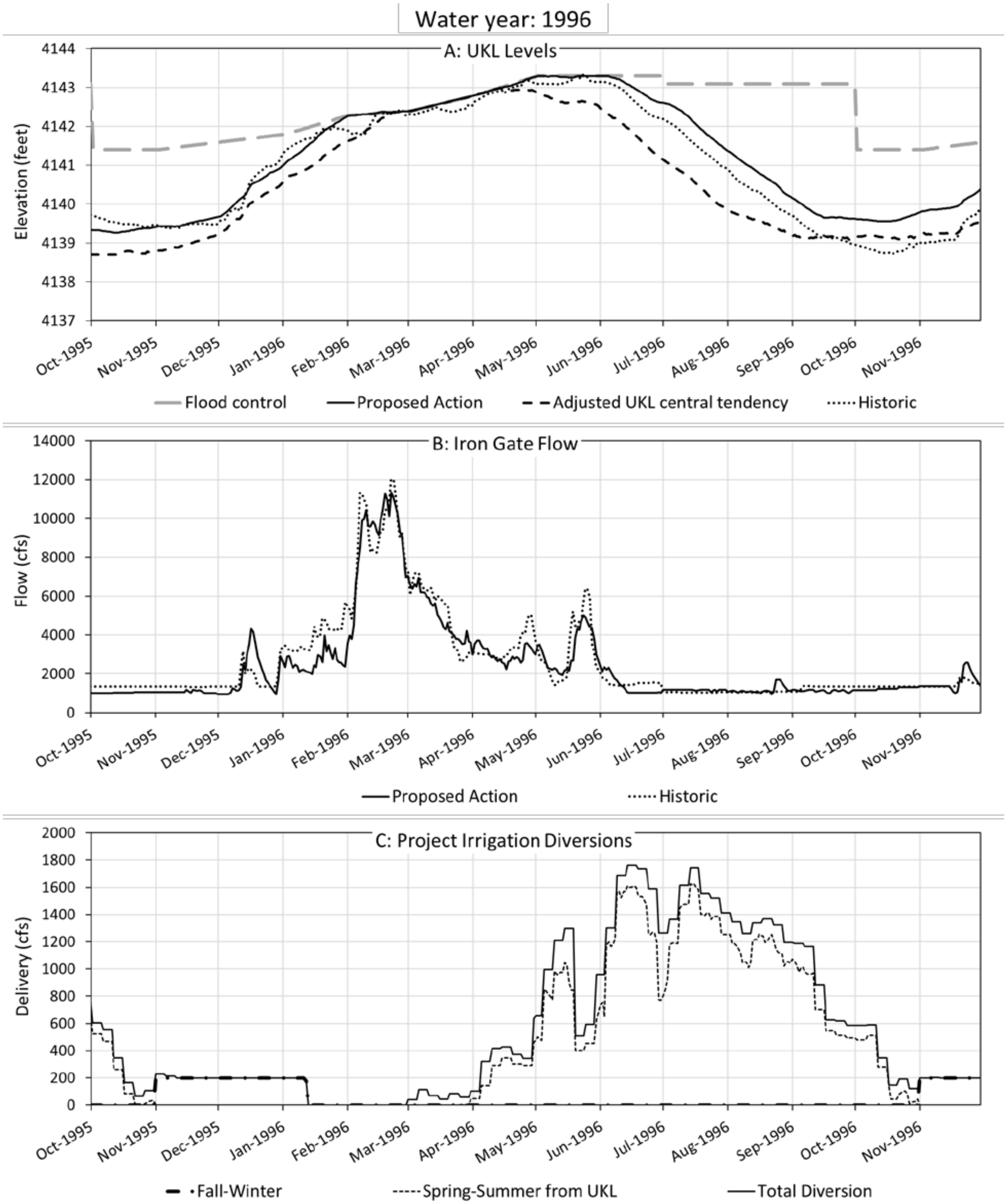

Figure B16. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1996.

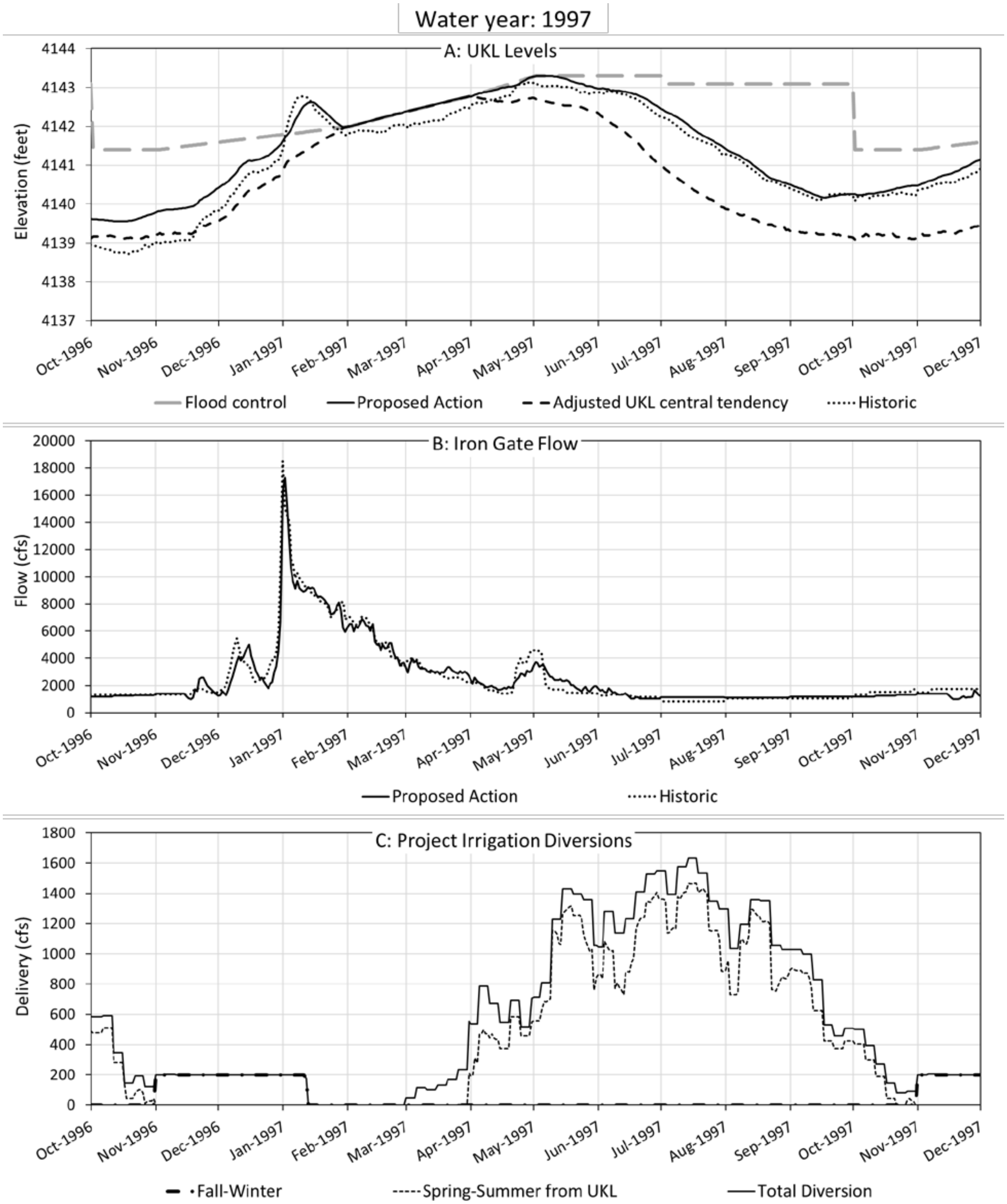

Figure B17. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1997.

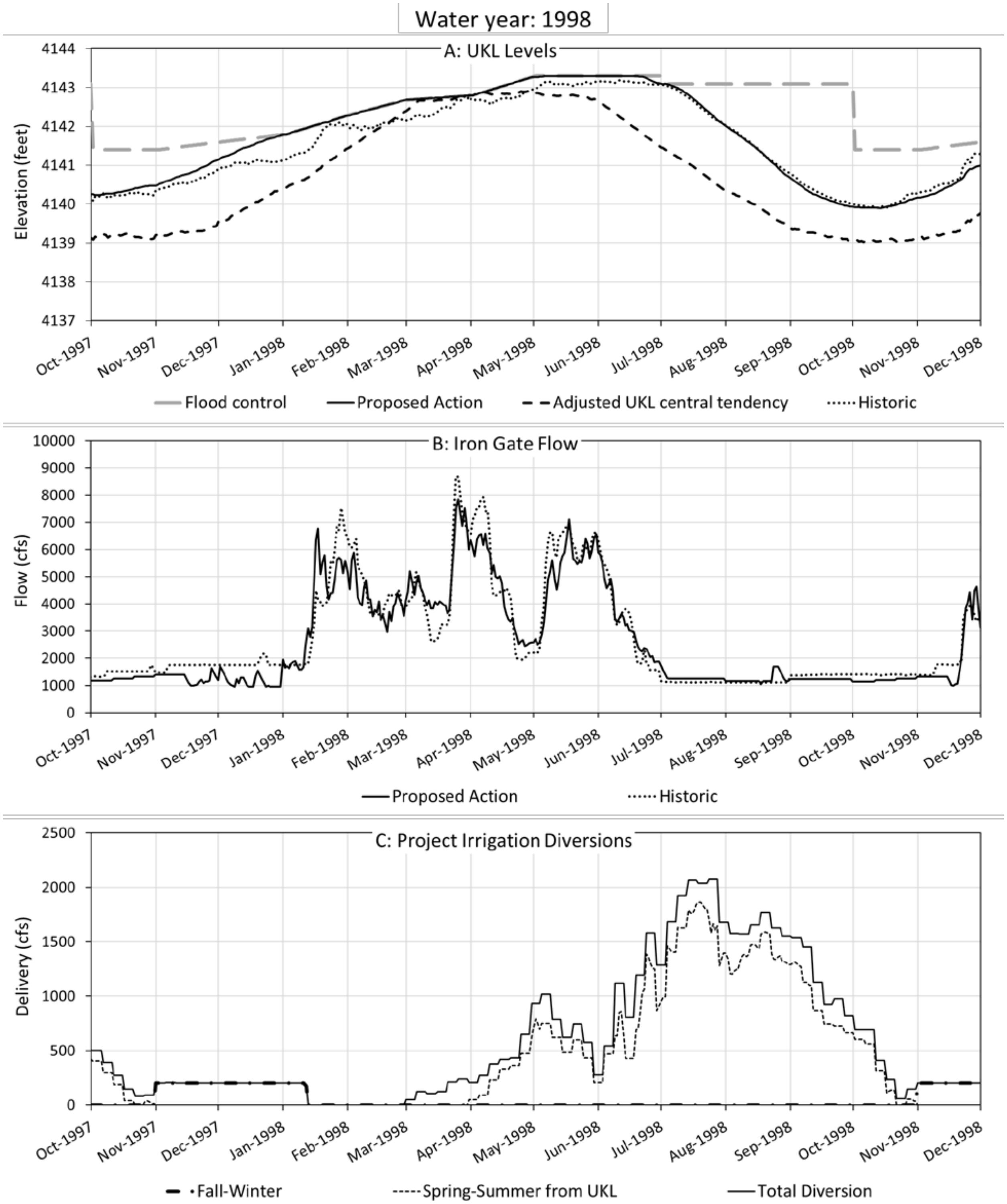

Figure B18. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1998.

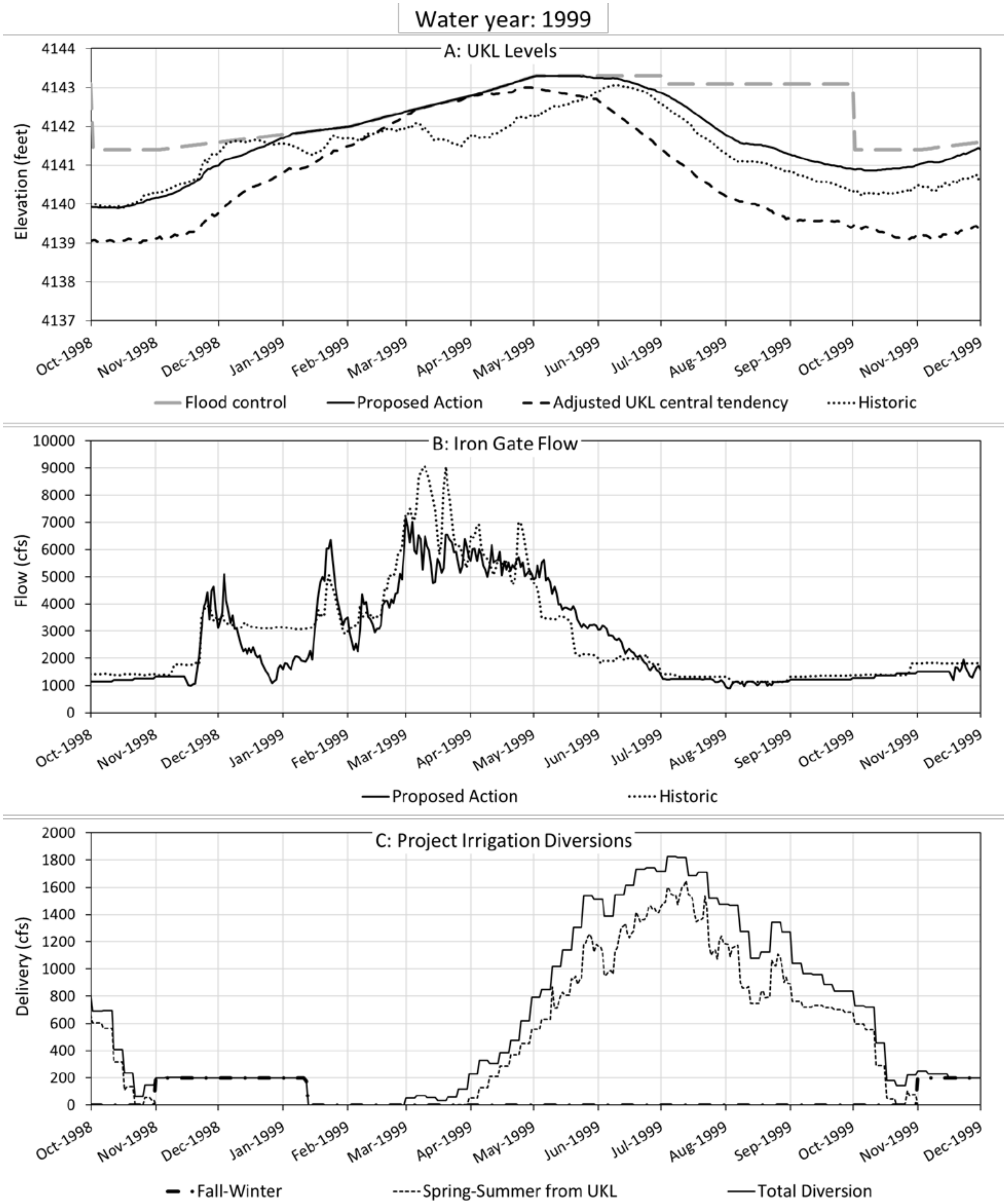

Figure B19. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1999.

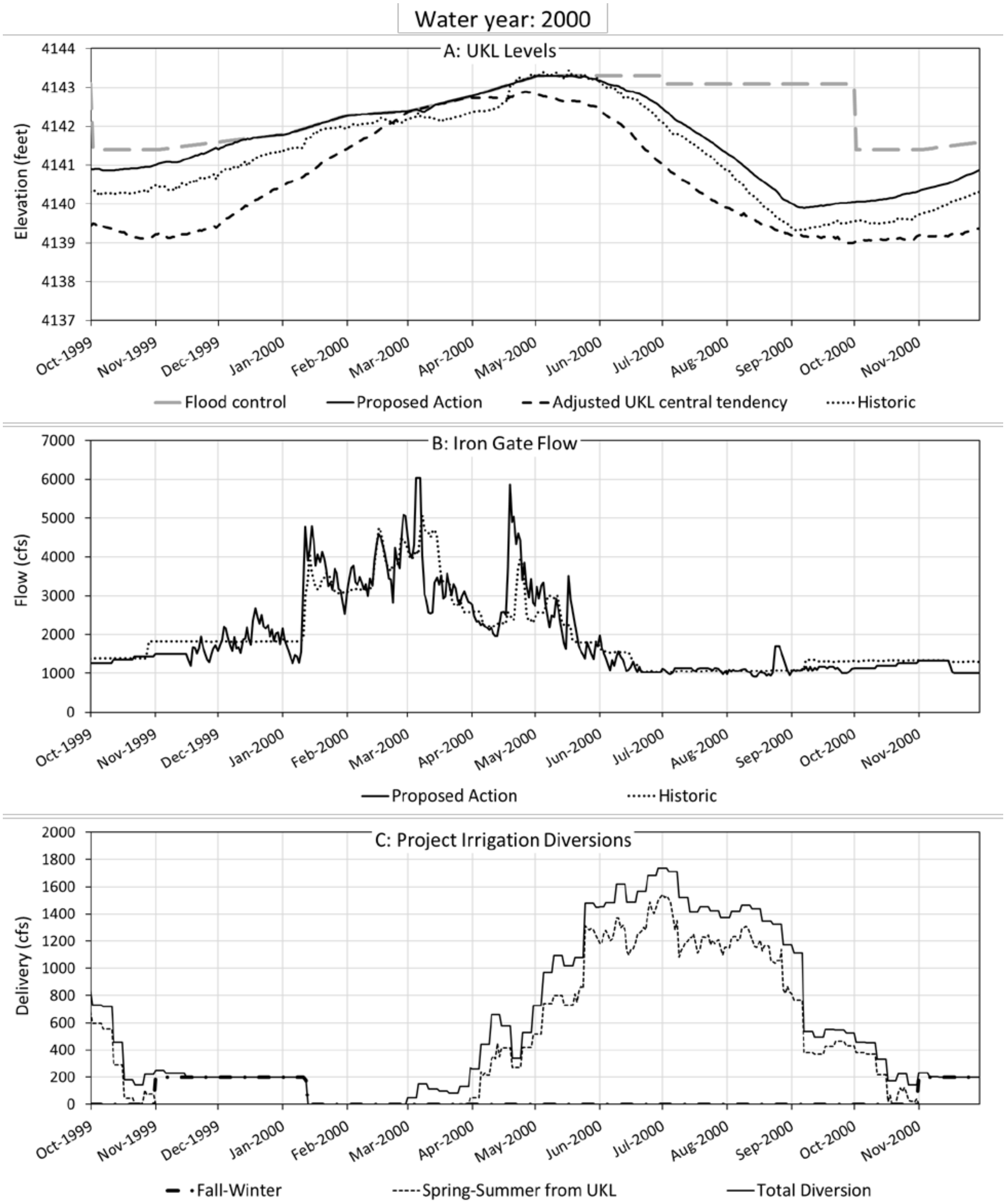

Figure B20. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 2000.

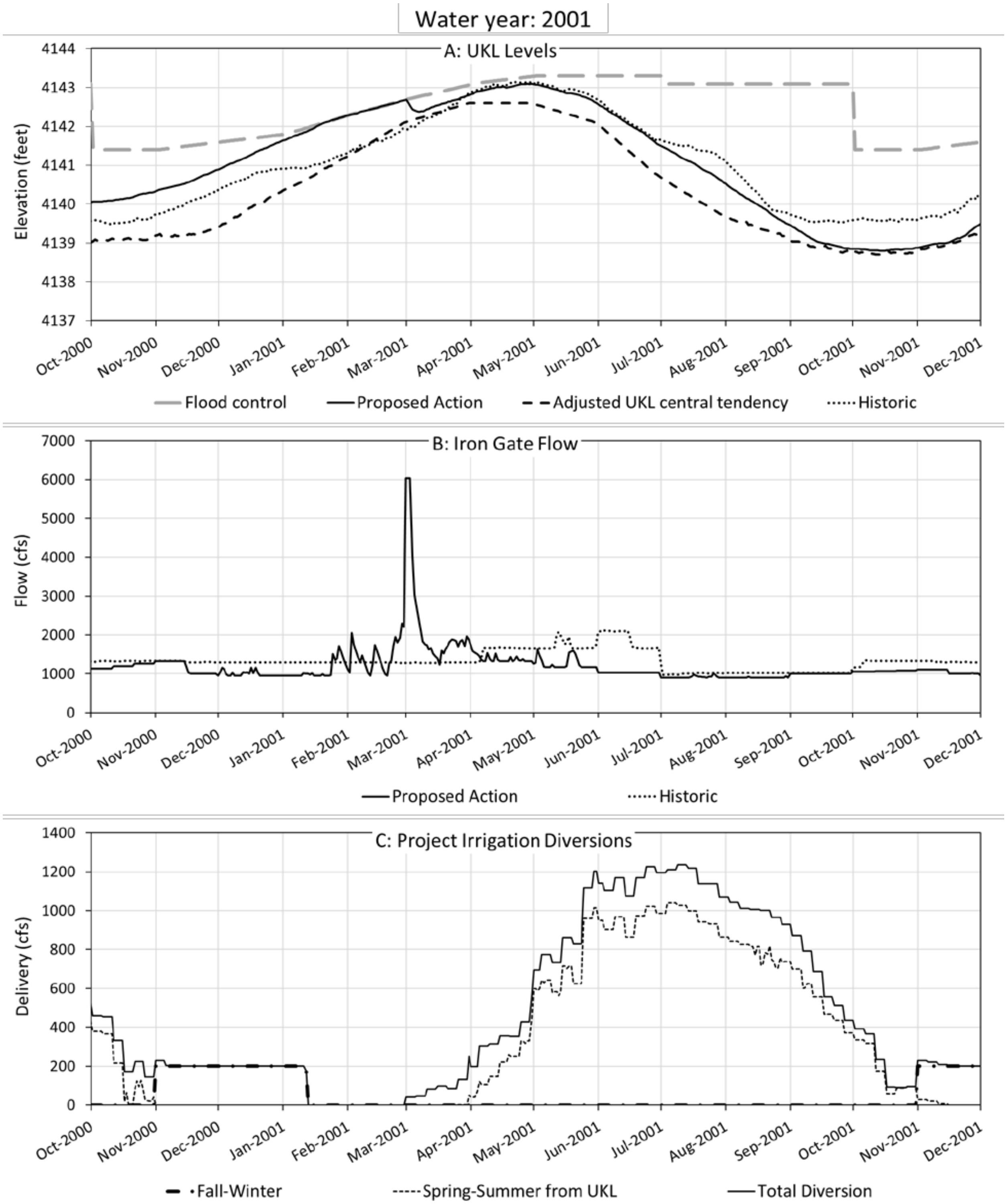

Figure B21. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 2001.

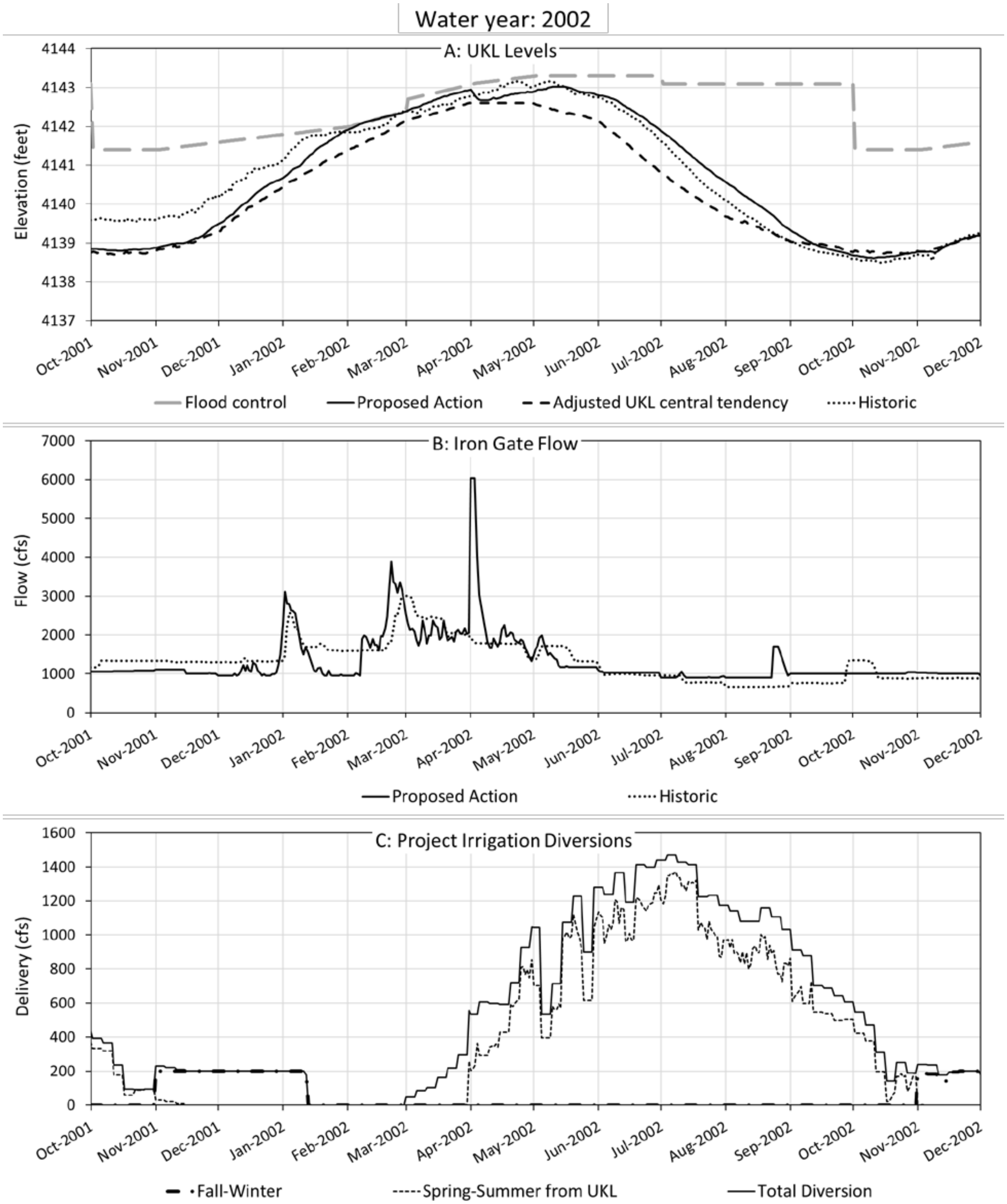

Figure B22. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 2002.

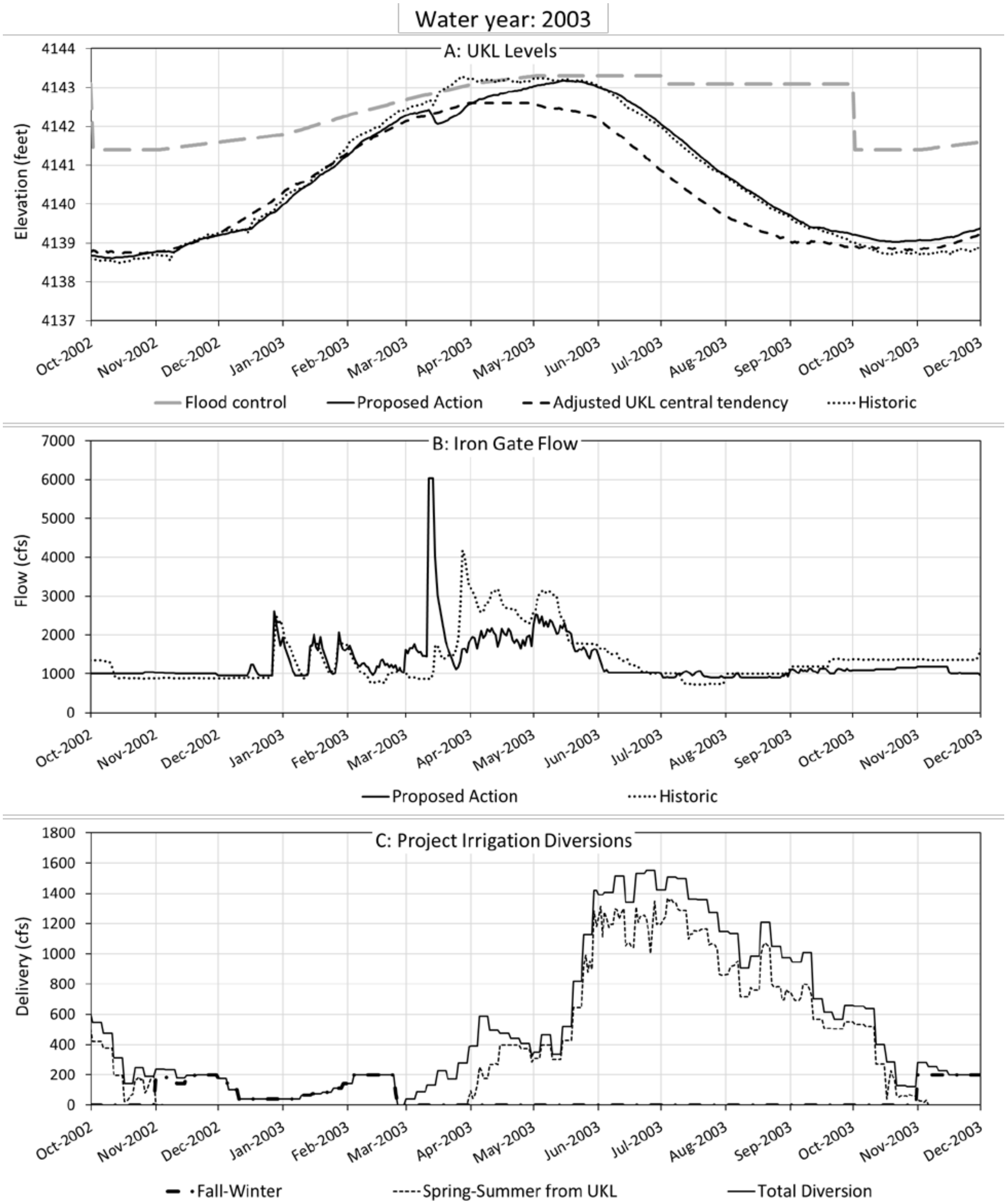

Figure B23. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 2003.

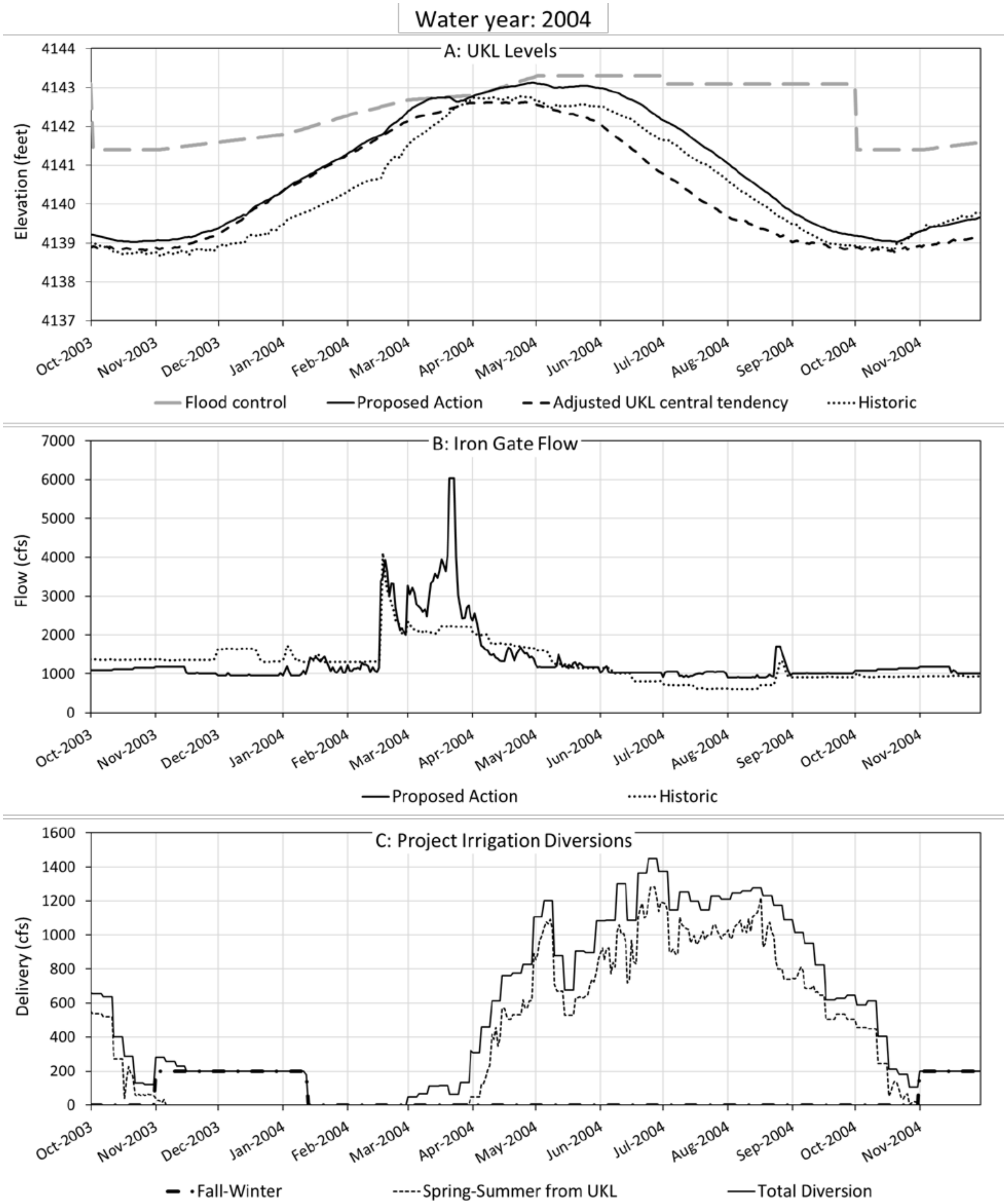

Figure B24. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 2004.

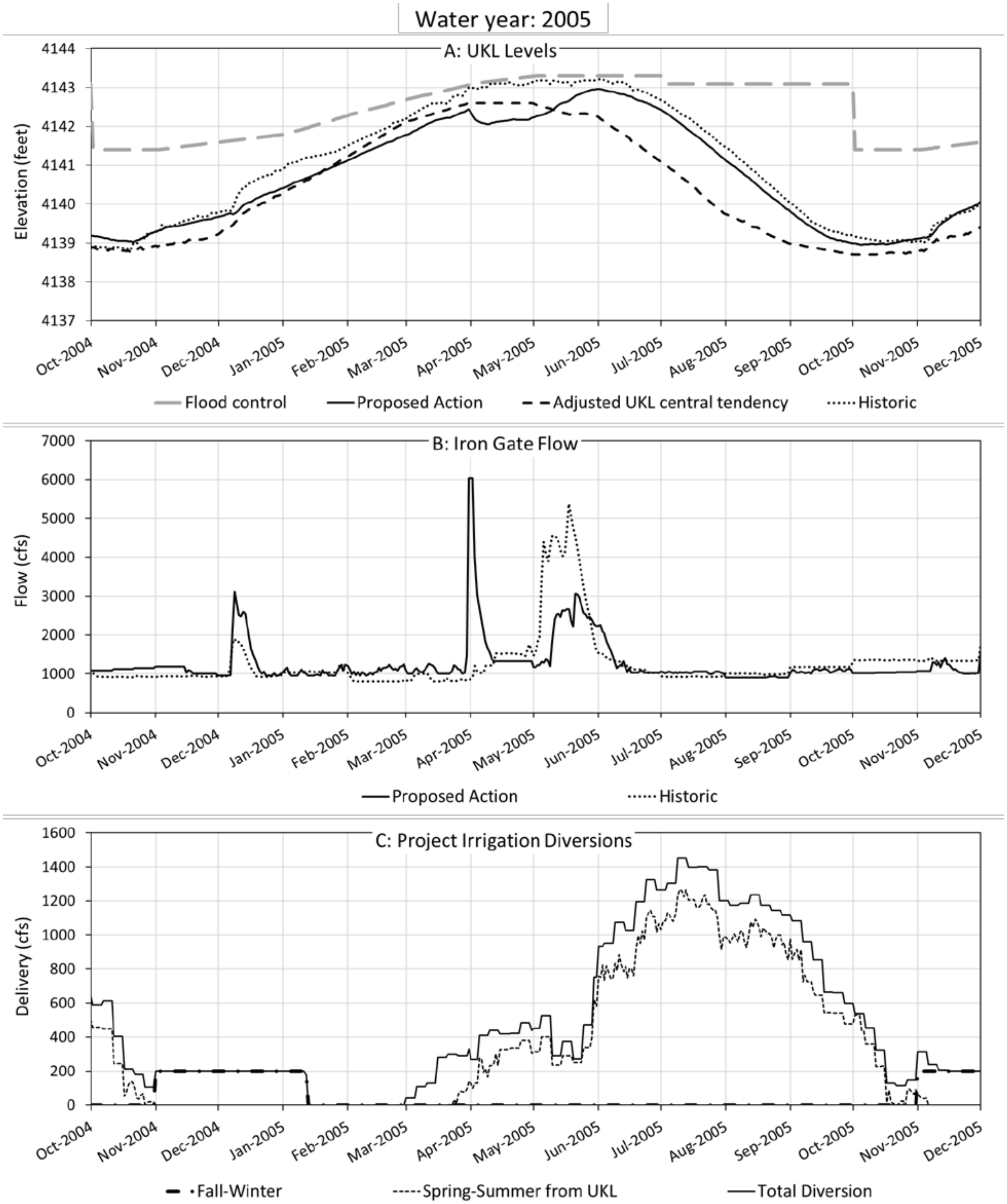

Figure B25. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 2005.

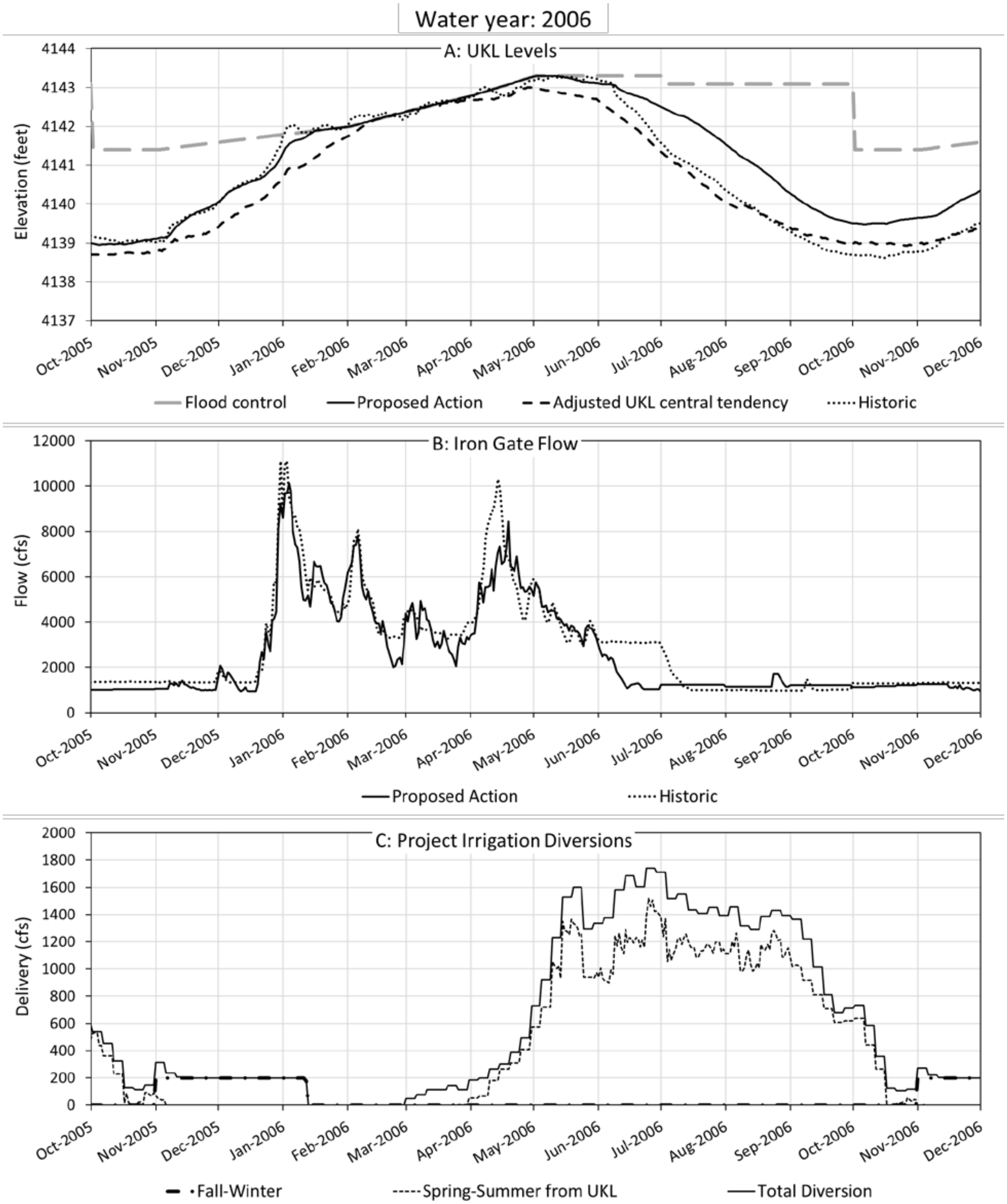

Figure B26. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 2006.

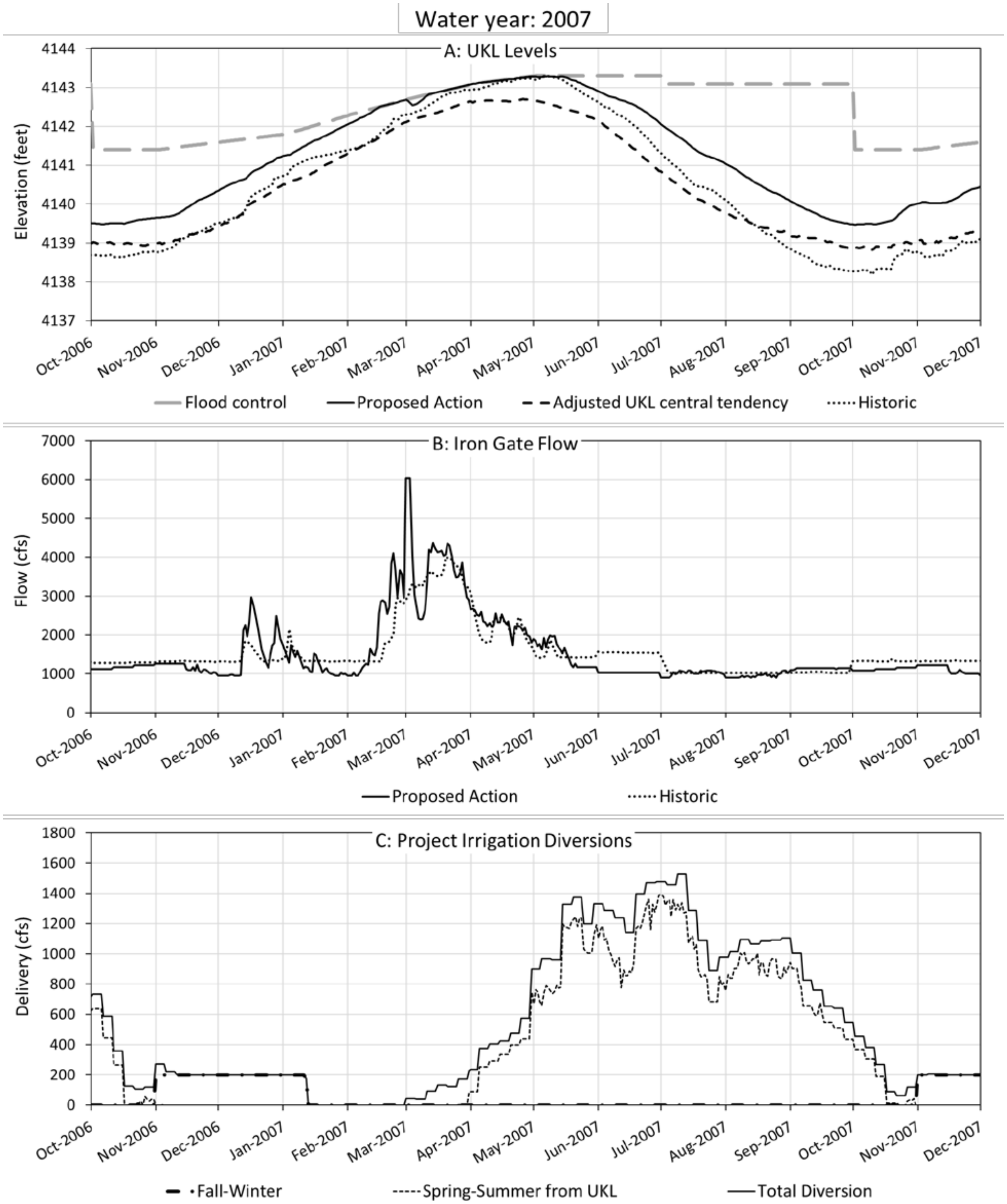

Figure B27. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 2007.

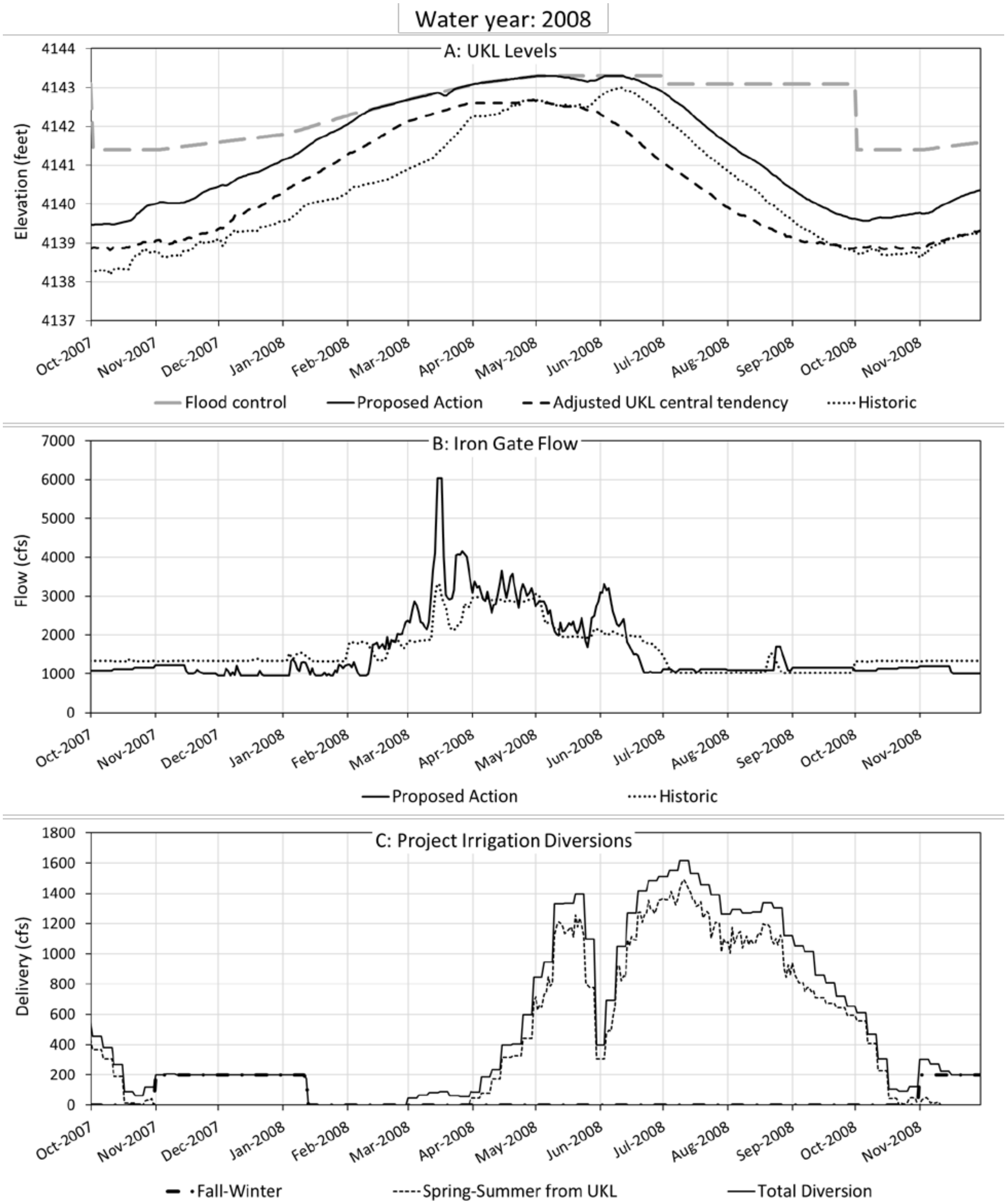

Figure B28. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 2008.

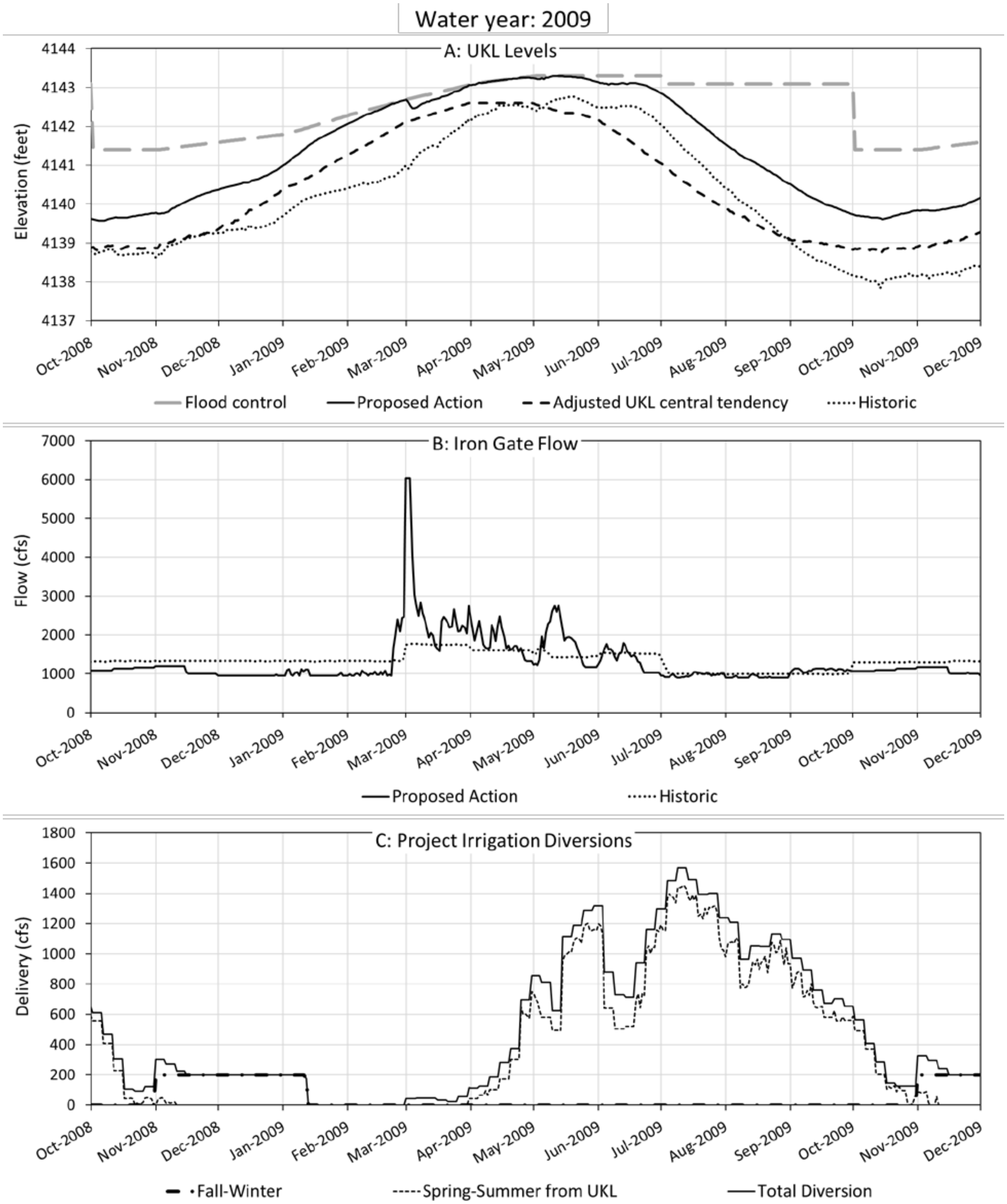

Figure B29. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 2009.

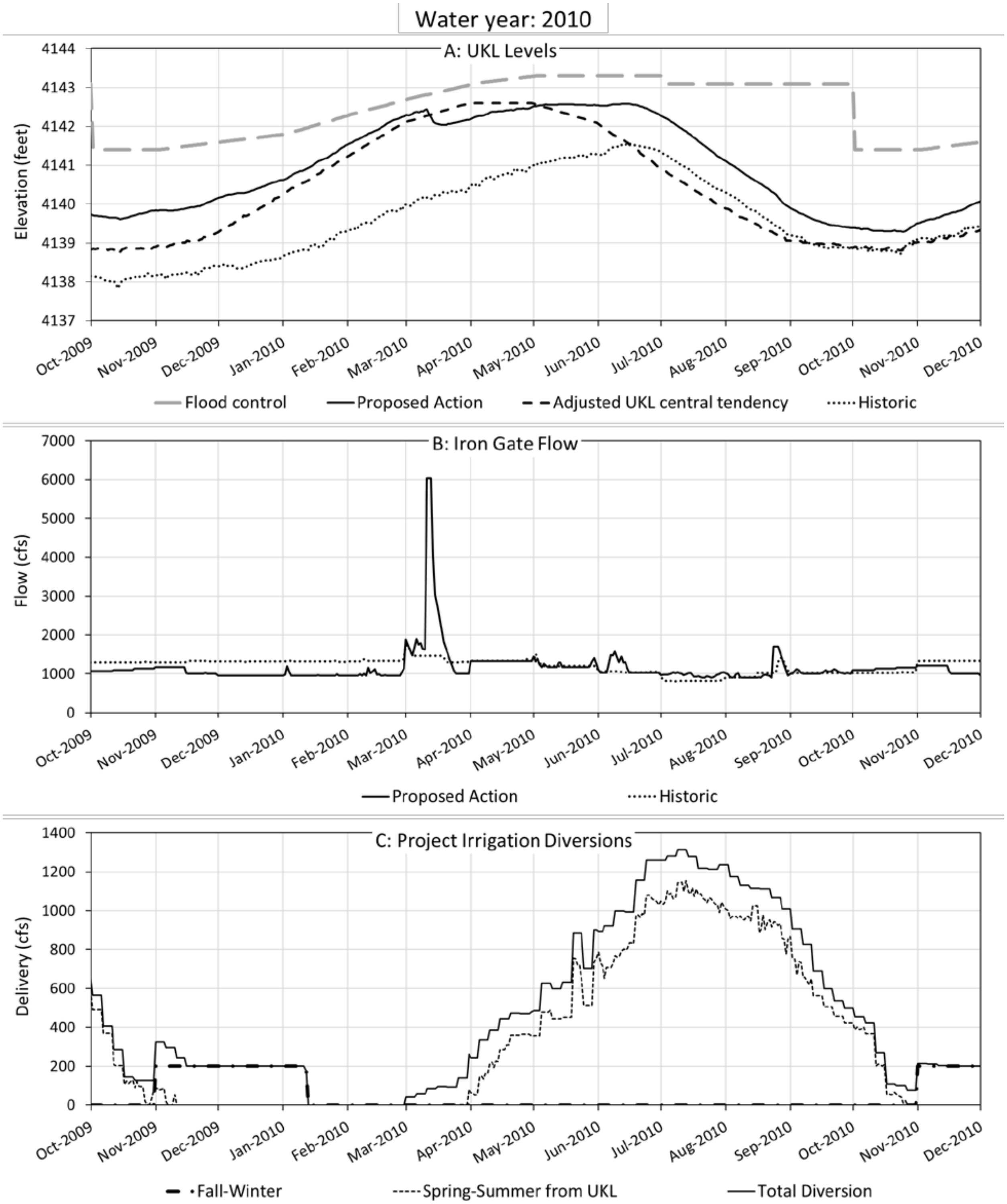

Figure B30. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 2010.

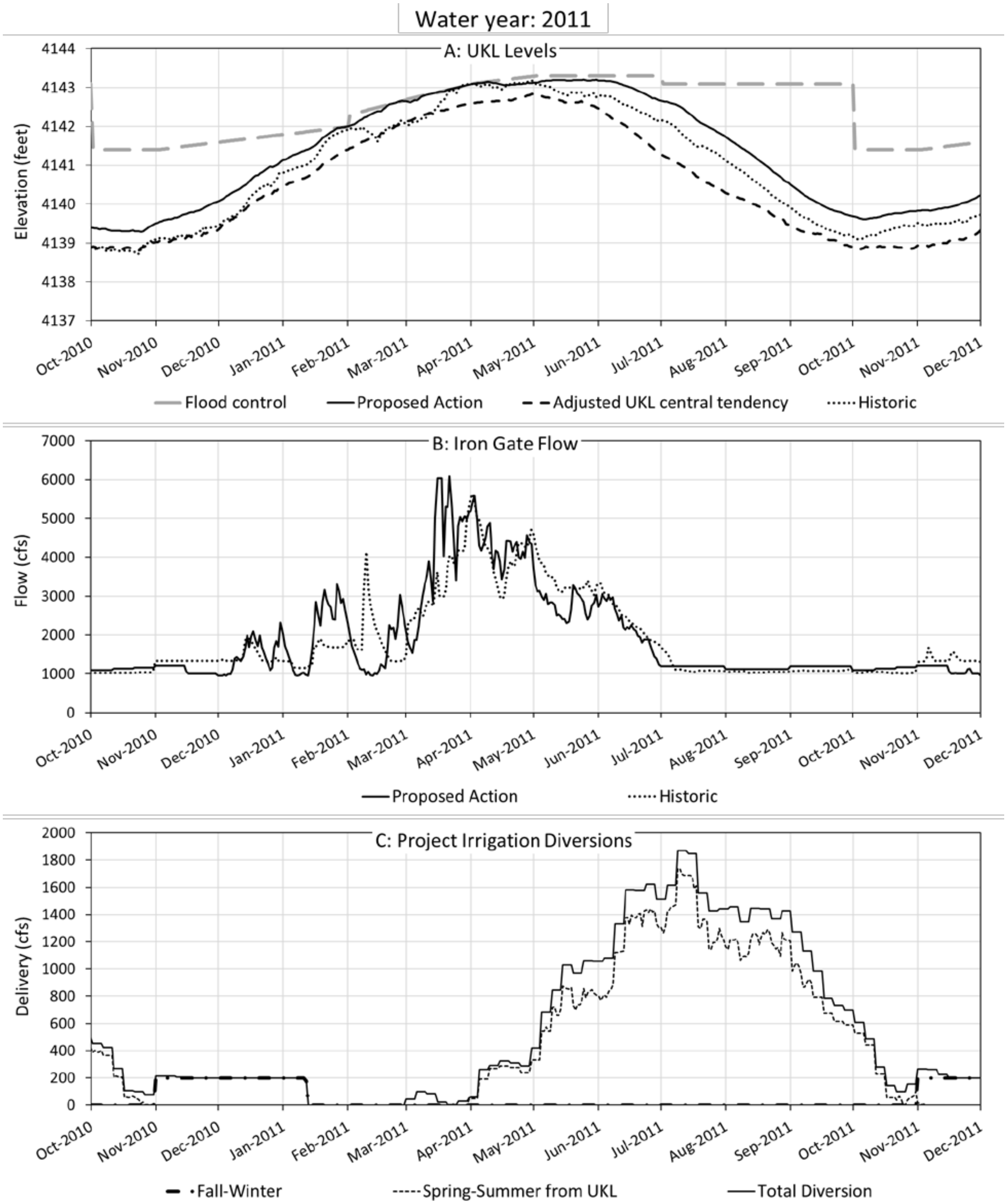

Figure B31. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 2011.

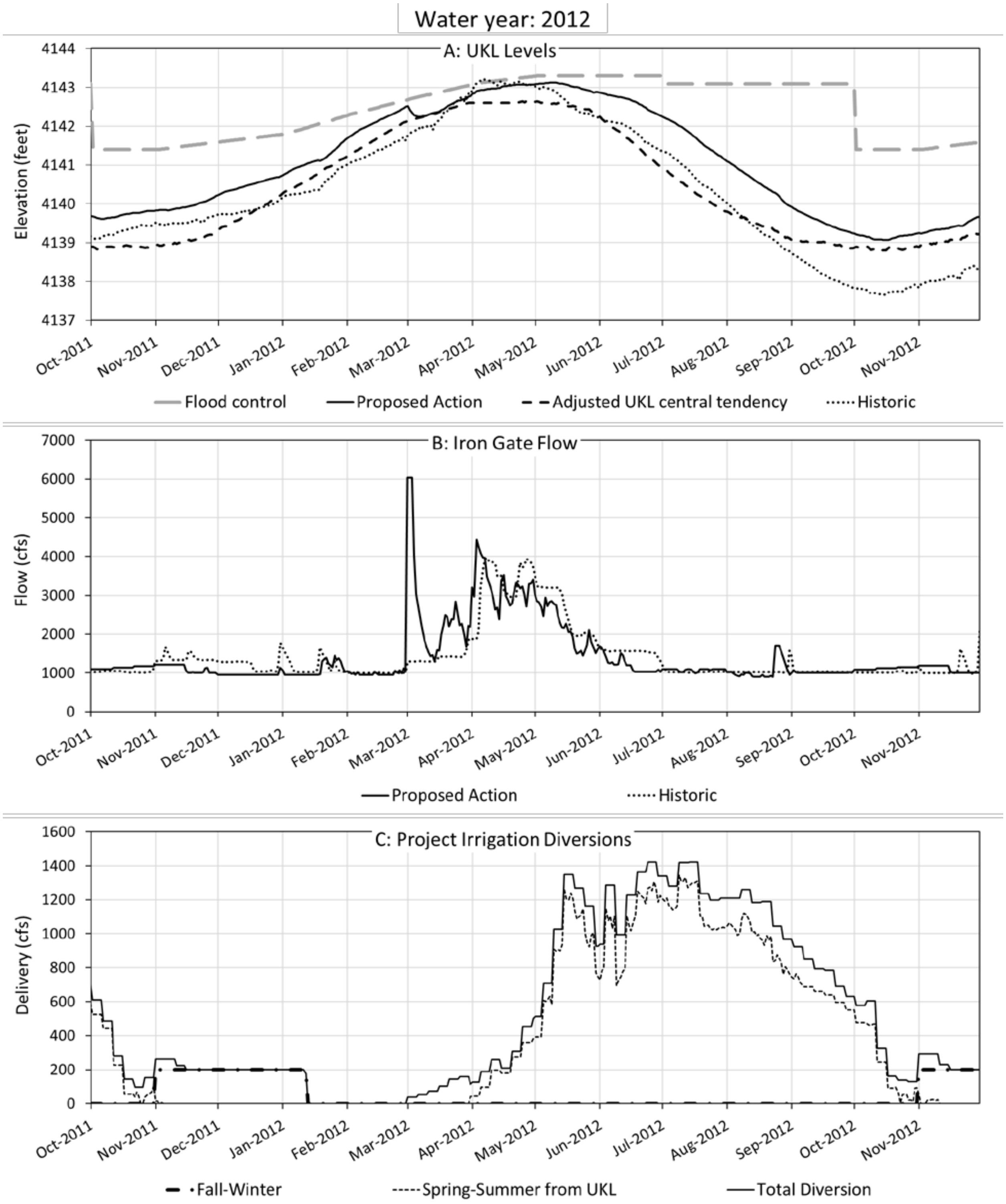

Figure B32. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 2012.

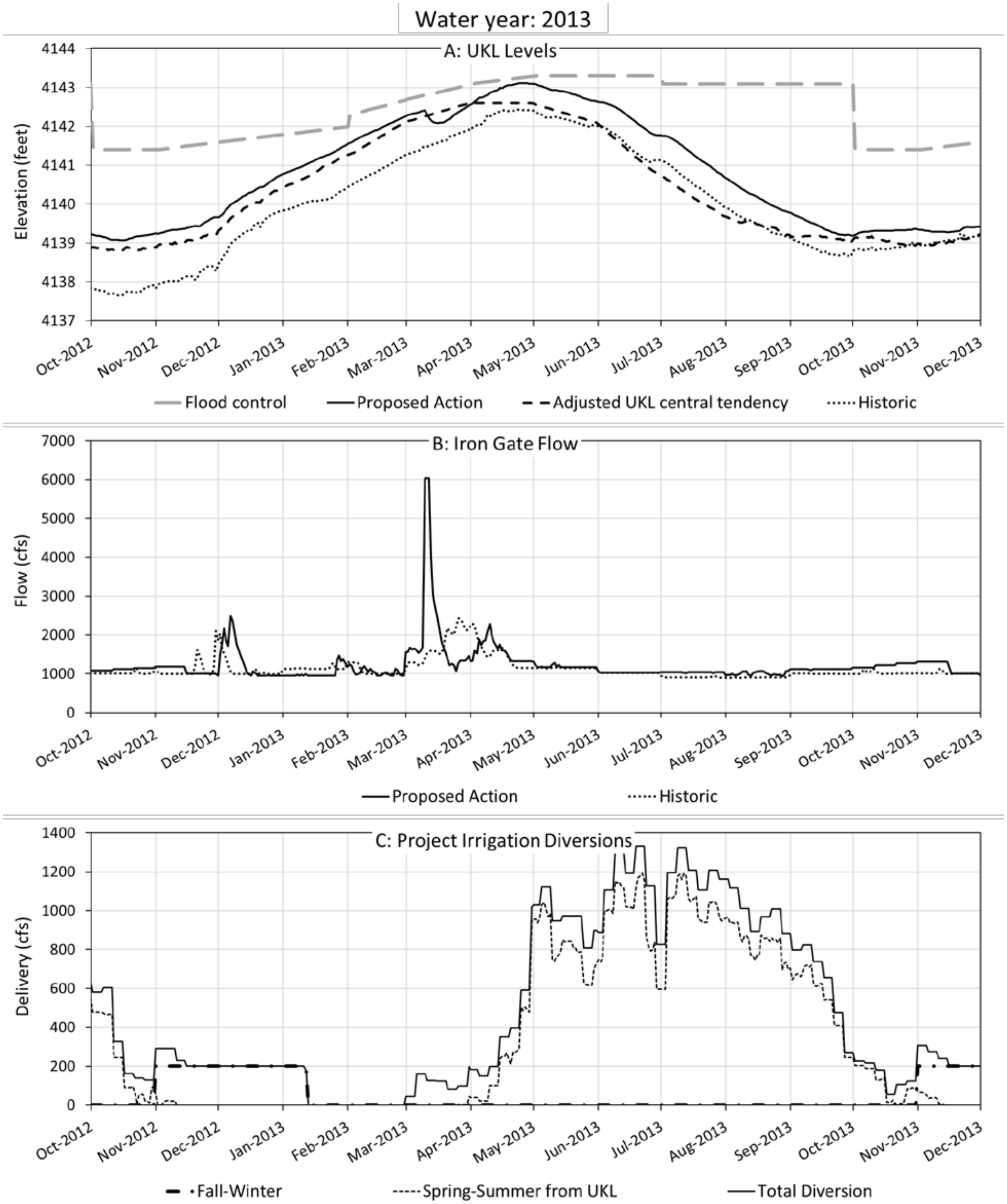

Figure B33. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 2013.

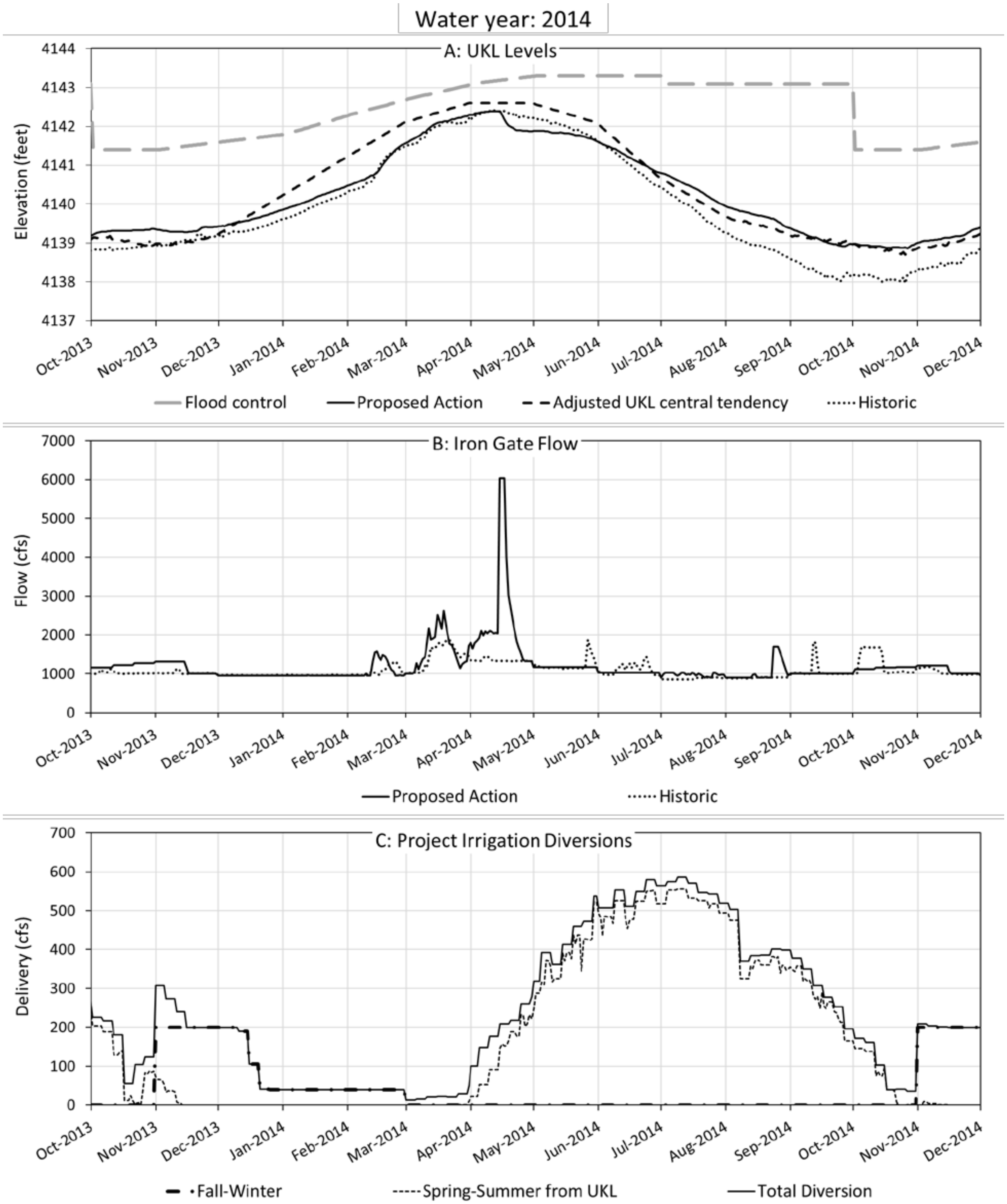

Figure B34. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 2014.

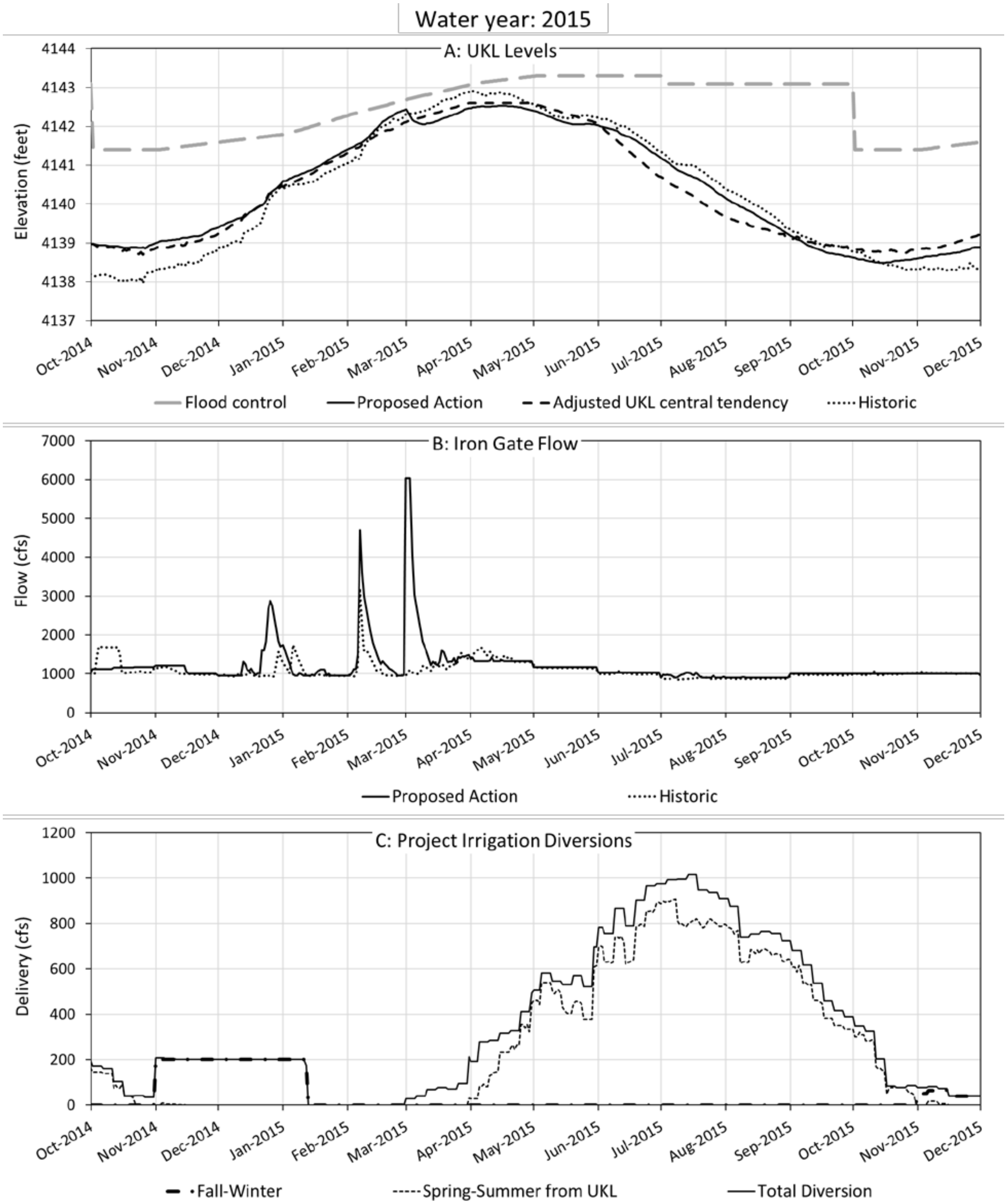

Figure B35. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 2015.

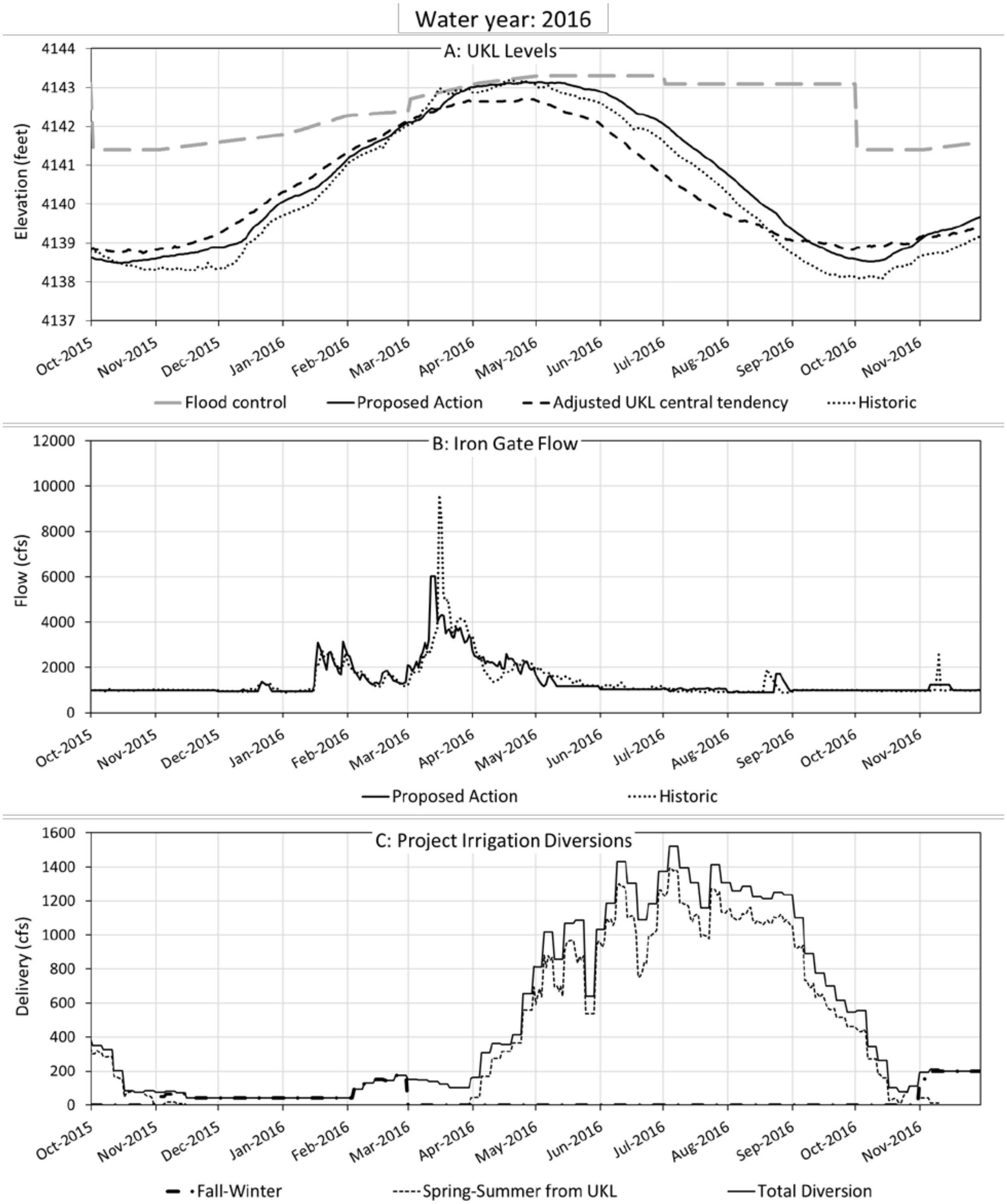

Figure B36. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 2016.

Section C: LKNWR Historical Deliveries

Table C1. Historical LK NWR Water Deliveries.

Water Year	Ady Canal Deliveries to LKNWR	D Plant Deliveries to LKNWR	Total Deliveries to LKNWR
1981	26.1	68.1	94.2
1982	10.1	120.1	130.2
1983	9.9	111.5	121.4
1984	10.4	120.4	130.8
1985	21.1	103.3	124.4
1986	20.9	104.6	125.5
1987	18.7	96.9	115.6
1988	17.2	93.9	111.1
1989	24.2	100.5	124.7
1990	22.7	95.7	118.4
1991	32.2	76.6	108.8
1992	14.8	41.5	56.3
1993	30.8	88.8	119.6
1994	35.5	49.8	85.3
1995	24.1	86.1	110.2
1996	32.7	115.4	148.1
1997	22.8	89.9	112.7
1998	21.0	97.2	118.2
1999	14.9	113.1	128.0
2000	20.9	79.3	100.2
2001	19.3	23.8	43.1
2002	38.4	77.3	115.7
2003	21.0	61.5	82.5
2004	46.2	51.3	97.5
2005	33.8	65.7	99.5
2006	23.2	112.3	135.5
2007	44.1	32.3	76.4
2008	27.2	54.9	82.1
2009	46.3	33.6	79.9
2010	6.6	10.0	16.6
2011	47.8	20.1	67.9
2012	38.0	10.4	48.4
2013	18.3	24.8	43.1
2014	7.0	12.4	19.4
2015	4.7	13.7	18.4
2016	24.4	22.1	46.5
Average 1981-2016	24.0	68.9	93.2

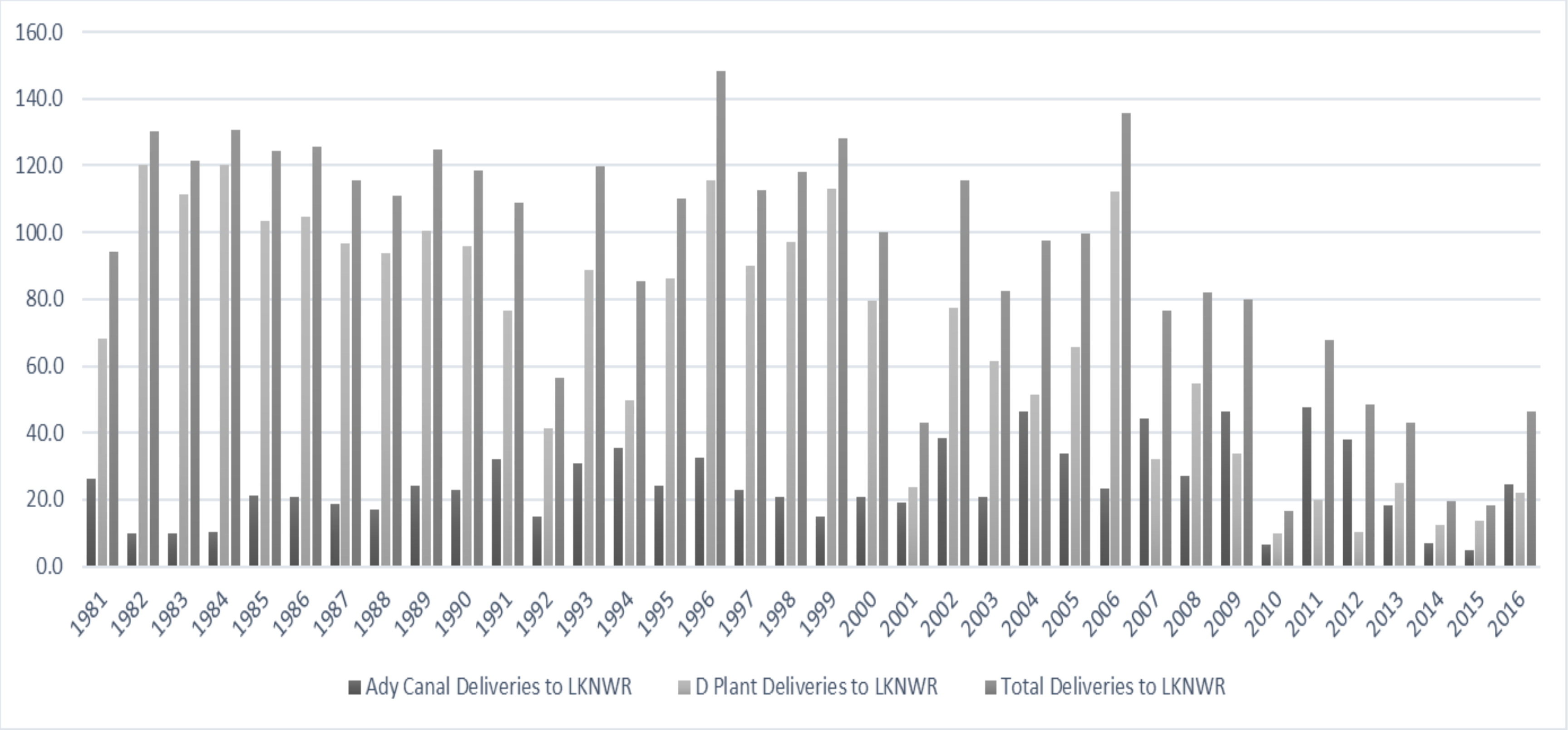

Figure C1. Historical deliveries to LKNWR by water year for the 36-year period of record considered in the Proposed Action. Deliveries are graphed as those delivered through Ady Canal (i.e. direct diversion from the Klamath River), D Plant pumping (i.e. deliveries made from Tule Lake Sumps), and total delivery through both delivery arcs.

Section D: Clear Lake Reservoir and Gerber Reservoir Water Supply Forecast Models

Table D1. Clear Lake Reservoir Operational Forecast Model. Example of the Clear Lake Reservoir operational forecast model from May 2018.

Date	Actual Elevation (Feet)	Actual Volume (Acre-Feet)	Actual Area (Acres)	Projected Inflow (Acre-Feet)	Projected Evaporation and Seepage (Acre-Feet)	Releases (Acre-Feet)	Modeled Volume (Acre-Feet)	Modeled Area (Acres)	Modeled Elevation (Feet)
1-May	4,531.01	228,000	21,640	5	328	125	228,000	21,640	4,531.01
2-May	4,531.00	227,780	21,640	5	328	125	227,780	21,640	4,531.00
3-May	4,530.99	227,560	21,600	5	327	125	227,560	21,600	4,530.99
4-May	4,530.98	227,350	21,600	5	327	125	227,350	21,600	4,530.98
5-May	4,530.97	227,130	21,600	5	327	125	227,130	21,600	4,530.97
6-May	4,530.95	226,700	21,600	5	327	125	226,700	21,600	4,530.95
7-May	4,530.94	226,480	21,600	5	327	165	226,480	21,600	4,530.94
8-May	4,530.92	226,050	21,600	5	327	165	226,050	21,600	4,530.92
9-May	4,530.90	225,620	21,600	5	327	188	225,620	21,600	4,530.90
10-May	4,530.86	224,760	21,560	5	327	188	224,760	21,560	4,530.86
11-May	4,530.86	224,760	21,560	5	327	188	224,760	21,560	4,530.86
12-May	4,530.82	223,900	21,560	5	327	377	223,900	21,560	4,530.82
13-May	4,530.79	223,260	21,510	5	326	377	223,260	21,510	4,530.79
14-May	4,530.77	222,820	21,510	5	326	377	222,820	21,510	4,530.77
15-May	4,530.73	221,960	21,510	5	326	377	221,960	21,510	4,530.73
16-May	4,530.69	221,110	21,460	5	325	377	221,110	21,460	4,530.69
17-May	4,530.67	220,680	21,460	5	325	377	220,680	21,460	4,530.67
18-May	4,530.65	220,250	21,460	5	325	377	220,250	21,460	4,530.65
19-May	4,530.62	219,610	21,460	5	325	377	219,610	21,460	4,530.62
20-May	4,530.60	219,180	21,460	5	325	377	219,180	21,460	4,530.60
21-May	4,530.57	218,540	21,420	5	325	377	218,540	21,420	4,530.57
22-May	4,530.54	217,900	21,420	5	325	377	217,900	21,420	4,530.54
23-May	4,530.51	217,250	21,420	5	325	377	217,250	21,420	4,530.51
24-May	4,530.51	217,250	21,420	5	325	377	217,250	21,420	4,530.51
25-May	4,530.53	217,680	21,420	5	325	198	217,680	21,420	4,530.53
26-May	4,530.58	218,750	21,420	5	325	0	218,750	21,420	4,530.58
27-May	4,530.60	219,180	21,460	5	325	0	219,180	21,460	4,530.60

Table D2. Gerber Reservoir Operational Forecast Model. Example of the Gerber Reservoir operational forecast model from May 2018.

Date	Actual Elevation (Feet)	Actual Volume (Acre-Feet)	Actual Area (Acres)	Projected Inflow (Acre-Feet)	Projected Evaporation and Seepage (Acre-Feet)	Releases (Acre-Feet)	Modeled Volume (Acre-Feet)	Modeled Area (Acres)	Modeled Elevation (Feet)
1-May	4832.89	84,833	3,538	38	54	71	84,833	3,538	4,832.89
2-May	4832.86	84,722	3,535	75	66	71	84,722	3,535	4,832.86
3-May	4832.84	84,648	3,533	75	66	71	84,648	3,533	4,832.84
4-May	4832.81	84,537	3,531	75	66	95	84,537	3,531	4,832.81
5-May	4832.78	84,426	3,528	75	66	143	84,426	3,528	4,832.78
6-May	4832.74	84,278	3,524	75	66	143	84,278	3,524	4,832.74
7-May	4832.68	84,056	3,519	75	66	214	84,056	3,519	4,832.68
8-May	4832.61	83,797	3,512	75	66	214	83,797	3,512	4,832.61
9-May	4832.55	83,575	3,507	75	66	214	83,575	3,507	4,832.55
10-May	4832.48	83,318	3,500	75	65	214	83,318	3,500	4,832.48
11-May	4832.4	83,030	3,493	75	65	214	83,030	3,493	4,832.40
12-May	4832.32	82,734	3,486	75	65	226	82,734	3,486	4,832.32
13-May	4832.24	82,444	3,478	75	65	226	82,444	3,478	4,832.24
14-May	4832.17	82,189	3,472	75	65	262	82,189	3,472	4,832.17
15-May	4832.09	81,894	3,464	75	65	262	81,894	3,464	4,832.09
16-May	4832.01	81,606	3,457	75	65	262	81,606	3,457	4,832.01
17-May	4831.95	81,385	3,451	75	65	262	81,385	3,451	4,831.95
18-May	4831.88	81,128	3,445	75	64	262	81,128	3,445	4,831.88
19-May	4831.79	80,804	3,437	75	64	262	80,804	3,437	4,831.79
20-May	4831.72	80,552	3,430	75	64	262	80,552	3,430	4,831.72
21-May	4831.64	80,264	3,423	75	64	262	80,264	3,423	4,831.64
22-May	4831.57	80,012	3,416	75	64	262	80,012	3,416	4,831.57
23-May	4831.49	79,724	3,409	75	64	262	79,724	3,409	4,831.49
24-May	4831.43	79,508	3,403	75	64	262	79,508	3,403	4,831.43
25-May	4831.44	79,544	3,404	75	64	139	79,544	3,404	4,831.44
26-May	4831.5	79,760	3,410	75	64	0	79,760	3,410	4,831.50
27-May	4831.52	79,832	3,412	75	64	0	79,832	3,412	4,831.52

Appendix 6A: Clear Lake Reservoir End of Month Surface Elevations

Appendix 6A. Clear Lake Reservoir end of month surface elevations (Reclamation datum, feet above mean sea level).

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
2017-18	4,529.67	4,529.76	4,529.72	4,529.82	4,529.79	4,530.57	4,531.02	4,530.56	4,529.81	4,528.83	4,527.92	4,527.21
2016-17	4,522.03	4,522.02	4,522.46	4,523.81	4,529.06	4,532.03	4,533.59	4,533.51	4,532.69	4,531.58	4,530.63	4,529.91
2015-16	4,518.33	4,518.36	4,518.60	4,521.03	4,523.58	4,525.83	4,525.98	4,525.54	4,524.74	4,523.65	4,522.53	4,521.94
2014-15	4,518.75	4,518.76	4,519.23	4,520.07	4,520.92	4,521.04	4,520.79	4,520.65	4,520.11	4,519.54	4,518.87	4,518.59
2013-14	4,521.09	4,521.06	4,521.02	4,521.09	4,521.27	4,521.69	4,521.61	4,521.11	4,520.47	4,519.77	4,519.28	4,518.86
2012-13	4,521.83	4,522.09	4,523.17	4,523.57	4,524.20	4,524.71	4,524.62	4,523.98	4,523.18	4,522.13	4,521.62	4,521.13
2011-12	4,525.76	4,525.69	4,525.68	4,525.71	4,525.61	4,525.91	4,526.22	4,525.63	4,524.74	4,523.62	4,522.59	4,522.08
2010-11	4,520.42	4,520.43	4,522.36	4,523.22	4,523.59	4,526.17	4,528.85	4,529.04	4,528.67	4,527.71	4,526.65	4,525.96
2009-10	4,521.86	4,521.88	4,522.09	4,522.15	4,522.26	4,522.74	4,523.03	4,522.57	4,522.19	4,522.06	4,520.94	4,520.62
2008-09	4,523.23	4,523.24	4,523.31	4,523.40	4,523.55	4,523.99	4,523.79	4,522.59	4,520.79	4,520.12	4,521.87	4,521.82
2007-08	4,523.59	4,523.57	4,523.68	4,523.94	4,524.48	4,526.61	4,527.33	4,527.27	4,526.60	4,525.35	4,524.18	4,523.40
2006-07	4,528.08	4,528.11	4,528.19	4,528.20	4,528.41	4,528.69	4,528.53	4,527.73	4,526.76	4,525.63	4,524.41	4,523.77
2005-06	4,521.68	4,522.18	4,525.30	4,527.12	4,528.23	4,529.86	4,532.32	4,532.08	4,531.30	4,530.27	4,529.14	4,528.31
2004-05	4,521.87	4,521.89	4,522.09	4,522.39	4,522.69	4,522.72	4,523.26	4,524.76	4,524.13	4,522.82	4,521.72	4,521.79
2003-04	4,521.86	4,522.07	4,522.38	4,522.82	4,524.60	4,526.29	4,526.31	4,525.69	4,524.72	4,523.42	4,520.62	4,518.34
2002-03	4,524.02	4,524.00	4,524.40	4,524.70	4,524.96	4,525.32	4,526.04	4,526.18	4,525.07	4,523.85	4,520.98	4,522.25
2001-02	4,525.60	4,525.86	4,526.52	4,526.90	4,527.35	4,527.89	4,528.51	4,528.16	4,527.19	4,526.13	4,524.90	4,524.15
2000-01	4,531.33	4,531.46	4,531.48	4,531.45	4,531.51	4,531.63	4,531.52	4,530.54	4,529.20	4,527.98	4,526.65	4,525.75
1999-00	4,534.17	4,534.07	4,534.06	4,534.45	4,535.02	4,536.12	4,536.49	4,535.98	4,535.06	4,534.06	4,532.99	4,531.54
1998-99	4,535.21	4,535.63	4,536.16	4,536.52	4,536.82	4,537.84	4,537.88	4,537.62	4,536.90	4,535.94	4,535.04	4,534.35
1997-98	4,534.35	4,534.32	4,534.36	4,536.02	4,536.86	4,538.57	4,538.48	4,538.53	4,538.30	4,537.39	4,536.34	4,535.64
1996-97	4,533.78	4,533.80	4,535.90	4,537.67	4,537.89	4,538.20	4,538.30	4,537.81	4,537.00	4,536.20	4,535.20	4,534.60
1995-96	4,529.94	4,530.00	4,530.45	4,531.26	4,535.62	4,537.13	4,537.45	4,537.40	4,536.64	4,535.65	4,534.71	4,534.00
1994-95	4,521.54	4,521.65	4,521.96	4,525.89	4,527.49	4,531.23	4,532.80	4,533.46	4,532.98	4,532.00	4,531.01	4,530.24
1993-94	4,526.04	4,525.96	4,526.05	4,526.09	4,526.20	4,526.30	4,525.84	4,525.39	4,524.49	4,523.16	4,521.43	4,521.70

Appendix 6A (continued). Clear Lake Reservoir end of month surface elevations (Reclamation datum, feet above mean sea level).

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1992-93	4,519.30	4,519.29	4,519.35	4,519.40	4,521.46	4,527.98	4,529.40	4,529.12	4,528.54	4,527.63	4,526.86	4,526.16
1991-92	4,522.50	4,522.51	4,522.80	4,522.85	4,523.00	4,522.84	4,522.75	4,521.77	4,521.18	4,520.44	4,519.82	4,519.42
1990-91	4,526.78	4,526.76	4,526.70	4,526.98	4,527.00	4,527.10	4,526.90	4,526.42	4,525.65	4,524.45	4,523.52	4,522.75
1989-90	4,531.82	4,530.80	4,530.82	4,530.95	4,531.05	4,531.54	4,531.24	4,530.55	4,529.90	4,528.78	4,527.74	4,527.08
1988-89	4,528.30	4,528.30	4,528.34	4,528.67	4,529.00	4,533.88	4,534.82	4,534.40	4,533.68	4,532.47	4,531.54	4,531.00
1987-88	4,531.17	4,531.10	4,531.30	4,531.42	4,532.00	4,532.68	4,532.54	4,532.18	4,531.20	4,530.20	4,529.13	4,528.30
1986-87	4,534.97	4,534.85	4,534.83	4,535.08	4,535.20	4,535.66	4,535.35	4,534.50	4,533.85	4,533.05	4,532.09	4,531.41
1985-86	4,534.11	4,534.20	4,534.14	4,534.40	4,537.80	4,539.55	4,539.27	4,538.78	4,537.85	4,536.76	4,535.63	4,535.14
1984-85	4,536.41	4,536.86	4,536.88	4,536.88	4,537.45	4,538.24	4,538.52	4,537.85	4,536.85	4,535.65	4,534.64	4,534.30
1983-84	4,537.02	4,537.05	4,539.43	4,539.60	4,540.11	4,541.63	4,542.28	4,541.89	4,541.27	4,540.33	4,538.97	4,537.86
1982-83	4,532.78	4,532.85	4,533.02	4,534.54	4,536.42	4,539.26	4,540.40	4,540.72	4,540.00	4,538.94	4,538.00	4,537.27
1981-82	4,524.42	4,525.95	4,528.48	4,529.02	4,532.40	4,533.70	4,536.60	4,536.14	4,535.45	4,534.65	4,533.50	4,532.71
1980-81	4,527.20	4,527.26	4,527.21	4,527.32	4,527.73	4,528.70	4,528.85	4,528.27	4,527.42	4,526.24	4,525.10	4,524.36
1979-80	4,524.33	4,524.55	4,524.85	4,527.26	4,529.66	4,530.70	4,530.94	4,530.61	4,530.30	4,529.05	4,528.10	4,527.41
1978-79	4,526.96	4,527.00	4,527.00	4,527.16	4,527.40	4,528.60	4,528.78	4,528.12	4,527.32	4,526.06	4,525.10	4,524.38
1977-78	4,525.95	4,525.96	4,526.58	4,528.10	4,528.55	4,529.57	4,531.09	4,530.80	4,529.90	4,528.86	4,527.88	4,527.20
1976-77	4,530.22	4,530.15	4,530.17	4,530.16	4,530.20	4,530.17	4,529.60	4,529.34	4,528.54	4,527.43	4,526.58	4,526.39
1975-76	4,533.60	4,533.57	4,533.61	4,533.68	4,533.70	4,534.27	4,534.24	4,533.35	4,532.47	4,531.45	4,531.20	4,530.37
1974-75	4,533.10	4,533.06	4,533.10	4,533.26	4,533.74	4,535.82	4,536.86	4,537.53	4,536.55	4,535.55	4,534.63	4,533.77
1973-74	4,530.73	4,531.16	4,532.34	4,534.00	4,534.18	4,536.90	4,537.94	4,537.27	4,536.25	4,535.30	4,534.34	4,533.41
1972-73	4,533.48	4,533.51	4,533.78	4,535.15	4,534.70	4,535.24	4,535.34	4,534.70	4,533.76	4,532.62	4,531.46	4,530.88
1971-72	4,533.17	4,533.18	4,533.28	4,534.33	4,535.82	4,538.92	4,539.14	4,538.40	4,537.30	4,535.84	4,534.52	4,533.56
1970-71	4,532.60	4,532.96	4,533.78	4,535.44	4,536.02	4,538.48	4,539.26	4,539.10	4,538.55	4,537.40	4,535.63	4,533.58
1969-70	4,531.23	4,531.20	4,531.97	4,535.82	4,536.50	4,537.45	4,537.15	4,536.50	4,535.84	4,534.70	4,533.65	4,532.86
1968-69	4,525.72	4,525.82	4,526.80	4,528.60	4,529.82	4,531.33	4,535.52	4,534.95	4,534.26	4,533.36	4,532.14	4,531.37

Appendix 6A (continued). Clear Lake Reservoir end of month surface elevations (Reclamation datum, feet above mean sea level).

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1967-68	4,528.88	4,528.80	4,528.79	4,528.83	4,530.31	4,530.60	4,530.07	4,529.51	4,528.60	4,527.23	4,526.58	4,525.82
1966-67	4,527.05	4,527.31	4,528.20	4,528.56	4,529.32	4,530.60	4,531.52	4,532.60	4,532.00	4,530.90	4,529.86	4,529.08
1965-66	4,530.47	4,530.55	4,530.50	4,530.62	4,530.70	4,531.63	4,531.70	4,531.12	4,530.27	4,529.05	4,527.90	4,527.34
1964-65	4,524.20	4,524.24	4,527.80	4,531.20	4,533.00	4,533.80	4,534.38	4,533.65	4,533.20	4,532.20	4,531.45	4,530.72
1963-64	4,524.00	4,524.05	4,524.15	4,524.30	4,524.30	4,524.90	4,527.86	4,527.40	4,527.34	4,526.20	4,525.14	4,524.45
1962-63	4,524.33	4,524.50	4,525.23	4,525.26	4,526.35	4,526.57	4,527.52	4,527.70	4,526.70	4,525.70	4,524.70	4,524.12
1961-62	4,521.33	4,521.47	4,521.70	4,521.87	4,523.37	4,524.25	4,525.50	4,525.10	4,524.08	4,522.88	4,521.90	4,521.28
1960-61	4,524.60	4,524.63	4,524.99	4,524.97	4,525.43	4,525.78	4,525.63	4,525.28	4,524.40	4,523.08	4,522.16	4,521.44
1959-60	4,527.85	4,527.77	4,527.76	4,527.81	4,528.08	4,528.85	4,529.10	4,528.86	4,527.83	4,526.48	4,525.49	4,524.80
1958-59	4,533.41	4,533.35	4,533.38	4,533.49	4,533.60	4,533.53	4,533.04	4,532.44	4,531.34	4,530.10	4,529.03	4,528.15
1957-58	4,533.42	4,533.70	4,534.30	4,534.78	4,538.11	4,539.05	4,540.72	4,540.14	4,538.90	4,537.50	4,535.90	4,534.51
1956-57	4,534.98	4,533.80	4,534.28	4,534.30	4,536.12	4,538.31	4,538.26	4,537.80	4,536.62	4,535.36	4,534.20	4,533.42
1955-56	4,527.30	4,527.52	4,530.83	4,535.13	4,536.03	4,539.73	4,541.61	4,541.21	4,540.04	4,538.45	4,537.03	4,535.81
1954-55	4,530.51	4,530.57	4,530.60	4,530.66	4,530.78	4,531.36	4,532.10	4,531.36	4,530.44	4,529.36	4,528.36	4,527.50
1953-54	4,531.37	4,531.50	4,531.80	4,531.96	4,533.45	4,535.10	4,535.33	4,534.49	4,533.90	4,532.69	4,531.64	4,530.86
1952-53	4,529.37	4,529.22	4,529.50	4,532.09	4,532.81	4,533.39	4,533.81	4,534.60	4,534.52	4,533.32	4,532.31	4,531.61
1951-52	4,522.58	4,522.54	4,522.93	4,523.25	4,523.97	4,527.59	4,533.14	4,533.00	4,532.23	4,531.38	4,530.37	4,529.68
1950-51	4,523.87	4,523.87	4,524.40	4,524.59	4,525.93	4,526.70	4,527.02	4,526.84	4,525.63	4,524.34	4,523.31	4,522.57
1949-50	4,524.60	4,524.57	4,524.56	4,524.75	4,525.81	4,527.21	4,527.95	4,527.37	4,526.67	4,525.46	4,524.47	4,523.88
1948-49	4,526.36	4,526.28	4,526.44	4,526.50	4,526.64	4,528.36	4,528.95	4,528.49	4,527.62	4,526.47	4,525.39	4,524.77
1947-48	4,526.71	4,526.66	4,526.67	4,527.00	4,527.08	4,527.37	4,528.57	4,529.31	4,528.87	4,527.87	4,526.99	4,526.51
1946-47	4,529.65	4,529.71	4,529.84	4,529.85	4,530.23	4,530.95	4,530.66	4,529.92	4,529.44	4,528.33	4,527.46	4,526.84
1945-46	4,530.92	4,531.19	4,531.51	4,532.13	4,531.75	4,533.47	4,534.14	4,533.47	4,532.59	4,531.62	4,530.65	4,529.93
1944-45	4,530.44	4,530.67	4,530.78	4,531.02	4,533.35	4,533.54	4,533.95	4,534.07	4,533.91	4,532.44	4,531.89	4,531.06
1943-44	4,534.00	4,533.97	4,533.94	4,533.96	4,533.98	4,534.07	4,534.37	4,533.72	4,533.25	4,532.22	4,531.27	4,530.60

Appendix 6A (continued). Clear Lake Reservoir end of month surface elevations (Reclamation datum, feet above mean sea level).

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1942-43	4,531.50	4,531.53	4,531.80	4,532.11	4,532.50	4,536.92	4,537.81	4,537.62	4,536.91	4,535.94	4,534.96	4,534.27
1941-42	4,529.08	4,529.09	4,530.26	4,531.99	4,533.43	4,534.45	4,534.93	4,535.10	4,534.37	4,533.31	4,532.38	4,531.77
1940-41	4,529.51	4,529.47	4,529.65	4,529.95	4,531.75	4,532.37	4,532.28	4,531.88	4,531.30	4,530.38	4,529.70	4,529.21
1939-40	4,527.61	4,527.54	4,527.91	4,528.92	4,531.63	4,533.27	4,533.70	4,533.05	4,532.00	4,531.00	4,530.03	4,529.63
1938-39	4,531.11	4,531.10	4,531.05	4,531.08	4,531.08	4,532.00	4,531.65	4,530.91	4,530.04	4,529.12	4,528.17	4,527.78
1937-38	4,521.60	4,522.00	4,524.65	4,524.90	4,525.65	4,530.58	4,534.85	4,534.80	4,533.80	4,532.95	4,531.95	4,531.32
1936-37	4,520.90	4,520.80	4,520.80	4,521.00	4,521.17	4,525.70	4,525.05	4,524.40	4,523.80	4,522.90	4,522.10	4,521.60
1935-36	4,518.50	4,518.50	4,518.70	4,519.45	4,521.60	4,523.30	4,524.35	4,524.00	4,523.36	4,522.40	4,521.60	4,521.15
1934-35	4,514.40	4,514.85	4,515.23	4,515.30	4,516.30	4,517.50	4,522.10	4,521.60	4,520.70	4,519.90	4,519.10	4,518.60
1933-34	4,517.70	4,517.65	4,517.90	4,518.05	4,518.33	4,518.10	4,517.67	4,517.00	4,516.41	4,515.62	4,515.00	4,514.50
1932-33	4,519.75	4,519.70	4,519.70	4,519.80	4,519.90	4,520.80	4,521.40	4,521.35	4,520.15	4,519.00	4,518.12	4,517.70
1931-32	4,517.05	4,517.08	4,517.30	4,517.45	4,517.53	4,523.60	4,523.65	4,523.25	4,522.32	4,521.40	4,520.50	4,519.84
1930-31	4,521.82	4,521.81	4,521.80	4,521.80	4,521.80	4,521.60	4,521.35	4,520.60	4,519.60	4,518.25	4,517.60	4,517.20
1929-30	4,522.88	4,522.84	4,523.02	4,523.22	4,524.95	4,525.85	4,525.60	4,524.90	4,523.76	4,522.63	4,522.04	4,521.84
1928-29	4,526.35	4,526.40	4,526.45	4,526.58	4,526.77	4,527.14	4,527.50	4,526.66	4,525.94	4,524.74	4,523.60	4,522.96
1927-28	4,525.52	4,525.88	4,526.07	4,526.07	4,526.68	4,527.62	4,529.96	4,530.65	4,530.00	4,529.03	4,528.03	4,527.15
1926-27	4,522.66	4,523.30	4,523.55	4,524.02	4,525.35	4,527.18	4,528.75	4,528.75	4,527.97	4,527.00	4,526.10	4,525.64
1925-26	4,526.71	4,526.75	4,526.83	4,526.83	4,527.16	4,527.10	4,526.71	4,526.00	4,524.86	4,523.81	4,523.00	4,522.66
1924-25	4,528.30	4,528.31	4,528.46	4,528.69	4,529.60	4,529.75	4,529.64	4,529.39	4,528.93	4,528.00	4,527.20	4,526.86
1923-24	4,534.30	4,534.20	4,534.16	4,534.19	4,534.42	4,534.23	4,533.92	4,533.28	4,532.39	4,531.38	4,530.20	4,529.06
1922-23	4,536.32	4,536.03	4,536.03	4,536.17	4,536.27	4,536.71	4,537.00	4,536.56	4,536.10	4,535.79	4,534.99	4,534.48
1921-22	4,535.00	4,534.95	4,534.91	4,535.00	4,535.13	4,535.74	4,538.80	4,538.93	4,538.31	4,537.61	4,536.99	4,536.60
1920-21	4,531.47	4,531.65	4,532.02	4,533.70	4,535.60	4,537.74	4,538.18	4,537.86	4,537.44	4,536.54	4,535.94	4,535.32
1919-20	4,534.00	4,533.90	4,533.90	4,533.90	4,533.83	4,534.01	4,534.22	4,533.75	4,533.17	4,532.52	4,531.94	4,531.55
1918-19	4,533.48	4,533.45	4,533.45	4,534.45	4,533.97	4,535.12	4,537.40	4,536.80	4,536.02	4,535.30	4,534.60	4,534.20

Appendix 6A (continued). Clear Lake Reservoir end of month surface elevations (Reclamation datum, feet above mean sea level).

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1917-18	4,536.48	4,536.38	4,536.25	4,536.20	4,536.18	4,536.80	4,536.59	4,536.10	4,535.37	4,534.60	4,533.98	4,533.70
1916-17	4,532.70	4,532.66	4,532.12	4,532.25	4,532.25	4,533.70	4,539.04	4,539.60	4,538.84	4,538.04	4,537.50	4,536.81
1915-16	4,531.85	4,531.90	4,531.88	4,532.02	4,533.45	4,535.15	4,535.60	4,535.20	4,534.65	4,534.05	4,533.35	4,532.95
1914-15	4,533.27	4,533.23	4,533.20	4,533.20	4,534.00	4,535.00	4,534.85	4,534.65	4,533.97	4,533.30	4,532.68	4,532.15
1913-14	4,529.80	4,529.75	4,529.75	4,531.30	4,532.15	4,535.80	4,536.24	4,535.83	4,535.44	4,534.77	4,534.00	4,533.40
1912-13	4,529.25	4,529.20	4,529.25	4,529.30	4,539.30	4,529.85	4,531.95	4,531.85	4,531.30	4,531.10	4,530.65	4,530.05
1911-12	4,529.75	4,529.65	4,529.80	4,530.00	4,530.50	4,530.80	4,531.30	4,531.40	4,531.10	4,530.65	4,530.20	4,529.55
1910-11	4,524.12	4,524.24	4,525.90	4,526.15	4,526.35	4,529.30	4,532.35	4,532.05	4,531.75	4,531.10	4,530.55	4,530.00

Appendix 6B: Gerber Reservoir Observed End of Month Surface Elevations

Appendix 6B. Gerber Reservoir observed end of month surface elevations (Reclamation datum, feet above mean sea level).

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
2017-18	4,824.91	4,825.25	4,825.24	4,826.16	4,826.64	4,831.59	4,832.91	4,831.48	4,829.46	4,826.93	4,824.46	4,822.39
2016-17	4,807.41	4,807.46	4,810.73	4,811.70	4,824.56	4,832.25	4,835.76	4,834.34	4,832.22	4,829.51	4,827.20	4,825.20
2015-16	4,797.90	4,797.91	4,799.80	4,809.57	4,815.97	4,822.05	4,822.19	4,820.19	4,817.55	4,814.19	4,810.65	4,807.36
2014-15	4,798.17	4,798.27	4,806.53	4,807.72	4,809.16	4,809.46	4,809.05	4,806.43	4,801.54	4,799.39	4,798.61	4,798.18
2013-14	4,806.33	4,806.29	4,806.26	4,806.32	4,807.98	4,810.57	4,810.98	4,807.66	4,803.43	4,799.52	4,798.71	4,798.18
2012-13	4,813.77	4,814.12	4,816.13	4,817.07	4,817.83	4,820.67	4,821.48	4,819.09	4,816.33	4,812.90	4,809.47	4,806.52
2011-12	4,819.97	4,819.95	4,819.99	4,820.26	4,820.81	4,824.58	4,826.99	4,825.37	4,822.99	4,819.98	4,816.71	4,814.02
2010-11	4,803.18	4,803.22	4,809.08	4,814.44	4,815.22	4,821.88	4,830.13	4,830.10	4,828.25	4,825.39	4,822.56	4,820.12
2009-10	4,812.24	4,812.07	4,812.80	4,813.34	4,815.24	4,816.12	4,817.79	4,817.46	4,815.30	4,811.40	4,807.20	4,803.28
2008-09	4,820.56	4,820.52	4,820.87	4,820.74	4,821.68	4,824.58	4,825.00	4,823.49	4,821.92	4,818.72	4,815.56	4,812.40
2007-08	4,819.80	4,819.81	4,819.96	4,820.37	4,820.65	4,826.60	4,831.86	4,830.70	4,828.98	4,826.18	4,823.33	4,820.81
2006-07	4,824.23	4,824.50	4,825.92	4,825.98	4,828.30	4,832.27	4,832.60	4,830.58	4,828.06	4,825.25	4,822.27	4,819.82
2005-06	4,807.44	4,809.23	4,820.64	4,826.60	4,831.32	4,835.88	4,836.22	4,834.60	4,832.57	4,829.76	4,827.06	4,824.57
2004-05	4,805.69	4,805.68	4,808.30	4,808.30	4,810.72	4,812.04	4,813.94	4,821.27	4,819.14	4,815.37	4,811.34	4,807.54
2003-04	4,808.25	4,808.28	4,808.99	4,810.41	4,815.39	4,822.44	4,822.33	4,820.15	4,817.26	4,813.52	4,809.36	4,805.98
2002-03	4,808.26	4,808.35	4,809.26	4,813.21	4,814.12	4,816.69	4,821.17	4,822.45	4,819.08	4,815.40	4,811.83	4,808.61
2001-02	4,810.59	4,810.86	4,811.35	4,816.32	4,818.32	4,822.69	4,824.50	4,822.84	4,819.76	4,816.10	4,812.30	4,808.50
2000-01	4,823.07	4,823.13	4,823.19	4,823.21	4,823.41	4,825.38	4,825.75	4,823.01	4,819.96	4,816.85	4,813.28	4,810.87
1999-00	4,823.80	4,823.56	4,823.68	4,825.50	4,828.48	4,832.54	4,835.00	4,833.46	4,830.73	4,827.98	4,825.11	4,823.40
1998-99	4,827.45	4,829.68	4,830.94	4,832.38	4,830.70	4,831.14	4,834.24	4,833.97	4,831.84	4,828.83	4,826.20	4,823.80
1997-98	4,824.40	4,824.42	4,824.56	4,830.82	4,833.76	4,836.19	4,835.65	4,836.29	4,835.16	4,832.68	4,830.39	4,828.00
1996-97	4,826.18	4,826.60	4,834.60	4,834.18	4,834.10	4,835.56	4,835.55	4,833.64	4,831.62	4,828.96	4,826.51	4,824.36
1995-96	4,825.39	4,825.40	4,827.50	4,829.67	4,835.04	4,835.88	4,835.83	4,835.72	4,833.54	4,830.97	4,828.42	4,826.36
1994-95	4,806.59	4,806.74	4,807.08	4,816.63	4,822.02	4,832.16	4,835.91	4,835.13	4,833.88	4,831.16	4,828.27	4,825.70
1993-94	4,821.96	4,821.96	4,822.20	4,822.32	4,822.94	4,823.30	4,822.48	4,820.80	4,817.81	4,814.08	4,810.16	4,806.78

Appendix 6B (continued). Gerber Reservoir observed end of month surface elevations (Reclamation datum, feet above mean sea level).

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1992-93	4,796.62	4,796.62	4,797.06	4,798.79	4,802.24	4,828.00	4,831.92	4,830.34	4,829.60	4,826.84	4,824.49	4,822.04
1991-92	4,797.98	4,797.96	4,798.04	4,798.18	4,800.74	4,801.28	4,801.14	4,798.86	4,798.36	4,797.73	4,797.01	4,796.52
1990-91	4,804.38	4,804.32	4,804.40	4,804.54	4,804.82	4,804.18	4,808.26	4,808.10	4,803.60	4,799.22	4,798.60	4,798.08
1989-90	4,815.18	4,815.16	4,815.20	4,816.58	4,817.48	4,821.33	4,821.20	4,818.94	4,816.12	4,812.25	4,808.70	4,804.56
1988-89	4,802.20	4,803.98	4,804.30	4,804.40	4,805.42	4,826.42	4,828.66	4,827.00	4,824.18	4,820.81	4,818.00	4,815.26
1987-88	4,813.24	4,813.18	4,813.54	4,814.00	4,815.80	4,819.12	4,819.53	4,817.53	4,815.00	4,810.95	4,806.90	4,802.40
1986-87	4,822.95	4,822.88	4,823.00	4,823.10	4,824.78	4,827.90	4,827.18	4,824.65	4,822.30	4,819.68	4,816.32	4,813.47
1985-86	4,823.47	4,823.51	4,823.58	4,825.91	4,834.07	4,835.60	4,834.93	4,833.32	4,830.58	4,827.68	4,824.54	4,823.10
1984-85	4,825.85	4,828.12	4,828.50	4,828.37	4,828.90	4,833.88	4,835.49	4,833.58	4,830.98	4,827.95	4,824.90	4,823.62
1983-84	4,826.26	4,826.92	4,826.82	4,824.64	4,826.50	4,836.19	4,835.80	4,834.85	4,833.15	4,830.25	4,827.68	4,825.48
1982-83	4,826.07	4,826.31	4,827.60	4,829.55	4,830.90	4,834.40	4,836.48	4,835.04	4,833.18	4,830.95	4,828.88	4,826.88
1981-82	4,804.44	4,811.50	4,821.60	4,822.20	4,833.50	4,835.85	4,835.90	4,834.58	4,832.76	4,830.70	4,827.94	4,825.93
1980-81	4,814.15	4,814.18	4,814.68	4,814.80	4,818.00	4,820.82	4,821.40	4,819.10	4,816.20	4,812.40	4,807.98	4,804.24
1979-80	4,805.72	4,807.30	4,809.00	4,817.26	4,824.18	4,826.15	4,827.05	4,825.00	4,822.80	4,819.80	4,816.50	4,814.23
1978-79	4,815.44	4,815.46	4,815.47	4,816.82	4,817.82	4,822.06	4,822.00	4,820.18	4,816.46	4,812.30	4,809.00	4,805.64
1977-78	4,802.42	4,804.40	4,809.17	4,816.38	4,819.01	4,824.76	4,828.17	4,827.00	4,824.10	4,821.08	4,817.98	4,815.70
1976-77	4,817.45	4,817.36	4,817.40	4,817.40	4,817.50	4,817.70	4,816.52	4,815.17	4,812.14	4,807.90	4,804.12	4,802.50
1975-76	4,822.66	4,822.80	4,823.63	4,823.70	4,824.69	4,828.38	4,830.25	4,827.30	4,824.52	4,821.15	4,820.48	4,817.76
1974-75	4,820.08	4,820.10	4,820.49	4,820.68	4,821.34	4,825.47	4,833.58	4,834.87	4,831.68	4,828.62	4,825.58	4,822.70
1973-74	4,812.98	4,815.62	4,820.00	4,824.17	4,824.77	4,833.27	4,834.84	4,832.90	4,829.73	4,827.04	4,823.89	4,820.76
1972-73	4,821.20	4,821.43	4,822.99	4,824.02	4,825.56	4,828.32	4,829.26	4,826.56	4,823.14	4,819.34	4,815.46	4,813.05
1971-72	4,824.20	4,824.41	4,824.70	4,826.55	4,833.04	4,835.07	4,835.50	4,833.15	4,830.22	4,826.68	4,823.39	4,821.22
1970-71	4,821.49	4,823.04	4,825.39	4,829.46	4,831.46	4,834.49	4,835.50	4,834.86	4,832.96	4,830.21	4,826.94	4,824.38
1969-70	4,821.80	4,821.81	4,824.60	4,832.08	4,832.03	4,835.00	4,834.59	4,832.57	4,830.03	4,826.78	4,823.64	4,821.63
1968-69	4,809.20	4,809.74	4,811.45	4,813.95	4,815.95	4,821.84	4,834.39	4,832.56	4,830.70	4,827.56	4,824.29	4,822.06

Appendix 6B (continued). Gerber Reservoir observed end of month surface elevations (Reclamation datum, feet above mean sea level).

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1967-68	4,820.62	4,820.50	4,820.62	4,820.85	4,825.65	4,825.91	4,824.71	4,822.84	4,819.52	4,815.48	4,812.90	4,809.64
1966-67	4,814.62	4,815.24	4,817.83	4,818.90	4,821.25	4,826.07	4,829.68	4,832.07	4,829.70	4,826.50	4,823.32	4,820.88
1965-66	4,822.70	4,822.83	4,822.85	4,823.14	4,823.21	4,828.30	4,828.94	4,826.32	4,823.91	4,820.80	4,817.50	4,815.38
1964-65	4,816.58	4,816.85	4,831.40	4,829.70	4,829.02	4,831.75	4,833.95	4,831.70	4,830.00	4,826.76	4,825.00	4,822.90
1963-64	4,817.26	4,817.57	4,817.66	4,818.10	4,818.12	4,818.80	4,827.70	4,825.90	4,826.10	4,822.70	4,819.70	4,817.20
1962-63	4,809.67	4,810.50	4,814.38	4,814.80	4,819.92	4,821.30	4,827.30	4,828.00	4,825.45	4,822.65	4,819.65	4,817.90
1961-62	4,794.27	4,795.93	4,798.80	4,799.14	4,803.80	4,809.00	4,818.87	4,817.47	4,814.10	4,809.85	4,805.60	4,801.05
1960-61	4,796.53	4,797.17	4,801.25	4,802.34	4,807.64	4,811.30	4,812.37	4,810.35	4,807.88	4,804.13	4,801.24	4,794.47
1959-60	4,801.01	4,800.56	4,800.52	4,800.64	4,805.36	4,813.50	4,815.07	4,815.26	4,811.74	4,806.92	4,802.52	4,796.98
1958-59	4,820.80	4,820.64	4,820.63	4,821.71	4,822.74	4,824.22	4,822.88	4,820.35	4,815.76	4,810.25	4,805.51	4,802.16
1957-58	4,821.05	4,822.75	4,825.00	4,821.05	4,822.75	4,825.00	4,825.70	4,834.82	4,833.38	4,835.30	4,833.25	4,831.24
1956-57	4,820.82	4,821.46	4,823.06	4,823.20	4,829.65	4,833.55	4,834.97	4,834.30	4,830.92	4,827.06	4,823.30	4,820.52
1955-56	4,803.38	4,804.90	4,821.50	4,825.57	4,823.44	4,830.74	4,832.32	4,832.90	4,830.30	4,826.72	4,823.39	4,820.62
1954-55	4,814.20	4,814.29	4,814.27	4,814.39	4,814.46	4,818.07	4,821.42	4,819.47	4,815.51	4,811.38	4,816.58	4,804.02
1953-54	4,822.00	4,822.81	4,822.29	4,821.03	4,823.05	4,829.63	4,831.64	4,828.39	4,825.88	4,821.68	4,817.84	4,815.25
1952-53	4,818.87	4,818.77	4,819.24	4,825.25	4,827.08	4,830.77	4,831.94	4,833.07	4,832.19	4,828.25	4,824.84	4,822.62
1951-52	4,810.49	4,810.77	4,812.26	4,812.75	4,811.60	4,813.97	4,831.86	4,830.96	4,828.60	4,825.34	4,821.99	4,819.66
1950-51	4,806.57	4,807.41	4,813.10	4,813.56	4,820.09	4,824.98	4,825.72	4,825.24	4,821.44	4,817.19	4,813.65	4,810.44
1949-50	4,806.88	4,806.92	4,807.03	4,809.10	4,814.13	4,819.88	4,823.04	4,820.98	4,818.00	4,813.14	4,809.01	4,806.31
1948-49	4,810.17	4,810.30	4,810.66	4,808.67	4,807.79	4,816.60	4,821.81	4,820.50	4,817.64	4,813.48	4,809.75	4,806.89
1947-48	4,808.31	4,808.35	4,808.46	4,811.72	4,812.74	4,815.11	4,819.50	4,820.47	4,818.88	4,815.14	4,812.07	4,810.33
1946-47	4,813.64	4,813.94	4,814.86	4,815.19	4,818.07	4,820.06	4,820.09	4,817.78	4,816.67	4,812.98	4,809.76	4,808.42
1945-46	4,821.02	4,821.76	4,822.65	4,816.13	4,812.71	4,823.19	4,827.81	4,825.45	4,822.57	4,819.17	4,815.97	4,813.94
1944-45	4,813.96	4,814.36	4,815.39	4,817.11	4,823.28	4,825.76	4,828.83	4,830.78	4,829.62	4,826.42	4,823.31	4,821.24
1943-44	4,820.53	4,820.61	4,820.66	4,820.79	4,820.98	4,823.90	4,824.88	4,822.55	4,821.54	4,818.79	4,815.94	4,814.26

Appendix 6B (continued). Gerber Reservoir observed end of month surface elevations (Reclamation datum, feet above mean sea level).

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1942-43	4,819.42	4,820.94	4,822.45	4,818.96	4,812.08	4,830.35	4,830.08	4,829.56	4,828.04	4,825.39	4,822.66	4,820.99
1941-42	4,817.55	4,817.68	4,820.48	4,820.36	4,819.94	4,825.09	4,827.32	4,828.67	4,826.74	4,823.98	4,821.54	4,820.02
1940-41	4,819.55	4,819.65	4,820.28	4,820.68	4,822.98	4,826.49	4,826.55	4,825.00	4,823.28	4,820.69	4,818.72	4,817.64
1939-40	4,812.39	4,812.30	4,814.18	4,817.85	4,825.66	4,831.60	4,830.13	4,828.16	4,825.55	4,822.83	4,820.54	4,819.60
1938-39	4,817.05	4,817.23	4,817.65	4,817.74	4,817.90	4,823.98	4,823.45	4,821.20	4,818.70	4,816.25	4,813.66	4,812.53
1937-38	4,818.20	4,819.05	4,821.47	4,820.77	4,817.42	4,818.12	4,831.58	4,826.93	4,824.55	4,821.65	4,819.07	4,817.31
1936-37	4,818.04	4,817.74	4,817.81	4,817.90	4,817.60	4,820.96	4,829.46	4,828.11	4,826.01	4,823.24	4,820.80	4,818.89
1935-36	4,816.52	4,816.51	4,816.64	4,817.44	4,820.30	4,828.11	4,830.30	4,827.28	4,824.50	4,821.92	4,820.00	4,818.72
1934-35	4,803.26	4,804.12	4,805.79	4,806.08	4,808.28	4,813.66	4,824.40	4,823.63	4,821.57	4,819.87	4,818.13	4,816.78
1933-34	4,811.52	4,811.40	4,811.63	4,813.20	4,814.49	4,814.95	4,814.25	4,812.35	4,810.22	4,807.39	4,804.98	4,803.35
1932-33	4,811.18	4,811.13	4,811.17	4,811.34	4,811.40	4,813.05	4,817.54	4,818.85	4,816.70	4,814.58	4,812.79	4,811.65
1931-32	4,794.81	4,795.11	4,795.29	4,795.71	4,796.09	4,817.58	4,819.11	4,818.49	4,816.96	4,814.82	4,812.97	4,811.68
1930-31	4,806.99	4,807.02	4,807.04	4,807.35	4,807.70	4,809.13	4,809.00	4,807.39	4,804.31	4,801.68	4,798.80	4,795.77
1929-30	4,811.16	4,811.00	4,811.80	4,812.04	4,816.85	4,818.63	4,818.70	4,817.08	4,814.58	4,811.82	4,808.90	4,807.16
1928-29	4,816.99	4,816.11	4,816.25	4,816.36	4,816.44	4,819.54	4,820.97	4,819.34	4,817.28	4,814.88	4,812.92	4,811.65
1927-28	4,822.28	4,821.88	4,819.86	4,817.75	4,820.88	4,826.97	4,829.10	4,827.01	4,824.55	4,822.90	4,820.73	4,818.50
1926-27	4,798.22	4,805.50	4,808.86	4,811.93	4,816.80	4,825.55	4,830.85	4,830.88	4,829.56	4,827.96	4,826.38	4,824.45
1925-26	4,804.98	4,804.95	4,805.41	4,805.46	4,808.55	4,809.12	4,808.80	4,806.90	4,804.30	4,802.06	4,800.15	4,798.45
1924-25	NA	NA	NA	4,797.70	4,805.00	4,806.50	4,808.90	4,809.20	4,808.50	4,806.90	4,805.80	4,805.10

APPENDIX 8 – KLAMATH COHO SALMON EFFECTS ANALYSIS TABLES AND FIGURES

Source: Unless otherwise stated, figures and tables developed by Mount Hood Environmental. Data provided by USGS and Reclamation.

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Table 8-1. Daily average IGD exceedance flows estimated for the Proposed Action, 1980-2016.

Exceedance	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
95%	1000	1000	950	950	950	1000	1325	1175	1025	900	900	1000
90%	1000	1000	950	950	950	1178	1325	1175	1025	900	900	1000
85%	1000	1000	950	950	950	1427	1325	1175	1025	900	900	1000
80%	1015	1000	950	950	955	1621	1350	1175	1025	900	900	1000
75%	1046	1000	950	950	1006	1747	1501	1175	1025	922	900	1000
70%	1082	1000	950	950	1052	1908	1654	1175	1025	955	900	1000
65%	1089	1000	950	983	1128	2130	1770	1241	1025	977	900	1000
60%	1104	1031	950	1031	1204	2363	1938	1392	1025	998	903	1000
55%	1122	1084	950	1097	1305	2614	2130	1562	1025	1020	926	1049
50%	1131	1160	976	1207	1553	2853	2349	1722	1025	1037	950	1090
45%	1144	1184	1031	1361	1825	3030	2628	1959	1078	1046	979	1119
40%	1157	1208	1117	1521	2142	3344	2936	2156	1227	1058	1019	1134
35%	1169	1222	1244	1743	2462	3795	3208	2369	1347	1080	1073	1152
30%	1184	1233	1502	2117	2753	4076	3503	2589	1503	1118	1099	1161
25%	1201	1319	1689	2448	3131	4697	4147	2834	1652	1122	1108	1170
20%	1254	1376	1971	2775	3601	5522	4520	3095	1786	1157	1128	1196
15%	1288	1502	2335	3232	4110	6030	5044	3418	2055	1193	1150	1214
10%	1325	1645	2939	4216	5110	6441	5565	3844	2438	1229	1178	1225
5%	1427	2740	4157	5708	7383	7533	6095	4501	3018	1250	1550	1231

Table 8-2: Flood frequency analysis on Klamath River for IGD gaging station observed daily discharge and proposed action daily discharge for the period of record from 1981-2016.

Source: MBK Engineers

		IGD Gaging Station Discharge (cfs)	
Flood Frequency	**Exceedance Probability**	**Observed Daily**	**Proposed Action Daily**
1.5-yr	67%	3,590	5,989
2-yr	50%	4,898	6,523
5-yr	20%	9,110	8,698
10-yr	10%	12,520	10,758
25-yr	4%	17,498	14,212
50-yr	2%	21,661	17,516
100-yr	1%	26,181	21,571

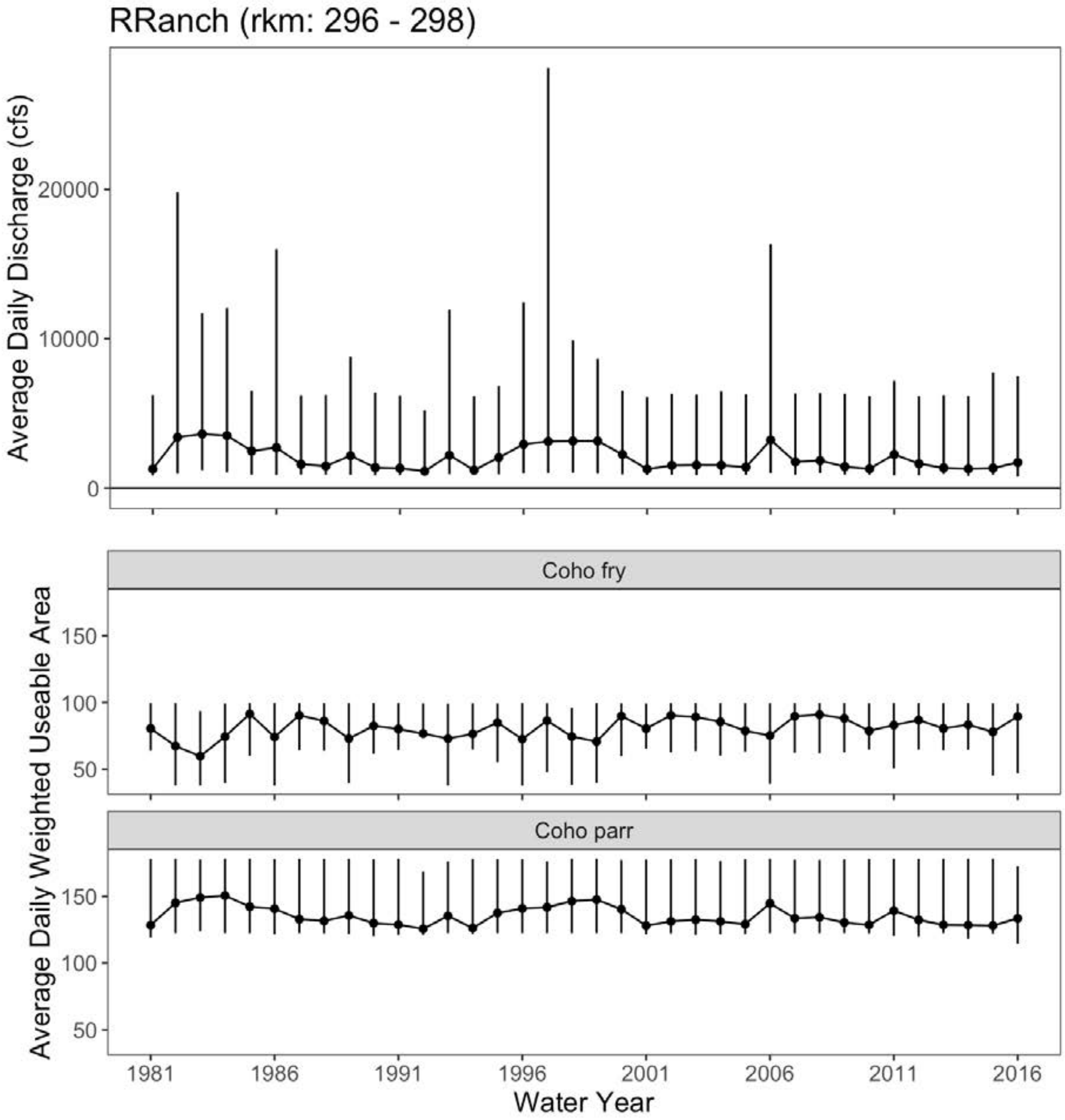

Figure 8-1. Average daily discharge (top panel) and corresponding weighted useable area (WUA) for coho parr (bottom panel) and fry (middle panel) modeled at the RR Ranch study site (rkm 296.7472 – 298.003) as a result of the Proposed Action for all water years (October 1 – September 30) included in the POR. Whiskers indicate modeled maximum and minimum values.

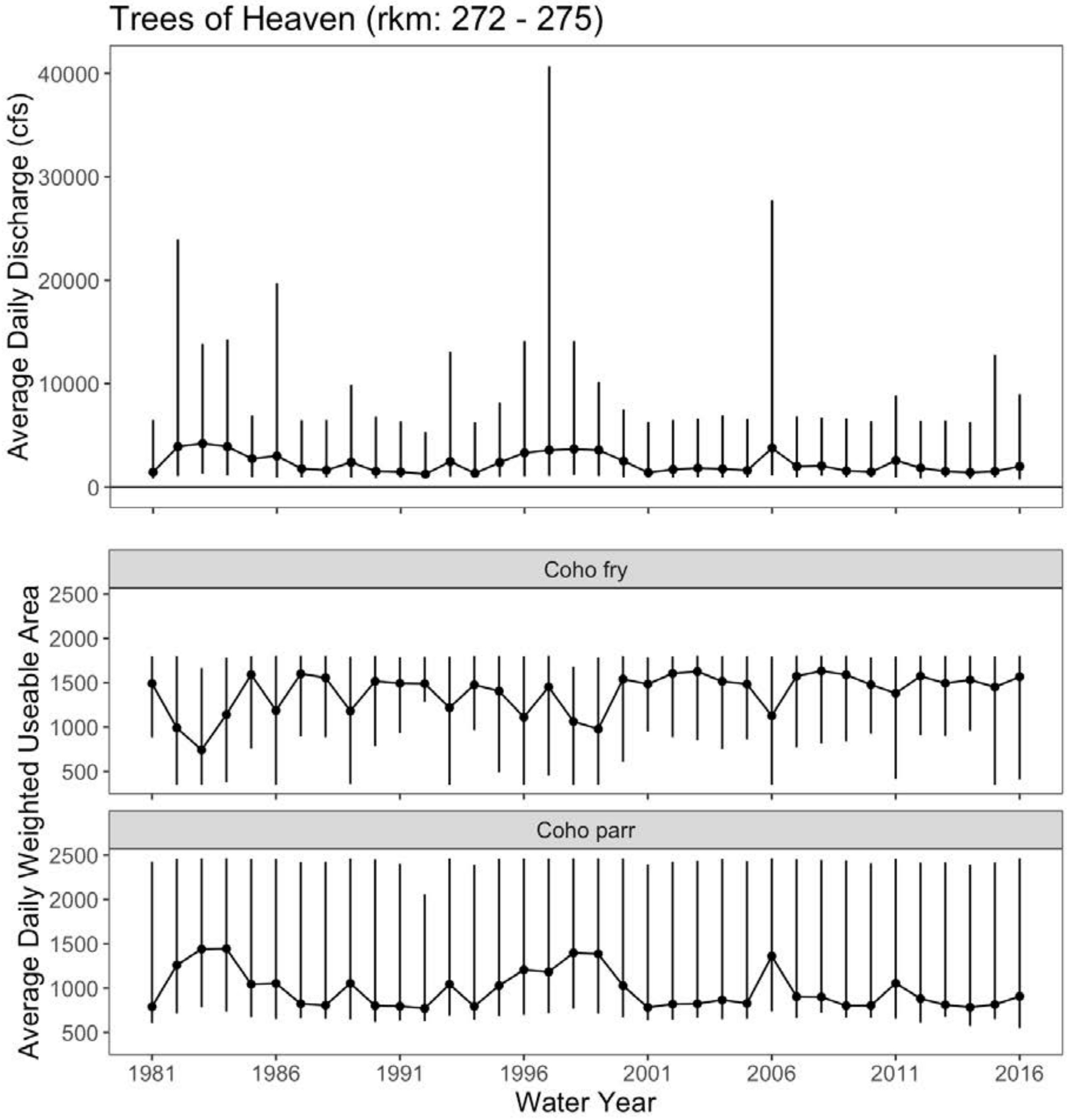

Figure 8-2. Average daily discharge (top panel) and corresponding weighted useable area (WUA) for coho parr (bottom panel) and fry (middle panel) modeled at the Trees of Heaven study site (rkm 272.8937 – 275.0743) as a result of the Proposed Action for all water years (October 1 – September 30) included in the POR. Whiskers indicate modeled maximum and minimum values.

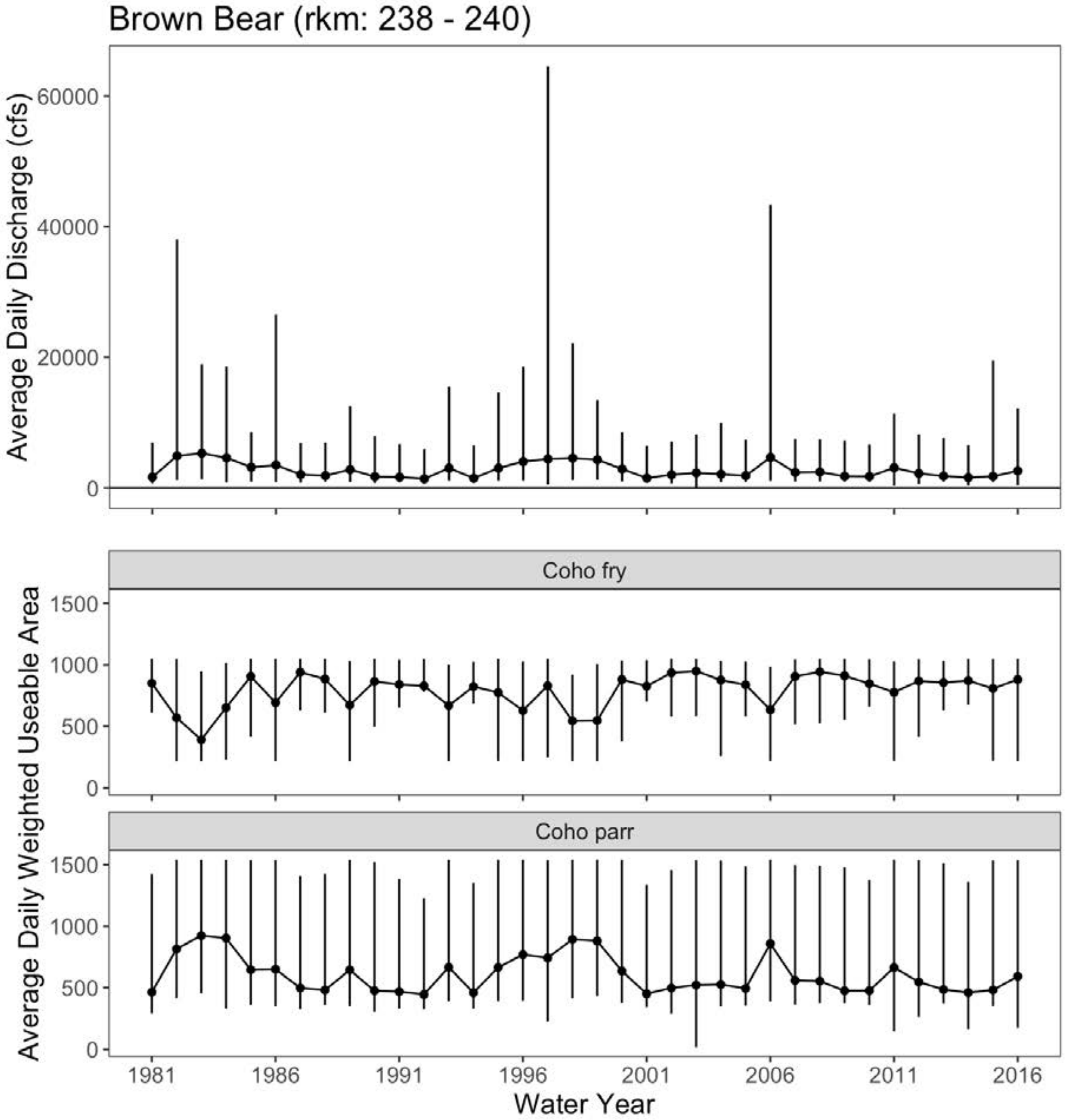

Figure 8-3. Average daily discharge (top panel) and corresponding weighted useable area (WUA) for coho parr (bottom panel) and fry (middle panel) modeled at the Brown Bear study site (rkm 238.7011 – 240.1118) as a result of the Proposed Action for all water years (October 1 – September 30) included in the POR. Whiskers indicate modeled maximum and minimum values.

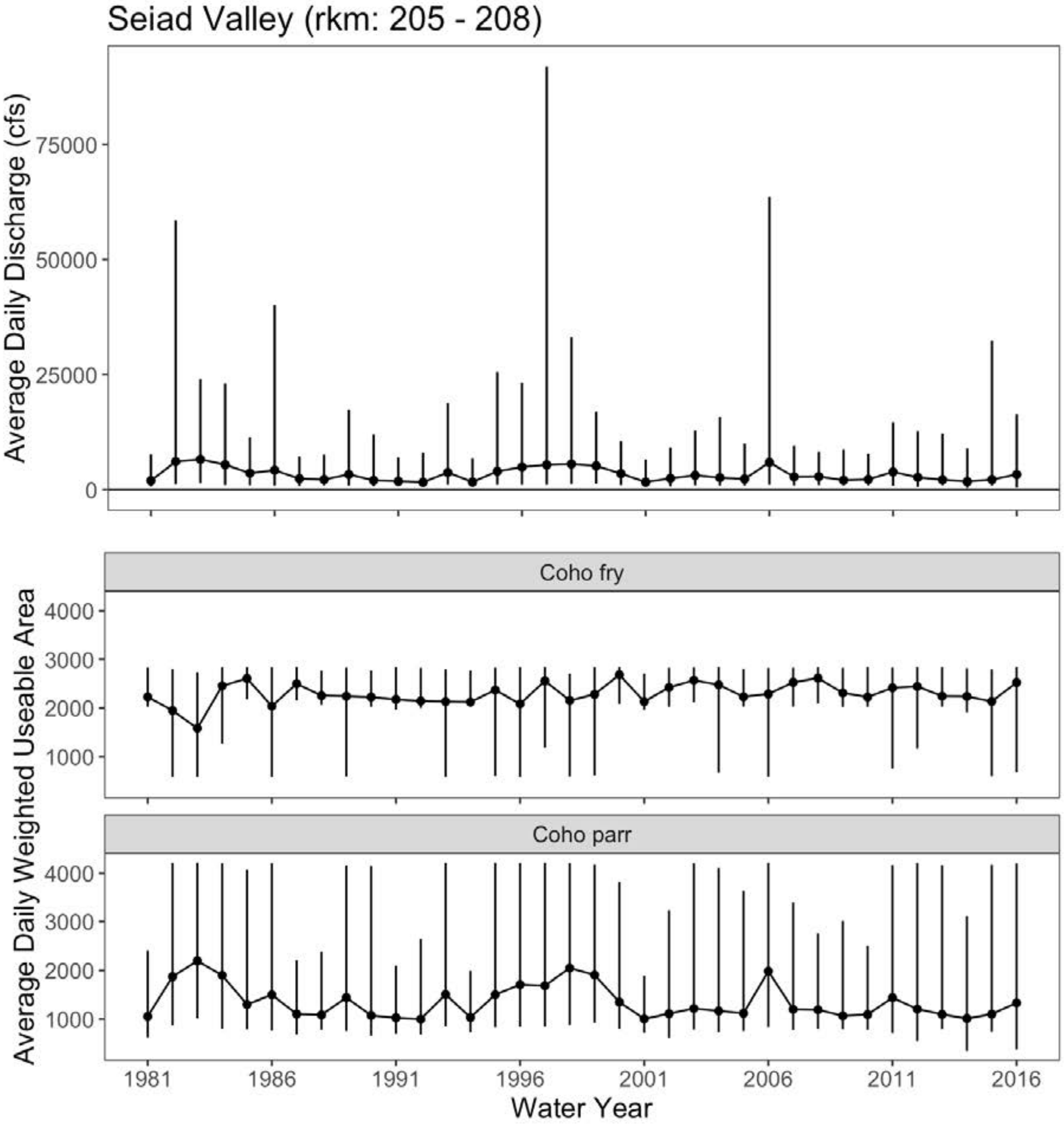

Figure 8-4. Average daily discharge (top panel) and corresponding weighted useable area (WUA) for coho parr (bottom panel) and fry (middle panel) modeled at the Seiad Valley study site (rkm 296.7472 – 298.003) as a result of the Proposed Action for all water years (October 1 – September 30) included in the POR. Whiskers indicate modeled maximum and minimum values.

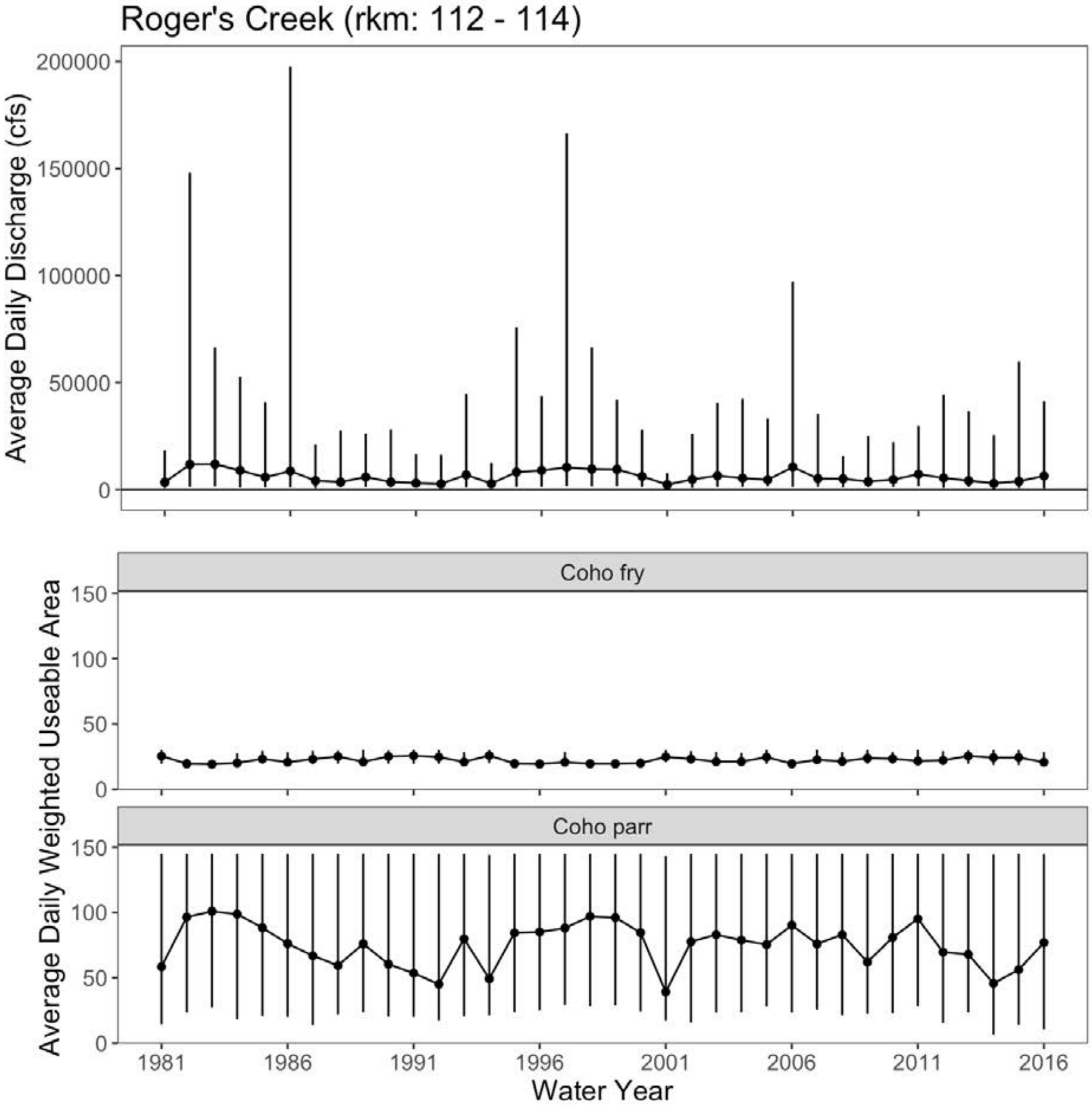

Figure 8-5. Average daily discharge (top panel) and corresponding weighted useable area (WUA) for coho parr (bottom panel) and fry (middle panel) modeled at the Roger's Creek study site (rkm 112.6402 – 114.4836) as a result of the Proposed Action for all water years (October 1 – September 30) included in the POR. Whiskers indicate modeled maximum and minimum values.

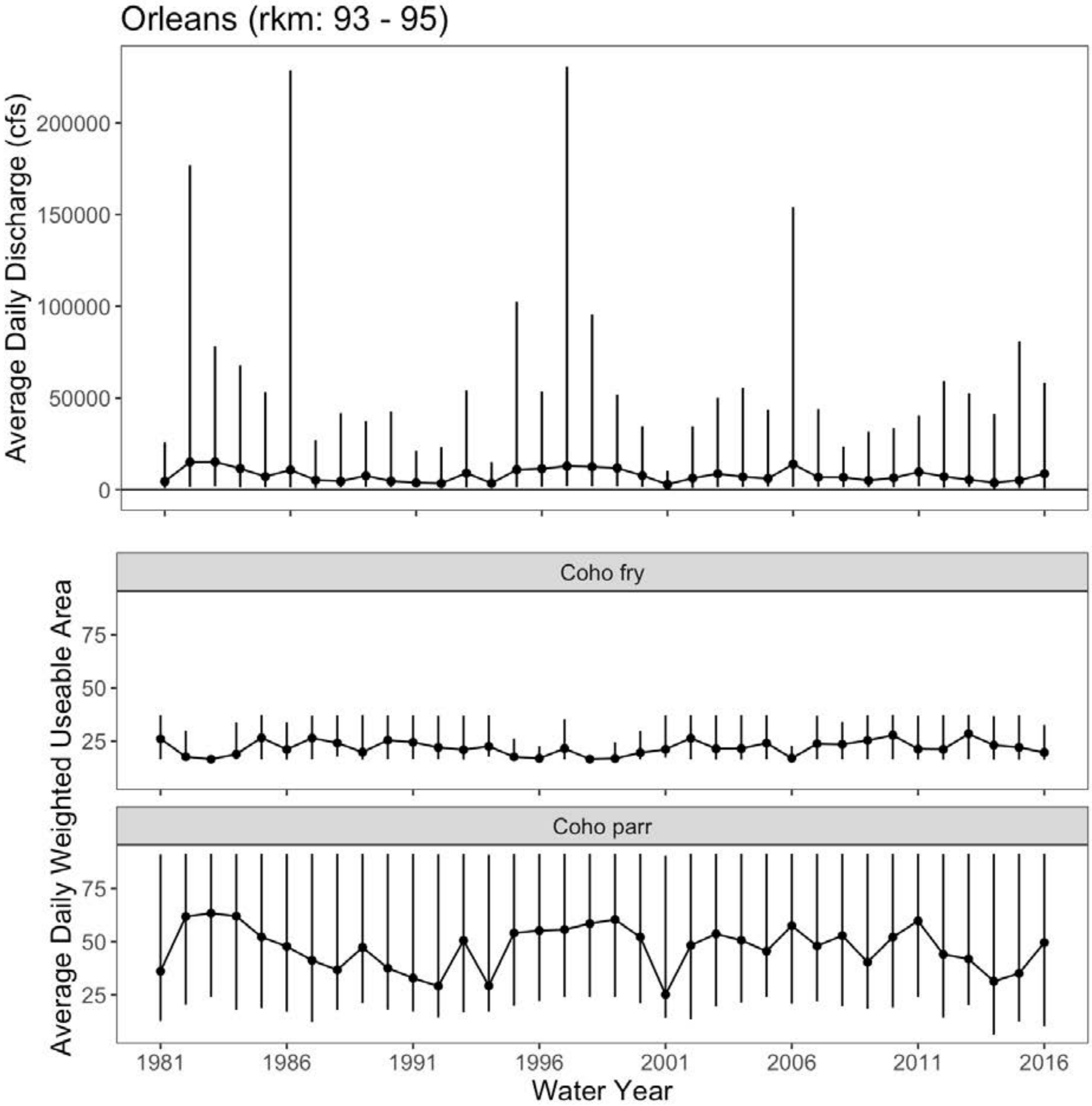

Figure 8-6. Average daily discharge (top panel) and corresponding weighted useable area (WUA) for coho parr (bottom panel) and fry (middle panel) modeled at the Orleans study site (rkm 93.8881 – 95.4474) as a result of the Proposed Action for all water years (October 1 – September 30) included in the POR. Whiskers indicate modeled maximum and minimum values.

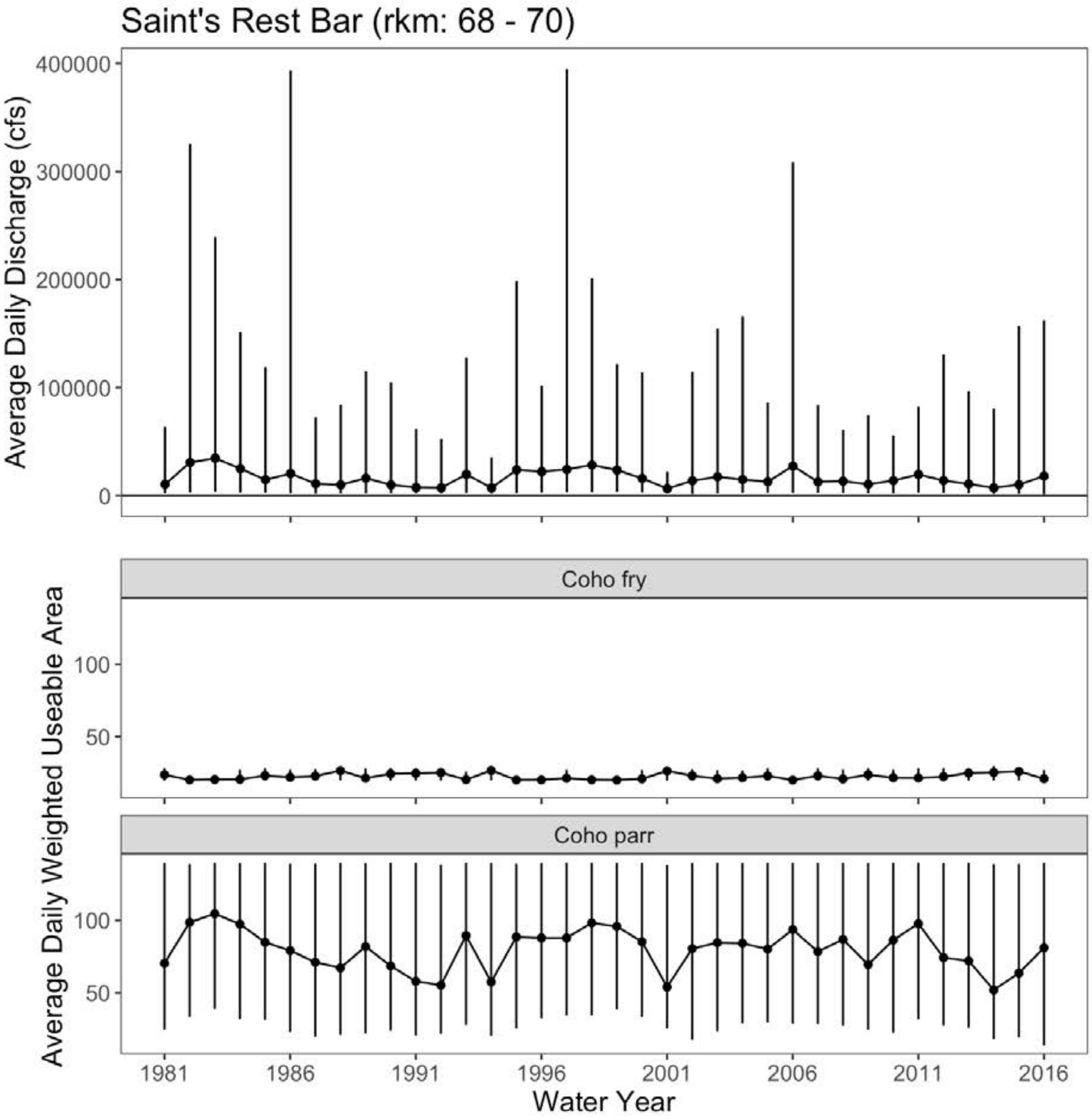

Figure 8-7. Average daily discharge (top panel) and corresponding weighted useable area (WUA) for coho parr (bottom panel) and fry (middle panel) modeled at the Saint's Rest Bar study site (rkm 68.7235 – 70.3264) as a result of the Proposed Action for all water years (October 1 – September 30) included in the POR. Whiskers indicate modeled maximum and minimum values.

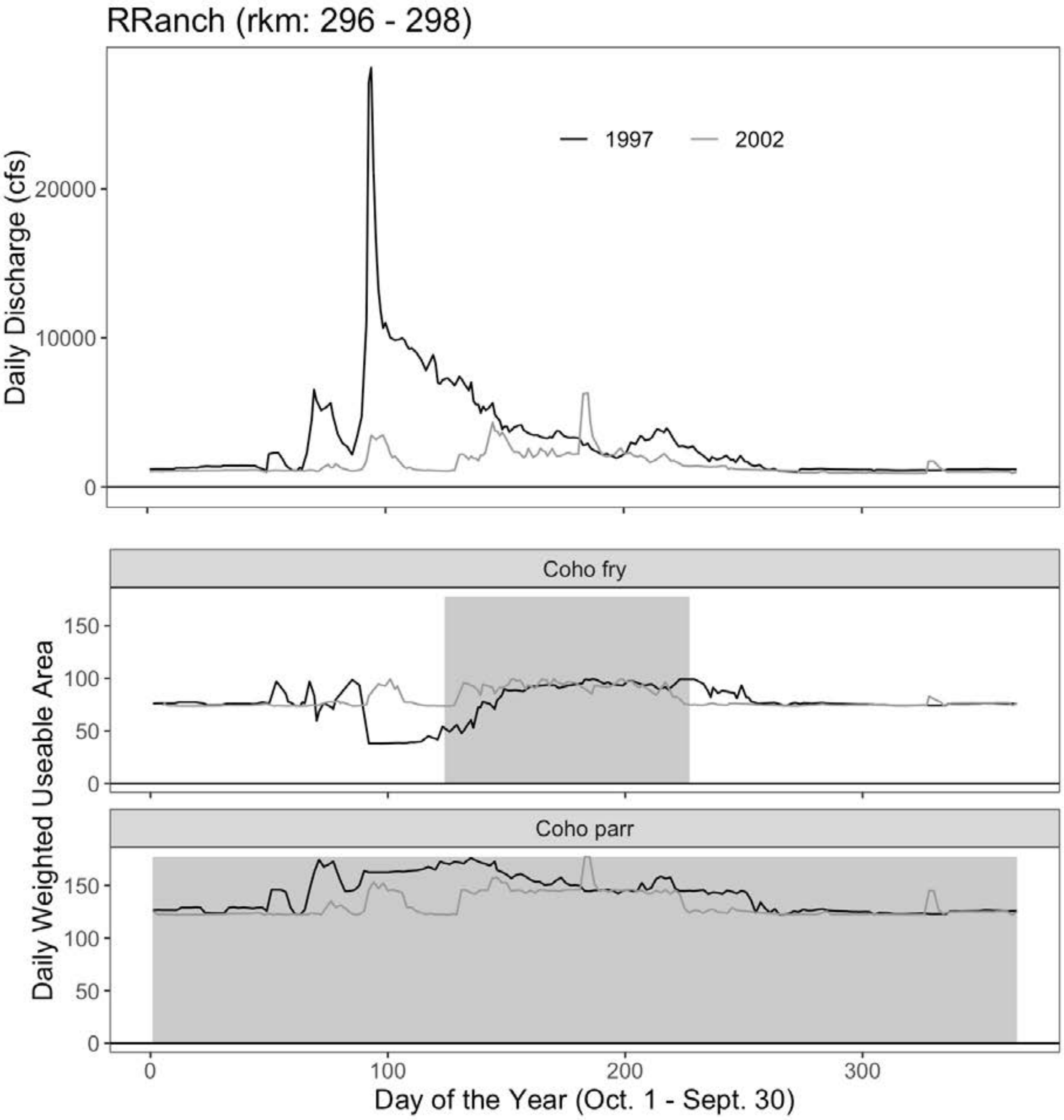

Figure 8-8. Daily discharge (top panel) and corresponding weighted useable area (WUA) for coho parr (bottom panel) and fry (middle panel) modeled at the RRanch study site (rkm 296.7472 – 298.003) as a result of the Proposed Action for water years 1997 (wet) and 2002 (dry). Shaded areas indicate the timing of presence of each life stage in the main stem Klamath River.

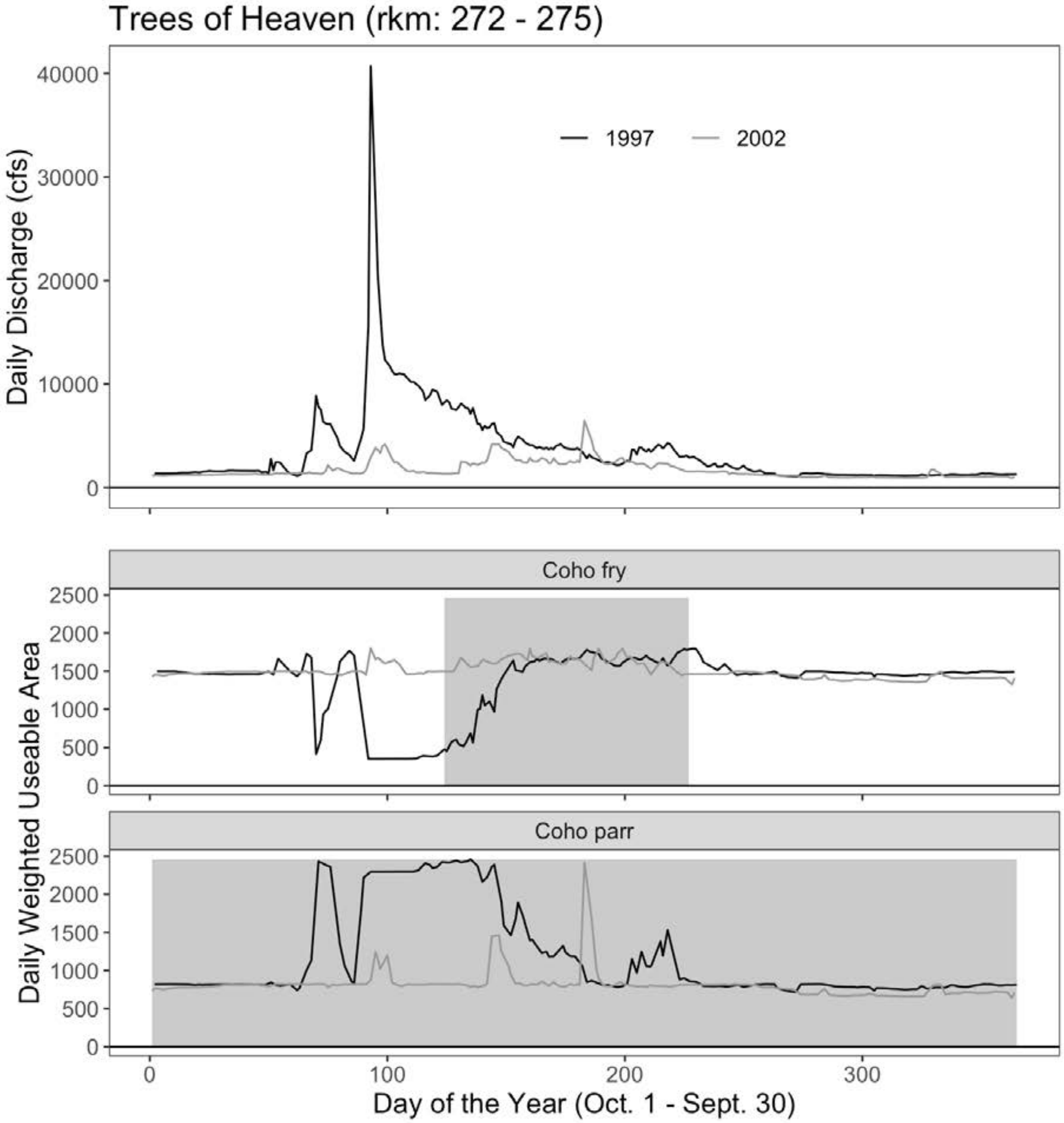

Figure 8-9. Daily discharge (top panel) and corresponding weighted useable area (WUA) for coho parr (bottom panel) and fry (middle panel) modeled at the Trees of Heaven study site (rkm 272.8937 – 275.0743) as a result of the Proposed Action for water years 1997 (wet) and 2002 (dry). Shaded areas indicate the timing of presence of each life stage in the main stem Klamath River.

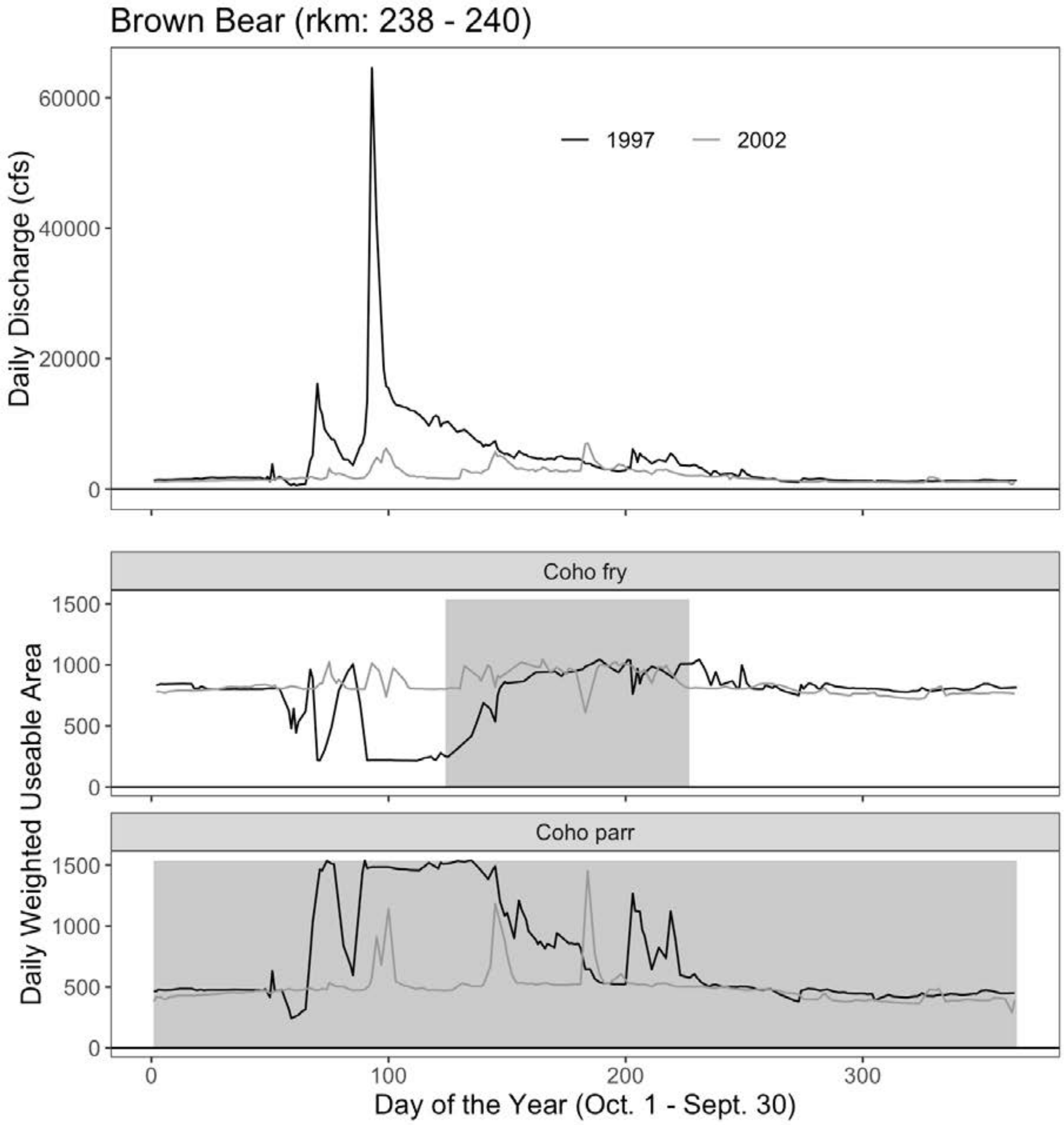

Figure 8-10. Daily discharge (top panel) and corresponding weighted useable area (WUA) for coho parr (bottom panel) and fry (middle panel) modeled at the Brown Bear study site (rkm 2238.7011 – 240.1118) as a result of the Proposed Action for water years 1997 (wet) and 2002 (dry). Shaded areas indicate the timing of presence of each life stage in the main stem Klamath River.

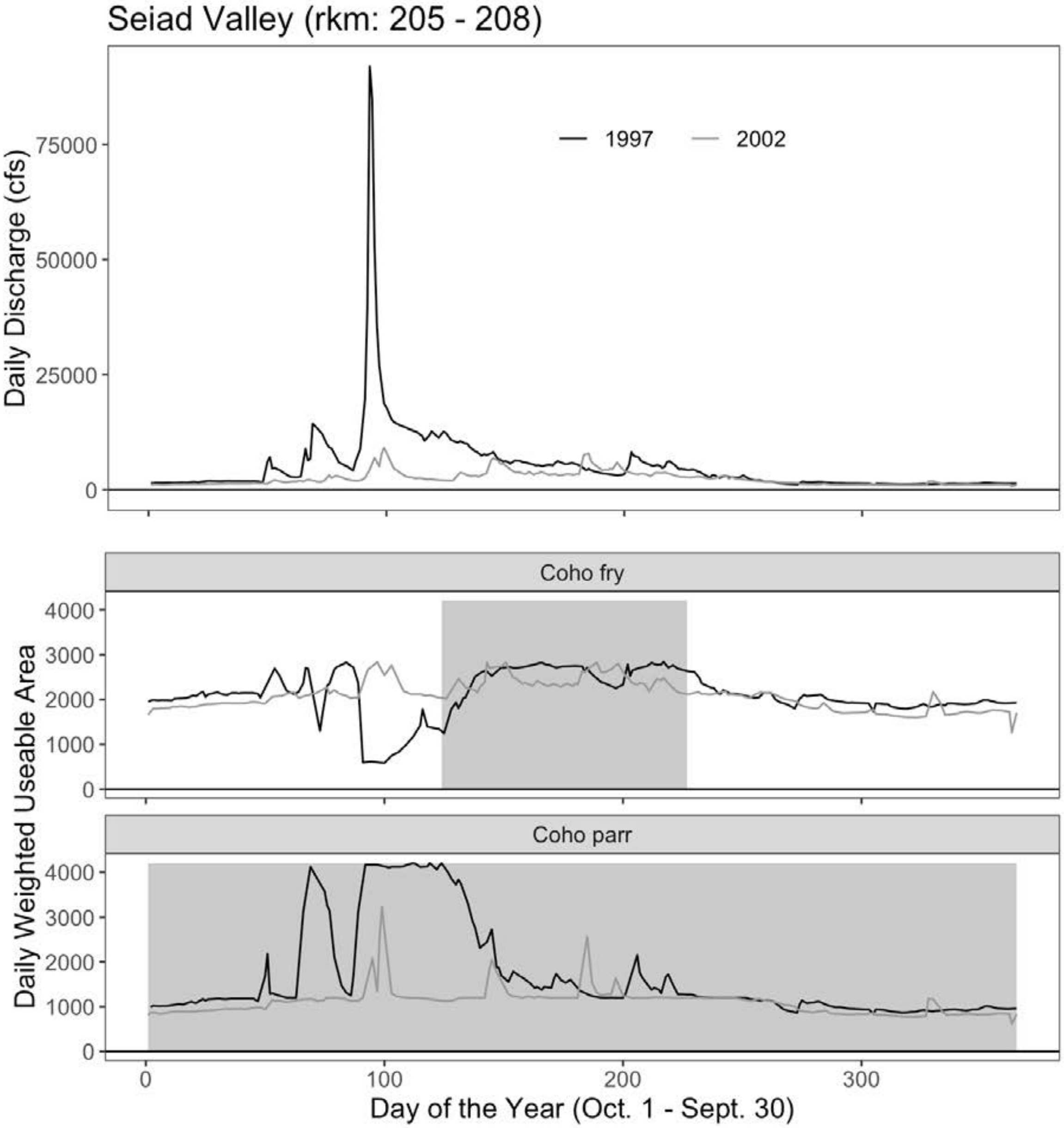

Figure 8-11. Daily discharge (top panel) and corresponding weighted useable area (WUA) for coho parr (bottom panel) and fry (middle panel) modeled at the Seiad Valley study site (rkm 205.8206 – 208.0594) as a result of the Proposed Action for water years 1997 (wet) and 2002 (dry). Shaded areas indicate the timing of presence of each life stage in the main stem Klamath River.

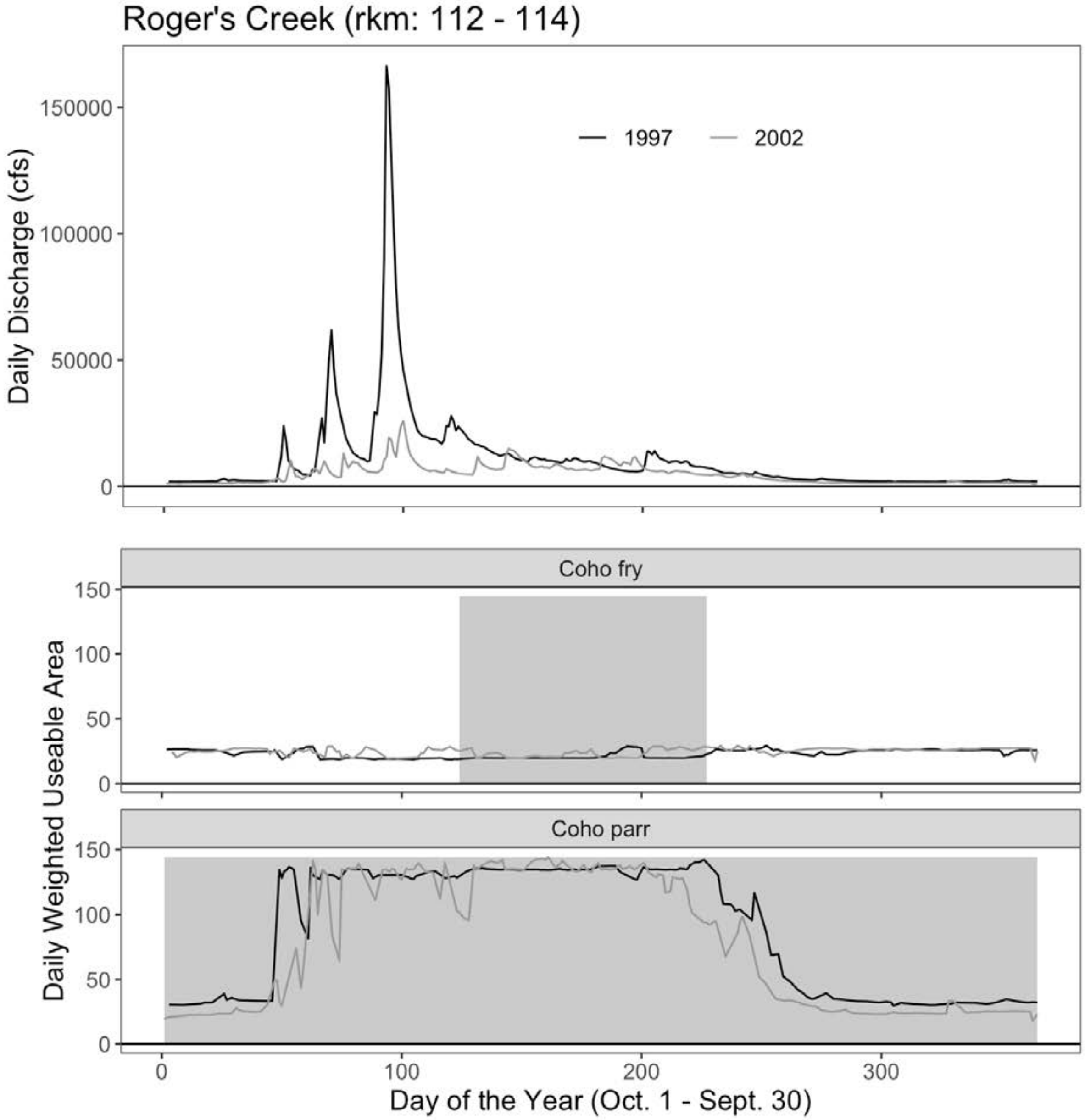

Figure 8-12. Daily discharge (top panel) and corresponding weighted useable area (WUA) for coho parr (bottom panel) and fry (middle panel) modeled at the Roger's Creek study site (rkm 112.6402 – 114.4836) as a result of the Proposed Action for water years 1997 (wet) and 2002 (dry). Shaded areas indicate the timing of presence of each life stage in the main stem Klamath River.

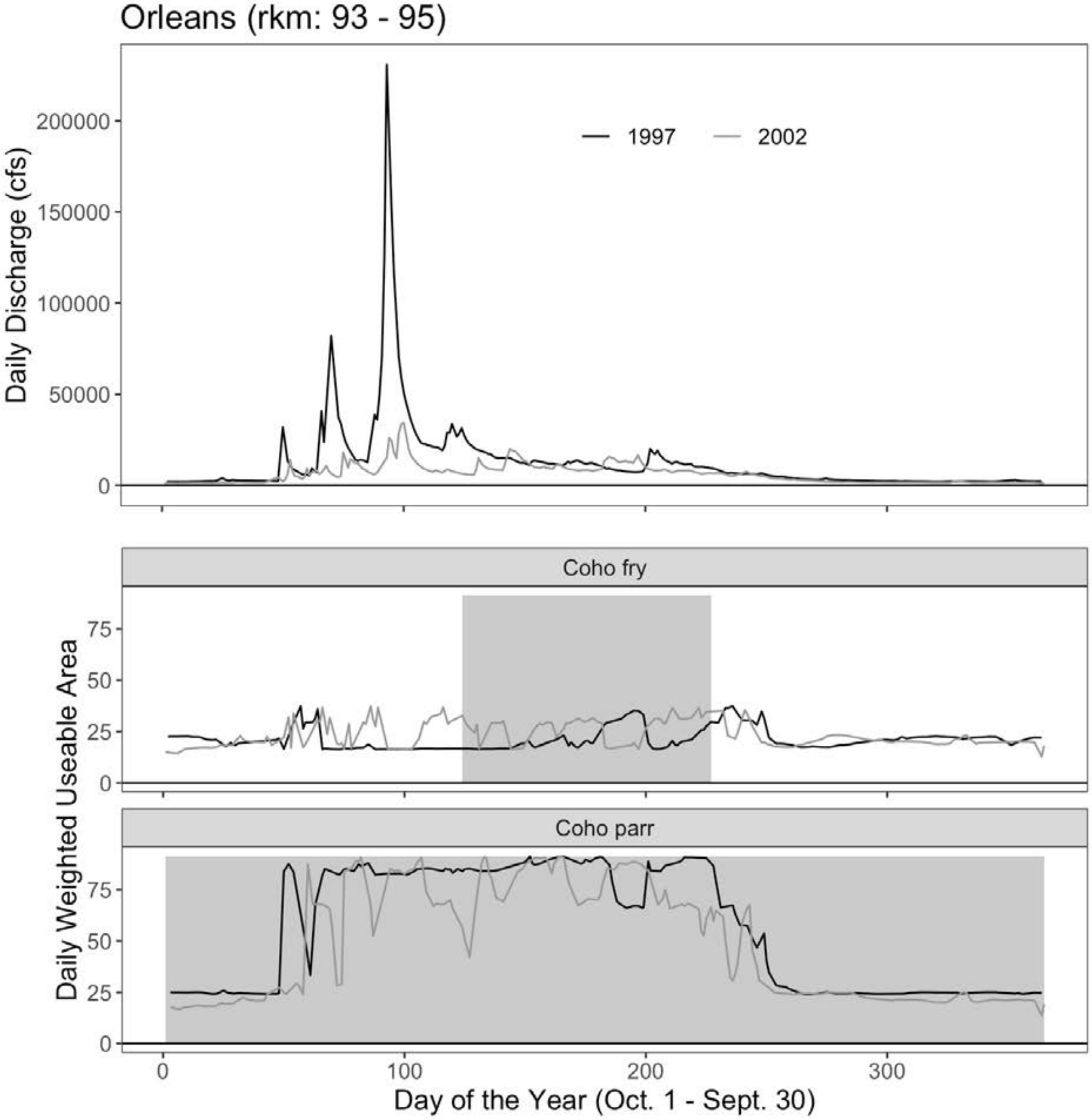

Figure 8-13. Daily discharge (top panel) and corresponding weighted useable area (WUA) for coho parr (bottom panel) and fry (middle panel) modeled at the Orleans study site (rkm 93.881 – 95.4474) as a result of the Proposed Action for water years 1997 (wet) and 2002 (dry). Shaded areas indicate the timing of presence of each life stage in the main stem Klamath River.

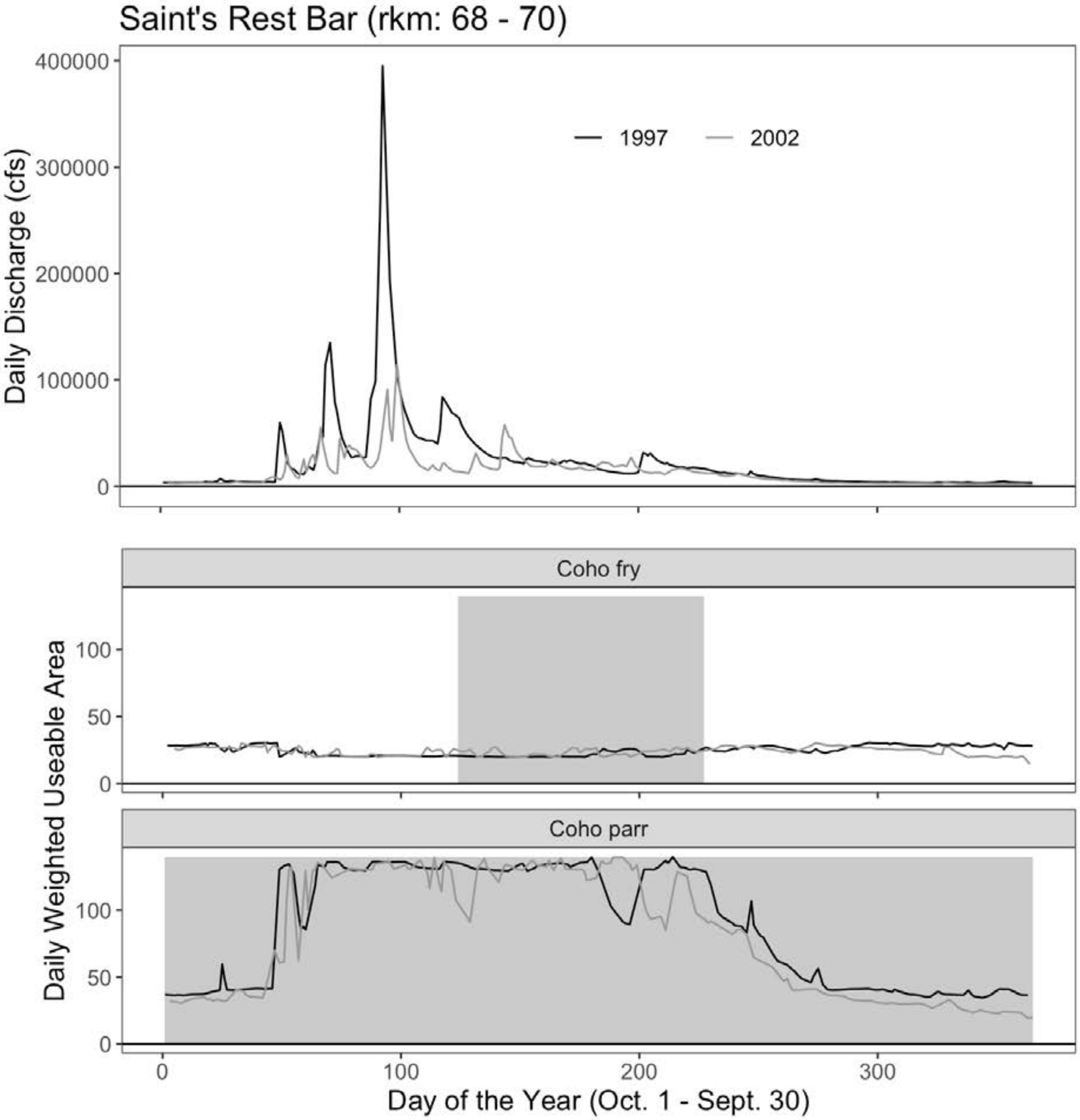

Figure 8-14. Daily discharge (top panel) and corresponding weighted useable area (WUA) for coho parr (bottom panel) and fry (middle panel) modeled at the Saint's Rest Bar study site (rkm 68.7235 – 70.3264) as a result of the Proposed Action for water years 1997 (wet) and 2002 (dry). Shaded areas indicate the timing of presence of each life stage in the main stem Klamath River.

Table 8-3. A comparison of daily average Klamath River water temperatures at IGD modeled under the Proposed Action and historical conditions, averaged by month for March – October 1981 – 2014. Negative numbers in the columns reporting differences refer to a reduction in temperature under the Proposed Action, relative to those under historical conditions.

	Proposed Action Temperature (°C)								**Historical Temperature (°C)**								**Temperature (°C) Difference**							
Year	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**
1981	7.4	10.1	13.2	16.6	20.0	21.6	19.7	14.7	7.4	10.1	13.2	16.6	20.0	21.6	19.7	14.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1982	6.6	7.4	13.4	17.2	19.4	20.7	18.5	12.8	6.6	7.4	13.4	17.2	19.4	20.7	18.5	12.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1983	8.1	7.7	11.9	18.5	19.2	20.5	18.3	13.3	8.1	7.7	11.9	18.5	19.2	20.5	18.3	13.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1984	7.5	9.0	12.6	17.2	20.4	21.6	18.7	12.5	7.5	9.0	12.6	17.2	20.4	21.6	18.7	12.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1985	6.0	11.6	14.0	17.0	20.9	21.5	17.4	12.5	6.0	11.6	14.0	17.0	20.9	21.5	17.4	12.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1986	9.8	11.4	12.5	17.7	20.7	21.7	19.2	12.2	9.8	11.4	12.5	17.7	20.7	21.7	19.2	12.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1987	7.2	10.4	14.8	18.2	20.7	20.5	19.0	15.4	7.2	10.4	14.8	18.2	20.7	20.5	19.0	15.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1988	8.0	11.4	12.9	15.7	19.6	21.7	19.6	15.2	8.0	11.4	12.9	15.7	19.6	21.7	19.6	15.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1989	6.3	11.1	14.1	17.5	19.8	20.6	17.8	13.6	6.3	11.1	14.1	17.5	19.8	20.6	17.8	13.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1990	5.9	11.8	14.6	15.8	19.7	21.8	18.8	14.2	5.9	11.8	14.6	15.8	19.7	21.8	18.8	14.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1991	6.5	9.1	11.3	15.1	18.9	20.9	19.7	16.1	6.5	9.1	11.3	15.1	18.9	20.9	19.7	16.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1992	6.9	10.9	15.1	18.7	20.8	21.8	19.8	15.4	6.9	10.9	15.1	18.7	20.8	21.8	19.8	15.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1993	6.6	9.2	13.8	16.8	18.7	20.0	18.3	14.4	6.6	9.2	13.8	16.8	18.7	20.0	18.3	14.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1994	6.4	9.6	13.5	17.1	20.5	21.7	19.2	14.9	6.4	9.6	13.5	17.1	20.5	21.7	19.2	14.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1995	8.0	9.1	12.6	16.7	19.9	20.9	18.7	14.3	8.0	9.1	12.6	16.7	19.9	20.9	18.7	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1996	7.2	11.0	13.3	16.7	20.6	21.8	18.9	14.3	7.2	11.0	13.3	16.7	20.6	21.8	18.9	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1997	7.6	10.5	13.8	17.3	19.6	21.7	19.8	14.8	7.6	10.5	13.8	17.3	19.6	21.7	19.8	14.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

1998	7.0	7.5	11.4	14.9	20.6	22.9	21.1	15.2	7.0	7.5	11.4	14.9	20.6	22.9	21.1	15.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1999	5.8	7.4	11.0	15.8	20.1	21.3	19.6	15.8	5.8	7.4	11.0	15.8	20.1	21.3	19.6	15.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2000	6.7	10.5	12.6	16.7	20.5	22.1	19.3	15.0	6.7	10.5	12.6	16.7	20.5	22.1	19.3	15.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2001	6.9	9.5	13.3	18.4	20.7	22.0	20.7	16.2	6.9	9.5	13.3	18.4	20.7	22.0	20.7	16.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2002	7.4	10.2	12.8	16.9	21.6	22.5	20.4	15.5	7.4	10.2	12.8	16.9	21.6	22.5	20.4	15.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2003	8.0	9.5	10.9	17.7	21.9	23.2	20.8	16.3	8.0	9.5	10.9	17.7	21.9	23.2	20.8	16.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2004	7.8	11.2	13.6	16.7	20.6	22.6	20.2	15.6	7.8	11.2	13.6	16.7	20.6	22.6	20.2	15.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2005	7.6	10.6	12.8	15.6	19.6	22.6	20.2	14.9	7.6	10.6	12.8	15.6	19.6	22.6	20.2	14.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2006	5.3	8.3	15.3	18.0	21.9	22.1	18.8	14.1	5.3	8.3	15.3	18.0	21.9	22.1	18.8	14.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2007	6.8	11.4	13.6	18.2	21.0	21.5	19.1	13.7	6.8	11.4	13.6	18.2	21.0	21.5	19.1	13.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2008	5.9	9.3	14.3	17.4	22.0	21.8	19.2	14.8	5.9	9.3	14.3	17.4	22.0	21.8	19.2	14.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2009	6.7	10.4	14.8	19.4	21.7	21.7	19.4	14.6	6.7	10.4	14.8	19.4	21.7	21.7	19.4	14.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2010	7.2	9.5	12.7	16.9	21.3	21.9	18.4	15.5	7.2	9.5	12.7	16.9	21.3	21.9	18.4	15.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2011	5.8	9.2	12.7	16.1	20.7	22.2	20.2	15.7	5.8	9.2	12.7	16.1	20.7	22.2	20.2	15.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2012	5.8	9.4	15.5	17.8	20.9	21.9	19.5	16.1	5.8	9.4	15.5	17.8	20.9	21.9	19.5	16.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2013	6.5	11.4	16.0	18.9	21.7	21.5	19.6	14.2	6.5	11.4	16.0	18.9	21.7	21.5	19.6	14.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2014	8.4	12.0	16.4	19.3	22.3	22.0	19.3	15.8	8.4	12.0	16.4	19.3	22.3	22.0	19.3	15.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ave.	**7.0**	**10.0**	**13.4**	**17.2**	**20.6**	**21.7**	**19.3**	**14.7**	**7.0**	**10.0**	**13.4**	**17.2**	**20.6**	**21.7**	**19.3**	**14.7**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Min.	**5.3**	**7.4**	**10.9**	**14.9**	**18.7**	**20.0**	**17.4**	**12.2**	**5.3**	**7.4**	**10.9**	**14.9**	**18.7**	**20.0**	**17.4**	**12.2**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Max.	**9.8**	**12.0**	**16.4**	**19.4**	**22.3**	**23.2**	**21.1**	**16.3**	**9.8**	**12.0**	**16.4**	**19.4**	**22.3**	**23.2**	**21.1**	**16.3**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Table 8-4. A comparison of daily average Klamath River water temperatures at rivermile 174.0 (just below the confluence with the Shasta River) modeled under the Proposed Action and historical conditions, averaged by month for March – October 1981 – 2014. Negative numbers in the columns reporting differences refer to a reduction in temperature under the Proposed Action, relative to those under historical conditions.

	Proposed Action Temperatures (°C)								**Historical Temperatures (°C)**								**Temperature (°C) Differences**							
Year	**Mar**	**Apr**	**May**	**Jun**	**Jul.**	**Aug.**	**Sep**	**Oct**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
1981	8.3	11.7	15.0	18.8	21.5	22.2	19.3	13.6	8.3	11.8	15.3	19.3	21.9	22.2	19.2	13.3	0.0	-0.1	-0.3	-0.5	-0.4	0.0	0.1	0.3
1982	7.1	8.2	14.4	18.4	20.9	21.3	18.0	12.3	7.0	8.2	14.8	19.2	21.1	21.3	18.1	12.4	0.1	0.0	-0.4	-0.8	-0.1	0.0	0.0	-0.1
1983	8.6	8.6	13.1	19.2	20.3	20.9	18.2	13.0	8.6	8.7	13.3	19.5	20.7	21.0	18.2	13.1	0.0	0.0	-0.3	-0.3	-0.4	-0.1	0.0	-0.1
1984	8.1	9.7	13.7	18.1	21.8	21.9	18.3	11.8	8.1	9.7	13.8	18.5	22.3	21.9	18.3	12.1	0.0	0.0	-0.1	-0.4	-0.5	0.0	-0.1	-0.3
1985	6.5	12.3	15.1	18.7	22.2	21.8	16.9	12.2	6.6	12.3	15.5	19.3	22.6	21.8	16.9	12.2	-0.1	0.0	-0.4	-0.5	-0.4	0.0	-0.1	0.0
1986	10.3	12.1	14.1	19.4	21.9	22.4	18.1	12.2	10.3	12.1	14.4	20.3	22.2	22.4	18.2	12.2	0.0	-0.1	-0.4	-1.0	-0.3	0.0	-0.1	0.0
1987	7.9	12.0	16.2	19.9	21.5	21.4	18.7	14.7	7.9	12.2	16.5	20.6	21.6	21.5	18.7	14.7	0.0	-0.3	-0.3	-0.6	-0.1	0.0	0.0	0.0
1988	8.7	12.3	14.5	17.6	21.8	22.3	19.2	14.5	8.8	12.5	14.8	18.2	22.4	22.3	19.2	14.5	-0.1	-0.1	-0.3	-0.6	-0.6	0.0	0.0	0.0
1989	6.8	11.8	15.1	19.1	21.2	20.9	17.7	12.9	6.8	11.9	15.2	19.8	21.7	20.9	17.7	12.9	0.0	-0.1	-0.1	-0.7	-0.5	0.0	0.0	0.0
1990	7.3	13.0	15.7	17.9	21.5	22.1	18.8	13.5	7.2	13.1	15.8	18.7	21.9	22.2	18.8	13.5	0.1	-0.1	-0.1	-0.8	-0.4	-0.1	0.0	0.1
1991	7.3	10.7	13.2	16.9	21.1	21.6	19.7	15.2	7.5	11.3	13.8	17.8	22.1	21.9	19.7	15.0	-0.2	-0.6	-0.6	-0.8	-1.0	-0.3	0.0	0.2
1992	8.6	12.3	17.1	20.1	22.3	22.4	19.3	14.3	9.5	13.0	18.4	20.9	23.1	22.9	19.0	14.2	-0.9	-0.7	-1.3	-0.8	-0.9	-0.4	0.3	0.1
1993	7.6	10.0	14.8	18.2	20.3	20.8	18.2	13.7	7.6	10.0	15.0	18.7	20.7	20.8	18.2	13.8	0.1	0.0	-0.2	-0.5	-0.4	0.0	0.0	-0.1
1994	8.2	11.1	15.5	19.1	22.2	22.1	19.0	13.5	8.8	12.0	16.1	19.8	22.9	22.3	19.0	13.4	-0.6	-1.0	-0.7	-0.7	-0.7	-0.2	0.0	0.1
1995	8.5	10.0	14.0	17.9	21.4	21.5	18.8	13.4	8.4	10.0	14.2	18.6	21.8	21.5	18.7	13.5	0.0	0.0	-0.2	-0.7	-0.4	0.0	0.0	-0.1
1996	7.8	11.7	14.3	18.2	22.2	22.3	18.3	13.5	7.7	11.7	14.4	18.4	22.3	22.3	18.4	13.5	0.0	0.0	-0.1	-0.1	-0.1	0.0	0.0	0.0

1997	8.3	11.3	15.3	18.8	21.2	22.1	19.4	13.9	8.4	11.4	15.5	19.0	21.5	22.1	19.3	13.9	-0.1	-0.1	-0.2	-0.1	-0.3	0.0	0.1	0.0
1998	7.9	8.7	12.4	16.5	22.3	23.2	20.4	14.1	7.9	8.8	12.4	16.7	22.4	23.2	20.5	14.0	0.0	-0.1	0.0	-0.2	-0.2	0.0	0.0	0.1
1999	6.4	8.3	12.1	16.9	21.4	21.4	19.3	14.8	6.4	8.3	12.6	17.3	21.4	21.4	19.3	14.8	0.1	0.0	-0.5	-0.3	0.1	0.0	0.0	-0.1
2000	7.5	11.5	14.1	18.8	21.7	22.5	18.8	14.0	7.5	11.6	14.2	18.9	21.7	22.5	18.8	13.9	0.0	-0.1	0.0	-0.1	0.0	0.0	0.0	0.1
2001	8.2	10.7	15.7	19.8	22.0	22.6	20.1	14.9	8.2	10.6	15.2	19.3	22.0	22.6	20.1	15.0	0.0	0.1	0.5	0.4	0.0	0.0	0.1	-0.1
2002	8.0	11.3	14.3	18.9	23.0	22.7	19.9	14.1	7.9	11.4	14.4	19.2	23.2	22.8	19.8	14.1	0.0	-0.1	-0.1	-0.2	-0.1	-0.1	0.1	0.0
2003	9.0	10.3	13.0	19.5	23.3	23.1	20.1	15.1	9.0	10.2	13.0	19.6	23.4	23.1	20.2	15.2	0.0	0.1	0.0	-0.2	-0.1	0.0	0.0	-0.2
2004	8.9	12.3	15.2	18.8	22.2	22.8	19.4	14.3	9.0	12.3	15.2	19.1	22.6	22.9	19.3	14.1	-0.1	-0.1	0.0	-0.3	-0.4	-0.1	0.1	0.2
2005	8.9	11.7	14.1	17.4	21.9	23.0	19.4	13.7	9.0	11.7	14.0	17.7	22.0	23.0	19.4	13.8	-0.2	0.0	0.2	-0.3	-0.1	0.0	0.0	-0.2
2006	6.0	9.2	16.1	19.5	23.2	22.3	18.5	13.1	5.9	9.2	16.2	19.0	23.1	22.3	18.5	13.1	0.1	0.0	-0.1	0.5	0.1	0.0	0.0	-0.1
2007	7.7	12.3	15.5	19.7	22.3	22.1	18.7	12.8	7.7	12.3	15.5	19.4	22.3	22.0	18.6	12.9	0.0	-0.1	0.0	0.3	0.0	0.0	0.0	-0.1
2008	6.7	10.2	15.2	18.8	23.0	22.2	19.0	13.6	6.8	10.2	15.4	18.8	23.0	22.2	19.0	13.8	-0.1	0.0	-0.2	0.0	0.0	0.0	0.0	-0.1
2009	7.6	11.5	16.2	20.4	23.3	22.2	19.3	13.6	7.6	11.7	16.5	20.3	23.4	22.2	19.2	13.6	-0.1	-0.1	-0.3	0.1	0.0	0.0	0.0	0.0
2010	8.4	10.7	14.2	18.6	22.9	22.3	18.2	14.3	8.1	10.7	14.4	19.1	23.0	22.3	18.2	14.3	0.2	0.0	-0.2	-0.5	-0.1	0.0	0.0	0.0
2011	6.5	10.0	13.5	17.3	21.8	22.8	19.9	14.3	6.5	9.9	13.5	17.4	21.9	22.8	19.8	14.3	0.0	0.1	0.0	-0.1	0.0	0.0	0.0	0.0
2012	6.7	10.6	16.5	19.0	22.3	22.6	19.3	14.7	6.7	10.6	16.5	19.0	22.3	22.6	19.3	14.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2013	7.7	12.8	17.3	20.6	23.6	22.0	19.2	13.3	7.7	12.8	17.3	20.6	23.6	22.0	19.2	13.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2014	9.6	13.4	18.0	20.8	24.0	22.7	19.3	15.0	9.6	13.4	18.0	20.8	24.0	22.7	19.3	15.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ave.	**7.9**	**11.0**	**14.8**	**18.8**	**22.1**	**22.1**	**19.0**	**13.8**	**7.9**	**11.1**	**15.0**	**19.1**	**22.3**	**22.2**	**18.9**	**13.8**	**0.0**	**-0.1**	**-0.2**	**-0.3**	**-0.3**	**0.0**	**0.0**	**0.0**
Max.	**6.0**	**8.2**	**12.1**	**16.5**	**20.3**	**20.8**	**16.9**	**11.8**	**5.9**	**8.2**	**12.4**	**16.7**	**20.7**	**20.8**	**16.9**	**12.1**	**-0.9**	**-1.0**	**-1.3**	**-1.0**	**-1.0**	**-0.4**	**-0.1**	**-0.3**
Min.	**10.3**	**13.4**	**18.0**	**20.8**	**24.0**	**23.2**	**20.4**	**15.2**	**10.3**	**13.4**	**18.4**	**20.9**	**24.0**	**23.2**	**20.5**	**15.2**	**0.2**	**0.1**	**0.5**	**0.5**	**0.1**	**0.0**	**0.3**	**0.3**

Table 8-5. A comparison of daily average Klamath River water temperatures at rivermile 136.8 (just below the confluence with the Scott River) modeled under the Proposed Action and historical conditions, averaged by month for March – October 1981 – 2014. Negative numbers in the columns reporting differences refer to a reduction in temperature under the Proposed Action, relative to those under historical conditions.

	Proposed Action Temperatures (°C)								**Historical Temperatures (°C)**								**Temperature (°C) Differences**							
Year	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug.**	**Sep.**	**Oct.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**
1981	8.5	12.2	15.7	20.4	23.3	23.4	19.8	13.5	8.4	12.4	16.1	21.3	24.3	23.4	19.8	13.1	0.1	-0.2	-0.3	-0.9	-1.0	0.0	0.0	0.4
1982	7.2	8.4	14.2	18.1	21.8	22.3	18.4	12.4	7.1	8.4	14.4	18.5	22.1	22.4	18.4	12.7	0.1	0.0	-0.2	-0.4	-0.3	-0.1	0.0	-0.2
1983	8.5	8.8	13.5	18.3	20.0	21.6	18.5	13.2	8.5	8.8	13.7	18.2	20.1	21.7	18.5	13.2	0.0	0.0	-0.2	0.1	-0.1	-0.1	0.0	0.0
1984	8.3	9.8	13.6	18.0	22.9	22.8	18.7	11.8	8.3	9.8	13.7	18.4	23.8	22.8	18.9	12.1	0.0	0.0	0.0	-0.4	-0.9	-0.1	-0.1	-0.2
1985	6.7	12.4	14.9	19.6	23.6	22.8	17.3	12.5	6.9	12.3	15.5	20.4	24.5	22.8	17.5	12.5	-0.1	0.0	-0.6	-0.8	-0.9	0.0	-0.1	0.0
1986	10.2	11.9	14.1	20.4	23.2	23.7	18.2	12.6	10.2	11.9	14.4	21.6	23.9	23.6	18.4	12.6	0.0	0.0	-0.4	-1.3	-0.7	0.0	-0.2	0.0
1987	8.1	12.3	16.8	21.3	22.8	22.9	19.1	14.8	8.1	12.9	17.1	22.3	23.3	23.0	19.0	14.8	0.0	-0.5	-0.4	-1.0	-0.5	-0.1	0.0	0.0
1988	8.9	12.6	15.1	18.2	23.6	23.6	19.8	14.6	9.1	12.8	15.3	18.8	24.9	23.6	19.8	14.6	-0.1	-0.2	-0.2	-0.6	-1.3	0.0	0.0	0.0
1989	7.1	12.2	14.9	19.8	22.5	21.9	18.4	13.1	7.0	12.3	15.0	20.7	23.5	22.0	18.3	13.0	0.0	-0.1	-0.1	-0.9	-1.0	-0.1	0.1	0.1
1990	7.9	13.2	16.0	18.8	23.2	23.1	19.5	13.6	7.8	13.6	16.0	19.7	24.1	23.3	19.5	13.5	0.1	-0.3	0.0	-0.9	-0.9	-0.3	0.0	0.1
1991	7.8	11.4	13.8	18.0	23.0	22.9	20.4	15.2	8.1	12.0	14.3	19.1	25.0	23.8	20.7	15.1	-0.2	-0.6	-0.6	-1.0	-1.9	-0.9	-0.3	0.2
1992	9.8	12.7	18.3	21.6	23.8	23.8	19.7	14.2	10.5	13.0	19.6	23.2	25.7	25.5	19.9	14.2	-0.8	-0.3	-1.2	-1.6	-1.9	-1.7	-0.2	0.1
1993	8.4	10.0	14.4	17.8	21.2	21.9	18.9	13.8	8.3	10.0	14.4	18.1	21.8	21.8	18.9	13.8	0.1	0.0	0.0	-0.4	-0.5	0.1	0.1	-0.1
1994	9.3	12.1	16.4	20.6	24.2	23.3	19.6	13.4	9.8	13.2	16.9	21.9	26.0	24.2	19.7	13.3	-0.6	-1.1	-0.5	-1.3	-1.8	-0.8	-0.1	0.1
1995	8.3	9.9	13.7	17.2	22.0	22.5	19.5	13.5	8.3	9.9	13.9	17.5	22.3	22.6	19.4	13.6	0.0	0.0	-0.2	-0.3	-0.3	0.0	0.1	-0.1
1996	7.9	11.3	13.9	18.5	23.6	23.4	18.7	13.6	7.9	11.3	13.9	18.8	23.8	23.5	18.8	13.5	0.0	0.0	0.0	-0.3	-0.2	-0.1	0.0	0.2

1997	8.6	11.3	15.7	19.6	22.7	23.1	19.7	14.1	8.7	11.5	16.1	20.0	23.3	23.1	19.6	14.0	-0.1	-0.2	-0.4	-0.4	-0.5	0.0	0.1	0.1
1998	8.2	9.0	12.4	16.5	22.6	24.0	20.7	14.2	8.1	9.1	12.4	16.6	22.8	24.0	20.7	13.8	0.0	-0.1	0.0	-0.1	-0.2	0.0	0.0	0.5
1999	6.7	8.7	12.3	16.9	22.3	22.3	19.8	14.7	6.6	8.7	12.7	17.0	22.3	22.3	19.7	14.7	0.1	0.0	-0.4	-0.1	0.0	0.0	0.0	0.0
2000	7.6	11.6	14.2	19.3	22.8	23.5	19.2	14.1	7.6	11.6	14.2	19.4	22.8	23.5	19.2	13.7	0.0	0.0	0.0	-0.2	0.0	0.0	0.1	0.3
2001	8.9	11.4	17.1	21.2	23.7	23.8	20.5	14.8	9.0	11.1	15.9	20.0	23.6	23.8	20.5	15.0	-0.1	0.3	1.2	1.2	0.0	0.0	0.0	-0.1
2002	8.0	11.6	14.3	20.0	24.6	23.9	20.4	13.9	8.0	11.7	14.4	20.2	24.9	24.3	20.5	14.0	0.1	-0.1	-0.1	-0.2	-0.3	-0.4	-0.1	0.0
2003	8.7	9.8	13.0	19.6	24.4	23.8	20.6	14.9	8.8	9.8	13.0	19.8	24.7	23.8	20.6	15.1	0.0	0.0	0.0	-0.1	-0.3	0.1	0.0	-0.2
2004	9.3	12.1	15.1	20.0	23.9	23.8	19.8	14.1	9.4	12.2	15.1	20.3	25.0	24.4	19.7	13.8	-0.1	0.0	0.0	-0.3	-1.1	-0.5	0.1	0.3
2005	9.4	11.8	14.1	17.7	23.7	24.3	19.7	13.6	9.6	11.6	14.0	18.1	23.9	24.3	19.7	13.8	-0.2	0.1	0.1	-0.4	-0.2	0.0	0.0	-0.2
2006	6.2	9.4	15.9	19.2	24.4	23.2	19.1	13.0	6.1	9.4	15.9	18.8	24.2	23.2	19.0	13.1	0.1	0.0	0.0	0.4	0.3	0.0	0.0	-0.1
2007	8.0	12.3	16.2	21.1	23.9	23.3	19.2	12.7	8.0	12.3	16.2	20.5	23.8	23.3	19.2	12.8	-0.1	0.0	0.0	0.6	0.0	0.0	0.0	-0.1
2008	7.1	10.4	14.2	19.1	24.2	23.3	19.6	13.5	7.2	10.4	14.0	18.7	24.2	23.3	19.7	13.6	0.0	0.0	0.2	0.4	0.0	0.0	0.0	-0.2
2009	7.9	11.8	15.9	20.8	25.0	23.4	19.9	13.5	8.0	11.9	16.1	20.8	25.0	23.4	20.0	13.5	-0.1	-0.2	-0.2	0.1	0.0	-0.1	-0.1	0.0
2010	8.9	10.6	13.3	16.8	23.7	23.4	18.7	14.2	8.6	10.6	13.5	16.7	23.9	23.4	18.7	14.1	0.3	0.0	-0.2	0.1	-0.2	0.1	0.0	0.1
2011	6.7	9.7	13.0	16.0	21.5	23.7	20.3	14.0	6.7	9.7	12.9	15.9	21.5	23.7	20.3	14.0	0.0	0.0	0.0	0.1	0.0	-0.1	0.0	0.0
2012	6.9	10.6	15.6	19.3	23.7	23.8	19.9	14.4	6.9	10.6	15.6	19.3	23.7	23.8	19.9	14.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2013	8.4	13.2	17.5	22.2	25.9	23.3	19.8	13.4	8.4	13.2	17.5	22.2	25.9	23.3	19.8	13.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2014	10.0	14.0	19.1	22.6	26.3	24.3	20.1	15.1	10.0	14.0	19.1	22.6	26.3	24.3	20.1	15.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ave.	**8.2**	**11.2**	**14.9**	**19.2**	**23.4**	**23.2**	**19.5**	**13.8**	**8.2**	**11.3**	**15.1**	**19.6**	**23.8**	**23.4**	**19.5**	**13.7**	**0.0**	**-0.1**	**-0.1**	**-0.3**	**-0.5**	**-0.1**	**0.0**	**0.0**
Min.	**6.2**	**8.4**	**12.3**	**16.0**	**20.0**	**21.6**	**17.3**	**11.8**	**6.1**	**8.4**	**12.4**	**15.9**	**20.1**	**21.7**	**17.5**	**12.1**	**-0.8**	**-1.1**	**-1.2**	**-1.6**	**-1.9**	**-1.7**	**-0.3**	**-0.2**
Max.	**10.2**	**14.0**	**19.1**	**22.6**	**26.3**	**24.3**	**20.7**	**15.2**	**10.5**	**14.0**	**19.6**	**23.2**	**26.3**	**25.5**	**20.7**	**15.1**	**0.3**	**0.3**	**1.2**	**1.2**	**0.3**	**0.1**	**0.1**	**0.5**

Table 8-6. A comparison of daily average Klamath River water temperatures at rivermile 62.5 (just below the confluence with the Salmon River) modeled under the Proposed Action and historical conditions, averaged by month for March – October 1981 – 2014. Negative numbers in the columns reporting differences refer to a reduction in temperature under the Proposed Action, relative to those under historical conditions.

	Proposed Action Temperatures (°C)								**Historical Temperatures (°C)**								**Temperature (°C) Differences**							
Year	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**
1981	8.4	11.3	14.7	19.3	22.6	23.1	19.6	13.2	8.3	11.4	14.7	19.3	22.9	23.1	19.4	13.1	0.0	-0.1	0.0	0.0	-0.2	0.0	0.1	0.1
1982	7.2	8.4	13.6	17.0	20.4	21.9	18.3	12.7	7.1	8.3	13.5	16.9	20.4	21.9	18.3	12.8	0.1	0.0	0.1	0.2	0.0	0.0	0.0	-0.1
1983	8.4	8.8	13.3	16.9	18.5	21.2	18.5	13.5	8.4	8.8	13.4	16.6	18.4	21.3	18.5	13.4	0.0	0.0	-0.1	0.4	0.2	-0.1	0.0	0.1
1984	8.5	9.6	13.0	16.9	22.0	22.4	18.7	11.9	8.5	9.6	13.0	16.8	21.9	22.3	18.7	12.1	0.0	0.0	0.0	0.1	0.2	0.0	0.0	-0.3
1985	6.9	11.9	14.0	18.9	22.9	22.3	17.3	12.7	7.0	11.9	14.0	18.9	22.9	22.3	17.3	12.7	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1986	10.2	11.5	13.3	19.8	22.2	23.2	17.8	13.0	10.2	11.4	13.4	20.1	22.1	23.2	17.8	13.0	0.0	0.0	-0.1	-0.2	0.1	0.0	-0.1	0.0
1987	7.9	12.2	16.2	20.4	22.2	22.8	19.1	14.9	7.9	12.3	16.4	20.4	22.2	22.9	19.1	14.8	0.0	-0.2	-0.1	0.0	0.0	0.0	0.0	0.1
1988	8.9	11.9	14.0	17.0	22.8	23.3	19.8	14.8	9.0	11.9	13.9	16.9	23.1	23.3	19.8	14.8	-0.1	0.0	0.1	0.1	-0.3	0.0	0.0	0.0
1989	7.2	12.2	14.3	18.8	21.6	21.8	18.3	13.2	7.2	12.3	14.2	18.7	21.5	21.8	18.3	13.1	0.0	-0.1	0.0	0.1	0.1	0.0	0.1	0.1
1990	8.2	12.8	14.4	17.2	22.6	22.7	19.5	13.6	8.2	12.9	14.3	16.9	22.8	22.8	19.4	13.5	0.1	-0.1	0.1	0.2	-0.2	-0.1	0.0	0.1
1991	7.4	10.7	12.9	17.1	22.5	22.7	20.5	15.3	7.4	10.5	12.9	17.0	23.1	23.0	20.6	15.2	0.0	0.2	0.0	0.1	-0.7	-0.3	-0.1	0.1
1992	10.0	12.3	17.7	20.9	23.2	23.4	19.7	14.3	10.4	12.2	17.8	21.0	23.4	24.0	19.5	14.3	-0.4	0.0	-0.1	-0.1	-0.3	-0.5	0.2	0.0
1993	8.7	9.7	13.5	16.3	19.7	21.6	18.9	13.8	8.7	9.7	13.5	16.4	19.6	21.7	18.8	13.8	0.1	0.0	0.0	0.0	0.2	-0.1	0.1	0.0
1994	9.3	11.6	15.3	19.5	23.8	23.1	19.7	13.4	9.4	11.8	15.2	19.6	24.5	23.3	19.7	13.3	-0.2	-0.1	0.1	-0.1	-0.6	-0.2	0.0	0.1
1995	7.9	9.5	13.0	16.1	21.0	21.9	19.4	13.4	8.0	9.5	13.1	15.9	21.0	21.9	19.3	13.5	0.0	0.0	-0.1	0.1	0.0	0.0	0.1	0.0
1996	8.0	10.6	13.1	17.3	22.5	23.0	18.6	13.5	8.0	10.6	13.0	17.4	22.6	23.0	18.5	13.4	0.0	0.0	0.0	-0.1	-0.1	0.0	0.0	0.1
1997	8.7	10.9	15.5	18.6	21.9	22.6	19.5	13.7	8.7	10.9	15.6	18.7	21.7	22.7	19.5	13.6	0.0	0.0	-0.2	-0.1	0.2	0.0	0.0	0.1

1998	8.2	9.0	12.1	16.2	21.3	23.3	20.3	13.8	8.2	9.0	12.1	16.1	21.3	23.3	20.3	13.6	0.0	-0.1	-0.1	0.1	0.0	0.0	0.0	0.2
1999	6.7	9.0	12.2	16.1	20.8	21.9	19.6	14.4	6.7	9.0	12.2	16.1	20.8	21.9	19.5	14.4	0.1	0.0	0.0	0.1	0.0	0.0	0.1	0.0
2000	7.7	11.4	13.7	18.5	21.9	23.0	19.1	13.8	7.7	11.4	13.8	18.5	21.9	23.0	19.0	13.6	0.0	0.0	0.0	-0.1	0.0	0.0	0.1	0.2
2001	9.1	10.7	16.4	20.1	23.3	23.6	20.4	14.8	9.1	10.7	16.0	19.7	23.3	23.6	20.4	14.8	0.0	0.0	0.4	0.4	0.0	0.0	0.0	0.0
2002	7.6	11.2	13.0	18.5	23.4	23.2	20.3	13.9	7.6	11.2	13.0	18.5	23.5	23.2	20.1	13.8	0.1	0.0	0.0	0.0	0.0	0.0	0.2	0.1
2003	8.5	9.3	12.2	18.2	23.6	23.3	20.4	15.0	8.6	9.4	12.2	18.2	23.5	23.3	20.3	15.0	0.0	-0.1	0.0	0.0	0.1	0.0	0.0	0.0
2004	9.5	11.3	13.5	18.6	23.3	23.5	19.6	13.7	9.6	11.3	13.4	18.4	23.5	23.5	19.6	13.6	-0.1	0.0	0.0	0.1	-0.2	-0.1	0.1	0.2
2005	9.4	10.2	13.4	16.4	23.1	23.9	19.4	13.5	9.4	10.2	13.4	16.4	23.1	23.9	19.4	13.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1
2006	6.6	9.6	15.2	18.0	23.4	22.5	18.9	12.9	6.4	9.6	15.2	18.1	23.4	22.5	18.9	12.9	0.1	0.0	0.0	-0.1	0.0	0.0	0.0	0.0
2007	8.0	11.2	14.9	19.7	23.7	23.2	19.3	12.6	8.1	11.2	14.9	19.6	23.6	23.2	19.3	12.6	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
2008	7.4	9.7	13.5	17.4	22.8	22.9	19.6	13.5	7.4	9.6	13.3	17.2	22.8	22.9	19.6	13.5	0.0	0.0	0.2	0.2	0.0	0.1	0.0	0.0
2009	7.8	10.9	14.5	19.9	24.6	23.3	20.0	13.4	7.9	10.9	14.5	19.8	24.6	23.3	20.0	13.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2010	8.4	9.4	11.2	14.6	21.7	22.5	18.5	13.9	8.3	9.4	11.2	14.4	21.5	22.6	18.5	13.8	0.1	0.0	0.1	0.2	0.1	0.0	0.0	0.0
2011	6.9	9.3	11.5	14.0	19.7	22.9	20.1	13.7	7.0	9.3	11.5	13.9	19.7	22.9	20.1	13.7	0.0	0.0	-0.1	0.1	0.0	0.0	0.0	0.0
2012	6.8	9.8	13.6	17.7	22.6	23.4	19.7	14.2	6.8	9.8	13.6	17.7	22.6	23.4	19.7	14.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2013	8.3	11.7	16.0	21.1	25.5	22.9	19.6	13.1	8.3	11.7	16.0	21.1	25.5	22.9	19.6	13.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2014	10.1	12.8	17.7	22.2	25.7	24.1	20.2	15.0	10.1	12.8	17.7	22.2	25.7	24.1	20.2	15.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ave.	**8.2**	**10.7**	**14.0**	**18.1**	**22.4**	**22.8**	**19.4**	**13.7**	**8.2**	**10.7**	**14.0**	**18.0**	**22.5**	**22.9**	**19.3**	**13.7**	**0.0**	**0.0**	**0.0**	**0.1**	**0.0**	**-0.1**	**0.0**	**0.0**
Min.	**6.6**	**8.4**	**11.2**	**14.0**	**18.5**	**21.2**	**17.3**	**11.9**	**6.4**	**8.3**	**11.2**	**13.9**	**18.4**	**21.3**	**17.3**	**12.1**	**-0.4**	**-0.2**	**-0.2**	**-0.2**	**-0.7**	**-0.5**	**-0.1**	**-0.3**
Max.	**10.2**	**12.8**	**17.7**	**22.2**	**25.7**	**24.1**	**20.5**	**15.3**	**10.4**	**12.9**	**17.8**	**22.2**	**25.7**	**24.1**	**20.6**	**15.2**	**0.1**	**0.2**	**0.4**	**0.4**	**0.2**	**0.1**	**0.2**	**0.2**