RECLAMATION
Managing Water in the West

Environmental Impact Statement Glossary Appendix

Long-Term Plan to Protect Adult Salmon in the Lower Klamath River
Draft

October 2016

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to 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.

Glossary

The definitions in this glossary include technical and regulatory terms used in the Long Term Plan to Protect Adult Salmon in the Lower Klamath River (LTP) Environmental Impact Statement (EIS). Some of the definitions of terms were specifically developed for the LTP EIS and may not be the same as definitions used for other programs in other places.

Term	Definition
acre-foot	The volume of water that would cover 1 acre to a depth of 1 foot, or 325,851 gallons of water. A flow of 1 cubic foot per second (cfs) for 1 day is approximately 2 acre-feet.
adaptive management	Systematic approach for improving resource management by learning from management outcomes.
adjudication	A process by which the comprehensive determination of all water rights in a stream system is made. In California, statutory adjudication happens if a claimant petitions the California State Water Resources Control Board (SWRCB) for an adjudication and the SWRCB finds the action necessary and in the public interest. The California Supreme Court has held that claimants or petitioners can include not only water users, but also those seeking recognition of public trust values on a streamwide basis.
affect/effect	To affect (a verb) is to bring about a change. An effect (usually a noun) is the result of an action.
affected environment	Existing biological, physical, social, and economic conditions of an area subject to change, both directly and indirectly, as a result of a proposed human action.
afterbay	A pool of water at the base of a dam; specifically, water after it has passed through a turbine.
air quality	Measure of the health-related and visual characteristics of the air, often derived from quantitative measurements of the concentrations of specific injurious or contaminating substances.
alevin	The life stage of a salmon between hatching from the egg and emergence from the stream gravels as a fry. Alevins are characterized by the presence of a yolk sac, which provides nutrition while the alevin develops in the redd.
alluvial	Deposition of sediment over a long period of time by a river; an alluvial layer; pertaining to the soil deposited by a stream.
alluvium	Soil particles transported and deposited by water.
alternatives	Courses of action that may meet the objectives of a proposed action at varying levels, including the most likely future without the project or action. An Environmental Assessment (EA) or an Environmental Impact Statement (EIS) identifies and objectively evaluates and analyzes all reasonable alternatives, including a no-action alternative.
ammocoete	Lamprey larva.
anadromous fish	Fish such as salmon or steelhead trout that hatch in fresh water, migrate to and mature in the ocean, and return to fresh water as adults to spawn.
anoxic conditions	Conditions with a deficiency of oxygen.
appropriative water rights	Water rights based on the principle of prior appropriations, or “first in time, first in right.”
aquatic	Living or growing in or on the water.
aquifer	An underground geologic formation of permeable rock that stores, transmits, and yields significant quantities of groundwater to wells and springs.
beneficial use	The uses of a water resource that are protected by state water quality standards. Beneficial uses include human consumption, aquatic life, recreation, and fish and wildlife habitat.

Glossary

Term	Definition
biodiversity	The variety of life and its processes, including the variety of living organisms, the genetic differences among them, and the communities and ecosystems in which they occur.
Biological Assessment (BA)	A document prepared for the Section 7 process under the Federal Endangered Species Act (ESA) of 1993, as amended, to determine whether a proposed major construction activity under the authority of a Federal action agency is likely to adversely affect listed species, proposed species, or designated critical habitat.
Biological Opinion (BO)	Document issued under the authority of the Federal ESA stating the U.S. Fish and Wildlife Service (USFWS) and/or the National Marine Fisheries Service (NMFS) finding as to whether a Federal action is likely to jeopardize the continued existence of a threatened or endangered species or result in the destruction or adverse modification of critical habitat.
blue-green algae	Algae that can cause problems in aquatic environments because some produce chemicals that are toxic to animals, including humans.
broodstock	Mature fish species used for breeding in hatcheries.
CalSim II model	A planning model designed to simulate the operations of the Central Valley Project (CVP) and State Water Project (SWP) reservoir and water delivery system under current and future conditions. CalSim-II is a specific application of the Water Resources Integrated Modeling System (WRIMS) to Central Valley water operations CalSim predicts how reservoir storage and river flows would be affected based on changes in system operations. CalSim output is typically used to help assess impacts on water supply, water quality, aquatic resources, and recreation.
candidate species	Any species undergoing status review by the U.S. Secretary of the Interior or U.S. Secretary of Commerce for listing as an endangered or a threatened species but not yet the subject of a proposed rule (see 50 Code of Federal Regulations (CFR) 424.02), or any species accepted as a candidate species by the California Fish and Game Commission pursuant to Fish and Game Code Section 2074.2.
carryover storage	Water remaining in storage in a reservoir or lake at the end of a water year.
catch	Within a recreational fishery area, refers to the number of fish captured.
census	A compilation of data on an aspect of the U.S. people and/or economy provided by the U.S. Bureau of the Census.
Central Valley Project (CVP)	Federally operated water management and conveyance system that provides water to agricultural, urban, and industrial users in California as defined by Section 3403(d) of the Central Valley Project Improvement Act (CVPIA), “all Federal reclamation projects located within or diverting water from or to the watershed of the Sacramento and San Joaquin rivers and their tributaries as authorized by the Act of August 26, 1937 (50 Stat. 850) and all Acts amendatory or supplemental thereto, ...”
Central Valley Project Improvement Act (CVPIA)	Public Law 102-575, Title 34. The CVPIA was signed into law by the President in October 1992. The CVPIA mandates major changes in management of the CVP particularly for the protection, restoration, and enhancement of fish and wildlife. Responsibilities for implementing the CVPIA are shared by the U.S. Department of the Interior, Bureau of Reclamation (Reclamation), and USFWS. The CVPIA puts fish and wildlife on an equal footing with agricultural, municipal, industrial, and hydropower users.
Central Valley Project water service contractor	Water users who have contracted with Reclamation for water developed by and conveyed through CVP facilities.
channel	Natural or artificial watercourse, with a definite bed and banks to confine and conduct continuously or periodically flowing water.
cohort	A group of fish spawned during a given period, usually within a year.
conference	The interagency cooperation process required for a Federal action that is likely to jeopardize the continued existence of a species proposed for listing, or result in the destruction or adverse modification of proposed critical habitat.
confined aquifer	An aquifer bounded above and below by impermeable or confining layers of distinctly lower permeability than the aquifer itself.
confluence	The meeting of two or more bodies of water, such as the point where a tributary joins the mainstem.

Term	Definition
conjunctive use	The planned use of groundwater in conjunction with surface water in overall management to optimize water resources.
conservation	Actions taken to minimize or compensate for project effects on ecosystem resources or to benefit or promote the recovery of listed species as an integral part of a proposed action
consultation	The process required of a Federal agency when any activity authorized, carried out, or conducted by that agency may affect a listed species or designated critical habitat; consultation is with USFWS or NMFS and may be either informal or formal.
contaminants	Any undesirable physical, chemical, biological, or radiological substance present in water as a result of human activities.
conveyance	The movement or transportation of water from one location to another location through various water transportation systems, such as canals, sloughs, channels, pipelines, ditches, etc.
cooperating agency	Under NEPA, the agencies having responsibility to assist the lead agency by participating in the NEPA process. The role of the cooperating agencies may include conducting environmental analyses of resources which the cooperating agency has jurisdiction by law or special expertise.
critical habitat	A description of the specific areas with physical or biological features essential to the conservation of a listed species and that may require special management considerations or protection. These areas have been legally designated via Federal Register notices.
cubic feet per second (cfs)	A measure of the volume rate of water movement. As a rate of stream flow, a cubic foot of water passing a reference section in 1 second of time. One cubic foot per second equals 0.0283 meters per second (7.48 gallons per minute). One cubic foot per second flowing for 24 hours produces approximately 2 acre-feet.
cumulative effect - ESA	Those effects of future non-Federal activities that are reasonably certain to occur within the action area of a Federal action subject to consultation.
cumulative effect – NEPA	For the NEPA, Federal regulations (40 CFR 1508.7) define cumulative effects as those effects that result from incremental impacts of a proposed action when added to other past, present, and reasonably foreseeable future actions, regardless of which agency (Federal or non-Federal) or person undertakes such actions. Cumulative effects can result from individually minor but collectively significant actions that take place over time.
cyanobacteria	Photosynthetic bacteria, also known as blue-green algae. Cyanobacteria form extensive and highly visible blooms in the freshwater and marine environment.
dead pool	Dead pool refers to water in a reservoir that cannot be drained by gravity through a dam's outlet works.
Decision-1641 (D-1641)	State Water Resources Control Board Water Right Decision (March 2000) that implemented the 1995 Bay-Delta Water Quality Control Plan.
delta	A low, nearly flat alluvial tract of land formed by deposits at or near the mouth of a river. In this report, “Delta” refers to the delta formed by the Sacramento and San Joaquin Rivers.
density	The mass of a substance per unit of volume of that substance (i.e., the density of water changes with changes in temperature).
direct effects	Related to socioeconomics, they are one or a series of production changes or expenditures made by producers/consumers as a result of an activity or policy. These initial changes are determined by an analyst to be a result of this activity or policy. Applying these initial changes to the multipliers in an IMPLAN model will then display how the region will respond, economically to these initial changes.
dissolved oxygen (DO)	A commonly employed measure of water quality. The concentration of free (not chemically combined) molecular oxygen (a gas) dissolved in water, usually expressed in milligrams per liter, parts per million, or percent of saturation. DO levels are considered the most important and commonly employed measurement of water quality and indicator of a water body's ability to support desirable aquatic life.

Glossary

Term	Definition
distinct population segment (DPS)	A subdivision of a vertebrate species that is treated as a species for purposes of listing under the Federal ESA. To be so recognized, a potential distinct population segment must satisfy standards specified in a USFWS or NMFS policy statement (see the February 7, 1996, Federal Register, pages 4,722-4,725). DPS standards require a DPS to be separable from the remainder of, and significant to, the species to which it belongs.
diversion	The act of taking water out of a river system or changing the flow of water in a system for use in another location.
drawdown	Lowering of the water level in a reservoir.
ecosystem	An interactive system that includes the organisms of a natural community association together with their abiotic physical, chemical, and geochemical environment.
electrical conductivity (EC)	The measurement of a materials ability to conduct an electrical current. Used as a surrogate measurement for salinity.
elevation	Elevation in feet above mean sea level (msl).
emergent	Flooded or ponded areas that support rooted, herbaceous vegetation with parts of the shoot both below and above water.
emergent vegetation	Aquatic plants rooted underwater that grow above (emerge from) the surface of the water (e.g., cattails).
employment (jobs)	Employment in IMPLAN is measured in number of jobs. A job is the annual average of monthly jobs in that industry (this is the same definition used by Quarterly Census of Employment Wages, Bureau of Labor Statistics, and Bureau of Economic Analysis nationally). Thus, 1 job lasting 12 months = 2 jobs lasting 6 months each = 3 jobs lasting 4 months each. A job can be either full-time or part-time.
endangered species	Any species or subspecies of bird, mammal, fish, amphibian reptile, or plant that is in serious danger of becoming extinct throughout all or a significant portion of its range.
Endangered Species Act (ESA) consultation	In compliance with the Federal ESA, the process by which a Federal agency presents information to the USFWS or National Oceanic and Atmospheric Administration (NOAA) Fisheries Service regarding actions that may affect listed species or their designated habitat.
Endangered Species Act (ESA) of 1973, as Amended	Federal legislation that is intended to provide a means to conserve the ecosystems upon which endangered and threatened species depend, and to provide programs for the conservation of those species, thus preventing extinction of plants and animals. The law is administered by the USFWS (U.S. Department of the Interior) and NMFS (U.S. Department of Commerce), depending on the species. Some relevant sections are as follows:
	§ Section 4 Part – Addresses the listing and recovery of species and designation of critical habitat.
	§ Section 6 Part – Focuses on cooperation with the States and that authorizes USFWS and NMFS to provide financial assistance to States that have entered into cooperative agreements supporting the conservation of endangered and threatened species.
	§ Section 7 Part – Requires all Federal agencies, in consultation with USFWS or NMFS, to use their authorities to further the purpose of the Federal ESA and to ensure that their actions are not likely to jeopardize the continued existence of listed species or result in destruction or adverse modification of critical habitat.
	§ Section 9 Part – Part Defines prohibited actions, including the import and export, take, possession of illegally taken species, transport, or sale of endangered or threatened species.
	§ Section 10 – Lays out the guidelines under which a permit may be issued to authorize prohibited activities, such as take of endangered or threatened species.
	§ Section 10(a)(1)(A) – Allows for permits for the taking of threatened or endangered species for scientific purposes or for purposes of enhancement of propagation or survival.
	§ Section 10(a)(1)(B) – Allows for permits for incidental taking of threatened or endangered species.

Term	Definition
endemic	Native to or confined to a certain region.
environmental consequences	For a project, the impacts to the affected environment that are expected from implementation of a given alternative.
Environmental Impact Statement (EIS)	An analysis required by the NEPA for all major Federal actions that evaluates the environmental risks of alternative actions.
environmentally preferable alternative	The alternative that will promote the national environmental policy as expressed in NEPA. Ordinarily, this means the alternative that causes the least damage to the biological and physical environment; it also means the alternative which best protects, preserves, and enhances historic, cultural, and natural resources.
Essential Fish Habitat (EFH)	Waters and substrate necessary for fish to spawn, breed, feed, or grow to maturity. Fish covered under Essential Fish Habitat include Pacific salmon and commercially valuable estuarine and marine fish species.
escapement (of fish)	That portion of an anadromous fish population that escapes the commercial and recreational fisheries and reaches the freshwater spawning grounds.
estuary	A partly enclosed coastal body of water with one or more rivers or streams flowing into it, and with a free connection to the open sea.
estuary area	Transition area between the land and ocean. The area is exposed to tides, waves, and wind but is partially protected by the surrounding land.
eutrophic	Waters rich in dissolved nutrients (especially nitrogen and phosphorus); leads to accelerated growth of algae and plants that depletes oxygen levels.
eutrophication	The degradation of water quality as a result of enrichment by nutrients, primarily nitrogen and phosphorus, which in turn results in excessive plant (principally algae) growth and decay.
evaporation	The change of a substance from the liquid phase to the gaseous (vapor) phase.
Evolutionarily Significant Unit (ESU)	A population or group of populations that is considered distinct (and hence a “species”) for purposes of conservation under the Federal ESA. To qualify as an ESU, a population must (1) be reproductively isolated from other conspecific populations, and (2) represent an important component in the evolutionary legacy of the biological species.
export	Water diversion from the Delta used for purposes outside the Delta.
extinct species	A species that no longer exists. For the Federal ESA, a species currently believed to be extinct.
fallowed land	Cultivated land that lies idle during a growing season.
Federal Register	The official daily publication for Rules, Proposed Rules, and Notices of Federal agencies and organizations, as well as Executive Orders and other presidential documents.
fish die-off	A fish die-off is determined by the magnitude and speed at which the population is affected – smaller returning populations can have fewer dead fish and still be classified as a fish die-off. However, returning populations are not always known. For the LTP EIS, classifying a fish die-off will depend on multiple factors, including fish population size, fish density, and other factors deemed critical by Reclamation and the LTP Technical Team.
fish ladder (fishway, fish passageway)	A structure on or around artificial barriers such as dams and locks to allow fish to move around the barrier during migration.
fisheries	A season or industry of commercial or sport fishing.
fishery	A community of fish and their habitat.
Flavobacter columnare (Columnaris)	A species of bacteria that causes the Columnaris disease, which infects freshwater fish.
flood storage reservation	The storage in a reservoir used to reduce the river’s flow downstream in a flood event.
floodplain	Part of a river valley composed of unconsolidated, river-borne sediment that is periodically flooded.
floodway	The channel of a river or other watercourse and adjacent land areas that convey flood waters.

Glossary

Term	Definition
flow	The volume of water passing a given point per unit of time.
	Instream Flow Requirements – Amount of water flow in a stream course required to sustain instream values.
	Minimum Flow – Lowest flow in a specified time period.
	Peak Flow – Maximum instantaneous flow in a specified time period.
	Return Flow – Portion of water previously diverted from a stream and subsequently returned to that stream or to another body of water.
focal species	Species of ecological and/or human value that is of priority interest for study or management.
forebay	Water stored behind a dam; specifically, water intended to go through a turbine.
fragmentation of habitat	Division of a large piece of habitat into a number of smaller, isolated patches that typically have substantially less ecological value than the contiguous habitat.
fry	Fry are young fish that have absorbed their yolk sac and emerged from the redd. They typically use low velocity, shallow habitats near the river banks. In the Central Valley, salmon fry are frequently defined as juveniles smaller than 50 millimeters in fork length.
Fully Protected species	The classification of Fully Protected was the State's initial effort in the 1960s to identify and provide additional protection to those animals that were rare or faced possible extinction. Lists were created for fish, mammals, amphibians and reptiles, birds and mammals. Please note that most fully protected species have also been listed as threatened or endangered species under the more recent endangered species laws and regulations. Fully Protected species may not be taken or possessed at any time and no licenses or permits may be issued for their take except for collecting these species for necessary scientific research and relocation of the bird species for the protection of livestock.
geographic information system (GIS)	A computer system that allows for input and manipulation of geographic data to allow researchers to manipulate, analyze, and display the information in a map format.
greenhouse gases (GHGs)	Gases including carbon dioxide, methane, and nitrous oxide that prevent heat from escaping from the atmosphere, resulting in climate change (also known as global warming).
groundwater	Any water naturally stored underground in aquifers, or that flows through and saturates soil and rock, supplying springs and wells.
groundwater level	Refers to the water level in a well, and is defined as a measure of the hydraulic head in the aquifer system.
groundwater management	The planned and coordinated management of a groundwater basin or portion of a groundwater basin with a long-term sustainability of the resource.
groundwater overdraft	A condition of a groundwater basin in which the amount of water withdrawn by pumping exceeds the amount of water that recharges the basin over a period of years, during which water supply conditions approximate average.
groundwater pumping	Quantity of water extracted from groundwater storage.
groundwater storage	The quantity of water in the zone of saturation.
habitat	The specific places where the environmental conditions (i.e., physical and biological conditions) are present that are required to support occupancy by individuals or populations of a given species.
hangover effect	A hypothesized theory in which background levels of *Ichthyophthirius multifiliis* (Ich) are elevated in the year following an outbreak leading to greater probability of another outbreak occurring with increased severity resulting in greater fish kill risk.
harm	An act that actually kills or injures wildlife. Such an act may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns including breeding, feeding, or sheltering (50 CFR 17.3).
hatchery	A place where large numbers of fish eggs are artificially fertilized and fry are hatched in an enclosed environment.
heavy metals	A metal of atomic weight greater than 23 that forms soaps on reaction with fatty acids. Examples are aluminum, lead, cobalt.

Term	Definition
herbaceous	Referring to a plant that has leaves and stems that die down at the end of the growing season to the soil level. They have no persistent woody stem above ground.
herpetofauna	Reptiles and amphibians of a specific region, habitat, or geological period.
histopathology	The study of changes in tissues caused by disease.
human environment	The natural and physical environment and the relationship of people with that environment.
hydrograph	A chart or graph showing the change in flow over time for a particular stream or river.
hypereutrophic	Very nutrient-rich lakes characterized by frequent and severe nuisance algal blooms and low transparency.
hypolimnion	The bottom, and most dense, layer of a stratified lake. It is typically the coldest layer in the summer and warmest in the winter. It is isolated from wind mixing and typically too dark for much plant photosynthesis to occur.
Ichthyophthirius multifiliis (Ich)	An endemic protozoan pathogen of freshwater fish, including anadromous populations of salmonids. The Ich pathogen is common in aquaculture and aquarium trade.
IMPLAN®	IMpact Analysis for PLANning, a regional input-output model that evaluates regional economic effects.
incidental take	Take of listed fish or wildlife species that results from, but is not the purpose of, carrying out an otherwise lawful activity conducted by a Federal agency or applicant.
Incidental Take Permit – Federal	Federal exception to Section 9 of the Federal ESA (16 USCA 1538); a permit issued pursuant to Section 10 of the Federal ESA (16 USCA 1539(a)(1)(B)).
indirect effect	An effect caused by an action that takes place later in time than the action, but is still reasonably certain to occur.
induced effects	Related to socioeconomics, they represent the response by an economy to an initial change that occurs through re-spending of income received by a component of value added (employee). The labor income is recirculated through the household spending patterns causing further local economic activity.
infectivity	The ability of a pathogen to establish an infection and the frequency at which the pathogen spreads from the host.
intake structure	Facility designed to divert water from the river or reservoir.
interest group	An agency or other entity that has expressed an interest, verbally or in writing, in becoming more involved in the development of a planned project.
invertebrate	Animals without backbones such as aquatic insects, worms, clams, and snails.
irrigation water	Water used primarily in the production of agricultural crops or livestock, including domestic use incidental thereto, and the watering of livestock. Irrigation water does not include water used for domestic uses, such as watering landscaping or pasture for animals (e.g., horses) that are kept for personal enjoyment. It generally applies only to landholdings greater than 2 acres.
jeopardize the continued existence of	To engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species.
juvenile	Young fish not having reached reproductive age. For anadromous salmonids, young fish are generally considered juveniles once they are greater than 50 millimeters in length.
Klamath Hydroelectric Project	A system of hydroelectric components that includes the dams, powerhouses, and other facilities for generation of hydroelectric power on the Klamath River and developed jointly by Reclamation and the California-Oregon Power Company (COPCO, the predecessor to PacifiCorp).
Klamath River Basin	The portion of land drained by the Klamath River and its tributaries. The Klamath River Basin is divided into the Upper Klamath Basin and the Lower Klamath Basin.
labor income	All forms of employment income, including Employee Compensation (wages and benefits) and Proprietor Income.
land cover type	The dominant features of the land surface. A land cover type can be defined by natural vegetation, water, or human uses (e.g., agricultural lands, landscaping).

Glossary

Term	Definition
land retirement	Permanent or long-term removal of land from agricultural production.
lead agency	The government agency that has the principal responsibility for carrying out or approving a project and therefore the principal responsibility for preparing NEPA documents. For the LTP EIS, Reclamation is the Federal lead agency under NEPA.
Level 2 (L-2) Refuge Water Supply	The minimum supply of water required at certain Federal, State, and private refuges for basic development and management of suitable habitat conditions for migrating waterfowl and wildlife pursuant to CVPIA Public Law 102-575, Title 34, Section 3406 (d)(1); measured in acre-feet of water. Level 2 (L-2) Water is water provided from the CVP yield and non-project water (existing water rights, entitlement water).
Level 4 (L-4) Refuge Water Supply	The full amount of water required at certain Federal, State, and private wildlife refuges for optimum development and management of suitable habitat conditions for migrating waterfowl and wildlife, pursuant to CVPIA Public Law 102-575, Title 34, Section 3406 (d)(2); measured in acre-feet of water.
listed species	Any species of fish, wildlife, or plant that has been determined to be endangered or threatened under Section 4 of the Federal ESA of 1993, as amended.
listing	The formal process through which USFWS or NMFS adds species to the Federal list of endangered and threatened wildlife and plants.
Lower Klamath Basin	The portion of the Klamath River Basin downstream of Iron Gate Dam.
lower Klamath River	The portion of the Klamath River from the confluence with the Trinity River to the Pacific Ocean.
LTP Technical Team	For the purpose of this EIS, the team of Federal, State, and tribal resource specialists, including fisheries biologists or pathologists, providing technical guidance.
mainstem	The principal river in a basin, as opposed to the tributary streams and smaller rivers that feed into it.
mean sea level (msl)	The average height of the sea's surface over a long period.
Memorandum of Understanding (MOU)	A means of gaining formal consensus between two or more parties on a particular complex issue.
microcystin	A toxin produced by the blue-green algal species *Microcystis aeruginosa*.
mitigation	To moderate, reduce, or alleviate the impacts of a proposed activity; includes, in order, (1) avoiding the impact by not taking a certain action or parts of an action; (2) minimizing impacts by limiting the degree or magnitude of the action and its implementation; (3) rectifying the impact by repairing, rehabilitating, or restoring the affected environment; (4) reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action; and (5) compensating for the impact by replacing or providing substitute resources or environments.
model	A tool used to mathematically represent a process that could be based on empirical or mathematical functions. Models can be computer programs, spreadsheets, or statistical analyses.
National Ambient Air Quality Standards (NAAQS)	The U.S. Environmental Protection Agency sets National Ambient Air Quality Standards (NAAQS), as required by the Clean Air Act as amended in 1990, for pollutants considered harmful to public health or the environment. NAAQS are in place for six pollutants: carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide.
National Environmental Policy Act (NEPA)	Federal legislation establishing the national policy that environmental impacts will be evaluated as an integral part of any major Federal action. Requires the preparation of an EIS for all major Federal actions significantly affecting the quality of the human environment.
National Wildlife Refuge (NWR)	A refuge managed by the USFWS.
nonnative species	Botanical, wildlife, and aquatic species that originate elsewhere and are brought into a new area, where they may dominate the local species or in some way negatively affect the environment for native species.

Term	Definition
nonpoint source pollution	A term in the Clean Water Act also called “polluted runoff,” water pollution produced by diffuse land-use activities. Occurs when runoff carries fertilizer, animal wastes, and other pollution into rivers, streams, lakes, reservoirs, and other bodies of water.
noxious weed	An alien, introduced or exotic undesirable plant species that outcompetes native species which does or is likely to cause economic or environmental harm.
nutrient loading	Discharging of nutrients from the watershed (basin) into a receiving water body (lake, stream, wetland).
output (sales)	Related to socioeconomics, output represents the value of industry production. In IMPLAN these are annual production estimates for the year of the data set and are in producer prices. For manufacturers this would be sales plus/minus change in inventory. For service sectors production = sales. For Retail and wholesale trade, output = gross margin and not gross sales.
PacifiCorp	An electric power company in the northwestern United States that owns and operates the Klamath River dams.
pathogenicity	The ability of an organism to cause disease.
pelagic	Relating to or occurring, living in, or frequenting the open ocean.
penstock	A pipe or conduit that carries water to a power generation turbine.
perennial	Flows continuously throughout the year.
periphyton	A complex mixture of algae, bacteria, their secretions, associated detritus, and various species of microinvertebrates attached to submerged surfaces in most aquatic ecosystems.
permeability	The ease with which water passes through sediment, depending on the composition and degree of packing of the sediment and viscosity of the water.
phytoplankton	Small, photosynthetic aquatic organisms, including diatoms, green algae, and cyanobacteria (blue-green algae).
place of use (POU)	The geographic area specified in a water right permit or license issued by the SWRCB, wherein the water may be used.
point source pollution	Pollution into bodies of water from specific discharge points such as sewer outfalls or industrial-waste pipes.
polychaete	Aquatic annelid worms belonging to the Class Polychaeta, segmented and have bristles for movement or attachment.
powerhouse	Structure that contains the power generation equipment such as the turbine, may be an enclosed building or an open area with concrete slabs and equipment.
preferred alternative	Alternative that the agency has determined is their preferred course of action.
preserve	To protect, keep, or maintain the condition of.
Project Team	The group of lead, cooperating, and responsible agencies responsible for evaluating the alternatives in the Environmental Impact Statement/Report.
proposed action	To increase lower Klamath River flows to reduce the likelihood, and potentially reduce the severity, of any fish die-off in future years due to crowded holding conditions for pre-spawn adults, warm water temperatures, and presence of disease pathogens which are likely the major factors contributing to the adult mortalities.
proposed species	A species of animal or plant that is proposed in the Federal Register to be listed under Section 4 of the Federal ESA.
public involvement	Process of obtaining citizen input into each stage of the development of planning documents. Required as a major input into any EIS.
public trust	The legal doctrine that protects the rights of the public to use water courses for commerce, navigation, fisheries, recreation, open space, preservation of ecological units in their natural state, and similar uses for which those lands are uniquely suited. It is based on the California State Constitution and goes back to English Common Law. The California Supreme Court states, “The state has an affirmative duty to take the public trust into account in the planning and allocation of water resources, and to protect public trust uses whenever feasible.” National Audubon (33Cal.3d 419 1983).
Reclamation	U.S. Department of the Interior, Bureau of Reclamation

Glossary

Term	Definition
Reclamation's Klamath Project	The system of reservoirs, dams, canals, and pumps built to drain and reclaim lake bed lands of the Lower Klamath and Tule Lakes, to store water of the Klamath and Lost Rivers, to divert irrigation supplies, and to control flooding of the reclaimed lands.
reclassify	To change a species' official status from threatened to endangered or vice-versa.
Record of Decision (ROD)	Concise, public, legal document required under the NEPA that identifies and publicly and officially discloses the responsible official's decision on an alternative selected for implementation. It is prepared following completion of an EIS.
recovery	The process by which the decline of an endangered or threatened species is stopped or reversed, or threats to its survival neutralized so that its long-term survival in the wild can be ensured, and it can be removed from the list of threatened and endangered species.
Recovery Plan	A document drafted by the USFWS, NMFS, or other knowledgeable individual or group, that serves as a guide for activities to be undertaken by Federal, State, or private entities in helping to recover and conserve endangered or threatened species.
redd	A nest prepared by a female fish in streambed gravel, where she deposits her eggs.
refuge	Wildlife refuges -- certain portions of land set aside and managed by the USFWS or California Department of Fish and Wildlife (CDFW) to provide a water supply and vegetative habitat for migrating waterfowl and wildlife.
relicensing	The administrative proceeding in which Federal Energy Regulatory Commission (FERC), in consultation with other federal and state agencies, decides whether and on what terms to issue a new license for an existing hydroelectric project at the expiration of the original license.
reservoir	Artificially impounded body of water.
reservoir storage capacity	Reservoir capacity normally usable for storage and regulation of reservoir inflows to meet established reservoir operating requirements.
resident fish	Fish that remain in freshwater and do not migrate to the ocean.
Resource Agencies	Government entities that have jurisdictional authority over various natural resources.
restoration	Measures that develop or improve the quality or quantity of existing conditions or resources.
reverse flow	The flows in the western Delta are tidally influenced, with channel flows both towards and away from the ocean during a tidal cycle and the net flow usually towards the ocean. Reverse flows are assumed to occur when the net flow in the western Delta is away from the ocean.
riffle	A shallow reach with swiftly flowing, turbulent water and some partially exposed river bed material.
riparian	Vegetation or other resources associated with a river that are dependent on groundwater and floodwater controlled by the river. The land adjacent to a natural watercourse such as a river or stream. Riparian areas often support vegetation that provides important wildlife habitat, and important fish habitat values when growing large enough to overhang the bank.
riparian corridor	Land adjacent to creeks, rivers, and streams where vegetation is strongly influenced by the presence of water.
riparian vegetation	Of, adjacent to, or living on, the bank of a river or, sometimes, of a lake, pond, etc.
river mile	Measure of distance in miles along a river from its mouth. River mile numbers begin at zero and increase further upstream.
river mouth	The place where a river ends by flowing into another body of water such as a lake, ocean, or another river.
riverine	Of or pertaining to rivers.
run (of salmonids)	A group of fish that is migrating from the ocean to spawn in the rivers or streams where they were born.
Sacramento-San Joaquin River Delta (Delta)	As described in Section 12220 of the California Water Code, an area that generally extends from Sacramento to the north, Tracy to the south, Interstate 5 to the east, and Collinsville to the west. The Delta covers approximately 738,000 acres.

Term	Definition
salinity	The amount of dissolved salts in a given volume of water.
salmonids	Of, belonging to, or characteristic of the family Salmonidae, which includes salmon, trout, and whitefish.
salts	Compounds derived from the reaction of an acid and a base.
scoping	The open process that continues throughout the planning and early stages of preparation of an EIS for determining the scope of issues to be addressed and for identifying the significant issues related to a proposed action. For an EIS, Federal agencies must use scoping to engage state, local, and tribal governments and the public in the early identification of concerns, potential impacts, additional disciplines to be included, relevant effects of past actions, and possible alternative actions.
sediment	Rock and mineral particles transported by water. Sediment relevant to wetlands tends to be relatively fine because the low gradients involved do not transport larger particles.
sedimentation	The deposition by settling of a suspended material.
sentinel fish	Fish species that accumulate contaminates in their tissues and are used as indicators of pollution.
settlement	A downward movement of a surface as a result of underlying soil compression or consolidation caused by an increased load or the loss of underlying soil (foundation) support.
smolt	A young salmon that has assumed the silvery color of the adult and is ready to migrate to the sea.
soil moisture content	The weight of water contained in a sample of soil, typically expressed as a percentage of the dry weight of the soil.
spawner	Parental stock of a fish. Typically refers to an adult anadromous fish, like a salmon, on its upstream migration to spawn.
spawning	The releasing and fertilizing of eggs by fish.
special-status species	Federal and State classifications for plant and animal species that either are listed as threatened or endangered, are formally recognized candidates for listing, or are declining to a point where they may be listed.
spill	Water released from reservoirs to comply with flood control criteria.
spillway	Overflow structure of a dam.
stage	Water surface elevation; the elevation above mean sea level (msl), typically measured in feet.
stakeholder	Anyone who lives in a watershed or has land management, administrative, or other responsibilities or interests in it. Stakeholders may be individuals, businesses, government agencies, or special-interest groups.
State Water Project (SWP)	A California State water storage and conveyance system that pumps water from the Delta for agricultural, urban, domestic, and industrial purposes. The SWP was authorized by legislation in 1951 and consists of 22 dams and reservoirs, which delivers water 600 miles from the Sacramento Valley to Los Angeles.
stratification (in lakes)	The formation of layers based on temperature, oxygen levels, salinity, and density that act as barriers to water mixing.
stressors	Physical, chemical, or biological perturbations to a system that adversely affect ecosystem processes, habitats, and species. Examples include water diversions, dams, reservoirs, weirs, levees, bridges and bank protection, dredging and sediment disposal, gravel mining, invasive aquatic plants, invasive aquatic organisms, invasive riparian and salt marsh plants, nonnative wildlife, predation and competition, contaminants, wildfire, fish and wildlife harvest, and artificial fish propagation.
subsidence	A local mass movement that involves principally the gradual downward settling or sinking of the earth's surface with little or no horizontal motion. It may be due to natural geologic processes or mass activity such as removal of subsurface solids, liquids, or gases, groundwater extraction, and wetting of some types of moisture-deficient loose or porous deposits.
subsistence	The way by which a culture obtains its food.
subspecies	A taxonomic rank below that of species, usually recognizing individuals that have certain heritable characteristics distinct from other subspecies of a species.

Glossary

Term	Definition
succession	The change in the composition and structure of a biological community over time in the absence of major disturbance (e.g., fire, flood, land clearing) in which the community modifies the physical environment to eventually establish an ecosystem that is as stable as possible at the site in question.
surface water diversion	Water that is diverted and/or pumped from aboveground sources such as rivers, streams, reservoirs, and lakes, as opposed to groundwater, which is pumped from an aquifer.
sustainable yield	Sustainable yield is a balance between pumping and basin recharge, and is expressed as the number of acre-feet of water per year that can be pumped from a basin on a long-term average annual basis.
tailwater	Water immediately downstream from a dam.
take	Under the Federal ESA, “To harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct” in regard to Federally listed, endangered species of wildlife (16 USCA 1532[19]). “Harm” is further defined as an act “which actually kills or injures.” Harm may include “significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding, or shelter” (50 CFR 17.3). Under the California Fish and Game Code, take is defined as “to hunt, pursue, catch, capture, or kill, or attempt to hunt, pursue, catch, capture, or kill” (California Fish and Game Code Section 86).
terrestrial species	Types of species of animals and plants that live on or grow from the land.
thalweg	The deepest part of a stream or river channel.
thermal refugia	Cool, well-oxygenated areas of rivers utilized by salmon and other species to avoid thermal stress.
theronts	The infective stage of a parasitic protozoa such as Ich. During this stage, the pathogen becomes water-borne and can be transmitted.
threatened species	Legal status afforded to plant or animal species that are likely to become endangered within the foreseeable future throughout all or a significant portion of their range, as determined by the USFWS or the NMFS.
tomites	Infective stages of a parasitic protozoa, such as Ich, produced by cysts (tomonts). Tomites are then released as theronts.
tomonts	The cyst stage of a parasitic protozoa such as Ich. During this stage, cysts are released into the aquatic environment.
Total Maximum Daily Load (TMDL)	A regulatory term in the Clean Water Act that describes the maximum amount of a pollutant that a body of water can receive while still meeting water quality standards.
toxigenic	Producing or containing toxins.
toxins	Substances that cause damage to a living tissue, impairment of the central nervous system, severe illness, or death when ingested, inhaled, or absorbed by the skin.
tributary	A stream flowing into a larger stream or a lake.
Trinity River Division (TRD)	The Trinity River Division, part of Reclamation’s Central Valley Project, consists of Trinity Dam and Trinity Lake, Trinity Powerplant, Lewiston Dam and Lake, Lewiston Powerplant, Clear Creek Tunnel, Judge Francis Carr Powerhouse, Whiskeytown Dam and Lake, Spring Creek Tunnel and Powerplant, Spring Creek Debris Dam and Reservoir, and related pumping and distribution facilities. The TRD transfers water from the Trinity River subbasin (part of the Klamath River Basin) to the Sacramento River Basin.
Trinity River Restoration Program (TRRP)	Restoration program to restore the Trinity River and its habitat for fish by augmenting flows, constructing rehabilitation sites, augmenting spawning gravel, and controlling fine sediments.
turbidity	A measure of the extent to which light passing through water is reduced owing to suspended materials.
Upper Klamath Basin	The portion of the Klamath River Basin located upstream of Iron Gate Dam.
water acquisition	The procurement (purchase) of water by Reclamation from willing sellers for delivery to and use by wildlife refuges.

Term	Definition
water rights	California recognizes riparian and appropriative water rights.
	Riparian Water Rights – Exist for lands that abut a waterway, or that overlie an underground stream. Generally, there is no riparian right to diffused surface waters or swamps. The extent of the frontage along a waterway in no way governs the quantity of the water right. Use of water through riparian rights must be on riparian land and within the watershed of a stream. Riparian rights may not be lost as a result of nonuse.
	Appropriative Water Rights – Water rights based on the principle of prior appropriations, or "first in time, first in right." To maintain appropriative water rights, the right to any water must be put to beneficial use. Nonuse of appropriative water rights may result in the loss of those water rights. In a conflict between a riparian water user and an upstream appropriator, the riparian user has priority, provided that the water is being used in a reasonable and beneficial manner.
water supply reliability	The certainty or degree to which water supplies are available for agricultural, municipal and industrial, and environmental purposes. For example, the degree to which water service contract holders receive their full-service contract amounts within acceptable quality, timing, and other service standards.
water transfer	Sales of water from the rights holder to another user by mutual agreement.
water year	The period of time beginning October 1 of one year and ending September 30 of the following year and designated by the calendar year in which it ends. Water Year 2008, for example, began October 1, 2007, and ended September 30, 2008. Water years are typically used in analyses of water supply rather than calendar years.
water year type	**Sacramento** – Classified based on the "Sacramento River Index" which defines the water year types based on flow in million acre-feet as follows: Wet - Equal to or greater than 9.2 Above Normal - Greater than 7.8, and less than 9.2 Below Normal - Greater than 6.5, and equal to or less than 7.8 Dry - Greater than 5.4, and equal to or less than 6.5 Critical - Equal to or less than 5.4.
	Trinity – Classified based on historical river flows in the Trinity River Basin. The Final Trinity Mainstem Fishery Restoration Environmental Impact Statement/Report defines the water year types based on flow in thousand acre-feet as follows: Extremely Wet - Equal to or greater than 2,000 Wet - Greater than 1,350, and less than 2,000 Normal - Greater than 1,025, and less than 1,350 Dry - Greater than 650, and less than 1,025 Critically Dry - Equal or less than 650.
watershed	The total land area that drains to any point in a stream. An area that drains to a particular channel or river, usually bounded peripherally by a natural divide of some kind such as a hill, ridge, or mountain.
wetland	Areas that are inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.
Wildlife Management Area (WMA)	A refuge managed by the CDFW.
willing sellers	A term used to describe entities (water districts, agencies, individuals, etc.) who would be interested in selling their water supplies under transfer guidelines established by the SWRCB and other regulatory agencies.

Glossary

Term	Definition
X2	The location (measured in kilometers from the Golden Gate Bridge) of 2 parts per thousand total dissolved solids. The length of time X2 must be positioned at set locations in the estuary each month is determined by a formula that considers the previous month's inflow to the Delta and a "Level of Development" factor, denoted by a particular year. X2 is currently used as the primary indicator in managing Delta outflows. The X2 indicator is also used to reflect a variety of biological consequences related to the magnitude of fresh water flowing downstream through the estuary and the upstream flow of salt water in the lower portion of the estuary. The outflow that determines the location of X2 also affects both the downstream transport of some organisms and the upstream movement of others and affects the overall water operations of the CVP and SWP.

RECLAMATION
Managing Water in the West

Environmental Impact Statement Analytical Tools Technical Appendix

Long-Term Plan to Protect Adult Salmon in the Lower Klamath River
Draft

October 2016

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to 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.

Contents

Figures

Tables

Attachments

Abbreviations and Acronyms

°C	degrees Celsius
°F	degree Fahrenheit
1-D	1-dimensional
7DADM	7-day average daily maximum
ANN	artificial neural network
AR4	Fourth Assessment Report
BA	Biological Assessment
BO	Biological Opinion
CES	Constant Elasticity of Substitution
cfs	cubic feet per second
cm	centimeter
CMIP3	Coupled Model Intercomparison Project Phase 3
CMIP5	Coupled Model Intercomparison Project Phase 5
CVP	Central Valley Project
CVPM	Central Valley Production Model
Delta	Sacramento-San Joaquin River Delta
DFG	California Department of Fish and Game
DSM2	Delta Simulation Model 2
DWR	California Department of Water Resources
EC	electrical conductivity
EIS	Environmental Impact Statement
GCM	global climate models
GHG	greenhouse gas emission
IMPLAN	IMpact Analysis for PLANning Model
I-O	input-output
IOS	Interactive Object-Oriented Salmonid Simulation
IPCC	Intergovernmental Panel on Climate Change
LTO BA	*Biological Assessment on the Continued Long-term Operations of the Central Valley Project and the State Water Project*
LTO	*Coordinated Long-Term Operation of the Central Valley Project and State Water Project*
LYRA	Lower Yuba River Accord
NAICS	North American Industry Classification System
NEPA	National Environmental Policy Act
OCO	Operations Control Office
PMP	Positive Mathematical Programming
RBM10	River Basin Model 10
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
ROD	Record of Decision

RPA	Reasonable and Prudent Alternatives
SALMOD	Salmonid Population Model
SWAP	Statewide Agricultural Production Model
SWP	State Water Project
SWRCB	State Water Resources Control Board
TAF	thousand acre-feet
TRD	Trinity River Division
UCCE	University of California Cooperative Extension
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Service
VIC	Variable Infiltration Capacity
Western	Western Area Power Authority
WRESL	water resources simulation language
YTFP	Yurok Tribal Fisheries Program

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Chapter 1
Overview of Analytical Framework and Modeling

This chapter summarizes the overall analytical framework and modeling methodology used to assess the No Action and action alternatives in this Environmental Impact Statement (EIS). Chapters 2 through 7 describe the tools and procedures used in the analyses for this EIS, including the application of these tools, the types of outputs generated, and the appropriate use of these outputs, by resource area. Attachment 1, “Selection of Analytical Tools,” describes the rationale for selection of the analytical tools used to assess resource area impacts.

Overview of the Modeling Approach

To support the impact analysis of the alternatives, numerical modeling of physical variables (or “physically based modeling”), such as river flows and water temperature, is required to evaluate changes to conditions affecting resources in the Klamath, Trinity, and Sacramento systems, including the Sacramento-San Joaquin River Delta (Delta). A framework of integrated analyses including hydrologic operations, hydrodynamics, water quality, and fisheries analyses is required to provide information for the comparative National Environmental Policy Act (NEPA) assessment of several resources, such as water supply, surface water, and aquatic resources.

As discussed in Chapter 2, “Description of Alternatives, the alternatives include operational changes of the Trinity River Division (TRD) of the Central Valley Project (CVP) in order to provide flow augmentation to the lower Klamath River in August and September in drier years. These operational changes and other external factors, such as climate and sea-level changes, influence the future conditions of reservoir storage, river flow, Delta flows, exports, water temperature, and water quality. Evaluation of these conditions is the primary focus of the physically based modeling analyses. Results of these physical models are used as input to fisheries models. In addition, economic models are used to evaluate impacts to agricultural production and regional economics.

Figure 1-1 shows the analytical tools applied in these assessments and the relationship between these tools. Each model included in Figure 1-1 provides information to the subsequent model in order to provide various results to support the impact analyses.

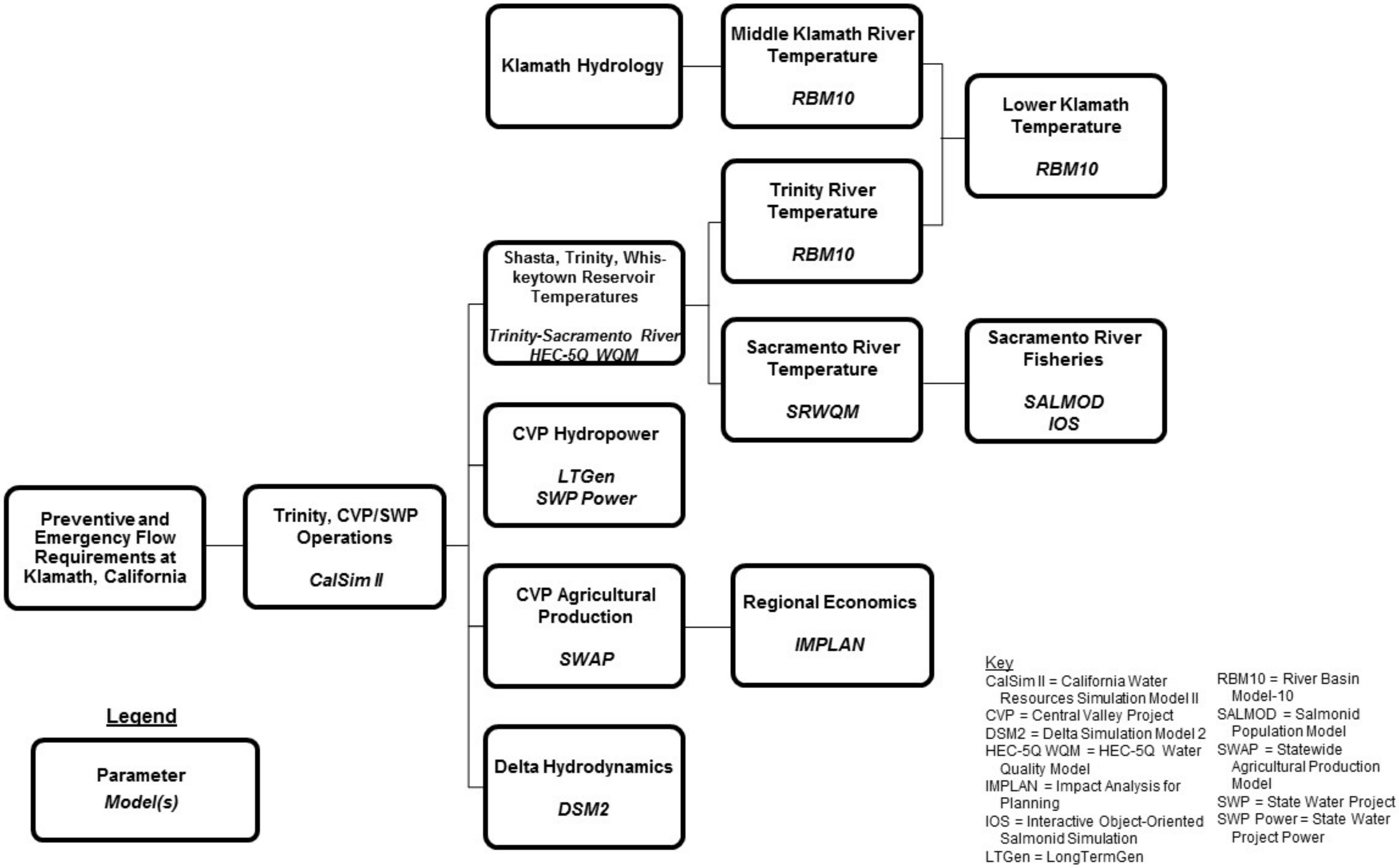

Figure 1-1. Analytical Framework Used to Evaluate Impacts of the Alternatives

Changes to the historical hydrology related to the future climate are applied in the CalSim II model and combined with the assumed operations for each alternative. The CalSim II model simulates the operation of the major CVP and State Water Project (SWP) facilities in the Central Valley and generates estimates of river flows, exports, reservoir storage, deliveries, and other parameters.

Temperature models for the primary river systems and streams (i.e., Trinity River, lower Klamath River, Sacramento River, Clear Creek) use the CalSim II reservoir storage, reservoir releases, river flows, and meteorological conditions to estimate reservoir and river temperatures under each alternative. Results from these temperature models are further used as an input to fisheries models (e.g., SALMOD, IOS) to assess changes in fisheries habitat due to flow and temperature.

Power generation models use CalSim II reservoir levels and releases to estimate power use and generation capability of the projects. Changes in energy generation and use reported by the hydropower models are subsequently used to assess changes in greenhouse gas emissions (GHG).

Agricultural deliveries resulting from CalSim II are used for assessment of changes in agricultural production and regional economics. Changes in land use reported by the agricultural economics model are subsequently used to assess changes in air quality.

Delta Simulation Model 2 (DSM2) Delta hydrodynamic and water quality models use CalSim II boundary inflow conditions for estimating tidally based flows, stage, velocity, and salt transport within the estuary.

The results from this suite of physically based models are used to describe the effects of each alternative considered in this EIS.

Climate Change and Sea-Level Rise Considerations

A growing body of evidence indicates that Earth’s atmosphere is warming. Records show that surface temperatures have risen about 0.7 degrees Celsius (°C) since the early twentieth century and that 0.5°C of this increase has occurred since 1978 (NAS 2006). Observed changes in oceans, snow and ice cover, and ecosystems are consistent with this warming trend (NAS 2006, IPCC 2007). In addition, global and regional sea levels have been increasing steadily over the past century and are expected to continue to increase throughout this century. Over the past several decades, sea level measured at tide gages along the California coast has risen at a rate of about 17 to 20 centimeters (cm) (6.7 to 7.9 inches) per century (Cayan et al. 2009).

This EIS uses a representation of potential climate change and sea-level rise change in numerical models that simulate hydrologic and hydrodynamic conditions in the study area in addition to changes in river flows due to changes in operations and diversions. For modeling purposes, the alternatives are simulated at anticipated 2030 conditions. In the evaluation of all alternatives at 2030, climate change and a sea-level rise of 15 cm were assumed to be inherent. For details on the incorporation of climate change and sea-level rise considerations in individual models, see the individual model chapters.

Model Results Presentation

Figures and tables are provided to illustrate and summarize the results in Chapters 4 through 14 of this EIS. The different types of presentations are explained below.

Exceedance Plots. Exceedance plots provide the percent of time that a given value is exceeded over the course of the analysis. Exceedance plots are generated by ranking or sorting the data and computing the percent of time that value is exceeded in the data. For example, for the Shasta storage end of September exceedance plot, Shasta storage values at the end of September for each simulated year are sorted in ascending order. The smallest value would have an exceedance of 100 percent since all other values would be greater than that value, and the largest value would have an exceedance of 0 percent. All the values are plotted with exceedance on the x-axis and the value of the parameter on the y-axis. Following the same example, if for one scenario, Shasta end of September of 2,000 thousand acre-feet (TAF) corresponds to 80 percent exceedance, it implies that Shasta end-of September storage is higher than 2,000 TAF in 80 percent of the years under the simulated conditions.

Long-Term Average Summary and Year Type Based Statistics Summary Tables. These tables provide parameter values for long-term and year type averages (using the Sacramento Valley 40-30-30 Index developed by the State Water Resources Control Board (SWRCB) or the Trinity Restoration water year types depending on location) for each month. Tables of water supply deliveries do not show the month by month comparison but rather delivery year (March-February) totals by water year type.

Appropriate Use of Model Results

Types of Evaluations

Resource area evaluations for the alternatives were based on quantitative and qualitative assessments using output from model simulations, other analytical tools, previous studies, or other existing information. Each resource area was evaluated by applying one or more of the following methods.

Comparison of Quantitative Simulations – Some models provide quantitative output used for direct comparisons between the No Action Alternative and the action alternatives to identify effects on resources from implementation. For example, output from system water supply operations simulations were directly compared to identify changes in reservoir levels, river flow, and water supply deliveries to the CVP and SWP.

Interpretation/Extrapolation from Quantitative Simulations – Many of the quantitative models providing output for direct comparisons of effects on resources, as described above, were used to interpret/extrapolate effects on other resources. For example, output from system water supply operation simulations informed the evaluation of effects to terrestrial resources due to changes in river flows. Similarly, other models were used solely to provide quantitative data for interpretation or extrapolation on the effects to various resources.

Interpretation/Extrapolation from Available Data or Previous Studies – Existing data and information from previous studies were used to interpret/extrapolate the effects on resources when model simulations were not available, needed or feasible. For example, implementation effects on cultural resources were identified in part through a review of previously conducted archaeological and historical studies.

Qualitative Description with Limited or No Data – When available data or previous studies were limited or unavailable, a qualitative description of the effects were developed using professional judgment and any limited data that were available.

Appropriate Use of Model Results

Interpretation of results from any of the above evaluation methods should consider the physical models developed and applied in the EIS analysis are generalized and simplified representations of a complex water resources system. A brief description of appropriate use of the model results to compare two scenarios or to compare against threshold values or standards is presented below.

Absolute vs. Relative Use of the Model Results. The models are not predictive models (in how they are applied in this project), and therefore the results cannot be considered as absolute with and within a quantifiable confidence interval. The model results are only useful in a comparative analysis and can only serve as an indicator of condition (e.g., compliance with a standard) and of trends (e.g., generalized impacts).

Statistical Comparisons. Using absolute differences computed at a point in time between model results from an alternative and a baseline to evaluate impacts is an inappropriate use of model results (e.g., computing differences between the results from a baseline and an alternative for a particular day or month and year within the period of record of simulation). Likewise computing absolute differences between an alternative (or a baseline) and a specific threshold value or standard is an inappropriate use of model results. Statistics computed based on the absolute differences at a point in time (e.g., average of monthly differences) are an inappropriate use of model results. Computing the absolute differences in this way disregards the changes in antecedent conditions between individual scenarios and distorts the evaluation of impacts of a specific action.

Appropriate statistics to use in summarizing model results are long-term averages and averages by month and water-year type, but the emphasis in using these results should be on evaluating the differences in these averages between alternatives, rather than the absolute values of averages for a particular alternative. Care should be taken to use the appropriate water year type for presenting water year type average statistics of model results (e.g., water year indices should reflect any climate change modifications at the analysis horizon). For this study, water year types are based on the projected climate and hydrology at year 2030.

References

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Chapter 2
Water Operations Modeling

As discussed in Attachment 1, “ Selection of Analytical Tools” to this Appendix, CalSim II was chosen as the model to simulate and evaluate water operations in the upper Trinity River Basin, Sacramento River Basin, San Joaquin River Basin, the Delta, and CVP facilities and Service Areas, including the TRD facilities.

The CalSim II simulation model uses single time-step optimization techniques to route water through a network of storage nodes and flow arcs based on a series of user-specified relative priorities for water allocation and storage. Physical capacities and specific regulatory and contractual requirements are input as linear constraints to the system operation using the water resources simulation language (WRESL). The process of conveying water through the channels and storing water in reservoirs is performed by a mixed-integer linear-programming solver. For each time step, the solver maximizes the objective function to determine a solution that delivers or stores water according to the specified priorities and satisfies all system constraints. The sequence of solved linear-programming problems represents the simulation of the system over the period of analysis.

CalSim II includes an 82-year modified historical hydrology (water years 1922-2003) developed jointly by the U.S. Department of the Interior, Bureau of Reclamation (Reclamation) and the California Department of Water Resources (DWR). Water diversion requirements (demands), stream accretions and depletions, rim basin inflows, irrigation efficiencies, return flows, nonrecoverable losses, and groundwater operations are components that make up the hydrology used in CalSim II. Sacramento Valley and tributary rim basin hydrologies are developed using a process designed to adjust the historical observed sequence of monthly stream flows to represent a sequence of flows at a future level of development. Adjustments to historic water supplies are determined by imposing future level land use on historical meteorological and hydrologic conditions. The resulting hydrology represents the water supply available from Central Valley streams to the system at a future level of development.

CalSim II uses rule-based algorithms for determining deliveries to north-of-Delta and south-of-Delta CVP and SWP contractors. This delivery logic uses runoff forecast information, which incorporates uncertainty and standardized rule curves. The rule curves relate storage levels and forecasted water supplies to project delivery capability for the upcoming year. The delivery capability is then translated into CVP and SWP contractor allocations that are satisfied through coordinated reservoir-export operations.

The CalSim II model utilizes a monthly time step to route flows throughout the river-reservoir system of the Central Valley. Although monthly time steps are reasonable for long-term planning analyses of water operations, a component of the EIS conveyance and conservation strategy includes operations that are sensitive to flow variability at scales less than monthly (i.e., the operation of the Fremont Weir). Initial comparisons of monthly versus daily operations at these facilities indicated that weir spills were likely underestimated and diversion potential was likely overstated using a monthly time step. For these reasons, a monthly to daily flow disaggregation technique was included in the CalSim II model for the Fremont Weir and the Sacramento Weir. The technique applies historical daily patterns, based on the hydrology of the year, to transform the monthly volumes into daily flows. Reclamation's 2008 *Biological Assessment on the Continued Long-term Operations of the Central Valley Project and the State Water Project* (LTO BA) Appendix D provides more information about CalSim II (Reclamation 2008a).

Application of CalSim II to Evaluate EIS Alternatives

Typical long-term planning analyses of the operations of the CVP and SWP have applied the CalSim II model to analyze system responses. CalSim II simulates future CVP and SWP project operations based on an 82-year monthly hydrology derived from the observed 1922-2003 period. Future land use and demands are projected for the appropriate future period. The system configuration of facilities, operations, and regulations forms the input to the model and defines the limits or preferences for operation. The configuration of the Delta, while not simulated directly in CalSim II, informs the flow-salinity relationships and several flow-related regressions for interior Delta conditions included in the model. The CalSim II model is simulated for each set of hydrologic, facility, operations, regulations, and Delta configuration conditions. Some refinement of the CVP and SWP operations related to delivery allocations and San Luis target storage levels are generally necessary to have the model reflect suitable Trinity-Sacramento basin and north-south CVP and SWP reservoir system balancing.

The CalSim II model produces outputs of river flows, exports, water deliveries, reservoir storage, water quality, and several derived variables such as X2 (distance in kilometers eastward from the Golden Gate Bridge to the location where salinity concentration is 2 parts per thousand), Delta salinity, OMR (combined Old and Middle River flows), and QWEST (westerly flow on the San Joaquin River past Jersey Point). The CalSim II model is most appropriately applied for comparing one alternative to another and drawing comparisons among the results – this is the method applied for the EIS. Each alternative is compared to the No Action Alternative to evaluate areas in which the project changes conditions and the seasonality and magnitude of such changes. The change in hydrologic response or system conditions is important information that informs the impact analysis related to water-dependent resources in Sacramento-San Joaquin watersheds.

Incorporation of Climate Change and Sea-Level Rise

Climate and sea level change were incorporated into the CalSim II model in two ways: changes to the input hydrology and changes to the flow-salinity relationship in the Delta due to sea-level rise.

Climate Change

In recent years, a suite of global climate models (GCM) has been developed and refined as part of the Coupled Model Intercomparison Project Phase 3 (CMIP3), part of the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4). To incorporate climate change into CalSim II modeling, climate change scenarios developed from an ensemble of 112 bias-corrected, spatially downscaled GCM simulations were considered. The future projected changes over the 30-year climatological period centered on 2025 (i.e., 2011-2040 to represent

2025 timeline) were combined with a set of historically observed temperatures and precipitation to generate climate sequences that maintain important multi-year variability not always reproduced in direct climate projections.

In an effort to summarize these 112 scenarios, five statistically representative climate change scenarios were developed to characterize the central tendency, and the range of the ensemble uncertainty. Since the ensemble is made up of many projections, it is useful to identify the median (50th percentile) change of both annual temperature and annual precipitation. In doing so, the state of climate change at this point in time can be broken into quadrants representing (1) drier, less warming, (2) drier, more warming, (3) wetter, more warming, and (4) wetter, less warming than the ensemble median (Q1 through Q4). In addition, a fifth region (Q5) can be described that samples from inner-quartiles (25th to 75th percentile) of the ensemble and represents a central region of climate change. In each of the five regions the sub-ensemble of climate change projections, made up of those contained within the region bounds, is identified. The Q5 scenario is derived from the central tending climate projections and thus favors the consensus of the ensemble.

For the purposes of this EIS, the Q5 climate change scenario for the period centered on 2025 is used for all alternatives analyses and represents conditions at 2030. Although projected changes in future climate contain significant uncertainty through time, several studies have shown that use of the median climate change condition is acceptable (for example, Pierce et al. 2009). The median climate change is considered appropriate for the EIS because of the comparative nature of the NEPA analysis. This EIS utilized the same climate change scenarios to develop CalSim II inputs as the *Coordinated Long-Term Operation of the Central Valley Project and State Water Project* (LTO) EIS (Reclamation 2015a). Additional information on the differences between Q5 and Q1-Q4 are presented in *Appendix 5A.A: CalSim II and DSM2 Modeling Methodology* of the LTO EIS.

After determining the climate change scenario to use for analysis, changes in runoff and stream flow are simulated through Variable Infiltration Capacity (VIC) modeling under this scenario. These simulated changes in runoff are applied to the CalSim II inflows as a fractional change from the observed inflow patterns (simulated future runoff divided by historical runoff). The changes in runoff are applied to runoff forecasts used for reservoir operations and allocation decisions; changes in stream flow are applied to all major streams in the Central Valley and Trinity River Basin. After determining the adjusted runoff and stream flows, water year types and other hydrologic indices that govern water operations or compliance were adjusted to be consistent with the new hydrologic regime. The changes in reservoir inflows, key valley floor accretions, and water year types and hydrologic indices were translated into modified input time series for the CalSim II model. Figure 2-1 shows inflows to Trinity Reservoir in CalSim II with and without the effects of climate change.

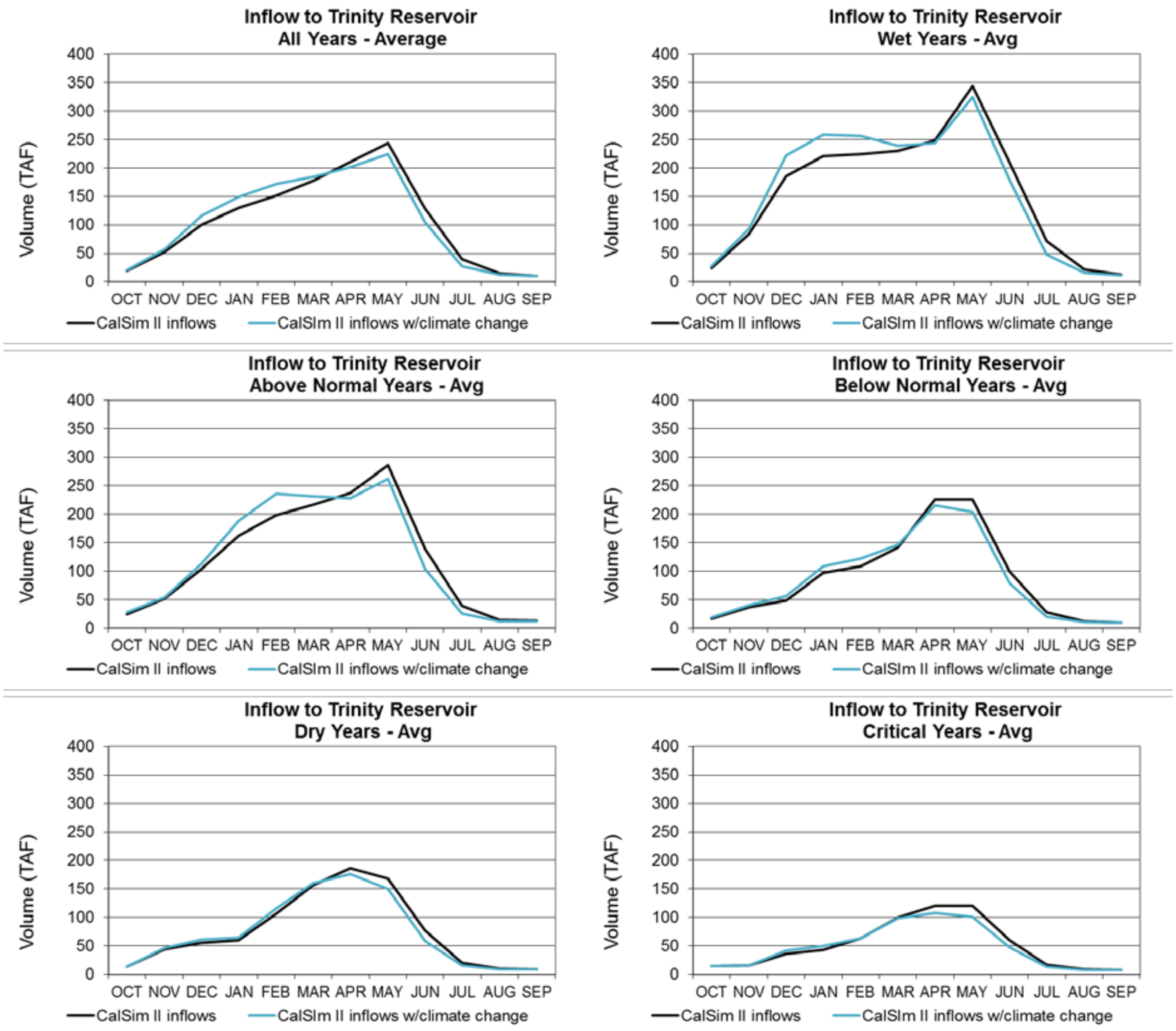


Figure 2-1. Comparison of Trinity Inflows in CalSim II With and Without the Effects of Climate Change

The CalSim II simulations do not consider future climate change adaptations that may manage the CVP and SWP system in a different manner than today to reduce climate impacts. For example, future changes in reservoir flood control reservation to better accommodate a seasonally changing hydrograph may be considered under future programs, but are not considered under the EIS. Thus, the CalSim II EIS results represent the risks to operations, water users, and the environment in the absence of dynamic adaptation for climate change.

Sea-Level Rise

Salinity in the Delta cannot be simulated accurately by the simple mass-balance routing and coarse time step used in CalSim II. Likewise, the upstream reservoirs and operational constraints cannot be modeled in the DSM2 model (Delta Simulation Model 2) (see Chapter 6 for discussion of DSM2 modeling). An artificial neural network (ANN) has been developed (Sandhu et al. 1999) that attempts to mimic the flow-salinity relationships as simulated in DSM2 while providing a rapid transformation of this information into a form usable by the CalSim II operations model. The ANN is implemented in CalSim II to constrain the operations of the upstream reservoirs and the Delta export pumps in order to satisfy particular salinity requirements. ANN requires retraining whenever the flow-salinity relationship in the Delta changes.

For the purposes of the EIS, the sea-level rise scenario for the period centered on 2025 is used (DWR et al. 2013). This period is considered because the EIS analysis is conducted using the assumed conditions at 2030. For sea-level rise simulation, it was assumed the projected sea-level rise at 2025 would be approximately 12 to 18 cm (5 to 7 inches) (Rahmstorf 2007, Vermeer and Rahmstorf 2009). Due to the considerable uncertainty in these projections and the state of sea-level rise science, the mid-range of the estimates of 15 cm (6 inches) were used. . This sea-level rise estimate is consistent with those outlined in the recent U.S. Army Corps of Engineers (USACE) guidance circular for incorporating sea-level changes in civil works programs (USACE 2013). An ANN developed to simulate salinity conditions with 15-cm sea-level rise was obtained from Reclamation and used in the CalSim II modeling.

No Action Alternative Development

This section presents the assumptions used in developing the CalSim II model simulations of the No Action Alternative for use in the EIS evaluation. The assumptions were selected to satisfy NEPA requirements. Assumptions that were applied to the CalSim II modeling are included in the following section. The No Action Alternative assumptions represent the continuation of existing policy and management direction at Year 2030 and include implementation of water operations components of the Reasonable and Prudent Alternatives (RPA) actions specified in the *Formal Endangered Species Act Consultation on the Proposed Coordinated Operations of the Central Valley Project and State Water Project* (USFWS 2008) and the NMFS 2009 *Biological Opinion and Conference Opinion on the Long- Term Operations of the CVP and SWP* (NMFS 2009).

Modeling Assumptions

The No Action Alternative was developed assuming projected Year 2030 conditions. The No Action Alternative includes projected climate change and sea-level rise assumptions corresponding to the Year 2030. Climate change results in changes in the reservoir and tributary inflows included in CalSim II. The CalSim II simulation for the No Action Alternative does not consider any adaptation measures that would result in managing the CVP and SWP system in a different manner than it is managed today to reduce climate impacts. Table 2-1 summarizes assumptions made in CalSim II modeling for this analysis.

Inflows/Supplies

The CalSim II model includes historical hydrology projected to Year 2030 under climate change assumptions and with projected 2020 modifications for operations upstream of the rim reservoirs.

Land Development

CalSim II uses a hydrology that is the result of an analysis of agricultural and urban land use and population estimates. The assumptions used for Sacramento Valley land use result from aggregation of historical survey and projected data developed for the California Water Plan Update (Bulletin 160-98). Generally, land-use projections are based on Year 2020 estimates; however, the San Joaquin Valley hydrology reflects draft 2030 land-use assumptions developed by Reclamation. Where appropriate, Year 2020 projections of demands associated with water rights and CVP and SWP water service contracts have been included.

Demands, Water Rights, and CVP and SWP Contracts

CalSim II demand inputs are preprocessed monthly time series for a specified level of development (e.g., 2020) and according to hydrologic conditions. Demands are classified as CVP project, SWP project, local project, or non-project. CVP and SWP demands are separated into different classes based on the contract type. A description of various demands and classifications included in CalSim II is provided in the 2008 LTO BA Appendix D (Reclamation 2008a).

1 Table 2-1. CalSim II Modeling Assumptions

	No Action Alternative[1]
Planning Horizon	2030
Period of Simulation	82 years (1922–2003)
HYDROLOGY	
Inflows/Supplies	Historical with modifications for operations upstream of rim reservoirs and with changed climate at Year 2030
Level of Development (land-use)	2020 and 2030 Level[2]
Demands	
Sacramento River Region (excluding the American River)	
CVP[3]	Land-use based, full build-out of contract amounts
SWP (FRSA)[4]	Land-use based, limited by contract amounts
Nonproject	Land-use based, limited by water rights and SWRCB Decisions for Existing Facilities
City of Antioch	Pre-1914 water right
Federal refuges[5]	Firm Level 2 water needs
Sacramento River Region – American River Basin[6]	
Water rights	Year 2025, full water rights
CVP	Year 2025, full contracts, including Freeport Regional Water Project (FRWP)
San Joaquin River Region[7]	
Friant Unit	Limited by contract amounts, based on current allocation policy
Lower basin	Land-use based, based on district level operations and constraints
Stanislaus River basin[8, 9]	Land-use based, based on New Melones Interim Operations Plan, up to full SEWD deliveries (155 TAF/year) depending on New Melones Index
San Francisco Bay, Central Coast, Tulare Lake, and South Coast Regions (CVP and SWP project facilities)	
CVP[3]	Demand based on contract amounts
Federal refuges[5]	Firm Level 2 water needs
CCWD[10]	CCWD Forecasted 2030 demands
SWP [4, 11]	Demand based on full Table A amounts (4.13 MAF/year)
Article 56	Based on 2001–2008 contractor requests
Article 21	MWD demand up to 200 TAF/month from December to March subject to conveyance capacity, KCWA demand up to 180 TAF/month and other contractor demands up to 34 TAF/month in all months, subject to conveyance capacity.
North Bay Aqueduct	77 TAF/year demand under SWP contracts, up to 43.7 cfs of excess flow under Fairfield, Vacaville, and Benicia Settlement Agreement. NOD Allocation Settlement Agreement terms for Napa and Solano
FACILITIES	
Systemwide	Existing facilities
Sacramento River Region	
Shasta Lake	Existing, 4,552 TAF capacity
Red Bluff Diversion Dam	Diversion dam operated with gates out all year, consistent with NMFS BO (June 2009) Action I.3.19.
Colusa Basin	Existing conveyance and storage facilities
Upper American River	PCWA American River pump station
Lower Sacramento River	FRWP

Table 2-1. CalSim II Modeling Assumptions (contd.)

	No Action Alternative[1]
Delta Region	
SWP Banks Pumping Plant (South Delta)	Physical capacity is 10,300 cfs but 6,680 cfs permitted capacity in all months up to 8,500 cfs during December 15–March 15, depending on Vernalis flow conditions[12]; additional capacity of 500 cfs (up to 7,180 cfs) allowed for reducing impact of NMFS BO (June 2009) Action IV.2.1[9] on SWP[13]
CVP C.W. "Bill" Jones Pumping Plant (formerly Tracy PP)	Permit capacity is 4,600 cfs in all months (allowed for by the Delta-Mendota Canal–California Aqueduct Intertie)
Upper DMC	Existing (exports limited to 4,200 cfs plus diversion upstream from DMC–constriction) plus 400 cfs Delta-Mendota Canal-California Aqueduct Intertie
Los Vaqueros Reservoir	Enlarged storage capacity, 160 TAF, existing pump location. Alternate Intake Project included[14]
San Joaquin River Region	
Millerton Lake (Friant Dam)	Existing, 520 TAF capacity
Lower San Joaquin River	City of Stockton Delta Water Supply Project, 30 mgd capacity
San Francisco Bay region	
South Bay Aqueduct	SBA rehabilitation, 430 cfs capacity from junction with California Aqueduct to Alameda County FC&WSD Zone 7 point
South Coast Region	
California Aqueduct East Branch	Existing Capacity
REGULATORY STANDARDS	
Trinity River	
Minimum Flow below Lewiston Dam	Trinity EIS Preferred Alternative (369-815 TAF/year)
Trinity Reservoir end-of-September minimum storage	Trinity EIS Preferred Alternative (600 TAF as able)
Clear Creek	
Minimum flow below Whiskeytown Dam	Downstream water rights, 1963 Reclamation proposal to USFWS and NPS, and USFWS predetermined CVPIA 3406(b)(2) flows15, and NMFS BO (June 2009) Action I.1.19
Upper Sacramento River	
Shasta Lake end-of-September minimum storage	NMFS 2004 Winter-run BO (1900 TAF in non-critical dry years), and NMFS BO (Jun 2009) Action I.2.19
Minimum flow below Keswick Dam	SWRCB WR 90-5, predetermined CVPIA 3406(b)(2) flows15, and NMFS BO (June 2009) Action I.2.29
Feather River	
Minimum flow below Thermalito Diversion Dam	2006 Settlement Agreement (700/800 cfs).
Minimum flow below Thermalito Afterbay outlet	1983 DWR and CDFW agreement (750 –1,700 cfs)
Yuba River	
Minimum flow below Daguerre Point Dam	D-1644 Operations (Lower Yuba River Accord)16

Table 2-1. CalSim II Modeling Assumptions (contd.)

	No Action Alternative[1]
American River	
Minimum flow below Nimbus Dam	American River Flow Management as required by NMFS BO (Jun 2009) Action II.1[9]
Minimum flow at H Street Bridge	SWRCB D-893
Lower Sacramento River	
Minimum flow near Rio Vista	SWRCB D-1641
Mokelumne River	
Minimum flow below Camanche Dam	FERC 2916-029, 1996 (Joint Settlement Agreement) (100–325 cfs)
Minimum flow below Woodbridge Diversion Dam	FERC 2916-029, 1996 (Joint Settlement Agreement) (25–300 cfs)
Stanislaus River	
Minimum flow below Goodwin Dam	1987 Reclamation, CDFW agreement, and flows required for NMFS BO (June 2009) Action III.1.2 and III.1.3[9, 17]
Minimum dissolved oxygen	SWRCB D-1422
Merced River	
Minimum flow below Crocker-Huffman Diversion Dam	Davis-Grunsky (180–220 cfs, November–March), and Cowell Agreement
Minimum flow at Shaffer Bridge	FERC 2179 (25–100 cfs)
Tuolumne River	
Minimum flow at Lagrange Bridge	FERC 2299-024, 1995 (Settlement Agreement) (94–301 TAF/year)
San Joaquin River	
San Joaquin River below Friant Dam/Mendota Pool	Full San Joaquin River Restoration flows
Maximum salinity near Vernalis	SWRCB D-1641
Minimum flow near Vernalis	SWRCB D-1641 (Feb-Apr 14 and May 16-June minimum flows only).[18] NMFS BO (June 2009) Action IV.2.1 Phase II flows not provided due to lack of agreement for purchasing water.
Sacramento-San Joaquin Delta	
Delta Outflow Index (flow and salinity)	SWRCB D-1641 and USFWS BO (December 2008) Action 49
Delta Cross Channel gate operation	SWRCB D-1641 with additional days closed from October 1–January 31 based on NMFS BO (June 2009) Action IV.1.29 (closed during flushing flows from October 1–December 14 unless adverse water quality conditions)
South Delta exports (Jones PP and Banks PP)	SWRCB D-1641 export limits, not including VAMP period export cap under the San Joaquin River Agreement; Vernalis flow-based export limits in April–May as required by NMFS BO (June 2009) Action IV.2.1 Phase II90 (additional 500 cfs allowed for July–September for reducing impact on SWP)13
Combined Flow in Old and Middle River (OMR)	USFWS BO (December 2008) Actions 1, 2, and 3 and NMFS BO (June 2009) Action IV.2.39

Table 2-1. CalSim II Modeling Assumptions (contd.)

	No Action Alternative[1]
OPERATIONS CRITERIA: RIVER-SPECIFIC	
Upper Sacramento River	
Flow objective for navigation (Wilkins Slough)	NMFS BO (June 2009) Action I.4[9]; 3,500 – 5,000 cfs based on CVP water supply condition
American River	
Folsom Dam flood control	Variable 400/670 flood control diagram (without outlet modifications)
Feather River	
Flow at mouth of Feather River (above Verona)	Maintain CDFW/DWR flow target of 2,800 cfs for April–September dependent on Oroville inflow and FRSA allocation
Stanislaus River	
Flow below Goodwin Dam	Revised Operations Plan and NMFS BO (June 2009) Action III.1.2 and III.1.3[9,17]
San Joaquin River	
Salinity at Vernalis	Grassland Bypass Project (full implementation)
OPERATIONS CRITERIA: SYSTEMWIDE	
CVP Water Allocation	
CVP settlement and exchange	100% (75% in Shasta critical years)
CVP refuges	100% (75% in Shasta critical years)
CVP agriculture	100%–0% based on supply. South-of-Delta allocations are additionally limited due to D-1641, USFWS BO (December 2008), and NMFS BO (June 2009)[9], and are always 0% when Shasta storage < 2400 TAF during Shasta critical years.
CVP municipal & industrial	100%–50% based on supply. South-of-Delta allocations are additionally limited due to D-1641, USFWS BO (December 2008), and NMFS BO (June 2009)[9]
SWP Water Allocation	
North of Delta (FRSA)	Contract specific
South of Delta (including North Bay Aqueduct)	Based on supply; equal prioritization between Ag and M&I based on Monterey Agreement; allocations are limited due to D-1641, USFWS BO (December 2008), and NMFS BO (June 2009)[9]
CVP/SWP Coordinated Operations	
Sharing of responsibility for in-basin use	1986 Coordinated Operations Agreement (FRWP, EBMUD, and 2/3 of the North Bay Aqueduct diversions are considered as Delta export, 1/3 of the North Bay Aqueduct diversion is considered as in-basin use)
Sharing of surplus flows	1986 Coordinated Operations Agreement
Sharing of restricted export capacity for project-specific priority pumping	Equal sharing of export capacity under SWRCB D-1641, USFWS BO (December 2008), and NMFS BO (June 2009) export restrictions9
Water transfers	Acquisitions by SWP contractors are wheeled at priority in Banks PP over non-SWP users; LYRA included for SWP contractors13
Sharing of export capacity for lesser priority and wheeling-related pumping	Cross Valley Canal wheeling (max of 128 TAF/year), CALFED ROD defined Joint Point of Diversion (JPOD)
San Luis Reservoir	San Luis Reservoir is allowed to operate to a minimum storage of 100 TAF

Table 2-1. CalSim II Modeling Assumptions (contd.)

	No Action Alternative[1]
CVPIA 3406(b)(2)	
Policy decision	May 2003 Department of Interior decision
Allocation	800 TAF/year, 700 TAF/year in 40-30-30 dry years, and 600 TAF/year in 40-30-30 critical years
Actions	Pre-determined non-discretionary USFWS BO (December 2008) upstream fish flow objectives (October-January) for Clear Creek and Keswick Dam, non-discretionary NMFS BO (June 2009) actions for the American and Stanislaus Rivers, and USFWS BO (December 2008) and NMFS BO (June 2009) actions leading to export restrictions[9]
Accounting adjustments	No discretion assumed under USFWS BO (December 2008) and NMFS BO (June 2009)[9], no accounting
WATER MANAGEMENT ACTIONS	
Water Transfer Supplies (long term programs)	
LYRA[13]	Yuba River acquisitions for reducing impact of NMFS BO export restrictions[9] on SWP
Phase 8	None
Water Transfers (short term or temporary programs)	
Sacramento Valley acquisitions conveyed through Banks PP	Post-analysis of available capacity[18]

Notes:

[1] These assumptions were initially developed under the direction of the DWR and Reclamation management team for the BDCP HCP and EIR/EIS. Additional modifications were made by Reclamation and DWR for subsequent planning studies, the most recent of which are the Reclamation 2015 Remand EIS Baseline, the DWR 2015 Delivery Capability Report, and draft studies for the Los Vaqueros Expansion Investigation (not released yet).

[2] The Sacramento Valley hydrology used in Future Condition CalSim-II models reflects 2020 land-use assumptions associated with Bulletin 160-98. The San Joaquin Valley hydrology reflects draft 2030 land-use assumptions developed by Reclamation to support Reclamation studies.

[3] CVP contract amounts have been reviewed and updated according to existing and amended contracts, as appropriate.

[4] SWP contract amounts have been updated as appropriate based on recent Table A transfers/agreements.

[5] Water needs for Federal refuges have been reviewed and updated, as appropriate. Refuge Level 4 (and incremental Level 4) water is not included.

[6] The Sacramento Area Water Forum agreement, its dry year diversion reductions, Middle Fork Project operations and “mitigation” water is not included.

[7] The newest CalSim-II representation of the San Joaquin River has been included in this model package (CalSim-II San Joaquin River Model, Reclamation, 2005). The model reflects the difficulties of ongoing groundwater overdraft problems. The 2030 level of development representation of the San Joaquin River Basin does not make any attempt to offer solutions to groundwater overdraft problems. In addition, a dynamic groundwater simulation is not yet developed for the San Joaquin River Valley. Groundwater extraction/recharge and stream-groundwater interaction are static assumptions and may not accurately reflect a response to simulated actions. These limitations should be considered in the analysis of result

[8] The CalSim-II model representation for the Stanislaus River does not necessarily represent Reclamation’s current or future operational policies. A suitable plan for supporting flows has not been developed for NMFS BO (June 2009) Action III.1.3.

[9] In cooperation with NMFS, USFWS, and CDFW, the Reclamation and DWR have developed assumptions for implementation of the USFWS BO (December 15, 2008) and NMFS BO (June 4, 2009) in CalSim-II.

[10] Demand forecasts are derived from CCWD’s Future Water Supply Study (CCWD, August 1996), with adjustments made for the future condition to estimate the demand distribution in 2030. Future condition demands represent Service Area C. Demands and demand pattern taken from April 2004 Planning Report. Water supplies are 195 TAF/yr CCP contract, water rights for Delta excess flows, and transfers.

Table 2-1. CalSim II Modeling Assumptions (contd.)

Notes: (contd.)

[11] Under existing conditions it is assumed that SWP Contractors demand for Table A allocations vary from 3.0 to 4.1 MAF/year. Under the Future No-Action baseline, it is assumed that SWP Contractors can take delivery of all Table A allocations and Article 21 supplies. Article 56 provisions are assumed and allow for SWP Contractors to manage storage and delivery conditions such that full Table A allocations can be delivered. Article 21 deliveries are limited in wet years under the assumption that demand is decreased in these conditions. Article 21 deliveries for the NBA are dependent on excess conditions only, all other Article 21 deliveries also require that San Luis Reservoir be at capacity and that Banks PP and the California Aqueduct have available capacity to divert from the Delta for direct delivery.

[12] The current USACE permit for Banks Pumping Plant allows for an average diversion rate of 6,680 cfs in all months. Diversion rate can increase up to 1/3 of the rate of San Joaquin River flow at Vernalis from Dec. 15th to Mar. 15th, up to a maximum diversion of 8,500 cfs, if Vernalis flow exceeds 1,000 cfs.

[13] Acquisitions of Component 1 water under the LYRA, and use of 500 cfs dedicated capacity at Banks PP during July–September, are assumed to be used to reduce as much of the impact of the April-May Delta export actions on SWP Contractors as possible.

[14] The CCWD Alternate Intake Project (also known as Middle River Intake Project), an intake at Victoria Canal, which operates as an alternate Delta diversion for Los Vaqueros Reservoir. Construction was completed in Fall of 2010.

[15] Delta actions, under USFWS discretionary use of CVPIA 3406(b)(2) allocations, are no longer dynamically operated and accounted for in the CalSim-II model. The Combined OMR flow and Delta export restrictions under the USFWS BO (December 15, 2008) and the NMFS BO (June 4, 2009) severely limit any discretion that would have been otherwise assumed in selecting Delta actions under the CVPIA 3406(b)(2) accounting criteria. Therefore, it is anticipated that CVPIA 3406(b)(2) account availability for upstream river flows below Whiskeytown, Keswick, and Nimbus dams would be very limited. It appears the integration of BO RPA actions will likely exceed the 3406(b)(2) allocation in all water year types. For these baseline simulations, upstream flows on the Clear Creek and Sacramento River are predetermined, based on CVPIA 3406(b)(2) based operations from the August 2008 BA Study 7.0 and Study 8.0 for Existing and Future No-Action baselines, respectively. The procedures for dynamic operation and accounting of CVPIA 3406(b)(2) are not included in the CalSim-II model.

[16] D-1644 and the LYRA are assumed to be implemented for existing and future conditions. The Yuba River is not dynamically modeled in CalSim-II. Yuba River hydrology and availability of water acquisitions under the LYRA are based on modeling performed and provided by the LYRA EIS/EIR study team.

[17] The model operates the Stanislaus River using a 1997 Interim Plan of Operation-like structure, i.e., allocating water for Stockton East Water District and CSJWCD, Vernalis water quality dilution, and Vernalis D-1641 flow requirements based on the New Melones Index. Oakdale Irrigation District and South San Joaquin Irrigation District allocations are based on their 1988 agreement and Ripon DO requirements are represented by a static set of minimum instream flow requirements during June thru Sept. Instream flow requirements for fish below Goodwin are based on NMFS BO Action III.1.2. NMFS BO Action IV.2.1's flow component is not assumed to be in effect.

[18] Only acquisitions of Lower Yuba River Accord Component 1 water included.

Key: % = percent
BO = Biological Opinion
CCWD = Contra Costa Water District
cfs = cubic feet per second
CSJWCD = Central San Joaquin Water Conservation District
CVP = Central Valley Project
CVPIA = Central Valley Project Improvement Act
D-1641 = SWRCB Water Right Decision Number D-1641
DMC = Delta-Mendota Canal
EBMUD = East Bay Municipal Utilities District
EIS = Environmental Impact Statement
FERC = Federal Energy Regulatory Commission
FRSA = Feather River service area
KCWA = Kern County Water Agency
LYRA = Lower Yuba River Accord
mgd = million gallons per day
NMFS = National Marine Fisheries Service
PP = power plant
SWP = State Water Project
SWRCB = State Water Resources Control Board
TAF = thousand acre feet

Action Alternatives

Methodology and Assumptions for Flow Augmentation Common to Both Action Alternatives

The Klamath, California gage (U.S. Geological Service (USGS) Gage 11530500) does not have a complete historical record that coincides with CalSim II, which evaluates operations from 1922 to 2003. To assess the potential flow augmentation operations required under the action alternatives, a long-term daily data set of the Klamath River at Klamath – consistent with the CalSim II period of analysis – is required. A long-term daily flow data set was needed to determine the duration, magnitude, and frequency of flow augmentation activities based on identified criteria for preventive base flow augmentation, preventive pulse flows, and emergency pulse flow augmentation. As a complete historical record was not available, a long-term daily flow data set was developed based upon available flow records and adjusted for operational considerations (e.g., current biological opinions, historic Copco Dam operations) and climate change.

Development of Hydrology Used in Determining Augmentation Quantities Including Klamath Climate Change

Flow in the lower Klamath River is largely influenced by contributions from both the Klamath and Trinity Rivers. Identified flow records considered in this analysis are shown in Figure 2-2 and the temporal availability of these flow records is provided in Table 2-2.

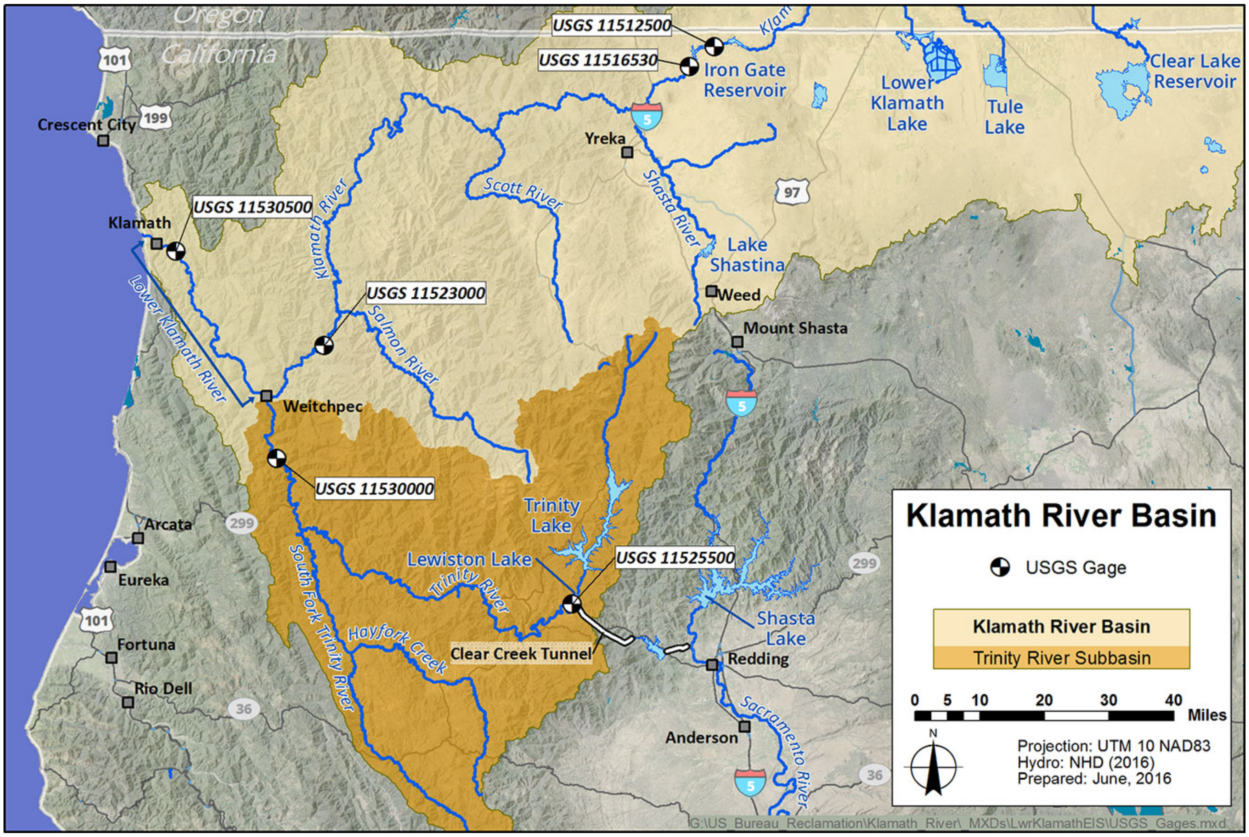


Figure 2-2. USGS Gages Utilized in Developing the Long-term Daily Hydrology for the Klamath River at Klamath, California

Table 2-2. USGS Gages Utilized in Developing the Long-term Daily Hydrology for the Klamath River at Klamath, California

Gage	Time Periods
USGS # 11530500 KLAMATH R NR KLAMATH CA	1911-1926, 1951-1995, 1998-2015
USGS # 11523000 KLAMATH R A ORLEANS	1928-2015
USGS # 11516530 KLAMATH R BL IRON GATE DAM	1960-2015
USGS # 11512500 KLAMATH R BL FALL C NR COPCO CA	1923-1961
USGS # 11530000 TRINITY R A HOOPA CA	1932-2015
USGS # 11525500 TRINITY R A LEWISTON CA	1911-2015

After review of historical flow data from these flow gages, as well as other flow gages in the Klamath and Trinity River basins, the period of analysis was reduced to August, September, and October to focus on the period when augmentation is expected to occur (i.e., when operations at Trinity Reservoir and releases at Lewiston Dam would be modified). The assumptions and process of developing the hydrology used in determining augmentation are described below.

Development and Application of Filter for Copco Hydropower Operations After 1961, Iron Gate Dam regulated hydropower discharges into the Klamath River. Prior to 1961, lower Klamath River flows were influenced by Copco Dam hydropower operations when Copco powerhouse was taken off line for maintenance, generally on a weekly basis. This maintenance activity manifested itself in the hydrologic signal as a one to three day marked decrease in flow. These deviations, from an otherwise generally stable flow condition, were removed by a forward looking algorithm that used either one, two, or three days of flow data, and then averaged flows before and after this short duration decrease. The original USGS data and the filtered daily time series for 1951 for the Klamath River at Orleans are shown in Figure 2-3. The hydropower operations are clearly apparent at approximately weekly intervals, and the filtered time series effectively represents the seasonal flow conditions. Similar conditions also existed for the Klamath River at Klamath.

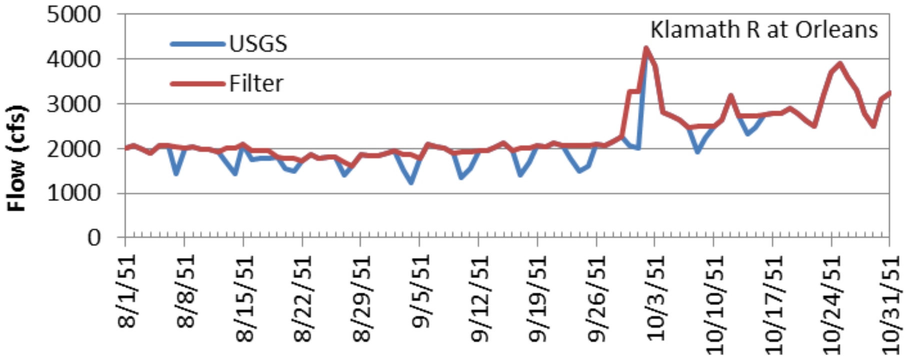


Figure 2-3. USGS Data and Filtered Time Series for Flow in the Klamath River at Orleans, 8/1/1951 to 10/31/1951

Filtered flows were limited to those below 3,000 cubic feet per second (cfs) for the Klamath River at Klamath gage and below 2,500 cfs for the Klamath River at Orleans gage. These targeted flows are of similar magnitude to the preventive base flow augmentation rate of 2,800 cfs, and minimized the filtering of flows due to rainfall-runoff events. Further, only decreases in one, two or three day flows greater than 400 cfs for the Klamath River at Klamath gage and greater than 200 cfs for the Klamath River at Orleans gage were filtered. These values were arrived at through a trial and error approach in order to filter out the maximum number of hydropower operations from the original USGS signal.

This filtering process resulted in overall increased flow in the system (represented by the area below the filtered time series (red line) and above the original USGS data (blue line) in Figure 2-2). To effectively conserve mass, the difference between the two time series was calculated on a daily basis and averaged over the August 1 to October 31 period, then subtracted from each daily value (see Figure 2-4).

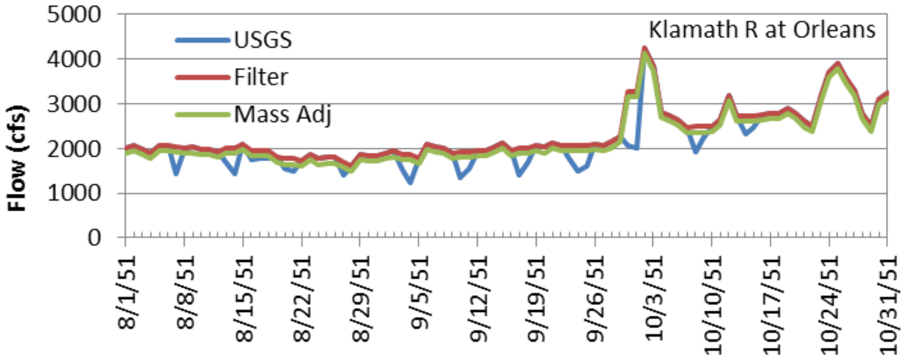


Figure 2-4. USGS data, Filtered Time Series, and Mass Adjusted Filtered Time Series for Flow in the Klamath River at Orleans, 8/1/1951 to 10/31/1951

These filtered data were subsequently used to:

a) Smooth USGS measured flows for the Klamath River at Klamath gage from 1922 to 1926, and from 1950 to 1961 – periods when data were available for this gage.

b) Develop regression equations to extend the record for the Klamath River at Klamath gage for periods where data were unavailable (1928 to 1950 and 1996 to 1997).

After 1961, Klamath River at Klamath gage flows were used directly, except for the periods noted above.

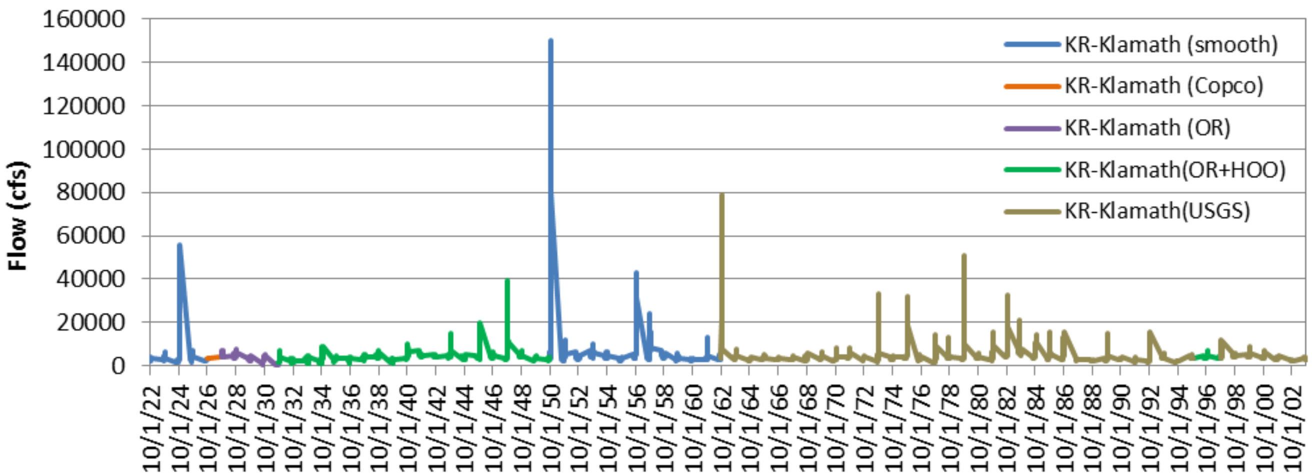
Development of Daily Flow Data for Missing Periods of Record Based on Statistical Relationships As identified in Table 2-2, historic daily flow data were available in the identified analysis period (i.e., 1922 to 2003) for the Klamath River at Klamath, California from 1922 to 1926, 1951 to 1995, and 1998 to 2003. Missing periods included 1927 to 1950, and 1996 to 1997. Regressions developed using available records from the Klamath River at Orleans and the Trinity River at Hoopa gages were utilized to develop all unavailable data except 1927 (which was developed using a relationship with flow data from the Klamath River below Fall

Creek near Copco) (Reclamation 2016a). Constraining the analysis to the three month period of August – October reduces the range of potential flows experienced during the winter and spring months when flows varied dramatically, ultimately yielding improved regression models. The data used in the development of the complete hydrology utilized for developing augmentation flows is presented in Table 2-3, as well as graphically in Figure 2-5.

Table 2-3. USGS Gages Used in Developing the Long-term Daily Hydrology for the Klamath River at Klamath, California

Period	Data Source	Notes
1922 – 1926	Klamath River at Klamath	Corrected for Copco hydropower signal
1927	Function of Klamath River below Fall Creek near Copco	
1928 – 1931	Function of Klamath River at Orleans	
1932 – 1950	Function of Klamath River at Orleans and Trinity River at Hoopa	
1951 – 1961	Klamath River at Klamath	Corrected for Copco hydropower signal
1962 – 1996	Klamath River at Klamath	
1997	Function of Klamath River at Orleans and Trinity River at Hoopa	
1998 – 2003	Klamath River at Klamath	

Key:
USGS = U.S. Geological Service



Key:
BO = Biological Opinion
cfs = cubic feet per second
KR-Klamath = Flow at Klamath River at Klamath (cfs)
ROD = Record of Decision

Figure 2-5. Derived Daily Time Series of Flows at Klamath River at Klamath (Without Adjustments for the Trinity River ROD, Klamath Project BO, and climate change): August to October Flows for 1922 to 2003

Modification of Long-Term Flow Data to Account for Trinity River Record of Decision and Klamath Project Biological Opinion Following development of the daily time series, additional modifications were required to reflect current operational requirements for Trinity River Division of the CVP and the Klamath Project. Specifically, minimum flow requirements identified in the Trinity River Record of Decision (ROD) and Klamath Project Biological Opinion (BO) – those flows that would have occurred if these operations had been in place for the 1922 to 2003 period – were incorporated.

Modification for Trinity River ROD Trinity River ROD minimum flow requirements were accommodated by comparing the historical daily flows in the Trinity River at Lewiston (USGS gage 11525500; uninterrupted record available from 1922 to 2003) with specified release requirements. The Trinity River ROD requires minimum releases from Lewiston Reservoir of 450 cfs in August and September and 300 cfs in October. When historical flows below Lewiston Dam were larger or smaller than these ROD flows, an adjustment was made to the developed flow at Klamath River at Klamath corresponding to the aforementioned difference between daily historical Lewiston release and the Trinity ROD requirement. If applicable, daily adjustments for the Klamath River at Klamath were offset by two days to account for travel time between Lewiston Dam and the Klamath gage. For example, if historical release from Lewiston Dam on September 7 was 400 cfs, developed flow at Klamath River at Klamath was adjusted up by 50 cfs on September 9. Trinity Reservoir storage was presumed to be sufficiently large to meet either increased releases (if historic flows were less than the specified Trinity River ROD flow) as well as accommodate increased storage (if flows are greater than the specified Trinity River ROD flows).

Modification for Klamath Project BO Klamath Project BO minimum flow requirements were assessed at Iron Gate Dam in a manner similar to the Trinity River ROD minimum flow requirements at Lewiston Dam. The Klamath Project BO requires minimum flows below Iron Gate Dam of 900 cfs in August and 1,000 cfs September. In this analysis, when historical flows were lower than these required minimums below Iron Gage Dam, an adjustment was made to the developed flow at Klamath River at Klamath corresponding to the aforementioned difference between daily historical flows below Iron Gate Dam and the Klamath Project BO requirements. For example, if historical flow below Iron Gate Dam was 750 cfs on August 1, developed flows at Klamath River at Klamath were adjusted up by 150 cfs. When historical flows below Iron Gate Dam were greater than the Klamath Project BO flow requirements, no action was taken (i.e., flows were not reduced and assumed to not be stored in mainstem reservoirs). This assumption was made because mainstem Klamath storage is limited, unlike storage availability in Trinity Reservoir on the Trinity River during this time of year (e.g., late summer/early fall).

A key consideration for Iron Gate Dam is the lack of a continuous flow record. For the period 10/1/1960 to 9/30/2003, the USGS gage for the Klamath River below Iron Gate Dam (USGS gage 11516530) was used to adjust flows to accommodate the Klamath Project BO minimum flow requirements. Due to limited relevant available data, Klamath River at Orleans gage data (USGS gage 11523000) were used to adjust flows to accommodate Klamath Project BO minimum flow requirements for the period of 10/1/1927 to 9/30/1960. For the period of 10/1/1922 to 9/30/1927, no relevant flow records were available and no adjustments were made.

Modification of Long-Term Flow Data to Account for Climate Change To adjust the daily flow data to reflect potential climate change, results of two Reclamation studies were considered, including climate change studies in support of the Secretarial Determination for Klamath Dam Removal and the on-going Klamath Basin Study. The Klamath Dam Removal climate change scenarios reflect a future time horizon of 2045 (2020-2069) (see Reclamation 2011). Five specific climate scenarios were selected based on their proximity to the vertices of the 25th, 50th, and 75th quartiles of the empirical distributions of precipitation and temperature. Klamath Basin Study climate change scenarios reflect a future time horizon of the 2030's (2020-2049). Central tendency scenarios were developed using a hybrid ensemble delta method, selecting 10 GCM projections as ensemble members that are closest to the intersections of the 50th percentile values of projected change in annual precipitation and temperature. Scenarios developed from both CMIP3 and Coupled Model Intercomparison Project Phase 5 (CMIP5) data sets have been examined for this analysis.

To develop daily flow time series for each climate change scenario, the following process was used:

- Calculated monthly regressions for perturbed flow as a function of historical or current condition flow for both Klamath Dam Removal (5 scenarios) and Klamath Basin Study (2 scenarios) climate change results.
- Calculated monthly average flows for the derived daily time series at Klamath River at Klamath gage.
- Applied the regressions to the derived time series' monthly flows to derive climate-perturbed monthly flow.
- Disaggregated the perturbed monthly flows reflecting climate change back to daily flows through application of the daily pattern in the historical trace.

It is acknowledged that this methodology lacks the additional step of adjusting by an annual perturbation factor. This was not possible, as the derived daily time series data were developed solely to address augmentation needs in August, September and October.

Table 2-4 presents estimated preventive base flow augmentation requirements for the derived daily time series, two climate change scenarios from the Klamath Dam Removal studies, and two climate change scenarios from the on-going Klamath Basin Study. In addition, for comparative purposes, Table 2-4 also includes estimated preventive base flow augmentation requirements for the time period of 2002 to 2015, based on historical flows adjusted for actual flow augmentation and Trinity River ROD and Klamath BO minimum flow requirements.

Table 2-4. Summary of Preventive Base Flow Augmentation Requirements for Derived Daily Time Series and Climate Change Scenarios

Description	Derived Daily Time Series	KDR 37	KDR 24	KBS CT3	KBS CT5	2002-2015 Historical Data Corrected for Actual Augmentation, Klamath Project BO, and Trinity River ROD
Climate Change Timeframe	No climate change	2045	2045	2030's	2030's	No climate change
Period	1922-2003	1922-2003	1922-2003	1922-2003	1922-2003	2002-2015
# of Years of Flow Augmentation for CalSim Analysis [1]	38	62	69	48	53	-
Average - All Years (acre-feet) [1]	6,158	16,705	24,043	11,026	14,334	14,794
Average - Years with Flow Augmentation (acre-feet) [1]	13,287	22,093	28,573	18,837	22,178	19,232
Percentage of Years with Flow Augmentation [1]	46%	76%	84%	59%	65%	71%

Note:

[1] Based on preventive base flow augmentation criteria of 2,800 cubic feet per second at the Klamath, California gage from August 22 to September 21.

Key:
% = percent
BO = Biological Opinion
KDR = Klamath Dam Removal
KBS = Klamath Basin Study
ROD = Record of Decision

Development of Flow Augmentation Quantities

The action alternatives include three different flow augmentation components: (1) a preventive base-flow release that targets increasing the base flow of the lower Klamath River to 2,800 cfs from mid-August to late September; (2) a preventive pulse flow to be used as a secondary measure to alleviate continued poor environmental conditions and signs of *Ichthyophthirius multifiliis* (Ich) infection in the lower Klamath River; and (3) a contingency volume, to be used on an emergency basis as a tertiary treatment to avoid a significant die-off of adult salmon when the first two components of the Proposed Action are not successful at meeting their intended objectives. Required augmentation was determined by evaluating developed representative daily flows at the Klamath River at Klamath against the 2,800 cfs flow target.

During the base-flow augmentation period of August 22 – September 21, if representative daily flows were less than 2,800 cfs, it was determined that a flow augmentation equal to the difference between the representative daily flow and 2,800 cfs was required (e.g., if representative flow on August 22 was 2,500 cfs, a flow augmentation of 300 cfs was required). A two day travel time from Lewiston to the Klamath River at Klamath was assumed; therefore, if representative flow on August 22 was 2,500 cfs, a flow augmentation of 300 cfs was required on August 20. This analysis was applied to the augmentation period for every water year in the

CalSim II period of analysis. The resulting base-flow augmentation quantities are presented with pulse flow quantities in the "Input to CalSim" section below.

During the preventive pulse flow period, a preventive pulse flow of 5,000 cfs for one day was targeted in the representative daily Klamath River at Klamath flow record. Ramping rates from Trinity River Mainstem Fisheries Restoration EIS (USFWS et al. 2000) were targeted to develop the preventive pulse flow requirements. If daily representative Klamath River at Klamath flows were less than the preventative pulse flow or required ramping up/down rates, it was determined that a preventive pulse flow augmentation equal to the difference between the representative daily flow and the pulse flow or ramping up/down rate requirements was required (e.g., if representative flow on the day of the targeted preventative pulse flow was 2,500 cfs, a preventative pulse flow augmentation of 2,500 cfs was required). A two day travel time from Lewiston to the Klamath River at Klamath was assumed for releasing flows to meet pulse flow requirements.

During the emergency pulse flow period, an emergency pulse flow of 5,000 cfs for five days was targeted in the representative daily Klamath River at Klamath flow record. Ramping rates from Trinity River Mainstem Fisheries Restoration EIS (USFWS et al. 2000) were also targeted in meeting the emergency pulse flow requirements. If daily representative Klamath River at Klamath flows were less than the emergency pulse flow or required ramping up/down rates, it was determined that an emergency pulse flow augmentation equal to the difference between the representative daily flow and the pulse flow or ramping up/down rate requirements was required (e.g., if representative flow on the day of the targeted emergency pulse flow was 2,500 cfs, an emergency pulse flow augmentation of 2,500 cfs was required). A two day travel time from Lewiston to the Klamath River at Klamath was assumed for releasing flows to meet pulse flow requirements.

Frequency and Timing of Pulse Flow Quantities

Implementing pulse flow analyses into CalSim II modeling required a means of determining the impacts of using different water sources for flow augmentation actions as described for each alternative. In order to do these assessments, there is a need to define the frequency of implementing the preventive pulse and emergency flow components of the action alternatives.

Period of Frequency Analysis The potential frequency-of-occurrence of the preventive pulse and emergency components were derived from review of the years in which augmentation actions occurred since the year of the die-off (Reclamation 2016b). As such, the analysis looks at a total of 14 years (i.e., 2002 to 2015) and characterizes the actions actually taken, as well as retroactively looks at the actions that could have been taken given the criteria upon which these two components of the action alternatives are based. For purposes of the analysis, it is assumed that 2002 would have been a year in which all three components (i.e., preventive base, preventive pulse flow, and emergency flows) would have been implemented. While it is unknown how implementation of these components would have influenced the outcome of that year, they were included in this review because of the extreme environmental conditions that came together to cause the unprecedented adult salmon die-off in that year.

Preventive Pulse Flow Frequency Determination The preventive pulse flow was determined to only be implemented in a subset of the years when the preventive base flow was implemented.

In addition, it was recognized that that there would not likely be a need for this pulse flow in every year that a base flow augmentation occurred because the criteria for implementing a preventive pulse flow would not have been met in every year. It appears appropriate to anticipate that in some flow augmentation years the preventive base flow would be adequate to thwart the need for this secondary response action. With this in mind, existing Ich monitoring results for the lower Klamath River (Yurok Tribe Ich monitoring data) were examined for each year that a flow augmentation release occurred (i.e., 2003, 2004, 2012 – 2015) and for three additional years that would have met the primary base flow action criteria (2007, 2008, and 2009; see Table 2-5). Using this approach, three years (i.e., 2003, 2014, and 2015) were identified when a preventive pulse flow would likely have been implemented because the threshold for low level infection and other criteria are anticipated to have been met. When including 2002 as a year that a preventive pulse would likely have been needed, 4 of 10 years (i.e., 40 percent of the time there is a preventive base flow augmentation) would have required a preventive pulse flow (See Table 2-6 in the section below).

Table 2-5. Ich Monitoring Results for Years When Flow Augmentation Actions Occurred (or Would Have Occurred Under the Action Alternatives)

Augmentation Year	Ich Counts[d]	Preventive Pulse Triggered (Y/N)	Data Source
2002[a]	Likely	Y	Guillen (2003); DFG (2003); YTFP (2004)
2003	Counts > 50 observed; weekly average as high as 24/gill arch	Y	Foott (2003)
2004[b]	0[b]	N	YTFP (2005)
2007	0	N	YTFP (2008)
2008	0	N	YTFP (2009)
2009	0	N	YTFP (2010)
2012	0	N	YTFP (2013)
2013	0	N	YTFP (2014)
2014	Counts > 600 observed	Y	YTFP (2015)
2015[c]	Average counts > 20 week of Aug 17. Max counts > 600	Y	YTFP (In progress); CDFW 2016
Events		4	
Sample size		10	
Frequency (%)		40	

Notes:

[a] assumption made that Ich counts would have met the criterion

[b] 2004 monitoring mentioned in a Yurok Tribe report on 2005 monitoring, but full 2004 results not reported.

[c] the first year that a preventive pulse flow was formally implemented

[d] Counts are qualified by criteria as defined by Reclamation (2015b), where low level infection (less than 30 Ich trophonts per gill arch) occur in the first two weeks of September on three adult salmon in one day.

Key: % = percent
CDFW = California Department of Fish and Wildlife (formerly California Department of Fish and Game)
DFG = California Department of Fish and Game
YTFP = Yurok Tribe Fisheries Program

Emergency Pulse Flow Frequency Determination The emergency flow was determined to only be implemented in years when the preventive pulse flow was implemented. Again, the same logic was used (as for the preventive pulse flow); that is, a successive level of treatment would be implemented only if the prior treatment is used and not successful. Using this logic, the emergency pulse flow was anticipated to be used when the preventative pulse flow was not effective. To determine the frequency of need, the years when emergency releases were used (i.e., 2014) were considered. 2002 was also chosen, due to the assumption that the large adult salmon die-off would have necessitated emergency pulse flow releases. Using this information, 2 of 10 years (i.e., 20 percent of the time there is a preventive pulse flow) would have required an emergency pulse flow release (see Table 2-6).

Table 2-6. Actual and Projected Occurrence of Preventive Pulse and Emergency Flow Actions Based on Prior Flow Augmentation Years (2003, 2004 and 2012 – 2015)

Augmentation Year	Actual Preventive Pulse Flow (Y/N)	Actual Emergency Pulse Flow (Y/N)	Retroactive Preventive Pulse Flow (Y/N)	Retroactive Emergency Pulse Flow (Y/N)
2002[a]	N	N	Y	Y
2003	Y	N	Y	N
2004	Y	N	N	N
2007	N	N	N	N
2008	N	N	N	N
2009	N	N	N	N
2012	N	N	N	N
2013	N	N	N	N
2014	Y	Y	Y	Y
2015	Y	N	Y	N
Events	4	1	4	2
Sample Size	10	10	10	10
Frequency	**40%**	**10%**	**40%**	**20%**

Note:
[a] Assume criteria for Preventive Pulse Flow and Emergency pulses would have been met in 2002
Key:
% = percent

Input to CalSim

The analysis of need for base flow augmentation resulted in the identification of 53 years of preventive base flow augmentation out of the 82 year period of record (Reclamation 2016c). Based on the above frequency of pulse flows analysis, an estimated 21 years of preventive pulse flows and an estimated 4 years of emergency pulse flow augmentation would occur over the 82 year period of record.

The criteria for implementing preventive pulse flows and emergency pulse flow augmentation actions are based upon observed fish health (i.e., Ich counts). However, analytical tools to predict fish health are not readily available for this analysis. Table 2-7 provides the estimated base flow augmentation volume, based upon the criteria identified for the action alternatives in this EIS, as well as the corresponding estimated occurrences of preventive pulse flows and emergency pulse flow augmentation. As shown in Table 2-7, the years with the largest estimated base flow augmentation generally were associated with years where both preventive pulse flows and emergency pulse flow augmentation occurred. For example, the three years with the largest estimated flow augmentation (i.e., 2014, 2015, and 2002) were also years with identified preventive pulse flows. Similarly, 2014 and 2002 were the only two years with identified emergency pulse flow augmentation and these two years also required the highest and third highest preventive base flow augmentation quantities, respectively.

Table 2-7. Retroactive Augmentation Summary (2002-2015)

Year	**Preventive Base Flow Augmentation[1] (acre-feet)**	**Actual Augmentation Volume (acre-feet)**	**Retroactive – Preventive Pulse Flow[2]**	**Retroactive – Emergency Pulse Flow Augmentation[2]**
2014	42,920	64,000	Yes	Yes
2015	37,313	48,000	Yes	-
2002	34,657	-	Yes	Yes
2009	25,460	-	-	-
2013	21,213	17,500	-	-
2007	11,197	-	-	-
2008	8,025	-	-	-
2004	4,804	36,313	-	-
2012	4,330	39,000	-	-
2003	2,400	38,000	Yes	-
2005	-	-	-	-
2006	-	-	-	-
2010	-	-	-	-
2011	-	-	-	-

Notes:

[1] Based on historical flow data (excluding climate change) at Klamath, California with preventive base flow criteria of 2,800 cubic feet per second from August 22 through September 21.

[2] Based on findings from Frequency of Action Analysis: Preventive Pulse and Emergency Flows Technical Memorandum (Reclamation 2016c).

For the purposes of CalSim modeling and based on the findings in Table 2-6, preventive pulse flows were assumed to occur in the 21 years with the 21 highest preventive base flow augmentation quantities. Similarly, emergency pulse flow augmentation was assumed to occur in the four years with the four highest preventative base flow augmentation quantities. These assumptions and quantities are summarized in Table 2-8, Table 2-9, and Figure 2-6.

Table 2-8. Summary of Preventative Base Flow Augmentation, Preventive Pulse Flow and Emergency Pulse Flow Augmentation Volume by Water Year

Water Year	**Preventive Base Flow Augmentation (acre – feet)**	**Preventive Pulse Flow Augmentation (acre-feet)**	**Emergency Pulse Flow Augmentation (acre-feet)**	**Total Augmentation (acre-feet)**
1922	25,860	7,271	-	33,131
1923	6,555	-	-	6,555
1924	26,161	7,271	-	33,432
1925	22,487	-	-	22,487
1926	27,369	7,271	-	34,640
1927	-	-	-	-
1928	-	-	-	-
1929	-	-	-	-
1930	31,775	4,990	-	36,765
1931	91,693	7,271	45,419	144,383
1932	42,359	7,271	-	49,630
1933	6,209	-	-	6,209
1934	42,658	7,271	-	49,929
1935	12,020	-	-	12,020
1936	5,816	-	-	5,816
1937	1,863	-	-	1,863
1938	-	-	-	-
1939	17,538	-	-	17,538
1940	-	-	-	-
1941	-	-	-	-
1942	-	-	-	-
1943	-	-	-	-
1944	-	-	-	-
1945	-	-	-	-
1946	-	-	-	-
1947	-	-	-	-
1948	-	-	-	-
1949	14,293	-	-	14,293
1950	2,919	-	-	2,919
1951	27,315	7,271	-	34,586
1952	-	-	-	-
1953	-	-	-	-
1954	-	-	-	-
1955	11,124	-	-	11,124
1956	-	-	-	-
1957	-	-	-	-
1958	-	-	-	-
1959	76	-	-	76
1960	13,666	-	-	13,666
1961	316	-	-	316
1962	5,660	-	-	5,660
1963	7,354	-	-	7,354
1964	30,283	7,271	-	37,554
1965	242	-	-	242
1966	21,814	-	-	21,814
1967	20,408	-	-	20,408
1968	22,496	-	-	22,496
1969	15,207	-	-	15,207

Table 2-8. Summary of Preventative Base Flow Augmentation, Preventive Pulse Flow and Emergency Pulse Flow Augmentation Volume by Water Year (contd.)

Year	Preventive Base Flow Augmentation (acre – feet)	Preventive Pulse Flow Augmentation (acre-feet)	Emergency Pulse Flow Augmentation (acre-feet)	Total Augmentation (acre-feet)
1970	27,736	7,271	-	35,007
1971	-	-	-	-
1972	7,436	-	-	7,436
1973	43,275	7,271	-	50,546
1974	7,886	-	-	7,886
1975	-	-	-	-
1976	2,911	-	-	2,911
1977	60,288	7,271	25,727	93,286
1978	-	-	-	-
1979	16	-	-	16
1980	-	-	-	-
1981	29,756	7,271	-	37,027
1982	-	-	-	-
1983	-	-	-	-
1984	-	-	-	-
1985	938	-	-	938
1986	9,354	-	-	9,354
1987	38,837	7,271	-	46,108
1988	50,965	7,271	-	58,236
1989	28,857	7,271	-	36,129
1990	17,611	-	-	17,611
1991	50,284	7,271	-	57,555
1992	51,790	7,271	-	59,061
1993	-	-	-	-
1994	67,787	7,271	39,378	114,437
1995	817	-	-	817
1996	216	-	-	216
1997	1,041	-	-	1,041
1998	-	-	-	-
1999	-	-	-	-
2000	31	-	-	31
2001	42,733	7,271	-	50,004
2002	56,811	7,271	39,034	103,116
2003	24,508	-	-	24,508

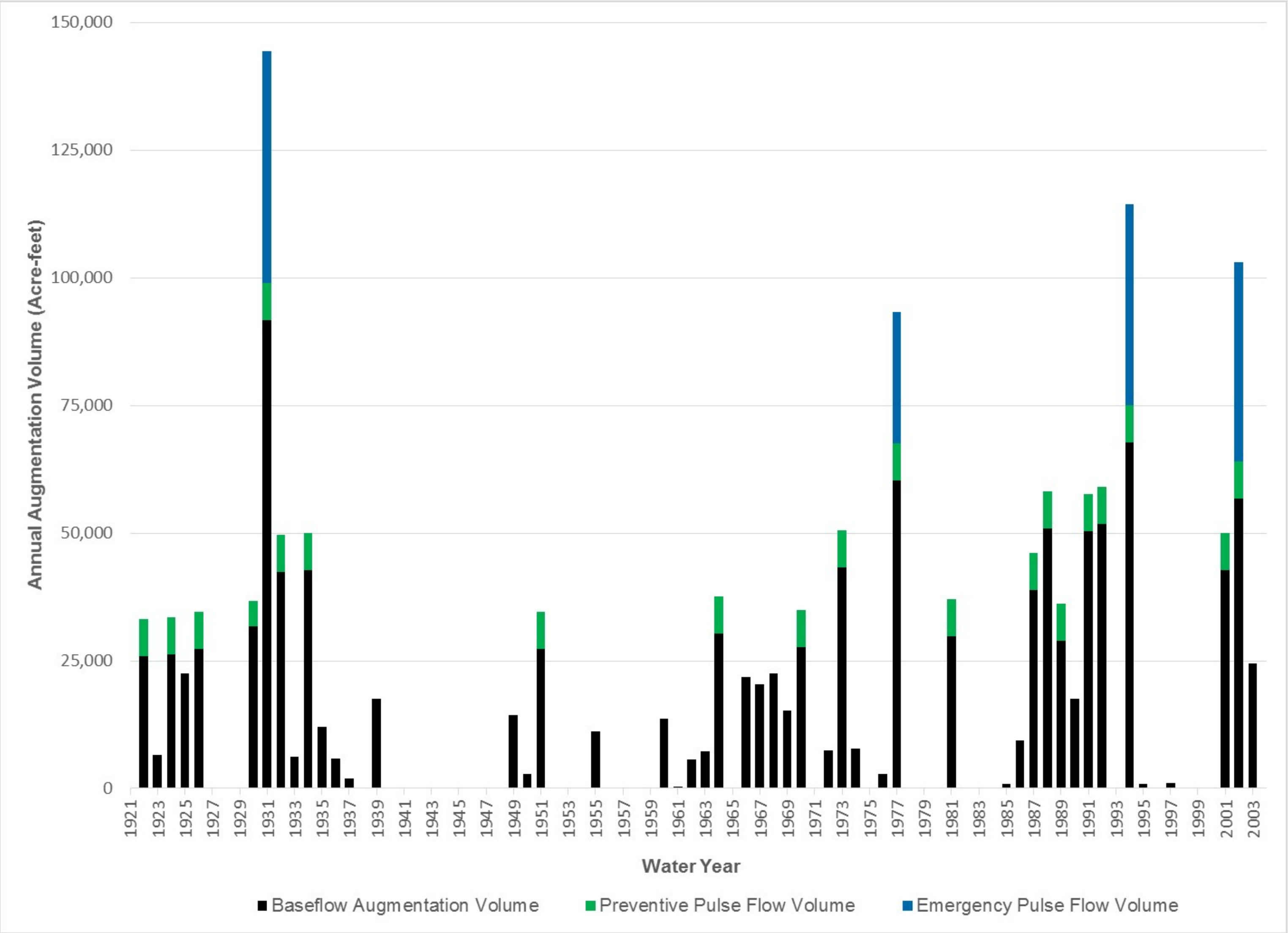


Figure 2-6. Estimated Flow Augmentation Volumes of Action Alternatives for the CalSim Period of Analysis

Table 2-9. Preventative Base Flow Augmentation for the 1922-2003 Period by Hydrologic Year Type

Critically Dry		**Dry**		**Normal**		**Wet**		**Extremely Wet**	
Year	**Preventive Base Flow Augmentation (acre-feet)**	**Year**	**Preventive Base Flow Augmentation (acre-feet)**	**Year**	**Preventive Base Flow Augmentation (acre-feet)**	**Year**	**Preventive Base Flow Augmentation (acre-feet)**	**Year**	**Preventive Base Flow Augmentation (acre-feet)**
1931	91,693	1992	51,790	2002	56,811	1973	43,275	2003	24,508
1994	67,787	1988	50,965	1989	28,857	1970	27,736	1969	15,207
1977	60,288	2001	42,733	1968	22,496	1951	27,315	1974	7,886
1991	50,284	1932	42,359	1966	21,814	1925	22,487	1995	817
1934	42,658	1987	38,837	1949	14,293	1967	20,408	1927	-
1924	26,161	1930	31,775	1960	13,666	1986	9,354	1938	-
1939	17,538	1964	30,283	1972	7,436	1963	7,354	1941	-
1923	6,555	1981	29,756	1936	5,816	1997	1,041	1942	-
1976	2,911	1926	27,369	1962	5,660	1965	242	1952	-
1929	-	1922	25,860	1937	1,863	1996	216	1956	-
1944	-	1990	17,611	1961	316	2000	31	1958	-
		1935	12,020	1959	76	1940	-	1978	-
		1955	11,124	1928	-	1946	-	1982	-
		1933	6,209	1943	-	1953	-	1983	-
		1950	2,919	1945	-	1954	-	1998	-
		1985	938	1948	-	1971	-		
		1979	16	1957	-	1975	-		
		1947	-			1980	-		
						1984	-		
						1993	-		
						1999	-		
# of Years	**Average Augmentation**	**# of Years**	**Average Augmentation**	**# of Years**	**Average Augmentation**	**# of Years**	**Average Augmentation**	**# of Years**	**Average Augmentation**
11	**33,261**	**18**	**23,476**	**17**	**10,536**	**21**	**7,593**	**15**	**3,228**

CalSim II Outputs

The hydrology and system operations models produce the following key parameters on a monthly time step:

- River flows and diversions
- Reservoir storage
- Delta flows and exports

- Delta inflow and outflow
- Deliveries to project and non-project users

Appropriate Use of CalSim II Results

CalSim II is a monthly model developed for planning level analyses. The model is run for an 82-year historical hydrologic period, at a projected level of hydrology and demands, and under an assumed framework of regulations. Therefore, the 82-year simulation does not provide information about historical conditions, but it does provide information about variability of conditions that would occur at the assumed level of hydrology and demand with the assumed operations, under the same historical hydrologic sequence. Because it is not a physically based model, CalSim II is not calibrated and cannot be used in a predictive manner. CalSim II is intended to be used in a comparative manner, which is appropriate for a NEPA analysis.

In CalSim II, operational decisions are made on a monthly basis, based on a set of predefined rules that represent the assumed regulations. The model has no capability to adjust these rules based on a sequence of hydrologic events such as a prolonged drought, or based on statistical performance criteria such as meeting a storage target in an assumed percentage of years.

Appropriate use of model results is important. Despite detailed model inputs and assumptions, the CalSim II results may differ from real-time operations under stressed water supply conditions. Such model results occur due to the inability of the model to make real-time policy decisions under extreme circumstances, as the actual (human) operators must do. Therefore, these results should only be considered an indicator of stressed water supply conditions under that alternative, and should not be considered to reflect what would occur in the future. For example, reductions to senior water rights holders due to dead-pool conditions in the model can be observed in model results under certain circumstances. These reductions, in real-time operations, may be avoided by making operational decisions on other requirements in prior months. In actual future operations, as has always been the case in the past, the project operators would work in real time to satisfy legal and contractual obligations given the current conditions and hydrologic constraints. Chapter 4, “Surface Water Resources and Water Supplies”, provides appropriate interpretation and analysis of such model results.

Reclamation’s 2008 LTO BA Appendix W (Reclamation 2008b) included a comprehensive sensitivity and uncertainty analysis of CalSim II results relative to the uncertainty in the inputs. The appendix provides a good summary of the key inputs that are critical to the largest changes in several operational outputs. Understanding the findings from the appendix may help in better understanding the alternatives.

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Chapter 3
Reservoir and River Temperature Modeling

The Trinity-Sacramento River HEC-5Q Water Quality Model was selected to simulate the water temperature in the Trinity Lake – Lewiston Reservoir section of the Trinity River and in the Sacramento River Basin.

Trinity-Sacramento River HEC-5Q Water Quality Model

The Trinity-Sacramento River HEC-5Q Water Quality Model is a HEC-5Q-based (one-dimensional) reservoir and river water quality and temperature model of the Trinity Upper Sacramento River system including Trinity Dam and Reservoir, Trinity River to Lewiston Reservoir, Lewiston Dam and Reservoir, Clear Creek Tunnel, Whiskeytown Dam and Reservoir, Clear Creek below Whiskeytown Dam, Spring Creek Tunnel, Shasta Dam and Reservoir, Keswick Dam and Reservoir, Sacramento River from Keswick to Knights Landing, Red Bluff Diversion Dam, Black Butte Dam, and downstream Stony Creek. The Trinity-Sacramento River HEC-5Q model was developed using integrated HEC-5 and HEC-5Q models. The HEC-5 component of the model simulates reservoir and river flow operations (usually daily). The HEC-5Q component is a 1-dimensional (1-D) water quality model that simulates reservoir and river temperatures and other water quality parameters based on the flow inputs and meteorological parameters. The model operates on a 6-hour time step to capture diurnal temperature fluctuations.

Application of Trinity-Sacramento River HEC-5Q Model to Evaluate EIS Alternatives

The version of this model used in the *Coordinated Long-Term Operation of the Central Valley Project and State Water Project (LTO) EIS* (Reclamation 2015) was obtained from Reclamation. This version of the model included recent updates, calibration and verification, and modified meteorological and equilibrium temperature data to incorporate the 2030 level of climate change required for this analysis, as described in the LTO EIS (Reclamation 2015). The model is set up to simulate the full CalSim II model 82-year simulation period (water years 1922 through 2003) on a 6-hour time step using daily flow data which includes a utility to disaggregate the mean monthly CalSim II reservoir operations and stream flows to daily values for use in the simulation. The 6-hour time step allows for analysis of diurnal temperature fluctuations required for the fishery analysis.

Modeling Assumptions

For each alternative, reservoir operations and resulting stream flows were disaggregated from the CalSim II monthly values to daily values using a utility program developed specifically for this purpose and included with the version of the model obtained from Reclamation. Each daily value was assumed equal to the mean monthly value for consistency with the Reclamation's 2015 LTO EIS.

The daily augmentation flows (Alternatives 1 and 2)and the modified Trinity ROD flows (Alternative 2 only) were averaged and converted to a mean monthly flow for use in the CalSim II simulation modeling as the required releases from Lewiston to the Trinity River. For the temperature modeling, the final CalSim II mean monthly release from Lewiston were disaggregated to daily flows using the daily augmentation pattern used to generate the mean monthly release requirement. These new daily flows were then used to replace the uniform daily flows at this location generated by the utility program.

Klamath and Trinity Rivers RBM10

River Basin Model 10 (RBM10) is a 1-D water temperature model based on a heat budget formulation to predict daily water temperatures along the longitudinal profile of a river (Yearsley et al. 2001, Yearsley 2009). The existing RBM10 models were used to simulate daily flows and water temperature in the Trinity River and the Klamath River. Both models used in the temperature modeling studies of Trinity River (Jones et al. 2016) and Klamath River (Perry et al. 2011) are calibrated and well documented.

The model utilizes a mixed Eularian-Lagrangian numerical scheme to assess flow and water temperature (Jones et al. 2016). Flow is a steady flow representation where inflows and outflows are represented through simple mass balance. Water temperature is solved using a Lagrangian frame of reference solving a simplified form of the advection-diffusion equation where diffusion is neglected:

$$\frac{dT}{dt} = \frac{1}{\rho C_p A_x}\left(W_x H_{\text{air-water}} + S_{\text{adv}}\right)$$

Where:

T = water temperature

t = time

r = water density

C_p = specific heat of water

A_x = stream cross sectional area at location x

$H_{\text{air-water}}$ = net heat flux at the air water interface

S_{adv} = heat contribution from tributary inflows

The river is represented by discrete segments, where each segment includes channel form information (e.g., stage-flow, velocity-flow, width-flow and cross sectional area-flow relationships). A heat budget formulation, represented by $H_{\text{air-water}}$ requires daily average meteorological data. Boundary conditions for flow and water temperature at the headwater and tributary locations are required. Specific details of the Trinity River and Klamath River RBM10 models are provided in Jones et al (2016) and Perry et al (2011), respectively.

Application of RBM10 to Evaluate EIS Alternatives

The Klamath River and the Trinity River models above were acquired from the USGS. These original models were based on “historic” conditions using field flow, temperature, and meteorological data. Simulations for all alternatives were performed for the period between 01/01/1980 and 09/30/2003 to overlap the CalSim II data set used in much of the EIS. The RBM10 models were run in series, with the Trinity River applied first to calculate flow and temperature conditions at the confluence with the Klamath River. Subsequently, these flows and temperature were used to represent the Trinity River inflows to the Klamath River RBM-10 model. The Klamath River RBM10 model starts at Link River Dam near Klamath Falls and extends to the Klamath River estuary.

While the majority of the model was unchanged, several model modifications were completed to align the modeling assumptions with the purpose of this project. Modification and refinements included adjusting meteorological terms to incorporate assumed climate change condition in the project area, calculating tributary inflow temperatures for both the Klamath and Trinity Rivers to reflect climate change, updating the Bowen Ratio factor calculation, and refining the accretion depletion term in the Trinity River flow model.

Meteorological Data

Climate change was incorporated into each simulation, creating an equal meteorological data set for each. Air temperature was increased 1.8 degree Fahrenheit (ºF) (1 ºC) for consistency with the LTO EIS (Reclamation 2015). Climate change impacts on hydrology were included in the simulated flows at Lewiston Dam through the Trinity-Sacramento River HEC-5Q Water Quality Model and CalSim II modeling. For the Trinity River and Klamath River RBM-10 models, meteorological conditions were modified by increasing air temperature 1.8ºF (1ºC). In addition to the air temperature increase, two terms in meteorological input files, i.e., vapor pressure term and factor for Bowen Ratio term were updated accordingly.

Equations 1 through 4 were used to predict future vapor pressure (Snyder and Shaw 1984):

$$\mathrm{e_s} = 6.108\exp\left[\frac{17.27\mathrm{T}}{\mathrm{T}+237.3}\right] \tag{1}$$

$$\mathrm{e} = \frac{\mathrm{RH}\times \mathrm{e_s}}{100} \tag{2}$$

$$\mathrm{D} = 237.3\mathrm{B}/(1-\mathrm{B}) \tag{3}$$

$$\text{where } \mathrm{B} = \ln(\mathrm{e}/6.108)/17.27 \tag{4}$$

$\mathrm{e_s}$: saturation vapor pressure (mb)

T: dry-bulb (air) temperature (ºC)

e: vapor pressure (mb)

RH: relative humidity (%)

D: dewpoint temperature (ºC)

It should be noted that there is no relative humidity input in the models' meteorological input file(s). For the current conditions, relative humidity values were calculated by using air temperature and vapor pressure inputs and the equations listed above. Climate change adjusted vapor pressure was calculated assuming relative humidity remains the same in the future.

To predict the future factor for Bowen Ratio, equations 5 and 6 were used.

$$\mathrm{R_B} = (\mathrm{c_a}\,\mathrm{P})/0.622 \cdot \lambda \tag{5}$$

where $\mathrm{c_a}$: heat capacity of air (cal/g/ ^{o}C), 0.24

P: pressure at the meteorological station (mb)

λ: latent heat of vaporization (cal/g)

$$\lambda = 597.3 - (0.564 \cdot \mathrm{T}) \tag{6}$$

T: air temperature (^{o}C)

With the previously mentioned increase in air temperature, predictions of vapor pressure and factor for Bowen Ratio terms (i.e., the terms/meteorological inputs which are a function of air temperature) were adjusted for the effects of climate change. These climate change adjusted values were applied to the meteorological data for both the Klamath and Trinity River RBM10 models in each of the three alternatives.

Tributary Water Temperature

In addition to the predictions in meteorological conditions which are mentioned above, the tributary water temperatures were adjusted for climate change by updating the Mohseni relationships (Mohseni et al. 1998), originally developed by Jones (Jones et al. 2016) for the Trinity River and Perry (Perry et al. 2011) for the Klamath River by accounting for an increase in air temperature of 1.8^{o}F (1^{o}C). No change in volume or timing associated with climate change was incorporated into the tributary flow rates.

The documented Mohseni equation in the USGS study (Jones et al. 2016) was updated to represent the current USGS assumed equation to estimate the temperatures for the Trinity River tributaries for the historic conditions run/scenario and the alternatives. The Mohseni equation (Mohseni et al. 1998) takes the form,

$$\mathrm{T_s} = \mu + \frac{\alpha-\mu}{1+e^{\gamma(\beta-T_a)}} \tag{1}$$

where $\mathrm{T_s}$: weekly mean water temperature (°C)

μ: minimum water temperature (°C)

α: maximum water temperature (°C)

β: water temperature at the point of inflection (°C)

γ: slope at the inflection point (°C)

T_a: weekly mean air temperature (°C).

The first "μ" term in Eq. (7) (prior to the fraction term) was excluded in the original USGS development of tributary temperatures in the Klamath and Trinity Rivers, and a new form (equation (Eq. 8)), was used to plot the graphs of the air temperature versus water temperature curves for each tributary following Jones et al. (2016).

$$T_s = \frac{\alpha-\mu}{1+e^{\gamma(\beta-T_a)}} \tag{8}$$

This equation was also used to estimate temperatures for the data gaps of the tributaries in the original model, and was used to predict the future water temperatures of the tributaries for all of the alternatives in which the climate change conditions are assumed to exist.

Bowen Ratio Factor

In the original USGS meteorological input files a factor for Bowen Ratio term was erroneously dependent on wind speed rather than air temperature (Eq. 6). This minor error was corrected and had no impact on model results. The updated factor for Bowen ratio terms was used for all of the alternatives in this study.

Trinity River Accretion/Depletion Refinement

In the previous Trinity River study (Jones et al, 2016) daily mean flow rates for tributaries were estimated based on the recorded flow difference between the USGS stream gages "11525500 downstream of Lewiston Dam" and "11530000 at Hoopa, California", and assigned flows based on their drainage basin areas. When simulated Lewiston Dam releases were made for certain alternatives, flow conditions deviated notably from historic conditions. As a result of the original accretion/depletion and subsequent tributary flow assignment approach, negative flow rates for the tributaries were observed during several short periods in the late summer and the early fall when the flow through the reach is low and the flow coming from Lewiston Dam increases and decreases relatively rapidly. To eliminate the negative values, tributary flows were linearly interpolated between the values before and after those short periods during abrupt flow changes. In Figure 3-1, South Fork Trinity River estimated flow rates before and after the update, and the Lewiston Dam release during one of the periods mentioned above are shown.

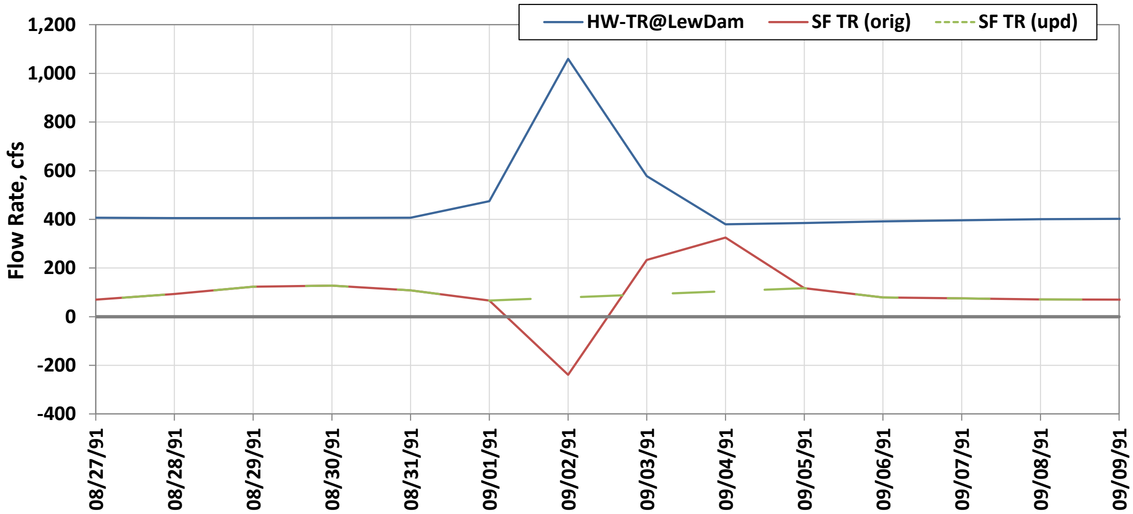


Figure 3-1. Daily mean Flow Rates of Headwater (HW) Boundary at Lewiston Dam, South Fork (SF) Trinity River (TR) Before and After the Update. 08/27/91 – 09/09/91

After the update on tributary flow estimations was completed, the total percentage change in the total volume of the tributaries in the model period was observed to be less than 0.05 percent.

Modeling Assumptions

After completing the model refinements listed above, the model was applied to the three alternatives with flow and temperatures provided from Trinity-Sacramento HEC-5Q Water Quality Model at Lewiston Dam forming the upstream boundary condition in the Trinity River. As noted previously, there were no changes to the upstream boundary condition in the Klamath River. Because the Klamath River RBM10 model starts at Upper Klamath Lake, over 200 miles upstream of the project area, minor changes of climate change in this boundary conditions are assumed negligible. That is, after traversing 200 plus miles of river under climate change meteorology with tributary inflow temperatures updated for climate change, the river was assumed to achieve an equilibrium and small changes in temperature at Upper Klamath Lake would have a minor impact on water temperature in the Klamath River at the confluence with the Trinity River. Any differences associated with this assumption would be identical with all three scenarios because no operational or flow modifications were made in the Klamath River modeling.

For temperatures in the Klamath River below the Trinity River a mass balance was used because there was not a representative model output node at this location. The mass balance:

$T_{DS} = [(Q_{KR})(T_{KR})+(Q_{TR})(T_{TR})]/(Q_{KR}+Q_{TR})$

where

T_{DS} = water temperature in the Klamath River below the confluence with the Trinity River

Q_{KR} = flow in the Klamath River upstream of the Trinity River

T_{KR} = water temperature in the Klamath River upstream of the Trinity River

Q_{TR} = flow in the Trinity River upstream of the Klamath River

T_{TR} = water temperature in the Trinity River upstream of the Klamath River

was used to calculate temperature in the Klamath River downstream of the Trinity River.

The RBM10 model simulates mean daily temperature values at locations along the river; the fishery analysis requires daily maximum and 7-day average daily maximum (7DADM) temperatures. These data values were simulated by determining the historical daily water temperature range from measurements along the Trinity River below Lewiston Dam and the Klamath River just above and below the Trinity River confluence. These historic ranges, coupled with the simulated RBM10 daily average water temperatures were used to estimate daily maximum water temperature. The resulting daily maximum water temperatures were used to compute the 7DADM. Climate change was not considered when assessing historic daily water temperature ranges, i.e., future climate change was assumed to have minimal impact on the daily range of water temperatures in the project area.

Daily Range

The *historic daily range* is the difference between the *historical daily maximum* and the *historical daily minimum* temperature (Figure 3-2). The calculated *daily maximum* water temperature is based on simulated daily average temperature and the *historic daily range*.

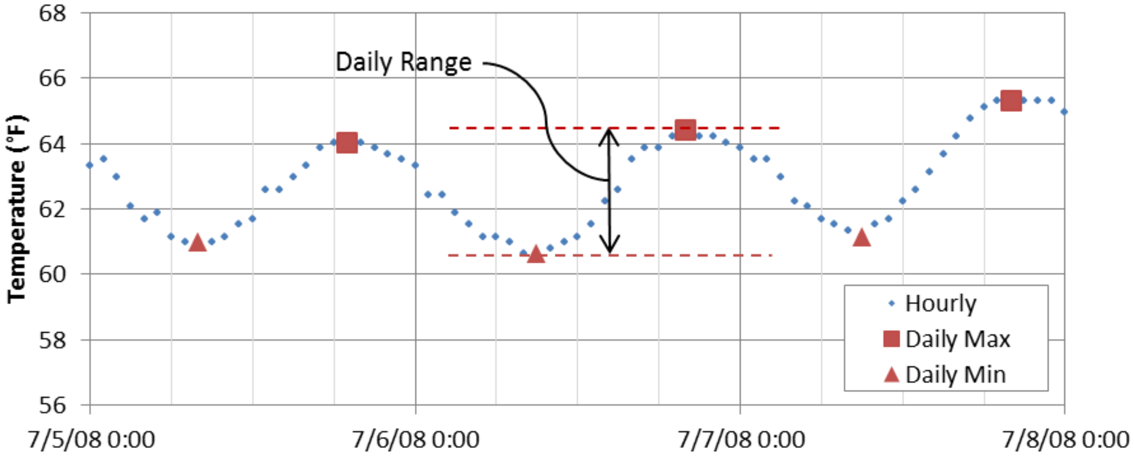
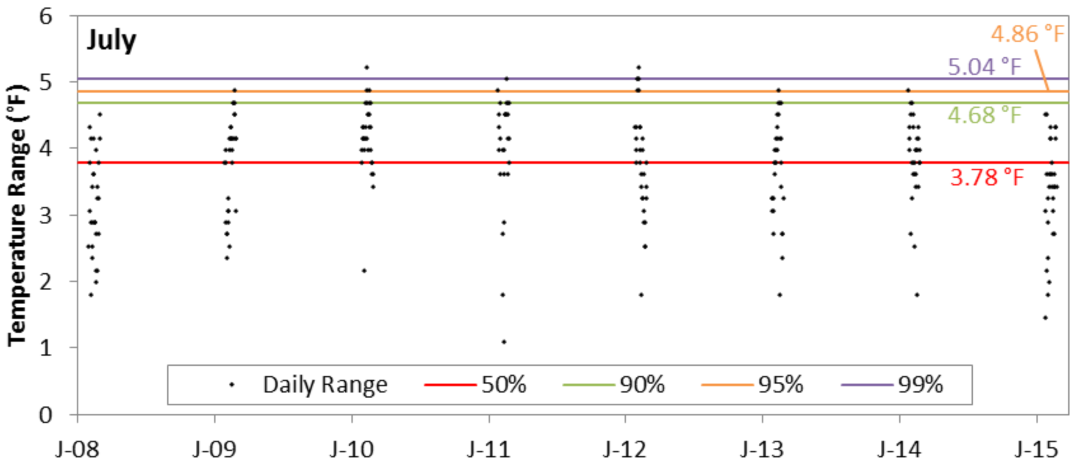


Figure 3-2. Illustration of How Historic Daily Temperature Range was Calculated

Non-Exceedance Probability After daily temperature ranges were calculated, monthly data were ranked for the 2008 to 2015 period and the 50th percentile, 90th percentile, 95th percentile and 99th percentile non-exceedance values were determined. Non-exceedance values define the likelihood that a daily temperature range, in a given month and at a particular location, would not exceed the identified value for the respective percentile values.

For example, in the figure below (Month: July; Location: Trinity River at Hoopa), the 50th percentile is 3.78°F, which means that 50 percent of the daily ranges in July at Hoopa are equal to or below 3.78°F (Figure 3-3). 90 percent, 95 percent, and 99 percent non-exceedance probabilities are also shown.



Note: Data taken from Trinity River at Hoopa, in July.

Figure 3-3. Daily Temperature Ranges Associated with 50 Percent, 90 Percent, 95 Percent and 99 Percent Non-exceedance Probabilities

Maximum Positive Deviation from Daily Average Temperatures After the daily ranges based on the associated non-exceedance probabilities were calculated, the *maximum positive deviation from daily average temperatures* was determined for each month. The maximum positive deviation from daily average temperature is half of the daily temperature range that is associated with the particular month and non-exceedance probability.

Table 3-1 is a sample of the table of the maximum positive deviation from the daily average. These values were calculated based on data for Trinity River at Hoopa. The higher the exceedance probability, the higher the 7DADM will be.

Table 3-1. Example Table of the Maximum Positive Deviation from a Daily Average

	Month											
Probability of Non Exceedance	**1** (°F)	**2** (°F)	**3** (°F)	**4** (°F)	**5** (°F)	**6** (°F)	**7** (°F)	**8** (°F)	**9** (°F)	**10** (°F)	**11** (°F)	**12** (°F)
0.50	0.5	0.7	0.9	1.3	1.6	1.9	1.9	1.6	1.3	1.1	0.7	0.5
0.90	0.9	1.1	1.5	2.1	2.3	2.4	2.3	2.2	1.7	1.4	1.1	0.9
0.95	1.0	1.2	1.6	2.2	2.4	2.5	2.4	2.3	1.8	1.4	1.2	1.0
0.99	1.1	1.4	1.8	2.4	2.6	2.7	2.5	2.9	2.0	1.7	1.4	1.4

Key:
ºF = degrees Fahrenheit

Daily Maximum Temperature

After the maximum positive deviations from the daily average were calculated, *daily maximum* temperatures of simulated RBM10 results (from 1980 to 2003) were calculated as follows:

Daily Maximum = Daily Average + Maximum Positive Deviation from Daily Average

The calculated daily maximum temperature is dependent upon the specified non-exceedance probability. For any given day, different daily maximum temperatures were calculated based on the different maximum positive deviations from the simulated daily average temperatures that were in turn dependent upon the selected non-exceedance probability (50, 90, 95, or 99th percentile) (Figure 3-4). These calculations were performed at all the study locations along the Trinity River and the Klamath River for the period between 1980 and 2003.

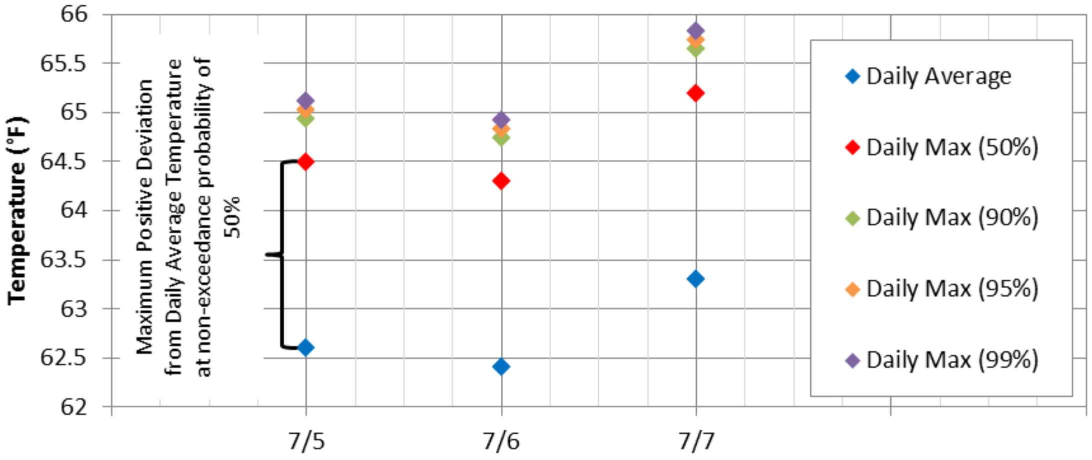


Figure 3-4. Example of Differing Values of Calculated Daily Maximum Temperature Based on the Specified Non-exceedance Probabilities

Seven-Day Average Daily Maximum (7DADM) Temperature

Seven-day running average temperature is the average of daily average temperatures from that day and the previous 6 days. The 7DADM is the running average of the daily maximum temperatures that have been calculated in the previous step (Figure 3-5). 7DADM were calculated for all years in the analysis for all months on the Trinity River. However, for the Klamath River 7DADM were only calculated for August and September.

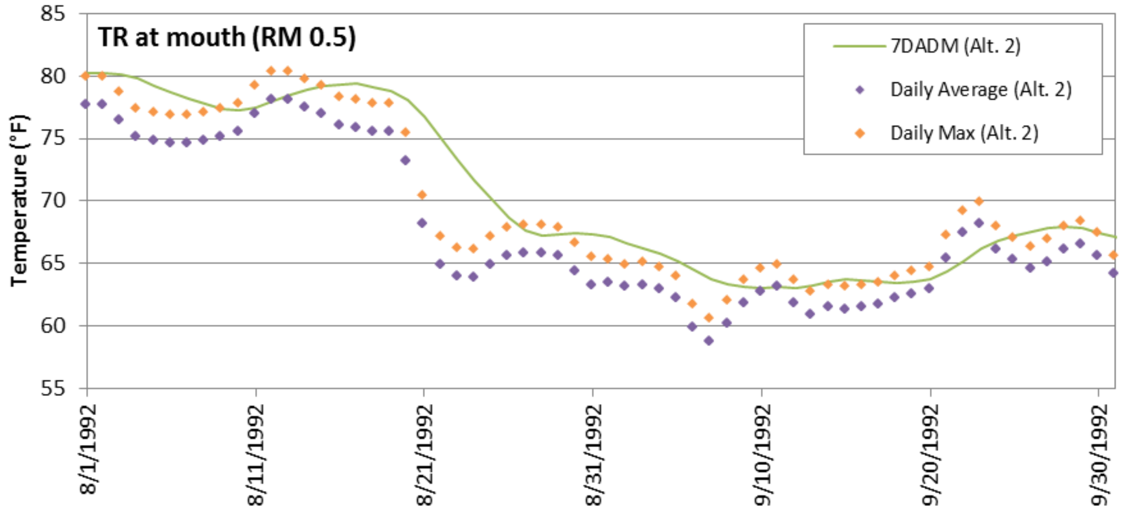


Figure 3-5. 7-Day Running Average of Daily Maximum Temperature (7DADM), Trinity River at Mouth

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Chapter 4
Fisheries Modeling

The analysis uses the Salmonid Population Model (SALMOD) to quantify fall-run, late fall-run, spring-run, and winter-run Chinook salmon survival and mortality for different life-stages within the Sacramento River, specifically from below Keswick Dam to the Red Bluff Pumping Plant (previously at Red Bluff Diversion Dam). The Interactive Object-Oriented Salmonid Simulation (IOS) model analysis is used to quantify winter-run Chinook salmon escapement and egg survival.

This section briefly describes the overall analytical approach and assumptions of both of these models.

Sacramento River SALMOD

The SALMOD model simulates the life-stage dynamics of fall-run, late fall-run, spring-run, and winter-run Chinook salmon populations within the Sacramento River, from below Keswick Dam to the Red Bluff Diversion Dam. The model uses daily flow and temperature data from the Sacramento River HEC5Q model to simulate the annual growth, movement, and mortality of the various riverine life stages of the four Chinook salmon runs based on an initial annual adult population that resets each biological year. The dynamics simulated are based on assumptions and relations specified in the model.

Application of SALMOD to Evaluate EIS Alternatives

The SALMOD model was used with output data from CalSim II and Trinity-Sacramento HEC-5Q Water Quality Model for each alternative to generate annual production (number of surviving members of each life stage) and annual mortality based on a variety of factors, including temperature and habitat (flow) based mortality. The Shasta Lake Water Resources Investigation Final EIS provides a detailed description of the SALMOD model structure, assumptions, and processes (Reclamation 2014).

Modeling Assumptions

For this analysis, the initial populations of adults were assumed to be 50,145 for fall-run, 9,306 for late fall-run, 489 for spring-run, and 5,710 for winter-run. These numbers are based on the geometric mean of 1999-2015 GrandTab spawning escapement data. In 1999, the Shasta Dam temperature control device was installed, resulting in a change in the population numbers. The assumed spawning distribution by reach is shown in Table 4-1. Assumptions of the spawning distributions were based on values used in the Shasta Lake Water Resource Investigation (Reclamation 2014).

Table 4-1. Upper Sacramento River Spawning Distributions

River Reach	Spawning Distribution (%) Fall-run	Spawning Distribution (%) Late Fall-run	Spawning Distribution (%) Spring-run	Spawning Distribution (%) Winter-run
Keswick Dam – Anderson Cottonwood Irrigation District (ACID) Dam	10.30	34.50	4.50	41.80
ACID Dam – Highway 44 Bridge	6.20	15.30	19.10	20.50
Highway 44 Bridge – Airport Road Bridge	11.10	22.80	31.70	35.40
Airport Road Bridge – Balls Ferry	19.2	18.30	17.60	1.90
Balls Ferry – Battle Creek	12.90	5.60	10.60	0.10
Battle Creek – Jellys Ferry	18.80	2.10	15.10	0.10
Jellys Ferry – Bend Bridge	13.60	1.00	1.50	0.20
Bend Bridge – Red Bluff Pumping Plant (previously Red Bluff Diversion Dam)	7.80	0.50	0.00	0.00

Key:
% = percent

Modeling Limitations

There are a number of acknowledged limitations and uncertainties inherent in SALMOD which limit the types of inferences that can be draw from the model. Like any model of a natural system, SALMOD is based on simplified rules and assumptions used to represent and approximate the complex factors that drive real-world conditions, which are of themselves often poorly or incompletely understood. While these assumptions can form a reasonably accurate and useful simulation of natural conditions, they cannot exactly replicate or predict actual conditions. These required simplifications and inherent uncertainties in model inputs naturally lead to uncertainties in the accuracy of model outputs for any individual model run relative to actual, real-world conditions.

Similarly, it should be noted that SALMOD is not a life cycle-population dynamics model, but rather a life stage model. SALMOD is intended to be used as an operations and alternatives screening tool, not a rigorous population dynamics model. By keeping the same starting population number, comparison against each alternative is able to be made. The identified limitations do not preclude the ability of SALMOD to identify potential effects to Chinook salmon caused by changes in operations. Some of the factors outside of the area of influence of the analysis for this EIS (for instance, ocean conditions) are poorly understood and are themselves subject of both environmental and anthropogenic forces, making them highly uncertain and thus difficult to quantify or even fully anticipate. Inclusion of those factors outside of the areas and life stages influenced by this project could obscure the modeling effort and as such, the influence of the project, by introducing significant uncertainty from factors (and life stages) that are not directly influenced by the project. Therefore, the model has been formulated to isolate the effect of the project on anadromous fish survival by excluding factors outside of the area of influence of this project.

In light of these uncertainties, SALMOD is not used as a predictive tool for explicit population estimation; rather it is used as a comparative tool to evaluate relative change between alternatives. If the modeling assumptions and parameters form a reasonably accurate representation of the relationship between input variables and outputs, and the nature of those relationships will not change between scenarios, the model is valid for comparing between alternatives despite its inherent uncertainty (identical assumptions will influence all scenarios and lead to similar uncertainties/inaccuracies that cancel out in the process of comparison). A valid use of the model results is to identify general trends (such as positive or negative responses) and the relative magnitude of impacts (such as percent changes). Simulated fish production values should be viewed as an index of production for each alternative, and should not be treated as an explicit prediction of absolute numbers of fish production under any alternative.

Interactive Object-Oriented Salmon Simulation Model for Winter-Run Chinook Salmon

The IOS model for winter-run Chinook Salmon simulates the entire life cycle of winter-run Chinook Salmon through successive generations. This approach allows for the evaluation of individual life-stage effects on the long-term trajectory of the population. A detailed description of the model and sensitivity analysis can be found in Zeug et al. (2012).

The IOS model is composed of six model stages that are arranged sequentially to account for the entire life cycle of the winter-run, from eggs to returning spawners. In sequential order, the IOS model stages are: (1) spawning, which models the number and temporal distribution of eggs deposited in the gravel at the spawning grounds; (2) early development, which models the impact of temperature on maturation timing and mortality of eggs at the spawning grounds; (3) fry rearing, which models the relationship between temperature and mortality of salmon fry during the river-rearing period; (4) river migration, which estimates the mortality of migrating salmon smolts in the Sacramento River between the spawning and rearing grounds and the Delta; (5) Delta passage, which models the impact of flow, route selection, and water exports on the survival of salmon smolts migrating through the Delta to San Francisco Bay; and (6) ocean survival, which estimates the impact of natural mortality and ocean harvest to predict survival and spawning returns (escapement) by age. Below is a detailed description of each model stage.

The IOS model uses a system dynamics modeling framework, a technique that is used for framing and understanding the behavior of complex systems over time. System dynamics models are made up of stocks (e.g., number of fish) and flows (e.g., sources of mortality) that are informed by mathematical equations. IOS was implemented in the software GoldSim, which enables the simulation of complex processes through creation of simple object relationships, while incorporating Monte Carlo stochastic methods.

Application of IOS to Evaluate EIS Alternatives

The Delta portion of the model is composed of eight reaches and four junctions (see Table 4-2) selected to represent primary salmonid migration corridors where high quality fish and hydrodynamic data were available. For simplification, Sutter Slough and Steamboat Slough are combined as the reach “SS,” and the forks of the Mokelumne River and Georgiana Slough are combined as “Geo/DCC.” The Geo/DCC reach can be entered by the Mokelumne River fall-run at the head of the South and North forks of the Mokelumne River or by Sacramento runs through the combined junction of Georgiana Slough and Delta Cross Channel (Junction C). The Interior

Delta reach can be entered from three different pathways: (1) Geo/DCC, (2) San Joaquin River via Old River Junction (Junction D), or (3) Old River via Junction D. Due to lack of data informing specific routes through the Interior Delta, or tributary-specific survival, the entire Interior Delta region is treated as a single model reach. The four distributary junctions depicted in the Delta portion of the model are: (1) Sacramento River at Freemont Weir (head of Yolo Bypass), (2) Sacramento River at head of Sutter and Steamboat Sloughs, (3) Sacramento River at the combined junction with Georgiana Slough and Delta Cross Channel, and (4) San Joaquin River at the head of Old River. Due to lack of data informing specific routes through the Interior Delta, or tributary-specific survival, the entire Interior Delta region is treated as a single model reach.

For Delta reaches where acoustic tagging data supported migration speed responses to flow (Sac1, Sac2, Geo/DCC), daily migration speed is influenced by mean daily flow. Migration speed is modeled as a logarithmic function of reach-specific flow occurring on the first day smolts entered a particular reach.

Table 4-2. Descriptions of Modeled Delta Reaches and Junctions in the IOS Model

Reach/ Junction	Description	Reach Length (kilometers)
Sac1	Sacramento River from Freeport to junction with Sutter Slough	41.04
Sac2	Sacramento River from Sutter Slough junction to junction with DCC	10.78
Sac3	Sacramento River from DCC to Rio Vista	22.37
Sac4	Sacramento River from Rio Vista to Chipps Island	23.98
Yolo	Yolo Bypass from entrance at Fremont Weir to Rio Vista	- [a]
SS	Combined reach of Sutter Slough and Steamboat Slough ending at Rio Vista	26.72
Geo/DCC	Combined reach of Georgiana Slough, DCC, and Sough and North forks of the Mokelumne River ending at confluence with San Joaquin River	25.59
Interior Delta	Begins at end of reach Geo/DCC, San Joaquin River via Junction D, or Old River via Junction D, and ends at Chipps Island	- [b]
A	Junction of Yolo Bypass and Sacramento River	Not applicable
B	Combined junction of Sutter Slough and Steamboat Slough with Sacramento River	Not applicable
C	Combined junction of DCC and Georgiana Slough with Sacramento River	Not applicable
D	Junction of Old River with San Joaquin River	Not applicable

Notes:

[a] Reach length for Yolo Bypass is currently undefined because reach length is not currently used to calculate Yolo Bypass speed and ultimate travel time.

[b] Reach length for the Interior Delta is undefined due to multiple pathways salmon can take. Timing through the Interior Delta does not affect Delta survival because there are no Delta reaches located downstream of the Interior Delta.

Key:
DCC = Delta Cross Channel

Reach-specific survival through a given Delta reach is calculated and applied the first day smolts enter the reach. For reaches where literature or available tagging data showed support for reach-level responses to environmental variables, survival is influenced by flow (Sac1, Sac2, Sac3, Sac4, SS, Interior Delta via San Joaquin River, and Interior Delta via Old River) or water exports (Interior Delta via Geo/DCC). For these reaches, daily flow (DSM2 data) or exports (CalSim II data) occurring the day of reach-entry is used to predict reach survival through the entire reach. For all other reaches (Geo/DCC and Yolo), reach survival is uninfluenced by Delta conditions and is informed by means and standard deviations of survival from acoustic tagging studies.

At each Delta junction in the model, smolts move in relation to the proportional movement of flow entering each route. Daily DSM2 flow data entering each route are used to inform the proportion of smolts entering each route at a junction. Smolts move in direct proportion to flow at all junctions except Junction C, where a non-proportional relationship is applied as defined by acoustic tagging study data.

Daily simulated water temperature data at Bend Bridge from the Sacramento River Basin Water Temperature Model were applied to inform temperature-dependent egg and fry survival. Daily mortality of eggs and fry is exponentially related to daily water temperature at Bend Bridge.

A major assumption of the IOS model is that surrogate fish data can be used to inform many model relationships. When local data are limited, model relationships can often be informed by field data from outside the study region, laboratory studies in controlled experimental settings, or artificially raised (hatchery) surrogates. For example, many model relationships rely on data from tagged hatchery surrogates because experimental studies often rely on easily accessible hatchery-origin fish and assume that fish responses are at least similar among individuals of different natal origins. In addition to limited data on wild fish, many of the model relationships are informed by data from a single Chinook Salmon race, thereby making the assumption that all races move, grow, and survive according to the same rules.

Modeling Assumptions

The IOS model uses scenario-specific daily DSM2, CalSim II, and Sacramento River Basin Water Temperature Model (Trinity-Sacramento HEC-5Q Water Quality Model) data as model input for each alternative as described above. Daily DSM2 data inform fish migration speed, reach-specific survival, and routing at Delta junctions. Daily export data from CalSim II are used to inform export-dependent survival of salmon smolts that enter the Interior Delta from the Geo/DCC reach. Sacramento River Basin Water Temperature Model data at Bend Bridge, California are used to inform temperature-dependent egg and fry survival in the egg development and fry rearing stages of the model.

References

Reclamation (U.S. Department of the Interior, Bureau of Reclamation). 2014. Shasta Lake Water Resources Investigation Final Environmental Impact Statement. December.

Zeug et al. (Zeug, S.C., P.S. Bergman, B.J. Cavallo and K.S. Jones). 2012. “Application of a life cycle simulation model to evaluate impacts of water management and conservation actions on an endangered population of Chinook Salmon.” *Environmental Modeling and Assessment* 17:455-467.

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Chapter 5
Hydropower Modeling

This section summarizes the power modeling methodology used for the No Action Alternative and action alternatives. Two spreadsheet tools were used to estimate average annual peaking power capacity, energy generation, and energy use at CVP and SWP facilities:

- LTGen (CVP_Power_Future): analyzes CVP facilities
- SWP_Power (SWP_Power_Future): analyzes SWP facilities

The LTGen tool includes 14 pumping and 11 generation CVP facilities. The SWP Power tool includes 13 pumping and 8 SWP generation facilities. Energy generation/use at the CVP and SWP facilities are determined using facility specific physical information and empirical energy factors provided by the Western Area Power Authority (Western) for CVP facilities and by the DWR Operations Control Office (OCO) for SWP facilities, with CalSim II mean monthly project operation data. The resulting monthly energy generation is split into on and off peak usage based on historical operation policies of the project intending to minimize energy costs. Transmission losses are estimated to estimate energy use and generation at load center, as a percentage of energy use or generation.

Capacity and ancillary services are not directly estimated by the tools. These parameters required a much shorter time step than the mean monthly timestep.

Application of LTGen and SWP_Power to Evaluate EIS Alternatives

The models used the appropriate monthly operations data from the CalSim II output for each alternative for the entire 1922 to 2003 simulation period.

Modeling Assumptions

These models assume that the action alternatives will not would have an effect on the physical features of any of the CVP or SWP facilities nor operative outside of their typical operating range.

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Chapter 6
Delta Hydrodynamics and Salinity Modeling

DSM2 is a one-dimensional hydrodynamic and water quality model used to simulate hydrodynamics, water quality, and particle tracking in the Delta. DSM2 represents the best available planning model for Delta tidal hydraulic and salinity modeling. It is appropriate for describing the existing conditions in the Delta, as well as performing simulations for the assessment of incremental environmental effects caused by future facilities and operations.

The DSM2 model has three separate components or modules: HYDRO, QUAL, and PTM.

HYDRO simulates velocities and water surface elevations and provides the flow input for QUAL and PTM. DSM2-HYDRO outputs are used to predict changes in flow rates and depths, and their effects on covered species, as a result of the EIS and climate change.

The QUAL module simulates fate and transport of conservative and non-conservative water quality constituents, including salts, given a flow field simulated by HYDRO. Outputs are used to estimate changes in salinity, and their effects on covered species, as a result of project implementation and climate change. The QUAL module is also used to simulate source water fingerprinting, which allows determining the relative contributions of water sources to the volume at any specified location. Reclamation’s 2008 *Coordinated Long-Term Operation of the Central Valley Project and State Water Project (LTO) Biological Assessment* (BA) Appendix F provides more information about DSM2 (Reclamation 2008).

DSM2-PTM simulates pseudo 3-D transport of neutrally buoyant particles based on the flow field simulated by HYDRO. This module was not used in this EIS analysis.

Additional information on DSM2 can be found on the DWR Modeling Support Branch website at http://baydeltaoffice.water.ca.gov/modeling/.

Application of DSM2 to Evaluate EIS Alternatives

DSM2 v8.0.6 was used in modeling of all alternatives in this EIS using a period of simulation consistent with the CalSim II model - water years 1922 to 2003. The model was modified to include the 2030 level of climate change by incorporating the 15-cm sea level rise consistent with the 2030 level climate change assumption. This is also consistent with the delta salinity ANN used in the CalSim II model for inclusion of in-delta response to operational and stream flow changes of the alternatives.

As used in this EIS, DSM2 HYDRO provides tidal flow, stage and velocity outputs at all locations in the model on a 15-minute time step. DSM2 QUAL provides salinity (electrical conductivity (EC)) on a 15-minute time step.

The agricultural diversions, return flows, and corresponding salinities used in DSM2 are on a monthly time step. The implementation of DCC gate operations in DSM2 assumes that the gates are open from the beginning of a month, irrespective of the water quality needs in the south Delta.

The input assumptions stated earlier should be considered when DSM2 EC results are used to evaluate performance of a baseline or an alternative against the standards. Even though CalSim II releases sufficient flow to meet the standards on a monthly average basis, the resulting EC from DSM2 may be over the standard for part of a month and under the standard for part of the month, depending on the spring/neap tide and other factors (for example, simplification of operations). It is recommended that the results are presented on a monthly basis. Frequency of compliance with a criterion should be computed based on monthly average results. Averaging on a sub-monthly (14-day or more) scale may be appropriate as long as the limitations with respect to the compliance of the baseline model are described in detail and the alternative results are presented as an incremental change from a baseline model.

Modeling Assumptions

The DSM2 model was used with CalSim II outputs of boundary inflow, export, and outflow conditions for each alternative. No other inputs or assumptions were changed.

References

Reclamation (U.S. Department of the Interior, Bureau of Reclamation). 2008. *Biological Assessment on the Continued Long-term Operations of the Central Valley Project and the State Water Project.* Appendix F Sacramento-San Joaquin Delta Hydrodynamic and Water Quality Model (DSM2 Model). August.

Chapter 7
Economics Modeling

The Statewide Agricultural Production Model (SWAP) and the IMpact Analysis for PLANning Model (IMPLAN) were selected for analysis of the potential change to agricultural and municipal economics respectively, which could result from changes in water supply.

This section describes the overall analytical approach and assumptions for use of these models in the analysis.

Statewide Agricultural Production Model

The SWAP model is a regional agricultural production and economic optimization model that simulates the decisions of farmers across 93 percent of agricultural land in California. It is an improvement and extension of the Central Valley Production Model (CVPM). The CVPM was developed in the early 1990s and was used to assess the impacts of the Central Valley Project Improvement Act (Reclamation and USFWS 1999). The SWAP model allows for greater flexibility in production technology and input substitution than CVPM does, and has been extended to allow for a range of analyses, including interregional water transfers and climate change effects. Its first application was to estimate the economic scarcity costs of water for agriculture in the statewide hydro-economic optimization model for water management in California, CALVIN (Draper et al. 2003). More recently, the SWAP model has been used to estimate the economic losses caused by salinity in the Central Valley (Howitt et al. 2009a), economic losses to agriculture in the Sacramento-San Joaquin Delta (Lund et al. 2007), and economic effects of water shortage to Central Valley agriculture (Howitt et al. 2009b). The model was updated and augmented for use by Reclamation in 2012 (Reclamation 2012). It is also being used in several ongoing studies of water projects and operations. The SWAP model has been subject to peer review and technical details can be found in “Calibrating Disaggregate Economic Models of Irrigated Production and Water Management” (Howitt et al. 2012).

The SWAP model has 27 base regions in the Central Valley. The model is also able to include agricultural areas of the Central Coast, the Colorado River region that includes Coachella, Palo Verde and the Imperial Valley, and San Diego, Santa Ana, and Ventura and the South Coast; however, data for those regions have not been updated recently. Figure 7-1 shows the numbered California agricultural areas covered in SWAP. Table 7-1 details the major water users in each of the regions.

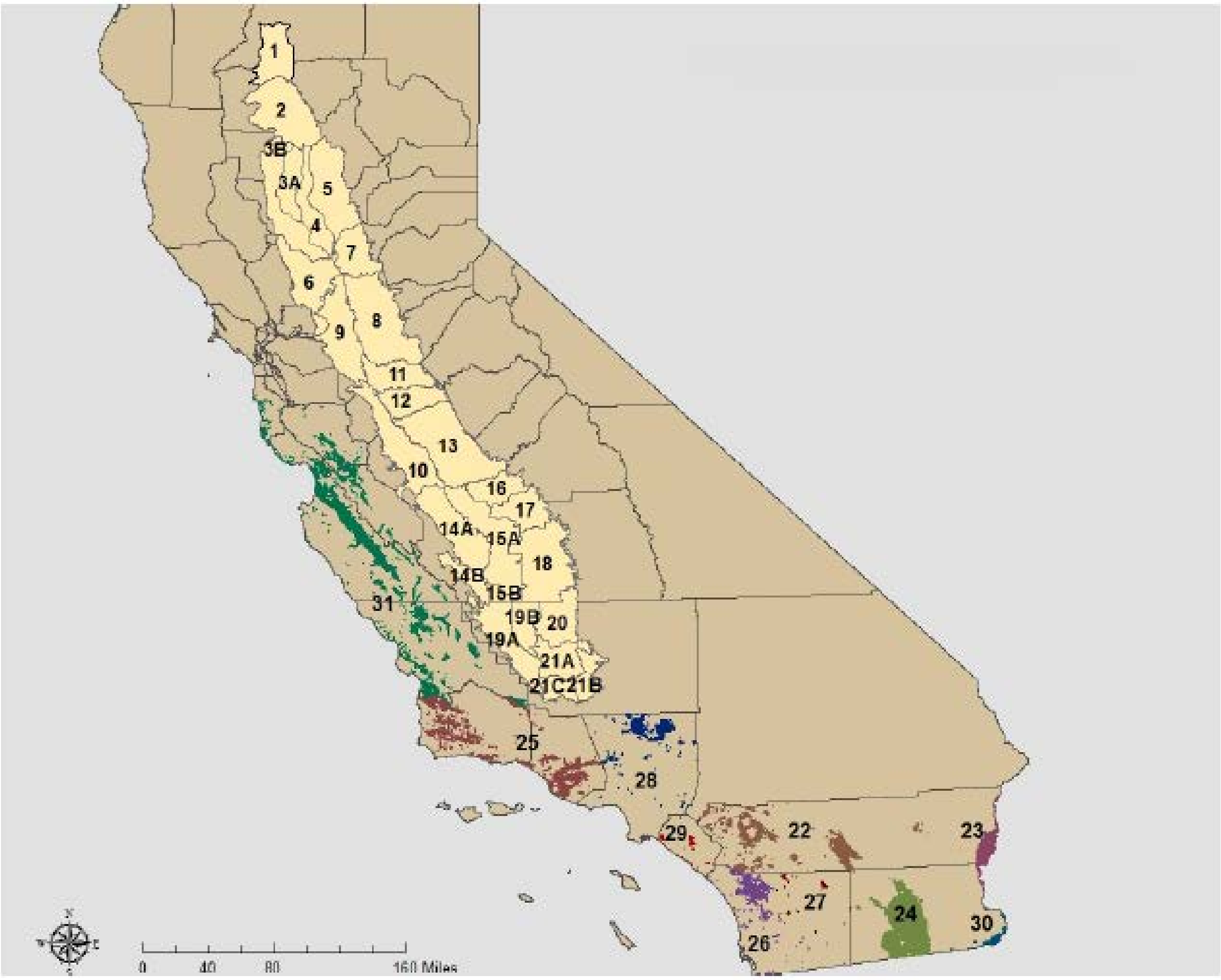

Figure 7-1. SWAP Model Coverage of Agriculture in California

1 Table 7-1. SWAP Model Region Summary

SWAP Region	Major Surface Water Users
1	CVP Users: Anderson Cottonwood I.D., Clear Creek C.S.D., Bella Vista W.D., and other Sacramento River Water Rights Settlement Contractors.
2	CVP Users: Corning Canal, Kirkwood W.D., Tehama, and other Sacramento River Water Rights Settlement Contractors.
3a	CVP Users: Glenn Colusa I.D., Provident I.D., Princeton-Codora I.D., Maxwell I.D., and Colusa Basin Drain M.W.C.
3b	Tehama Colusa Canal Service Area. CVP Users: Orland-Artois W.D., most of Colusa County, Davis W.D., Dunnigan W.D., Glide W.D., Kanawha W.D., La Grande W.D., and Westside W.D.
4	CVP Users: Princeton-Codora-Glenn I.D., Colusa I.C., Meridian Farm W.C., Pelger Mutual W.C., Reclamation District 1004, Reclamation District 108, Roberts Ditch I.C., Sartain M.D., Sutter M.W.C., Swinford Tract I.C., Tisdale Irrigation and Drainage Company, and other Sacramento River Water Rights Settlement Contractors.
5	Most Feather River Region riparian and appropriative users.
6	Yolo and Solano Counties. CVP Users: Conaway Ranch and other Sacramento River Water Rights Settlement Contractors.
7	Sacramento County north of American River. CVP Users: Natomas Central M.W.C., other Sacramento River Water Rights Settlement Contractors, Pleasant Grove-Verona W.M.C., and Placer County Water Agency.
8	Sacramento County south of American River and northern San Joaquin County.
9	Direct diverters within the Delta region. CVP Users: Banta Carbona I.D., West Side W.D., and Plainview W.D.
10	Delta Mendota service area. CVP Users: Panoche W.D., Pacheco W.D., Del Puerto W.D., Hospital W.D., Sunflower W.D., West Stanislaus W.D., Mustang W.D., Orestimba W.D., Patterson W.D., Foothill W.D., San Luis W.D., Broadview W.D., Eagle Field W.D., Mercy Springs W.D., San Joaquin River Exchange Contractors.
11	Stanislaus River water rights: Modesto I.D., Oakdale I.D., and South San Joaquin I.D.
12	Turlock I.D.
13	Merced I.D. CVP Users: Madera I.D., Chowchilla W.D., and Gravelly Ford W.D.
14a	CVP Users: Westlands W.D.
14b	Southwest corner of Kings County.
15a	Tulare Lake Bed. CVP Users: Fresno Slough W.D., James I.D., Tranquillity I.D., Traction Ranch, Laguna W.D., and Reclamation District 1606.
15b	Dudley Ridge W.D. and Devil’s Den W.D. (Castaic Lake).
16	Eastern Fresno County. CVP Users: Friant-Kern Canal Water Authority, Fresno I.D., Garfield W.D., and International W.D.
17	CVP Users: Friant-Kern Canal, Hills Valley I.D., Tri-Valley W.D., and Orange Cove I.D.
18	CVP Users: Friant-Kern Canal, County of Fresno, Lower Tule River I.D., Pixley I.D., portion of Rag Gulch W.D., Ducor I.D., County of Tulare, most of Delano-Earlimart I.D., Exeter I.D., Ivanhoe I.D., Lewis Creek W.D., Lindmore I.D., Lindsay-Strathmore I.D., Porterville I.D., Sausalito I.D., Stone Corral I.D., Tea Pot Dome W.D., Terra Bella I.D., and Tulare I.D.
19a	SWP Service Area, including Belridge W.S.D., Berrenda Mesa W.D.
19b	SWP Service Area, including Semitropic W.S.D.
20	CVP Users: Friant-Kern Canal Water Authority, Shafter-Wasco I.D.
21a	CVP Users: Cross Valley Canal water users and Friant-Kern Canal Water Authority.
21b	Arvin Edison W.D.
21c	SWP service area: Wheeler Ridge-Maricopa W.S.D.
23-30	Central Coast, Desert, and Southern California.

2

Notes:

The list above does not include all water users. It is intended only to indicate the major users or categories of users. All regions in the Central Valley also include private groundwater pumpers.

3

Key:
C.S.D. = Community Service District
I.C. = Irrigation Company
I.D. = Irrigation District
M.W.C. = Mutual Water Company
W.D. = Water District
W.S.D. = Water Storage District

Application of SWAP to Evaluate EIS Alternatives

EIS modeling objectives accomplished with the SWAP model included the evaluation of the following potential impacts:

- Effects on irrigated agricultural acreage
- Effects on total production value

Modeling Assumptions

This section is a non-technical overview of the underlying assumptions and inputs of the SWAP model. It is important to note that SWAP, like any model, is a representation of a complex system and requires assumptions and simplifications to be made. All analyses using SWAP should be explicit about the assumptions and provide sensitivity analysis where appropriate. More detailed assumptions regarding calibration using mathematical programming, crop demand functions, water supply and groundwater pumping, and more see Reclamation 2012.

The SWAP model assumes that growers select the crops, water supplies, and other inputs to maximize profit subject to resource constraints, technical production relationships, and market conditions. Growers face competitive markets, where no one grower can influence crop prices. The competitive market is simulated by maximizing the sum of consumer and producer surplus subject to the following characteristics of production, market conditions, and available resources:

- Constant Elasticity of Substitution (CES) production functions for every crop in every region. CES has four inputs: land, labor, water, and other supplies. CES production functions allow for limited substitution between inputs, which allows the model to estimate both total input use and input use intensity. Parameters are calculated using a combination of prior information and the method of Positive Mathematical Programming (PMP) (Howitt 1995a, Howitt 1995b).
- Marginal land cost functions are estimated using PMP. Additional land brought into production is assumed to be of lower value and thus requires a higher cost to cultivate. The PMP functions capture this cost by using acreage response elasticities, which relate change in acreage to changes in expected returns and other information.
- Groundwater pumping cost including depth to groundwater.
- Crop demand functions.
- Resource constraints on land, labor, water, and, if applicable, other input availability by region.
- Other agronomic and economic constraints. For example, a minimum regional silage production to meet dairy herd feeding requirements can be imposed if appropriate.

The model chooses the optimal amounts of land, water, labor, and other input use subject to these constraints and definitions. Profit is revenue minus costs, where revenue is price multiplied by yield per acre then multiplied by total acres. Trade-offs among production inputs are described by the CES production functions. Costs are observable input costs plus the PMP cost function, which represents changes in marginal productivity of land. Downward-sloping crop demand curves guarantee that with all else constant, as production increases, crop price decreases (and vice-versa). Over time, crop demands may shift, driven by real income growth and population increases. External data and elasticities are used to estimate the magnitude of these shifts.

The SWAP model incorporates CVP and SWP agricultural water supplies, other local surface water supplies, and groundwater. As conditions change within a SWAP region (e.g., the quantity of available project water supply increases or the cost of groundwater pumping increases), the model optimizes production by adjusting the crop mix, water sources and quantities used, and other inputs. Land will be fallowed when that is the most cost-effective response to resource conditions.

The SWAP model is used to compare the long-run response of agriculture to potential changes in CVP and SWP agricultural water delivery, other surface or groundwater conditions, or other economic values or restrictions. Results from the CalSim II model are used as inputs into SWAP through a standardized data linkage tool.

The model self-calibrates using PMP, which has been used in models since the 1980s (Vaux and Howitt 1984) and was formalized in 1995 (Howitt 1995a). PMP allows the modeler to infer the marginal cost and return conditions affecting decisions of farmers while only being able to observe limited average production cost and return data. PMP captures this information through a nonlinear cost or revenue function introduced to the model.

SWAP Model Coverage

Crops are aggregated into 20 crop groups, which are the same across all regions. Each crop group may represent a number of individual crops, but many are dominated by a single crop. Irrigated acres represent acreage of all crops within the group, while production costs and returns are represented by a single proxy crop for each group. The current 20 crop groups were defined in collaboration with Reclamation and DWR and updated in March 2011. For each group, the representative (proxy) crop is chosen based on four criteria:

- A detailed production budget is available from the University of California Cooperative Extension (UCCE).
- It is the largest or one of the largest acreages within a group.
- Its water use (applied water) is representative of water use of the crops in the group.
- Its gross and net returns per acre are representative of the crops in the group.

The relative importance of these criteria varies by crop. Crop group definitions and the corresponding proxy crop are shown in Table 7-2.

Table 7-2. Statewide Agricultural Production Model Crop Groups

SWAP Definition	Proxy Crop	Other Crops
Almonds and Pistachios	Almonds	Pistachios
Alfalfa	Alfalfa hay	–
Corn	Grain corn	Corn silage
Cotton	Pima cotton	Upland cotton
Cucurbits	Summer squash	Melons, cucumbers, pumpkins
Dry Beans	Dry beans	Lima beans
Fresh Tomatoes	Fresh tomatoes	–
Grain	Wheat	Oats, sorghum, barley
Onions and Garlic	Dry onions	Fresh onions, garlic
Other Deciduous	Walnuts	Peaches, plums, apples
Other Field	Sudan grass hay	Other silage
Other Truck	Broccoli	Carrots, peppers, lettuce, other vegetables
Pasture	Irrigated pasture	–
Potatoes	White potatoes	–
Processing Tomatoes	Processing tomatoes	–
Rice	Rice	–
Safflower	Safflower	–
Sugar Beet	Sugar beets	–
Subtropical	Oranges	Lemons, misc. citrus, olives
Vine	Wine grapes	Table grapes, raisins

SWAP Model Inputs and Supporting Data Land use data in the SWAP model correspond to the year 2010 and were prepared by DWR analysts and the current version of the SWAP model calibrates to 2010 as a relatively normal base year. All prices and costs in SWAP are in constant 2010 dollars for consistency with the land use data. Table 7-3 summarizes input data and sources used in the SWAP model.

Table 7-3. SWAP Model Input Data Summary

Input	Source	Notes
Land Use	DWR	Base year 2010.
Crop Prices	County agricultural commissioners	By proxy crop using 2010-2012 average prices, indexed to 2010 price level.
Crop Yields	UCCE crop budgets	By proxy crop for various years (most recent available).
Interest Rates	UCCE crop budgets	Crop budget interest costs adjusted to year 2010.
Land Costs	UCCE crop budgets	By proxy crop for various years (most recent available). In 2010 dollars.
Other Supply Costs	UCCE crop budgets	By proxy crop for various years (most recent available). In 2010 dollars.
Labor Costs	UCCE crop budgets	By proxy crop for various years (most recent available). In 2010 dollars.
Surface Water Costs	Reclamation, DWR, individual districts	By SWAP model region. In 2010 dollars.
Groundwater Costs	PG&E, individual districts	Total cost per acre-foot includes fixed, O&M, and energy cost. In 2010 dollars.
Irrigation Water	DWR	Average crop irrigation water requirements in acre-feet per acre.
Available Water	CVPM, DWR, Reclamation, individual districts	By SWAP model region and water supply source.
Elasticities	Russo et al. 2008	California estimates.

Key:
CVPM = Central Valley Production Model
DWR = California Department of Water Resources
O&M = operations and maintenance
PG&E = Pacific Gas & Electric Company
SWAP = Statewide Agricultural Production Model
UCCE = University of California Cooperative Extension

2030 Assumptions Analysis of alternatives assumed 2030 conditions. Projected CVP and SWP water deliveries were provided by CalSim II results as described in Chapter 2, “Water Operations Modeling.” The SWAP model includes future crop demand functions based on shifts over time due to growth in population and changes in real income per capita forecasted to 2030 conditions.

Model Limitations and Applicability The SWAP model is an optimization model that makes the best (most profitable) adjustments to water supply and other changes. Constraints can be imposed to simulate restrictions on how much adjustment is possible or how fast the adjustment can realistically occur. Nevertheless, an optimization model can tend to over-adjust and minimize costs associated with detrimental changes or, similarly, maximize benefits associated with positive changes.

SWAP does not explicitly account for the dynamic nature of agricultural production; it provides a point in time comparison between two conditions. This is consistent with the way most economic and environmental impact analysis is conducted, but it can obscure sometimes important adjustment costs.

SWAP also does not explicitly incorporate risk or risk preferences (e.g., risk aversion) into its objective function. Risk and variability are handled in two ways. First, the calibration procedure for SWAP is designed to reproduce observed crop mix, so to the extent that crop mix incorporates farmers' risk spreading and risk aversion, the starting, calibrated SWAP base condition will also. Second, variability in water delivery, prices, yields, or other parameters can be evaluated by running the model over a sequence of conditions or over a set of conditions that characterize a distribution, such as a set of water year types.

Groundwater is an alternative source to augment local surface, SWP, and CVP water delivery in all SWAP regions. The cost and availability of groundwater therefore has an important effect on how SWAP responds to changes in delivery. However, SWAP is not a groundwater model and does not include any direct way to adjust pumping lifts and unit pumping cost in response to long-run changes in pumping quantities. Economic analysis using SWAP must rely on an accompanying groundwater analysis.

Impact Analysis for Planning Model

The IMPLAN model is the most widely used input-output (I-O) impact model system in the United States. Much more than a set of multipliers, it provides users with the ability to define industries, economic relationships and projects to be analyzed. It can be customized for any county, region, or state, and used to assess the "ripple effects" or "multiplier effects" caused by increasing or decreasing spending in various parts of the economy. This is used primarily to assess the economic impacts of facilities or industries, or changes in their level of activity in a given area.

IMPLAN is a static model that estimates impacts for a snapshot in time when the impacts are expected to occur, based on the makeup of the economy at the time of the underlying IMPLAN data. IMPLAN measures the initial impact to the economy but does not consider long-term adjustments as labor and capital move into alternative uses. This approach is used to compare the alternatives. Realistically, the structure of the economy will adapt and change; therefore, the IMPLAN results can only be used to compare relative changes between alternatives and the No Action Alternative and cannot be used to predict or forecast future employment, labor income, or output (sales).

I-O models measure commodity flows from producers to intermediate and final consumers. Purchases for final use (final demand) drive the model. Industries produce goods and services for final demand and purchase goods and services from other producers. These other producers, in turn, purchase goods and services. This buying of goods and services (indirect purchases) continues until leakages from the analysis area (imports and value added) stop the cycle. These indirect and induced effects (the effects of household spending) can be mathematically derived using a set of multipliers. The multipliers describe the change in output for each regional industry caused by a 1-dollar change in final demand. Figure 7-2 illustrates the concept of I-O modeling.

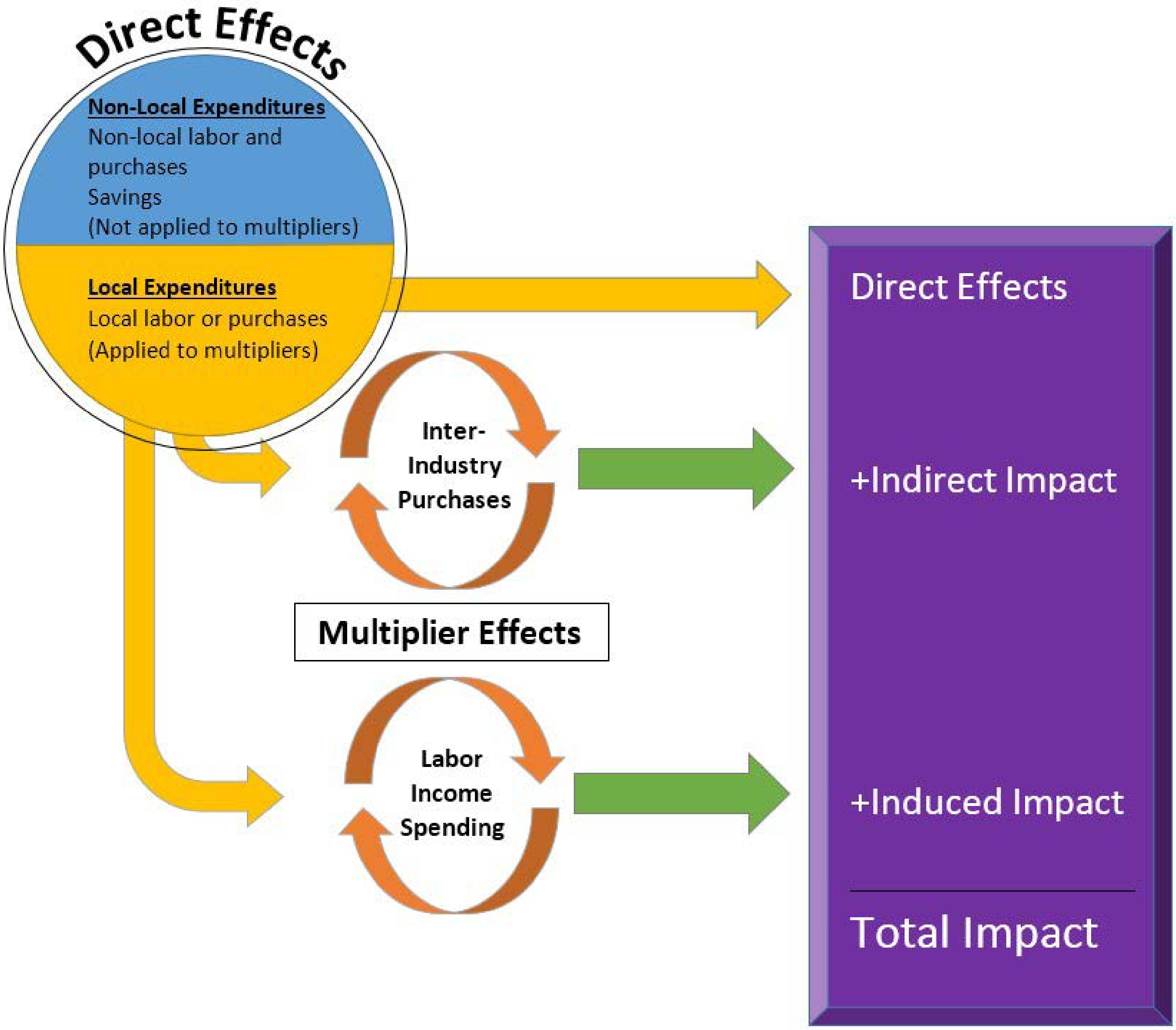

Figure 7-2. Input-Output Modeling Concept

IMPLAN includes estimates of final demands and final payments for each county developed from government data, a national average matrix of technical coefficients, mathematical tools which help the user make the I-O model, and tools which allow the user to change data, conduct impact analysis, and generate reports.

Application of IMPLAN to Evaluate EIS Alternatives

Regional economic impacts are concerned with the effects of changes in the economy of a region. The magnitudes of the economic impacts are determined by the interactions between linkages within the local/regional economy and the leakages from this economy to the larger economy. Economic linkages are the relationships between industries, businesses, factors of production (e.g., labor and capital) and government created by trade and other exchange, such as taxes, within and among regions. Economic linkages create multiplier effects in a regional economy as money is circulated by trade. The magnitudes of impacts resulting from economic linkages are limited by the amount of leakage that occurs within the region. Economic leakages are a measure of the income shares spent outside of the region. Thus, the more the economic leakage, the less the multiplier effect. Economic leakages are generally higher the smaller the regional economy. For example, the economic leakages for a county are larger than those for the state which are larger than those for the nation.

The regional economic impacts identified in EIS Chapter 11, "Agricultural Resources" were evaluated for each alternative. Modeling objectives included the evaluation of the following potential impacts:

- Effects on regional employment
- Effects on regional total economic output

Modeling Assumptions

The primary assumption attributable to IMPLAN concerns linkages among regions. Each of the IMPLAN models is a single-region model. Other than assumptions on imports, exports, and regional purchases, the models do not explicitly recognize inter-regional interdependencies among sectors. It is believed that the regions defined for the IMPLAN models are sufficiently large so that each is relatively self-sufficient as an economic entity.

No incremental changes in agricultural production over the long-term condition (82-year simulation period analyzed in this EIS) among Alternatives 1 and 2 as compared to the No Action Alternative were estimated. Therefore, no IMPLAN analyses were conducted for regional economic impacts associated with the changes in irrigated agriculture production over the long-term condition. For the analyses of dry and critical dry year conditions, the direct inputs from the SWAP model were used as input into the relevant agricultural sector within each of the regions. Table 7-4 shows the crop categories from the SWAP model and the IMPLAN sector to which each of these crop categories was assigned.

Table 7-4. Mapping SWAP Model Results to IMPLAN Sectors

SWAP Definition	IMPLAN Sector
Almonds and Pistachios	Tree nut farming
Alfalfa	All other crop farming
Corn	Grain farming
Cotton	Cotton farming
Cucurbits	Vegetable and melon farming
Dry Beans	Grain farming
Fresh Tomatoes	Vegetable and melon farming
Grain	Grain farming
Onions and Garlic	Vegetable and melon farming
Other Deciduous	Fruit farming
Other Field	Grain farming
Other Truck	Vegetable and melon farming
Pasture	All other crop farming
Potatoes	Vegetable and melon farming
Processing Tomatoes	Vegetable and melon farming
Rice	Grain farming
Safflower	Oilseed farming
Sugar Beet	Sugarcane and sugar beet farming
Subtropical	Fruit farming
Vine	Fruit farming

Model Input Data

The economic data for the IMPLAN model come from the system of national accounts for the United States based on data collected by the U.S. Department of Commerce’s Bureau of Economic Analysis, the U.S. Department of Labor’s Bureau of Labor Statistics, and other Federal and State government agencies. Data are collected for 440 distinct producing industry sectors of the national economy corresponding to the North American Industry Classification System (NAICS). Industry sectors are classified on the basis of the primary commodity or service produced. Corresponding data sets are also produced for each county in the United States, allowing analyses at the county level and for geographic aggregations such as clusters of contiguous counties, individual states, or groups of states. Initially, MIG Inc., and now the IMPLAN Group LLC provide annual IMPLAN I-O datasets representing the state of the economy for any region. Since these data rely on the release of Federal economic data, the release of the IMPLAN I-O dataset typically lags by a year or two. For this EIS, the 2009 IMPLAN I-O data were used. Data provided for each industry sector include outputs and inputs from other sectors, value added, employment, wages and business taxes paid, imports and exports, final demand by households and government, capital investment, business inventories, marketing margins, and inflation factors (deflators). These data are provided both for the 440 producing sectors at the national level and for the corresponding sectors at the county level. Data on the technological mix of inputs and levels of transactions between producing sectors are taken from detailed input-output tables of the national economy. National and county level data are the basis for IMPLAN calculations of input-output tables and multipliers for local areas.

Regional IMPLAN Model

The regional economic analysis was conducted using results from the agricultural production impact analyses. The incremental impact results, estimated by the SWAP model were input into the regional IMPLAN models as the direct change caused by each of alternative as compared to the No Action Alternative. The IMPLAN models were then used to estimate the secondary (indirect and induced) regional employment, income, and output.

Study Areas

IMPLAN models of the multi-county regions were used to measure impacts in terms of total changes in employment and economic output. Table 7-5 lists the counties included in the IMPLAN models for the Sacramento Valley and San Joaquin Valley in the Central Valley Bay-Delta Region.

Table 7-5. Categorization of Counties by Regions

Region	Categorization in the IMPLAN Model For SWAP model Output
Central Valley and Bay-Delta Region – Sacramento Valley	Shasta Tehama Glenn Colusa Butte Yuba Nevada Sutter Placer
Central Valley and Bay-Delta Region – San Joaquin Valley	Stanislaus Madera Merced Fresno Tulare Kings Kern

Key:
SWAP = Statewide Agricultural Production Model

IMPLAN models of each regions were used to estimate the secondary employment and income impacts associated with changes in irrigated agricultural production. Each regional model follows county lines and incorporates, to the extent allowed by available data, the distinct sector characteristics of the region modeled.

Model Limitations

One of the major limitations with the I-O methodology is the assumption of fixed proportions: for any good or service; all inputs are combined in fixed proportions that are invariant with the level of output. Hence, there is no substitution among production inputs and no economies of scale are possible. Additionally, each production function incorporates fixed, invariant technology.

I-O methodology does not model price effects that might be important to a region. The methodology also assumes that resources that become unemployed or employed due to a change in final demand have no alternative employment.

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Analytical Tools Technical Appendix

Attachment 1 – Selection of Analytical Tools

Long-Term Plan to Protect Adult Salmon in the Lower Klamath River Environmental Impact Statement

Draft

Selection of Analytical Tools

This attachment to the Analytical Tools Technical Appendix describes available tools to evaluate various physical, biological, and economic resources, and the tools selected for application in this EIS. Analytical tools used to assess resource area impacts were selected based on applicability to the impact analysis, acceptance of use, and availability for use to meet the project schedule.

The action alternatives, to augment lower Klamath River flows during periods of potential *Ichthyophthirius multifiliis* (Ich) infestation, have the potential to cause impacts directly in the lower Klamath River Basin, and indirectly in the Sacramento-San Joaquin River Basins through changes in imports of Central Valley Project (CVP) water from Trinity Reservoir to the Sacramento River Basin.

A technical analysis process was designed to define the timing and magnitude of the lower Klamath River flow augmentation as defined in Chapter 2 of this appendix. The CVP and State Water Project (SWP) systems were then simulated to supply the required augmentation flows from Trinity Lake and to determine any changes in imports to the Sacramento and San Joaquin River basins and resulting system re-operation. When the water operations were finalized, subsequent analyses of water supply, temperature, fisheries, hydropower, and economics were performed to support the impact analysis required in the EIS.

Many of the available analytical tools identified for potential use in this EIS have been developed for use in a single basin, either the Klamath River basin (including the Trinity River) or the Sacramento and San Joaquin River basins, requiring a separate selection process for different analytical tools in each of the basins. The Trinity Reservoir, Trinity River downstream to Lewiston Reservoir and the Lewiston Reservoir are operationally included in both basins with the import of water from the Trinity to the Sacramento basins. The CalSim II and Trinity-Sacramento HEC-5Q Water Quality models both include the Trinity Reservoir, Trinity River downstream to the Lewiston Reservoir and the Lewiston Reservoir as well as the Sacramento – San Joaquin River basins. To accommodate this the geographic regions are defined as:

- **Klamath River Basin**, including Trinity River Downstream from Lewiston Dam – Includes the Klamath River and the Trinity River from Lewiston Reservoir to the confluence with the Klamath River.

- **Sacramento River, Sacramento-San Joaquin River Delta (Delta) and CVP Facilities and Service Areas** Includes the CVP and SWP affected waterways, including the Sacramento, Feather, and American Rivers, and the Delta.

Water Operations

Since the action alternatives affect the timing and quantity of Trinity import to the Sacramento River basin, there is a potential for impacts to CVP facilities and service areas, including the Delta. Water operations tools considered and selected for the Klamath River Basin and CVP facilities and service areas are discussed below.

Klamath River Basin, including Trinity River Downstream from Lewiston Dam

Klamath Basin Economic and Hydrology Model

The Klamath Basin Economic and Hydrology Model (KB_HEM) estimates changes in on-farm agriculture production on Klamath Project lands that result from changes to agricultural inputs such as water availability and the cost of power. The current application of the model uses previously developed with and without project hydrology developed by Reclamation and does not simulate water operations.

Klamath Project Planning Model

The Klamath Project Planning Model (KPPM) was developed jointly by Reclamation, the National Marine Fisheries Service (NMFS), and the U.S. Fish and Wildlife Service (USFWS) specifically for Endangered Species Act (ESA) consultation on the Klamath Project. It is based on the Water Resources Integrated Modeling System (WRIMS), the same platform used in the CalSim II and CalSim 3.0 models. This water resources system planning model simulates deliveries to the Klamath Project from the Upper Klamath Lake, Clear Lake and Gerber Lake. The model includes the reach of the Klamath River upstream of Iron Gate Dam to Klamath Lake and does not include the project area in the lower Klamath River.

Selected Tool – None Selected, Interpretation/Extrapolation from Available Data or Previous Studies

The action alternatives will have no impact on Klamath River operations or flows upstream from the confluence with the Trinity River. Neither of the existing tools include the lower Klamath River. As the action alternatives do not require modified operations of Reclamation’s Klamath Project, PacifiCorp Klamath Project or other facilities on the Klamath River above confluence with the Trinity River, operational modeling for these facilities is not required. Accordingly, no Klamath Basin operations tool was selected.

Sacramento River, Delta and CVP Facilities and Service Areas

This section describes the analytical tools available to simulate and evaluate water operations in the Sacramento River Basin, San Joaquin River Basin, the Delta, and the CVP facilities and Service Areas, including the Trinity River Division facilities.

CalSim II

CalSim II is a specific application of WRIMS to simulate Central Valley water operations. The CalSim II model simulates the operations of the CVP and SWP throughout the Trinity River, Sacramento River, the Delta and the San Joaquin River over an historical range of hydrologic conditions. CalSim II provides outputs for reservoir storage, river flows, diversions, Delta flows and exports, and deliveries to project and non-project users. There are also predefined linkages (i.e., output is used in other models) from the CalSim II model to the temperature, fisheries, hydropower, and economic models anticipated for use in this analysis.

CalLite

The California Department of Water Resources (DWR) and Reclamation developed CalLite as an interactive screening model for evaluating various Central Valley water management alternatives. CalLite simulates the hydrology of the Central Valley, reservoir operations, delivery allocation decisions, Delta salinity, and habitat-ecosystem flow indices over an 82-year planning period. CalLite maintains the hydrologic, operational and institutional integrity of CalSim; the results obtained from a typical CalLite run (less than10 minute run time) are within 1 percent of a corresponding CalSim run (20 minute run time). The CalLite model does not have predefined connections to the temperature, fisheries, hydropower, and economic models that were anticipated for use in this analysis.

CalSim 3.0

CalSim 3.0 is a disaggregation of the CalSim II schematic, using over 1,000 nodes and dynamically linking to a groundwater model to represent land use-based demands and local hydrology impacts of operations alternatives and potential future climates. Although public release of CalSim 3.0 is anticipated for summer or fall 2016 it is not available in the timeframe required for this analysis.

Selected Tool – CalSim II

The CalSim II model was selected for use in this analysis. The CalSim II model is readily available and widely accepted as an appropriate model for EIS purposes, and has recently been used in several system-wide evaluations including the Coordinated Long-Term Operation of the CVP and SWP EIS (Reclamation 2015), San Joaquin River Restoration Program (SJRRP) Program Environmental Impact Statement/Environmental Impact Report (PEIS/R) (Reclamation and DWR 2012), Upper San Joaquin River Basin Storage Investigation (USJRBSI) EIS (Reclamation 2014a), Shasta Lake Water Resource Investigation (SLWRI) EIS (Reclamation 2014b), and Los Vaqueros Enlargement EIS/EIR (Reclamation 2010). The pre-defined linkages with other, subsequent, models anticipated to be utilized in this EIS process allows efficient performance of the required technical analysis to meet the project schedule.

Reservoir and River Temperature and Water Quality

Multiple tools have been developed to evaluate water temperatures and water quality in both rivers and reservoirs. These tools are described for each basin.

Klamath River Basin

The following section describes the tools available for the Klamath River Basin.

Klamath and Trinity River Resource Management Associates (RMA-2 and RMA-11)

The Klamath and Trinity River Resource Management Associates models (RMA-2 and RMA-11, in combination referred to as RMA 2/11) based models are one-dimensional daily hourly flow and water temperature models that use a heat budget formulation to quantify heat flux at the air-water interface. RMA-2 is a hydrodynamic model that solves the St. Venant equations for dynamic flow conditions. RMA-11 uses output from RMA-2 to determine the fate and transport of heat energy through the stream using a full heat budget approach. Both models use the finite element method to solve governing equations of flow and fate/transport.

The Trinity River RMA-2/11 models use meteorological data, observed streamflow data, and observed water temperatures to simulate flow (velocity and stage) and water temperature conditions in the Trinity River for six years of continuous model simulations (2000 through 2005). Spatial domain for the Trinity River is Lewiston Dam to the Klamath River confluence a distance of 177 kilometers (110 miles) with hourly output available approximately every 100 meters (328 feet). Tributaries water temperatures are represented as daily average values.

The Klamath River RMA-2/11 models use meteorological data, observed streamflow data, and observed water temperatures to simulate flow (velocity and stage) and water temperature conditions in the Klamath River. Currently, 11 years of continuous model simulations 2000-2010 are available. Spatial domain for the Klamath River is Link River Dam to the Klamath River estuary (253 miles or 407 kilometers) with hourly output available approximately every 150 meters (492 feet). Tributaries water temperatures are represented as daily average values.

Klamath and Trinity River Basin Model

The Klamath and Trinity River Basin Models (RBM10) are one-dimensional flow-balance models that assumes flow changes are translated downstream instantaneously. RBM10 uses a simple equilibrium flow model. It utilizes a heat budget formulation to quantify the heat flux at the air-water interface. Heat energy is conveyed through the system based on flow and system geometry.

The Trinity RBM10 model uses meteorological, streamflow, and water temperature data as model inputs to simulate a continuous 34-year time series (1980 to 2013). Spatial domain for the Trinity River is Lewiston Dam to the Klamath River confluence 177 kilometers (110 miles) divided into 31 segments (mean reach length = 5.8 kilometers (3.6 miles), reach lengths range from 1.9 to 9 kilometers (1.2 to 5.6 miles). Tributaries water temperatures are represented as weekly average values. The model for the Trinity River has been recently (April 2016) released to the public.

The Klamath RBM10 model uses meteorological data, observed streamflow data, and observed water temperatures are used as model inputs to simulate a continuous 50-year time series (1961 to 2010). Spatial domain for the Klamath River is Link River Dam to the Klamath Estuary (approximately 407 kilometers [253 miles]) divided into 85 segments (mean reach length = 12.9 kilometers [8 miles]), reach lengths range from 0.8 to 52.5 kilometers (0.5 to 32.6 mi). Reservoirs are represented as vertically and laterally mixed (e.g., no stratification). Tributaries water temperatures are represented as weekly average values.

Klamath Reservoirs Water Quality Model (CE-QUAL-W2)

There are four reservoirs on the Klamath River: Keno, J.C. Boyle, Copco 1, and Iron Gate reservoirs which are currently represented with CE-QUAL-W2. Copco 2 is a small afterbay/forebay for Copco 1 and is not included in the CE-QUAL-W2 model, but is, however, evaluated with the RMA 2/11 models as a slow and deep river reach. CE-QUAL-W2 is a two-dimensional, laterally averaged hydrodynamic and water-quality model. The models use finite difference methods to solve governing equations of flow and fate/transport. All reservoirs are spatially represented with segment lengths on the order of 305 meters (1000 feet) and vertical layer thicknesses between 0.6 to 0.9 meters (2 to 3 feet), and produce hourly output. Models represent individual reservoirs and are available for 2000 through 2004, and 2006 through 2009 for selected river reaches and reservoirs.

Selected Tool – Klamath and Trinity River RBM10

The Klamath and Trinity River RBM10 models were selected for use in this analysis to assess sub-daily temperature biological metrics (e.g., 7-day average of the daily maximum temperatures) as the tools are within the public domain, include the geographic extent required for the analysis, and are currently being applied by resource agencies within the basin. The RBM10 models operate on a daily time step and simulate mean daily temperatures for the spatial and temporal coverage required. A summary of the RBM10 models is provided in Table 1 below.

Table 1. Summary of Klamath and Trinity River RB10 Temperature Models

Model	Dimension	Spatial	Temporal	Domain	Reservoir	Reservoir Operations	Period	Documented	Public Domain
RBM10 Trinity	1-D	5.8 km	Daily	Lewiston Dam to Klamath River	n/a	n/a	1980-2013	Yes	Yes
RBM10 Klamath	1-D	12.9 km	Daily	Link River Dam to Estuary	Laterally and vertically averaged	n/a	1961-2010	Yes	Yes

Key:
D = Dimensional
km = kilometer
n/a = not applicable

Sacramento River, Delta, and CVP Facilities and Service Areas

Reservoir and river water temperature and water quality models for the Sacramento River, Delta, and CVP Facilities and Service Areas are described below.

Trinity-Sacramento River HEC-5Q Water Quality Model

The Trinity-Sacramento River HEC-5Q Water Quality Model is a HEC-5Q-based (one-dimensional) reservoir and river water quality and temperature model of the Trinity Upper Sacramento River system including Trinity Dam and Reservoir, Trinity River to Lewiston Reservoir, Lewiston Dam and Reservoir, Clear Creek Tunnel, Whiskeytown Dam and Reservoir, Clear Creek below Whiskeytown Dam, Spring Creek Tunnel, Shasta Dam and Reservoir, Keswick Dam and Reservoir, Sacramento River from Keswick to Knights Landing, Red Bluff Diversion Dam, Black Butte Dam, and downstream Stony Creek. The model operates on a 6-hour time step to capture diurnal temperature fluctuations.

Reclamation Monthly Water Temperature Models

The Reclamation monthly water temperature models make up a collection of monthly time-step water temperature models used to simulate water temperatures in the Trinity, Sacramento, Feather, and American River basins for use in the Reclamation Mortality Models (fisheries models described later in this attachment). The monthly time-step of these models provides limited utility for this analysis.

Trinity and Lewiston Reservoir Temperature Models

These models are a WQRRS-based one-dimensional of Trinity Lake and a CE-QUAL-W2-based two-dimensional model of Lewiston Reservoir developed in support of the Trinity River Restoration Program. These models provide water temperatures in Trinity and Lewiston reservoirs.

Selected Tool – Trinity-Sacramento River HEC-5Q Water Quality Model

The Trinity-Sacramento River HEC-5Q Water Quality Model was selected for use in this analysis. This model includes a utility program and procedures to accept monthly operations data from the CalSim II model (the selected operations model), and disaggregate the monthly reservoir operations and stream flows to a daily time step to provide an appropriate level of detail to support subsequent analysis. The model is readily available and widely accepted as an appropriate model for analytical purposes, and has recently been used in several large investigations including the SLWRI, and North of Delta Offstream Storage, and the Coordinated Long-Term Operation of the CVP and SWP EIS (Reclamation 2015). A version of the model with 2030 level of climate change incorporated into the meteorological data has been developed for these projects. The pre-defined linkages with the selected CalSim II operations model and other, subsequent, models anticipated to be utilized in this EIS process, and the incorporation of 2030 level of climate change in the default input data set allows efficient performance of the required technical analysis to meet the project schedule.

Fisheries

Multiple fisheries tools have been developed for the Klamath, Trinity, and Sacramento (including tributaries) River basins, and the Delta.

Klamath River Basin

Klamath Basin fisheries tools include the models described below.

Klamath River Ecosystem Diagnosis and Treatment Model

The Ecosystem Diagnosis and Treatment (EDT) model is habitat-based structured to account for the effects of environmental conditions as salmon follow variable life-history ‘trajectories’ through space and time to complete the life cycle. It is used to predict salmon productivity and capacity as a function of varying ecosystem conditions. This model evaluates the potential effects of changing habitat conditions after reintroducing anadromous fish in the upper Klamath River (upstream from Iron Gate Dam).

Klamath Coho Integrated Modeling Framework

The Klamath Coho Integrated Modeling Framework (IMF) is a life-cycle model that evaluates effects of changing water operations on each life stage of Coho Salmon. It estimates Coho Salmon production based on habitat and environmental conditions including flow and water temperature. Because Coho Salmon abundance has not been adequately monitored (i.e., imprecise population estimates), the model relies on habitat carrying capacity to estimate production potential in the Klamath Basin. The Klamath Coho IMF covers the Klamath River from Iron Gate Dam to the estuary.

Klamath River Stream Salmon Simulator

The Klamath River Stream Salmon Simulator (S3) model is used to predict the effects of water management alternatives on the production of juvenile Chinook Salmon. It contains multiple sub-models reflecting the interaction between the physical and biological processes that affect growth, movement, and survival at any given life stage. The S3 model tracks the cause of mortality (redd scour, habitat limitations, disease) throughout the sub-adult life history over time within the mainstem Klamath River from Keno Dam to the estuary. This model was being updated, with an expected completion date sometime in 2016, and is not available at the time of the EIS development in its updated version.

SALMOD

SALMOD is a salmon production model that simulates population dynamics for freshwater salmonids. This model is used to show how habitat quality and carrying capacity are characterized by the hydraulic and thermal properties of individual mesohabitats. The model tracks a population of spatially distinct cohorts that originate as eggs and grow from one life stage to another as a function of water temperature. SALMOD was developed for the Trinity River for the Trinity River Restoration Program evaluation. It has habitat data from prior to any restoration activities. SALMOD was also developed for the Klamath River to the estuary.

Selected Tool – None Selected, Interpretation/Extrapolation from Available Data or Previous Studies

The action alternatives have no effect on Klamath River flows upstream from the confluence with the Trinity River, as all augmentation flows will be released from Trinity Reservoir. Most of the fisheries models for the Klamath Basin are either incomplete, do not reflect current conditions, or not necessary based on the available input data. Furthermore, none of the available tools were developed to evaluate Ich and are likely not suitable for use as an evaluation of the effectiveness of augmentation flows/temperature reduction on reducing Ich.

The fisheries evaluation will be conducted using results from the RBM10 models, providing the water temperatures and hydraulic conditions in the Klamath and Trinity Rivers, relationship flow-habitat relationship and a desktop (e.g., spreadsheet model) analysis.

Sacramento River, Delta, and CVP Facilities and Service Areas

Fisheries models developed for the Sacramento River, Delta, and CVP facilities are described in this section.

Sacramento River SALMOD

SALMOD, described above, was used to assess the effects of any changes in flows and temperatures in the Sacramento River between Keswick Dam and Red Bluff on habitat quality and quantity and ultimately on juvenile production of all Central Valley runs of Chinook salmon. SALMOD uses inputs from CalSim II and the Trinity-Sacramento River HEC-5Q Model.

Interactive Object-Oriented Simulation Model for Winter-run Chinook Salmon

The Interactive Object-oriented Simulation (IOS) model for winter-run Chinook Salmon is a ‘life-cycle’ model that estimates the long-term response of Sacramento River winter-run Chinook Salmon to changing environmental conditions (e.g., river discharge, water temperature, habitat quality on a reach scale). IOS simulates all life stages of Sacramento River winter-run

Chinook Salmon and models individual daily cohorts of fish through their entire life cycle. It was used for comparing the relative effect of different flow, temperature, and water export scenarios on the winter-run Chinook Salmon population that spawns in the upper reaches of California's Sacramento River, migrates downriver and through the Delta to the Pacific Ocean, and returns to the upper Sacramento River to spawn. The model uses inputs from CalSim II and the Trinity-Sacramento River HEC-5Q Model.

Reclamation Salmon Mortality Model

The Reclamation Salmon Mortality Model is used to assess proportional temperature-exposure mortality of three life stages (pre-spawned eggs, fertilized eggs, and pre-emergent fry) for each run of Chinook Salmon in conjunction with the spawning distribution data in the Trinity, Sacramento, Feather, American, and Stanislaus Rivers. It operates on a daily time-step using a linear interpolation between monthly water temperature model outputs. This model requires water temperature data from the Reclamation Monthly Water Temperature Models which are not proposed for use in this analysis, as well as results from the Trinity-Sacramento River HEC-5Q Model.

Sacramento River Ecological Flows Tool

Sacramento River Ecological Flows Tool (SacEFT) to evaluate the effects of the project on riparian species. SacEFT is a decision support tool emphasizing the trade-offs for key ecosystem targets associated with alternative conveyance, water operations and climate futures in the Sacramento River and San Francisco Delta eco-regions.

Oncorhynchus Bayesian Analysis Model

Oncorhynchus Bayesian Analysis model (OBAN), is used to evaluate the effects of multiple covered activities on winter-run Chinook Salmon survival and population dynamics and viability. OBAN uses stages to characterize the salmon life history and estimates the stage-specific vital rates (e.g., survival) from abundance indices. Environmental factors are incorporated into the modeling framework and the vital rates are estimated with uncertainty using probability models (Bayesian estimation). OBAN, while publicly available, does not necessarily have a large user-base with access to, or working knowledge of, the required software and tools.

NMFS Life Cycle Model

NMFS is developing a Chinook Salmon life cycle model, focusing initially on winter-run Chinook Salmon. This model is not complete yet, nor available for public use.

Delta Passage Model

The Delta Passage Model (DPM) is used to estimate Chinook Salmon survival through the Delta. It is based on an accounting of the migratory pathway and location-specific mortality as Chinook Salmon smolts travel through a simplified network of reaches and junctions in the Delta. It takes into account fish migratory speed and travel time, flow, Delta exports, and predation, and quantifies survival of all four runs of Chinook Salmon in the Delta.

Selected Tools –SALMOD, Winter-run Chinook Salmon Interactive Object-Oriented Simulation Model, and Interpretation/Extrapolation from Available Data or Previous Studies

Two fisheries models, SALMOD and IOS were selected for application for this EIS. SALMOD is the best available tool for predicting project-related outcomes (on a relative, not absolute, basis) for all four runs of Chinook Salmon (steelhead effects can be assumed similar to late fall-run Chinook Salmon) species in the upper Sacramento River. SALMOD input was developed in a coordinated effort between USFWS, CDFW, and Reclamation, and has been peer reviewed. It has been approved for use in several other studies, including the 2008 Biological Assessment on the Continued Long-Term Operations of the CVP and SWP (Reclamation 2008) and resulting 2009 BO and Conference Opinion on the Long-Term Operations of the CVP and SWP (NMFS 2009), the Coordinated Long-Term Operation of the CVP and SWP EIS (Reclamation 2015) and the SLWRI EIS (Reclamation 2014b).

The IOS model is the best life cycle model available at the time of this analysis for the Sacramento River winter-run Chinook Salmon. The IOS model was used to evaluate the effects to winter-run Chinook Salmon for the Coordinated Long-Term Operation of the CVP and SWP EIS (Reclamation 2015).

Both models have pre-defined linkages with the CalSim II operations model and the Trinity-Sacramento River HEC-5Q Model to allow efficient performance of the required technical analysis to meet the project schedule.

Hydropower

This section includes descriptions of analytical tools that assess hydropower.

Klamath River Basin

Selected Tool – None Selected, Interpretation/Extrapolation from Available Data or Previous Studies

The proposed action has no impact on flows in the Klamath River basin upstream from the confluence with the Trinity River. All of the flow augmentation is expected to come from Trinity Reservoir on the Trinity River, with hydropower impacts on the Trinity River included in the Sacramento – San Joaquin River Basin models described in the next section.

Sacramento River, Delta, and CVP Facilities and Service Areas

LTGen

The LTGen Model estimates monthly power generation, capacity, and project use (e.g., pumping plant demand) for each CVP generation or pumping facility for each month of a CalSim II simulation. The model uses simplified factors to separate peak and non-peak generation and project use and provides an estimate of net-revenue based on price forecasts.

SWP_Power

The SWP Power Model computes monthly power generation, capacity, and project use (e.g., pumping plant demand) for each SWP power facility for each month of the CalSim II simulation.

The model uses simplified factors to separate peak and non-peak generation and project use and provides an estimate of net-revenue based on price forecasts.

Selected Tool – LTGen and SWP_Power

Both the LTGen and SWP_Power models were selected for use in this EIS. The models are readily available, widely accepted as an appropriate model for EIS analyses, and have recently been used in several large investigations including the SJRRP PEIS/R, USJRBSI EIS, SLWRI EIS. The models are specifically developed to use pre-defined linkages with the selected CalSim II operations model for efficient performance of the required technical analysis to meet the project schedule.

Delta Hydrodynamics and Salinity

This section includes descriptions of analytical tools that assess Delta hydrodynamics.

Sacramento River, Delta, and CVP Facilities and Service Areas

Delta Simulation Model Version 2

Delta Simulation Model Version 2 (DSM2) is a one-dimensional hydrodynamic and water quality simulation model of the Delta developed by the California Department of Water Resources specifically for the Delta. The DSM2 model operates on a 15-minute time-step in order to capture the tidal influences throughout the system of interconnected channels forming the Delta. The model utilizes CalSim II simulation output to obtain boundary conditions and simulates the operation of internal flow control structures.

The model consists of several linked modules, each with a specific purpose.

- DSM2 Hydro simulates the hydrodynamics, flow direction and magnitude, throughout the interconnected delta channels under tidal influence.
- DSM2 Qual simulates the water quality, or salinity, at all locations in the delta given a hydrodynamic property set from DSM2 Hydro.
- DSM2 PTM simulates fate and transport of a neutrally buoyant particles through space and time given a hydrodynamic property set from DSM2 Hydro.
- DSM2 Fingerprinting simulates the proportion of water from different sources at specific locations in the Delta based on a given hydrodynamic property set from DSM2 Hydro

RMA Bay-Delta Model

The RMA Bay-Delta Model is a two-dimensional hydrodynamic, salinity, and particle tracking model of the Sacramento-San Joaquin River Delta. The model produces output data similar to the DSM2 model but with greater hydraulic resolution at the cost of increased data requirements and execution time.

Selected Tool – DSM2 Hydro and Qual

The DSM2 model modules Hydro and Qual were selected for use in this analysis. The model is readily available and widely accepted as an appropriate model for EIS purposes, and has recently been used in several large investigations including the Coordinated Long-Term Operation of the CVP and SWP EIS (Reclamation 2015), SJRRP PEIS/R (Reclamation and DWR 2012), USJRBSI EIS (Reclamation 2014a), and SLWRI EIS (Reclamation 2014b) and Los Vaqueros Enlargement. The model was specifically developed to use pre-defined linkages with the selected CalSim II operations model for efficient performance of the required technical analysis to meet the project schedule. Use of the other modules is not anticipated but could be easily accommodated if they do become necessary.

Agricultural Economics

Agricultural economics are important, particularly in the Klamath and Sacramento River basins. Analytical tools to evaluate the agricultural economics are included in this section.

Klamath River Basin

Klamath Basin Hydro-economic Model (KB_HEM)

The KB_HEM estimates changes in on-farm agriculture production on Klamath Project lands that result from changes to agricultural inputs such as water availability and the cost of power.

Selected Tool – None Selected, Interpretation/Extrapolation from Available Data or Previous Studies

The proposed action has no impact on flows in the Klamath River basin upstream of the confluence with the Trinity River. All of the flow augmentation comes from Trinity Reservoir on the Trinity River.

Sacramento River, Delta, and CVP Facilities and Service Areas

The following models/tools can be used in the Sacramento River, Delta, and CVP Facilities and Service Areas.

Central Valley Production Model (CVPM)

CVPM projects cropping patterns, land use, and water use in the Central Valley of California by considering land availability, water availability and cost, irrigation technology, market conditions, and production costs. The model considers 26 crops and 22 hydrologic regions covering the Central Valley of California and selects those crops, acreage, water supplies, and irrigation technologies that maximize profit subject to certain constraints including availability of land, water and other legal, physical, and economic limitations on an annual time step.

Statewide Agricultural Production Model

The Statewide Agricultural Production Model (SWAP) model is a regional economic model of irrigated agricultural production that simulates the decisions of agricultural producers in California with changes in water supply conditions to maximize net income. SWAP incorporates CVP and SWP water supplies, other local water supplies, and groundwater. For each SWAP region the model optimizes production by adjusting cropping patterns, water sources and quantities used, and fallows land when that appears to be the most cost-effective response to water resource changes.

Agricultural Water Pricing Model

Estimates the water transfer cost to agricultural producers through application of a water transfer pricing model and through consideration of conveyance costs to agricultural service areas.

Selected Tool – SWAP

The SWAP model was selected for use in this analysis because it is widely accepted, has been used in numerous other major water resource projects is readily available, has sufficient detail for project analysis, and has defined linkages with other models that were used in this EIS.

Regional Economics

Sacramento River, Delta, and CVP Facilities and Service Areas analytical tools that are used for evaluating regional impacts are described in this section.

Impact Analysis for Planning

IMpact Analysis for PLANning Model (IMPLAN) is an input-output model that predicts changes in industry output, value added, and employment as direct, indirect, and induced economic effects for affected industries within a study area. Common uses for water resources planning include estimates of income and employment effects to local communities with new water project construction expenditures and regional economic effects with changes in agricultural production due to water supply availability.

Selected Tool – IMPLAN

IMPLAN was selected for use in this analysis because it is widely accepted, has been used in numerous other major water resource projects, has sufficient detail for project analysis, and is readily available to help meet the project schedule.

Summary of Selected Tools

Modeling tools used for evaluations in this EIS are as follows:

- **CalSim-II** is a statewide water resource planning tool and is a specific application of the WRIMS to simulate Central Valley water operations. CalSim-II provides information about CVP and SWP operations, including reservoir storages, river and canal flows, and project deliveries. Output from CalSim-II is used as an input to all other models listed below, except IMPLAN.

- **Trinity-Sacramento River HEC-5Q Water Quality Model** is a water temperature model that uses Sacramento River flows and inflows, and Shasta, Trinity, and Whiskeytown reservoir storages from CalSim-II to determine water temperatures in the Trinity River from Trinity Lake to Lewistion and in the Sacramento River between Shasta Lake and Red Bluff.

- **SALMOD, Version 3.8**, uses CalSim-II Sacramento River flows and inflows, and water temperatures from the Trinity-Sacramento River HEC-5Q Model to simulate Chinook salmon mortality and escapement.

- **IOS** uses scenario-specific daily DSM2, CalSim II, and Trinity-Sacramento River HEC-5Q Model data as model input to estimate winter-run Chinook survival at multiple life stages

- **Statewide Agricultural Production Model (SWAP), Version 6**, is an agricultural production and economics model that uses CalSim-II water supply deliveries to agricultural contractors to simulate the decisions of agricultural producers (farmers) in California. The model selects crops, water supplies, and irrigation technology to maximize profit.

- **Delta Simulation Model Version 2 (DSM2), Version 8.0.6**, is a Sacramento-San Joaquin River Delta (Delta) hydrodynamic and water quality model that uses CalSim-II Delta inflows, outflows, and exports to determine Delta water quality and water levels.

- **LongTermGen (LTGen), Version 1.18, and State Water Project Power (SWP_Power), Benchmark Study Team (BST) April 6, 2010**, version, are power generation models for the CVP and the SWP, respectively, that use CalSim-II reservoir storages, releases, and project pumping to determine the energy generation and usage of the CVP and SWP.

- **IMPLAN, Version 3.0.17.2**, is a regional economic model that uses construction cost estimates to simulate the effect of construction-related expenditures on the regional economy in terms of changes in industry output, employment, and income.

Attachment 1 References

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RECLAMATION
Managing Water in the West

Environmental Impact Statement Biological Resources – Terrestrial Technical Appendix

Long-Term Plan to Protect Adult Salmon in the Lower Klamath River

Draft

October 2016

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to 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.

Special-Status Terrestrial Species

Tables 1-1 and 1-2 list special-status wildlife and plant species that potentially occur within the area of potential effect and could be affected by changes under the action alternatives.

Table 1-1. Special-Status Wildlife Species

Common Name	Scientific Name	Status[1] Federal/State /Other	General Habitat in Area of Potential Effect	Regions with Potential Occurrence	Impact Potential
Trinity bristle snail	*Monadenia infumata setosa*	—/T/—	Riparian and conifer forest habitats in the southern Klamath Mountains; known to occur along the Trinity River in the vicinity of Big Bar.	Klamath River (Trinity River)	Hydrologic changes are not expected to affect known or potential habitat.
Big Bar hesperian snail	*Vespericola pressleyi*	—/—/USFS	Riparian areas and conifer forest habitats with wet microsites; known to occur along the lower Trinity River and tributaries.	Klamath River (Trinity River)	Hydrologic changes are not expected to affect known or potential habitat.
Valley Elderberry Longhorn Beetle	*Desmocerus californicus dimorphus*	T/—/—	Riparian habitats and found only in association with its host plant, blue elderberry (*Sambucus nigra* subsp. *caerulea*).	Sacramento Valley and Delta	Hydrologic changes are not expected to affect known or potential habitat.
Western bumble bee	*Bombus occidentalis*	—/—/SSC, BLM, USFS	Various habitats where flowering trees, shrubs, forbs, or crops are present.	Sacramento Valley and Delta, Klamath River	Hydrologic changes are not expected to affect known or potential habitat.
Foothill yellow-legged frog	*Rana boylii*	—/—/SSC, BLM, USFS	Riverine habitats with rocky or cobble substrates.	Klamath River	Hydrologic changes are not expected to affect known or potential habitat.
Western pond turtle	*Emys marmorata*	—/—/USFS	Riverine, lacustrine, and various other wetland habitats. Uses adjacent upland habitats for nesting.	Sacramento Valley and Delta, Klamath River	Hydrologic changes are not expected to affect known or potential habitat.
Giant garter snake	*Thamnophis gigas*	T/T/—	Marshes, ponds, sloughs, small lakes, low-gradient streams, and agricultural wetlands, including irrigation and drainage canals, rice fields, and adjacent uplands.	Sacramento Valley and Delta	Hydrologic changes are not expected to affect known or potential habitat.
Tule greater white- fronted goose (wintering)	*Anser albifrons elgasi*	—/—/SSC	Breed in western Alaska and winter in the Central Valley where they occur in various wetland, grassland, and agricultural habitats.	Sacramento Valley and Delta	Hydrologic changes are not expected to affect known or potential habitat.

Table 1-1. Special-Status Wildlife Species (contd.)

Common Name	Scientific Name	Status^1 Federal/State /Other	General Habitat in Area of Potential Effect	Regions with Potential Occurrence	Impact Potential
Double-crested cormorant	*Phalacrocorax auritus*	—/—/WL	Riverine, lacustrine, and various other wetland habitats. Widespread distribution but local breeder.	Sacramento Valley and Delta, Klamath River	Hydrologic changes are not expected to affect known or potential habitat.
Least Bittern (nesting)	*Ixobrychus exilis*	—/—/ BCC, SSC	Freshwater and brackish marsh habitats in the Sacramento Valley and Delta.	Sacramento Valley, Delta	Hydrologic changes are not expected to affect known or potential habitat.
Cooper's hawk	*Accipiter cooperii*	—/—/WL	Riparian woodland and forest habitats in the Sacramento Valley and Delta regions. Riparian, hardwood, hardwood-conifer, and conifer habitats in the Klamath River region.	Sacramento Valley and Delta, Klamath River	Hydrologic changes are not expected to affect known or potential habitat.
Sharp-shinned hawk	*Accipiter striatus*	—/—/WL	Riparian woodland and forest habitats in the Sacramento Valley and Delta regions. Riparian, hardwood, hardwood-conifer, and conifer habitats in the Klamath River region.	Sacramento Valley and Delta, Klamath River	Hydrologic changes are not expected to affect known or potential habitat.
Swainson's Hawk	*Buteo swainsoni*	—/T/BCC, BLM	Nests in riparian woodlands and forests, roadside trees, tree rows, isolated trees, woodlots, and trees in farmyards and rural residences. Forages in various grassland and agricultural habitats.	Sacramento Valley and Delta	Hydrologic changes are not expected to affect known or potential habitat.
Bald Eagle	*Haliaeetus leucocephalus*	—/E/BCC, BLM, FP, USFS	Nests within or near large riverine and lacustrine habitats. Also use other wetland, grassland, woodland, and agricultural habitats for foraging and during dispersal/wintering.	Sacramento Valley and Delta, Klamath River	Hydrologic changes are not expected to affect known or potential habitat.
Osprey	*Pandion haliaetus*	—/—/WL	Large riverine and lacustrine, and occasionally other wetland habitats.	Sacramento Valley and Delta, Klamath River	Hydrologic changes are not expected to affect known or potential habitat.
White-faced Ibis (nesting colony)	*Plegadis chihi*	—/—/WL	Freshwater marsh and irrigated/flooded agricultural habitats.	Sacramento Valley	Hydrologic changes are not expected to affect known or potential habitat.

Table 1-1. Special-Status Wildlife Species (contd.)

Common Name	Scientific Name	Status[1] Federal/ State/Other	General Habitat in Area of Potential Effect	Regions with Potential Occurrence	Impact Potential
California Black Rail	*Laterallus jamaicensis coturniculus*	—/T/BCC, BLM, FP	Freshwater and tidal emergent marsh habitats.	Sacramento Valley and Delta	Hydrologic changes are not expected to affect known or potential habitat.
California Ridgeway's Rail	*Rallus longirostris obsoletus*	E/E/FP	Tidal emergent marsh habitats.	Delta	Hydrologic changes are not expected to affect known or potential habitat.
Black Tern	*Childonias niger*	—/—/SSC	Freshwater marsh and irrigated/flooded agricultural habitats.	Sacramento Valley	Hydrologic changes are not expected to affect known or potential habitat.
Greater Sandhill Crane (nesting and wintering)	*Grus canadensis tabida*	—/T/BCC, BLM, FP	Breed in meadow, grassland, and agricultural habitats in northeastern California. Winter in the Sacramento Valley between Butte Sink and the Delta, and occur in wetland, grassland, and agricultural habitats.	Sacramento Valley and Delta	Hydrologic changes are not expected to affect known or potential habitat.
Western Yellow-billed Cuckoo	*Coccyzus americanus occidentalis*	T/E/BCC, USFS	Large tracts of riparian habitat along the Sacramento River and Feather River in the Sacramento Valley. Also thought to potentially occur along the Trinity and Klamath Rivers, though known observations in the North Coast Region are limited to lowland estuarine areas (Eel River bottoms, Smith River Estuary).	Sacramento Valley, Klamath River	Hydrologic changes are not expected to affect known or potential habitat.
Purple martin	*Progne subis*	—/—/SSC	Riparian habitats in the Sacramento Valley and Delta regions. Riparian, hardwood, hardwood-conifer, and conifer habitats in the Klamath River region.	Sacramento Valley and Delta, Klamath River	Hydrologic changes are not expected to affect known or potential habitat.
Bank swallow	*Riparia riparia*	—/T/BLM	Riparian and other lowland habitats with vertical banks, bluffs, and cliffs with fine-textured or sandy soils for nesting.	Sacramento Valley and Delta, Klamath River	Hydrologic changes are not expected to affect known or potential habitat.
Yellow-breasted chat	*Icteria virens*	—/—/SSC	Riparian scrub, woodland, and forest habitats.	Sacramento Valley and Delta, Klamath River	Hydrologic changes are not expected to affect known or potential habitat.

Table 1-1. Special-Status Wildlife Species (contd.)

Common Name	Scientific Name	Status^1 Federal/State/Other	General Habitat in Area of Potential Effect	Regions with Potential Occurrence	Impact Potential
Yellow Warbler	*Dendroica petechia brewsteri*	—/—/BCC, SSC	Riparian scrub and woodland habitats.	Sacramento Valley and Delta, Klamath River	Hydrologic changes are not expected to affect known or potential habitat.
Song sparrow ("Modesto" population)	*Melospiza melodia*	—/—/SSC	Riparian and emergent wetland habitats.	Sacramento Valley and Delta	Hydrologic changes are not expected to affect known or potential habitat.
Tricolored blackbird	*Agelaius tricolor*	—/C/BCC, BLM	Emergent wetland, riparian scrub, grassland, and agricultural habitats.	Sacramento Valley and Delta	Hydrologic changes are not expected to affect known or potential habitat.
Pallid bat	*Antrozous pallidus*	—/—/BLM, SSC, USFS	Riparian, emergent wetland, hardwood, hardwood-conifer, and conifer habitats.	Sacramento Valley and Delta, Klamath River	Hydrologic changes are not expected to affect known or potential habitat.
Townsend's big-eared bat	*Corynorhinus townsendii*	—/C/BLM, USFS	Riparian, emergent wetland, hardwood, hardwood-conifer, and conifer habitats.	Sacramento Valley and Delta, Klamath River	Hydrologic changes are not expected to affect known or potential habitat.
Spotted bat	*Euderma maculatum*	—/—/BLM, SSC	Riparian and emergent wetland habitats.	Sacramento Valley	Hydrologic changes are not expected to affect known or potential habitat.
Western red bat	*Lasiurus blossevillii*	—/—/SSC	Riparian and emergent wetland habitats.	Sacramento Valley and Delta	Hydrologic changes are not expected to affect known or potential habitat.
Long-eared myotis	*Myotis evotis*	—/—/BLM	Riparian, emergent wetland, hardwood, hardwood-conifer, and conifer habitats.	Sacramento Valley and Delta, Klamath River	Hydrologic changes are not expected to affect known or potential habitat.
Fringed myotis	*Myotis thysanodes*	—/—/BLM, USFS	Riparian, emergent wetland, hardwood, hardwood-conifer, and conifer habitats.	Sacramento Valley and Delta, Klamath River	Hydrologic changes are not expected to affect known or potential habitat.
Yuma myotis	*Myotis yumanensis*	—/—/BLM	Riparian, emergent wetland, hardwood, hardwood-conifer, and conifer habitats.	Sacramento Valley and Delta, Klamath River	Hydrologic changes are not expected to affect known or potential habitat.

Table 1-1. Special-Status Wildlife Species (contd.)

Common Name	Scientific Name	Status[1] Federal/State /Other	General Habitat in Area of Potential Effect	Regions with Potential Occurrence	Impact Potential
Ringtail	*Bassariscus astutus*	—/—/FP	Riparian, hardwood, hardwood-conifer, and conifer habitats.	Sacramento Valley and Delta, Klamath River	Hydrologic changes are not expected to affect known or potential habitat.
Pacific marten	*Martes caurina*	—/—/USFS	Hardwood, hardwood-conifer, and conifer habitats.	Klamath River	Hydrologic changes are not expected to affect known or potential habitat.
Pacific marten	*Martes caurina humboldtensis*	—/C/SSC, USFS	Hardwood, hardwood-conifer, and conifer habitats.	Klamath River	Hydrologic changes are not expected to affect known or potential habitat.
Pacific fisher - West Coast DPS	*Pekania pennanti*	—/—/BLM, SSC, USFS	Riparian, hardwood, hardwood-conifer, and conifer habitats.	Klamath River	Hydrologic changes are not expected to affect known or potential habitat.

Notes:

[1] See Status Codes abbreviations.

Key:
Status Codes:
BCC = U.S. Fish and Wildlife Service Bird Species of Conservation Concern
BLM = Bureau of Land Management Sensitive Species
DPS = Distinct Population Segment
C = Candidate for Listing as Threatened or Endangered
E = Endangered
FP = California Department of Fish and Wildlife Fully Protected
SSC = California Department of Fish and Wildlife Species of Special Concern
T = Threatened
USFS = Region 5 U.S. Forest Service Sensitive Species
WL = California Department of Fish and Wildlife Watch List

Table 1-2. Special-Status Plant Species

Common Name	Scientific Name	Status[1] Federal/State/Other	General Habitat in Area of Potential Effect	Regions with Potential Occurrence	Impact Potential
Ferris' milk-vetch	*Astragalus tener* var. *ferrisiae*	—/—/BLM, CRPR 1B.1	Sub-alkaline flats in grassland and seasonal wetland habitats.	Sacramento Valley and Delta	Hydrologic changes are not expected to affect known or potential habitat.
Bristle-stalked sedge	*Carex leptalea*	—/—/CRPR 2B.1	Marsh and swamp habitats.	Klamath River	Hydrologic changes are not expected to affect known or potential habitat.
Soft Bird's-beak	*Chloropyron molle* ssp*. molle*	E/R/CRPR 1B.2	Coastal salt marsh and swamp habitats.	Delta	Hydrologic changes are not expected to affect known or potential habitat.
Bolander's Water Hemlock	*Cicuta maculata* var*. bolanderi*	—/—/CRPR 2B.1	Freshwater or brackish marsh and swamp habitats.	Sacramento Valley and Delta	Hydrologic changes are not expected to affect known or potential habitat.
Suisun Thistle	*Cirsium hydrophilum* var. *hydrophilum*	E/—/CRPR 1B.1	Salt marsh and swamp habitats.	Delta	Hydrologic changes are not expected to affect known or potential habitat.
Woolly rose-mallow	*Hibiscus lasiocarpos* var. *occidentalis*	—/—/CRPR 1B.2	Freshwater marsh and riparian habitats.	Sacramento Valley and Delta	Hydrologic changes are not expected to affect known or potential habitat.
Delta Tule Pea	*Lathyrus jepsonii* var*. jepsonii*	—/—/CRPR 1B.2	Freshwater and brackish marsh and swamp habitats.	Delta	Hydrologic changes are not expected to affect known or potential habitat.
Mason's Lilaeopsis	*Lilaeopsis masonii*	—/R/CRPR 1B.1	Freshwater and brackish marsh and swamp, and riparian scrub habitats.	Delta	Hydrologic changes are not expected to affect known or potential habitat.
Delta mudwort	*Limosella australis*	—/—/CRPR 2B.1	Freshwater and brackish marsh and swamp, and riparian scrub habitats.	Delta	Hydrologic changes are not expected to affect known or potential habitat.
Antioch Dunes evening-primrose	*Oenothera deltoides* ssp. *howellii*	E/E/CRPR 1B.1	Remnant river bluffs and sand dunes in the eastern portion of the Delta (east of Antioch).	Delta	Hydrologic changes are not expected to affect known or potential habitat.
Eel-grass pondweed	*Potamogeton zosteriformis*	—/—/CRPR 2B.2	Lake, stream, pond, and marsh and swamp habitats.	Sacramento Valley and Delta	Hydrologic changes are not expected to affect known or potential habitat.
White beaked-rush	*Rhynchospora alba*	—/—/CRPR 2B.2	Freshwater marsh and swamp habitats.	Klamath River	Hydrologic changes are not expected to affect known or potential habitat.

Table 1-2. Special-Status Plant Species (contd.)

Common Name	Scientific Name	Status[1] Federal/State/Other	General Habitat in Area of Potential Effect	Regions with Potential Occurrence	Impact Potential
Sanford's arrowhead	*Sagittaria sanfordii*	—/—/BLM, CRPR 1B.2	Freshwater marsh and swamp habitats, ponds, ditches.	Sacramento Valley and Delta	Hydrologic changes are not expected to affect known or potential habitat.
Suisun Marsh Aster	*Symphyotrichum lentum*	—/—/CRPR 1B.2	Brackish and freshwater marsh and swamp habitats.	Delta	Hydrologic changes are not expected to affect known or potential habitat.
Brazilian watermeal	*Wolffia brasiliensis*	—/—/CRPR 2B.3	Freshwater marsh and swamp habitats.	Sacramento Valley and Delta	Hydrologic changes are not expected to affect known or potential habitat.

Notes:

[1] See Status Codes abbreviations.

Key:

Abbreviations

Delta = Sacramento-San Joaquin River Delta

Status Codes:

E = Endangered

R = Rare

California Rare Plant Rank (CRPR) Codes:

1B = Plants rare, threatened, or endangered in California and elsewhere

2B = Plants rare, threatened, or endangered in California, but more common elsewhere

CRPR Threat Ranks:

.1 = Seriously threatened in California (over 80 percent of occurrences threatened / high degree and immediacy of threat)

.2 = Moderately threatened in California (20-80 percent occurrences threatened / moderate degree and immediacy of threat)

.3 = Not very threatened in California (less than 20 percent of occurrences threatened / low degree and immediacy of threat or no current threats known)

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RECLAMATION
Managing Water in the West

Environmental Impact Statement Cumulative Effects Technical Appendix

Long-Term Plan to Protect Adult Salmon in the Lower Klamath River
Draft

October 2016

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to 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.

Contents

Figures

Tables

Abbreviations and Acronyms

BO	Biological Opinion
CDFW	California Department of Fish and Wildlife
CEQA	California Environmental Quality Act
DOI	U.S. Department of the Interior
DWR	California Department of Water Resources
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
FERC	Federal Energy Regulatory Commission
MW	megawatt
NEPA	National Environmental Policy Act
NID	Nevada Irrigation District
NMFS	National Marine Fisheries Service
PG&E	Pacific Gas and Electric
SWP	State Water Project

Chapter 1
Cumulative Effects

This appendix provides an overview of National Environmental Policy Act (NEPA) cumulative effects requirements; the methodology used to identify past, present, and reasonably foreseeable future projects or actions; and a description of the reasonably foreseeable future projects or actions considered as part of the cumulative effects analysis for the Long-Term Plan to Protect Adult Salmon in the Lower Klamath River Environmental Impact Statement (EIS).

NEPA Cumulative Effects Requirements

Cumulative effects impacts on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time (40 Code of Federal Regulations Section 1508.7).

Cumulative Effects Methodology

As described in the *Potential Mechanisms for Change and Analytical Methods* sections in Chapters 4 through 14, the impact analyses for all resource areas are primarily based upon changes in reservoir operations and flows related to the release of augmentation flows under the action alternatives as modeled in CalSim II. For the No Action Alternative and action alternatives, the CalSim II model incorporates past, present, and reasonably foreseeable future actions anticipated to occur by the year 2030, such as the release of full restoration flows under the San Joaquin River Restoration Program. In addition, the CalSim II model incorporates anticipated climate change and sea-level rise for 2030. The CalSim II model also incorporates anticipated demands based on county general plan population projections for 2030. The Analytical Tools Technical Appendix provides additional information about assumptions related to projects, climate change, and sea-level rise reasonably expected to occur by the year 2030 that are included in the CalSim II modeling simulations.

However, not all reasonably foreseeable projects are currently included in the CalSim II modeling simulations. Chapter 2, “Additional Reasonably Foreseeable Future Projects or Actions,” of this appendix presents additional reasonably foreseeable projects that meet the NEPA Council on Environmental Quality guidance on cumulative effects analysis that are not currently included in the CalSim II model simulations. In order to provide a complete cumulative effects analysis, additional screening of reasonably foreseeable projects was developed to provide a complete list of projects to be considered for the *Cumulative Effects Analysis* sections found in Chapters 4 through 14 of the EIS. To determine potential additional reasonable foreseeable projects or actions in the study area for this EIS, relevant public documents prepared by Federal, State, and local governments were reviewed and a preliminary list of actions was developed. These documents include released EISs, Environmental Assessments, management and land use plans, and other environmental compliance documents (e.g., California Environmental Quality Act (CEQA) documents, Federal Energy Regulatory Commission (FERC) relicensing applications). Actions were then evaluated for inclusion in the cumulative effects analysis based on three criteria that all must be met to be considered reasonably foreseeable:

- The action has an identified project sponsor actively pursuing project development, has completed final NEPA or CEQA compliance documents, as appropriate, and appears to be “reasonably foreseeable” given other considerations such as site suitability, funding, economic viability, and regulatory limitations.
  - For actions being developed through federally authorized feasibility studies, legislation providing for construction authorization of a project is also required.
- Available information defines the action in sufficient detail to allow meaningful analysis.
- The action could affect resources potentially affected by the action alternatives.

The cumulative effects analyses in Chapters 4 through 14 of this EIS provide an evaluation (by resource category) of the cumulative effects based on both the projects, water demands, climate change and sea-level rise included in the CalSim II modeling and the projects and actions identified in Chapter 2 of this appendix. Projects and conditions (e.g., climate change, sea-level rise) included in the CalSim II modeling are evaluated quantitatively in Chapters 4 through 14. Projects included in Chapter 2 of this appendix are evaluated qualitatively in the cumulative effects section of Chapters 4 through 14.

Chapter 2
Additional Reasonably Foreseeable Projects or Actions

The additional reasonably foreseeable projects or actions, beyond those projects and actions incorporated in to the CalSim analyses, are described in this chapter. These projects are located within the Klamath River Basin, and Sacramento and San Joaquin River basins (i.e., generally corresponding to Central Valley Project facilities and service areas).

Additional reasonable foreseeable future projects or actions within the Klamath River Basin are described first and then projects or actions within areas of the Central Valley Project Facilities and Service Areas are described. The projects and actions are organized generally from north to south within those regions, as shown in Figure 2-1.While most projects and actions represented in Figure 2-1 have regional significance, the figure only represents the physical location of these projects or actions.

Table 2-1 is a summary table of the additional reasonably foreseeable projects that are physically within the geographic area affected by the action alternatives and overlap areas or effects within each resource area. The reasonably foreseeable projects are assumed to be implemented by 2030. Chapters 4 through 14 provide the cumulative effects analysis for each resource area.

Project ID	Name
01	Klamath River Main-Stem Dam Removal
02	Hoopa Valley Tribe Various Watershed Restoration Projects
03	FERC Relicensing for SWP Oroville Project
04	FERC Relicensing for Yuba River Watershed Hydroelectric Projects
05	FERC Merced River and Merced Falls Hydroelectric Projects

Note: Project and action physical locations are approximate.

Figure 2-1. Additional Reasonably Foreseeable Projects or Actions

Table 2-1. Additional Reasonably Foreseeable Projects that are Physically Within the Geographic Area Affected by the Action Alternatives and Overlap Areas or Effects Within the Resource Area

Project	Water Supply and Management	Surface Water Quality	Groundwater Resources/ Groundwater Quality	Biological Resources - Fisheries	Biological Resources: Terrestrial	Hydropower Generation	Air Quality, GHG Emissions, and Global Climate Change	Agricultural Resources	Socioeconomics	Indian Trust Assets	Environmental Justice
Klamath River Basin											
Klamath River Main-Stem Dam Removal	X	X		X		X	X		X	X	X
Hoopa Valley Tribe Various Watershed Restoration Projects				X	X				X	X	X
Central Valley Project Facilities and Service Areas											
FERC License Renewal for SWP Oroville Projects	X	X		X		X	X				
FERC Relicensing for Yuba River Watershed Hydroelectric Projects	X			X		X	X				
FERC Merced River and Merced Falls Hydroelectric Projects	X					X	X				

Key:
FERC = Federal Energy Regulatory Commission
GHG = greenhouse gas
SWP = State Water Project

Klamath River Basin

Klamath River Main-Stem Dam Removal

Built between 1903 and 1962, PacifiCorp's Klamath Hydroelectric Project consists of seven hydroelectric developments and one non-generating dam (PacifiCorp 2016). In 2012, the U.S. Department of Interior (DOI) and California Department of Fish and Game (now known as California Department of Fish and Wildlife [CDFW]) released the Klamath Facilities Removal Final EIS/Environmental Impact Report (EIR) that analyzed the potential impacts to the environment from the proposed removal of four PacifiCorp Dams (J.C. Boyle, Copco 1, Copco 2, and Iron Gate, collectively referred to as the Four Facilities) on the Klamath River under the Klamath Hydroelectric Settlement Agreement.

On April 6, 2016, the U.S. Department of the Interior, U.S. Department of Commerce, PacifiCorp, and the states of Oregon and California signed an agreement that, following a process administered by Federal Energy Regulatory Commission (FERC), is expected to remove the Four Facilities on the Klamath River by 2020. The amended dam removal agreement, which uses existing non-Federal funding and follows the same timeline as the original 2010 Klamath Hydroelectric Settlement Agreement, will be filed with FERC for consideration under their established processes. Under the agreement, dam owner PacifiCorp will transfer its license to operate the Klamath River dams to a private company known as the Klamath River Renewal Corporation. This company will oversee the dam removal in 2020. PacifiCorp will continue to operate the dams until they are decommissioned.

State and Federal officials also signed a separate agreement with irrigation interests and other parties known as the 2016 Klamath Power and Facilities Agreement. This agreement is intended to help Klamath Basin irrigators avoid potentially adverse financial and regulatory impacts associated with the return of fish runs to the Upper Klamath Basin, which are anticipated after dams are removed (Reclamation 2016).

Hoopa Valley Tribe Watershed Restoration Projects

There are ongoing tributary enhancement projects to improve fish habitat and identified priority riparian habitat along Mill and Supply Creeks located within the Hoopa Valley Indian Reservation. The channel rehabilitation will result in immediate short-term habitat creation and support long-term natural physical and biological stream processes. This will be accomplished by removing levees and channelization to reconnect the Mill or Supply Creek channels to a restored floodplain, increasing short-term and long-term large wood loading, implementing riparian re-vegetation, and creating off-channel side channels and ponds for Coho Salmon refugia. Through these recovery actions, the quality and quantity of salmonid habitat in Mill and Supply Creeks will increase, helping to increase the populations of Coho Salmon and other salmonids in the Trinity Basin. From a watershed-wide perspective, restoration of the valley floor reach of these tributaries is an opportunity to restore substantial low-gradient winter rearing habitat for both natal and non-natal salmonids in the Trinity Basin. Oversight and project management are provided by Hoopa Tribal Fisheries, National Marine Fisheries Service (NMFS), Trinity Valley Consulting Engineers, and CDFW staff (NMFS 2015).

Central Valley Project Facilities and Service Areas

Federal Energy Regulatory Commission License Renewal for SWP Oroville Projects

The Oroville Facilities, as part of State Water Project (SWP), are operated for flood management, power generation, water quality improvement in the Delta, recreation, and fish and wildlife enhancement. The objective of the relicensing process was to continue operation and maintenance of the Oroville Facilities for electric power generation, along with implementation of any terms and conditions to be considered for inclusion in a new FERC hydroelectric license. The initial FERC license for the Oroville Facilities, issued on February 11, 1957, expired on January 31, 2007. The Final EIR and Final EIS were completed in 2007 (FERC 2007). At this time, the revised Biological Opinion (BO) for U.S. Fish and Wildlife Service has been issued, however the revised BO for NMFS has not been issued. FERC has not yet issued the new 50-year license for the proposed action, and is currently issuing a license annually to California Department of Water Resources (DWR).

Federal Energy Regulatory Commission Relicensing for Yuba River Watershed Hydroelectric Projects

Nevada Irrigation District is applying for a new license for the Yuba-Bear Project (FERC Project No. 2266), and Pacific Gas and Electric (PG&E) are applying for the Drum-Spaulding Project (FERC Project No. 2310). The Yuba-Bear Project is located on the Middle and South Yuba rivers, Bear River, and Jackson and Canyon creeks. Concurrently, PG&E is applying for a license renewal for the Drum-Spaulding Project which is located on the Bear and Yuba rivers. Operations of the two projects are coordinated through multiple facilities and management actions. The Final EIS for these projects was issued in late 2014 (FERC 2014).

Federal Energy Regulatory Commission License Renewal for Merced River and Merced Falls Hydroelectric Projects

The Merced River Hydroelectric Project (FERC No. 2179), and the Merced Falls Hydroelectric Project (FERC No. 2467) are currently in the FERC relicensing process.

On February 26, 2012, Merced Irrigation District filed an application for a new license with FERC for the continued operation and maintenance of its 101.25-megawatt (MW) Merced River Hydroelectric Project. The Merced River Hydroelectric Project is located on the Merced River in Mariposa County and includes both Lake McClure and McSwain Reservoir, two powerhouses (New Exchequer and McSwain), and recreation facilities. The initial FERC license expired on February 28, 2014. The objective of the relicensing process is to continue operation and maintenance of the Merced River Hydroelectric Project facilities for electric power generation, along with implementation of any terms and conditions to be considered for inclusion in a new FERC hydroelectric license (MID 2016).

PG&E filed an application for a new license with FERC for the continued operation and maintenance of its 3.4-MW Merced Falls Hydroelectric Project. The Merced Falls Project is located at RM 55 on the border of Merced and Mariposa Counties, California.

The applications for the two projects are being processed together because they: (1) are located contiguously on the Merced River; (2) the Merced Falls Project's operation depends entirely on flows released by the upstream Merced River Project; and (3) downstream of the Merced River Project, the environmental effects of both projects are interrelated. The Final EIS for these two projects was released in December 2015 (FERC 2015).

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____. 2014. Final Environmental Impact Statement for Hydropower License for Upper Drum-Spaulding Hydroelectric Project, No. 2310-193, Lower Drum Hydroelectric Project, Project No. 14531-000, Deer Creek Hydroelectric Project, Project No. 14530-000, and Yuba-Bear Hydroelectric Project, Project No. 2266-102. California.

____. 2015. Final Environmental Impact Statement for Hydropower Licenses Merced River Hydroelectric Project, FERC Project No. 2179-043, and California Merced Falls Hydroelectric Project, FERC Project No. 2467-020, California.

MID (Merced Irrigation District). 2016. MID Hydro. Accessed: April 15, 2016. http://www.mercedid.com/index.cfm/water/hydro/

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RECLAMATION
Managing Water in the West

Environmental Impact Statement Statutory Authority Appendix

Long-Term Plan to Protect Adult Salmon in the Lower Klamath River
Draft

October 2016

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation’s natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to 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.

Contents

Abbreviations and Acronyms

CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
FWCA	Fish and Wildlife Coordination Act
Reauthorization Act of 1995	Trinity River Basin Fish and Wildlife Management Reauthorization Act of 1995
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
ROD	Record of Decision
SWRCB	State Water Resources Control Board
TRD	Trinity River Division
TRD Act	Trinity River Division Act of 1955

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Statutory Authority Appendix

Trinity River Division Act

Construction of the Trinity River Division (TRD) of the Central Valley Project (CVP) was authorized by the Act of August 12, 1955 (Public Law 84-386) (TRD Act). In section 2 of the 1955 TRD Act, Congress directed that the operation of the TRD should be integrated and coordinated with the operation of the CVP, subject to two conditions set forth as distinct Provisos in section 2 of that Act. The first of these two Provisos states that the Secretary of the Interior is authorized and directed to "adopt appropriate measures to insure the preservation and propagation of fish and wildlife" including certain minimum flows in the Trinity River deemed at the time as necessary to maintain the fishery. The second Proviso directs that not less than 50,000 acre-feet of water shall be released and made available to Humboldt County and other downstream users.[1]

The recently released Solicitor's Opinion, M-37030, concludes that each of the two Provisos in section 2 of the TRD Act are "separate and independent limitations on the TRD's integration with, and thus diversion of water to, the CVP" and that the two Provisos may "require separate releases of water as requested by Humboldt County and potentially other downstream users pursuant to Proviso 2 and a 1959 Contract between the U.S. Department of the Interior, Bureau of Reclamation (Reclamation) and Humboldt County."[2] M- Opinion 37030 at 2. Formal opinions of the Solicitor are binding on the Department of the Interior and its bureaus.

Section 2 of the TRD Act and, in particular, Proviso 1 of section 2 was the subject of the recent decision by the District Court for the Eastern District of California in *San Luis Delta Mendota Water Authority v. Jewell*, 52 F. Supp 3d 1020 (E.D. Cal. 2014) regarding the fall flow augmentation in 2013. In that decision, the court concluded that Proviso 1 was limited in scope to the Trinity River basin and did not provide authorization for the Secretary of the Interior to implement the 2013 flow releases to benefit fish in the lower Klamath River. *Id*. at 1063. The court also noted that remand was not appropriate because the focus of Plaintiffs' complaint was the completed 2013 flow releases.[3] The District court did not enter an order enjoining any further releases after 2013, and in 2014 the court did not enjoin flow releases.

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[1] Reclamation's water permits from the State of California includes the following condition:

> "Permittee shall release sufficient water from Trinity and/or Lewiston Reservoirs into the Trinity River so that not less than an annual quantity of 50,000 acre-feet will be available for the beneficial use of Humboldt County and other downstream users."

Condition 9.

[2] The 1959 water delivery contract between Reclamation and Humboldt County includes the following:

> "The United States agrees to release sufficient water from Trinity and/or Lewiston Reservoirs into the Trinity River so that not less than an annual quantity of 50,000 acre-feet will be available for the beneficial use of Humboldt County and other downstream users."

Contract, Article 8.

[3] The decision of the district court is currently on appeal to the Ninth Circuit Court of Appeals.

As discussed in more detail in the Solicitor's Opinion, the 1955 TRD Act and its legislative history support the view that the Act authorizes the Proposed Action to augment flows in the lower Klamath River to protect fish migrating through this area to the Trinity River. See M-Opinion 37030 at 9-13. The two Provisos in section 2 of the 1955 TRD Act were included specifically to protect the interests of downstream entities, ensuring that the interests of those downstream from the Project all the way to the ocean would be protected from the impacts of the Project.[4] The legislative history specifically shows that, prior to the passage of the 1955 TRD Act, in-basin users became concerned that the construction of the TRD would deprive them of their needs, and they thus sought to ensure that only water that was "surplus" to the needs of the downstream interests in the Trinity and lower Klamath River basins would be exported to the Central Valley.[5]

In a similar vein, the district court in its decision in *Tehama Colusa Canal Authority v. Interior,* 819 F. Supp 2nd 956 (2011), *aff'd* 721 F.3d 1086 (9th Cir. 2013), held that Congress can expressly provide for in-basin priority of water over the export of that water for general use by the CVP. The court noted that one purpose of the Trinity River division is "to transport Trinity River water to the Sacramento River," but then specifically cited Proviso 2 of the 1955 Act as a limitation on this authority. *Id*. at 982.

The court concluded that the 1955 Act:

> *Demonstrate[s] that Congress knew how to create a preference in the allocation of CVP water for an area when it wanted to do so. The [1955] Act prioritizes 50,000 acre feet of CVP water to Humboldt County. Congress created an express legislative priority for use of CVP water with particularized statutory language applicable to the Trinity River Division Unit.*[6]

Id. This analysis is consistent with the analysis and conclusions in the Solicitor's Opinion, which supports the use of Proviso 2 of section 2 of the TRD Act for the release of water from Trinity Reservoir for beneficial use to Humboldt County and other downstream users below Trinity Reservoir. The use of Trinity Reservoir water for fishery purposes is a beneficial use of water that is consistent with Proviso 2 of Section 2 of the TRD Act, the contract between Reclamation and Humboldt County and the Trinity Division water rights. The Solicitor's Opinion also recommended that Reclamation conduct "an appropriate level of analysis" in response to a request to release Trinity Reservoir water pursuant to Proviso 2 to consider the proposed use of the water and any other requirements or limitations that may apply to such release. There is thus, no absolute requirement that a specific quantity of water must be released in any given year,

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[4] *See, e.g.* S. Rept. No. 1154, 84th Cong., 1st Sess. (1955), p. 5 ("An asset to the Trinity River Basin, as well as the whole north coastal area, are the fishery resources of the Trinity River. The development of the Trinity River was planned with a view to maintaining and improving fishery conditions.")

[5] The bill reported by the House committee, H.R. 4663, emphasized:

That there is available for importation from the Trinity River, water that is surplus to the present and future water requirements of the Trinity and Klamath River basins, and that surplus water, in the amount proposed in the Trinity River division plan, can be diverted without detrimental effect on fishery resources. House Rept. No. 602, 84th Cong., 1st Sess. At 4 (May 19, 1955).

[6] The court also discussed a similar limitation on the integration of the New Melones Division of the CVP in its authorizing legislation.

rather the quantity and timing is based on the "appropriate level of analysis." Further, the Solicitor's Opinion states "a release made under Proviso 2 may also be part of the long-term management strategy regarding instream flows in the lower Klamath River." M- Opinion 37030 at 15.

The Trinity River Basin Fish and Wildlife Management Reauthorization Act of 1995

The Trinity River Basin Fish and Wildlife Management Reauthorization Act of 1995 (1995 Reauthorization Act), Pub. L No. 104-143, 110 Stat. 1338 (which was enacted after the Central Valley Project Improvement Act (CVPIA) and does not cite that statute) is among the statutes that may also provide authority for the augmentation flow releases.

The district Court in *SLDMWA v. Interior*, suggested that Reclamation could have relied on the 1995 Reauthorization Act as authority to make the augmentation releases. *SLDWMA* at 1061-62. The court also implied that this statute is not limited in the same manner as the court had interpreted the 1955 Act, and instead serves as "an acknowledgement that rehabilitation of fish and wildlife in the Trinity River Basin may require rehabilitation of fish habitat in the lower Klamath River." *Id*.

The 1995 Reauthorization Act modified the Trinity River Basin Fish and Wildlife Management Act of 1984, adding an additional subparagraph to Section 1 of that Act that states:

> *(5) Trinity Basin fisheries restoration is to be measured not only by returning adult anadromous fish spawners, but by the ability of dependent tribal, commercial, and sport fisheries to participate fully, through enhanced in-river and ocean harvest opportunities, in the benefits of restoration.*

The 1995 Act also modified the last subparagraph in Section 1, altering it to include a reference to the aiding ocean populations and the resumption of commercial and recreational fishing activities. The revised subparagraph (7) states:

> *(7) the Secretary requires additional authority to implement a management program, in conjunction with other appropriate agencies, to achieve the long-term goals of restoring fish and wildlife populations in the Trinity River Basin, and, to the extent these restored populations will contribute to ocean populations of adult salmon, steelhead, and other anadromous fish, such management program will aid in the resumption of commercial, including ocean harvest, and recreational fishing activities.*

The 1995 Act also expanded the reach of the authorized fishery restoration activities, amending Section 2(a)(1)(A) so that it states:

> *(a) Subject to subsection (b), the Secretary, in consultation with the Secretary of Commerce where appropriate, shall formulate and implement a fish and wildlife management program for the Trinity River Basin designed to restore the fish and*

> *wildlife populations in such basin to the levels approximating those which existed immediately before the start of the construction referred to in section 1(1) and to maintain such levels. . . . Such program shall include the following activities:*
>
> *(1) The design, construction, operation, and maintenance of facilities to –(A) Rehabilitate fish habitats in the Trinity River between Lewiston Dam and Weitchpec and in the Klamath River downstream of the confluence with the Trinity River.*

Both the House and Senate noted that this change was intended to authorize restoration activity in the Klamath River below the confluence with the Trinity River. S. Rpt. 104-253, 104th Cong. (1996) ("This section authorizes restoration activity in the Klamath River below its confluence with the Trinity River . . ."); H.R. Rpt. 104-395, 104th Cong. (1995) ("Section 3 also authorizes restoration activity in portions of the Klamath River . . .").

The Act also amended section 3 of the 1984 Act to add a new subsection (d), stating:

> *(d) Task Force actions or management on the Klamath River from Weitchpec downstream to the Pacific Ocean shall be coordinated with, and conducted with the full knowledge of, the Klamath River Basin Fisheries Task Force and the Klamath Fishery Management Council, as established under Public Law 99-552. The Secretary shall appoint a designated representative to ensure such coordination and the exchange of information between the Trinity River Task Force and these two entities.*

In addition, the 1995 Act added a section that states:

> *Sec. 5. – Nothing in this Act shall be construed as establishing or affecting any past, present, or future rights of any Indian or Indian tribe or any other individual or entity.*

In the October 1, 2014 Decision and Order, Judge O'Neill suggested that Reclamation could rely on the 1995 Act as authority to make releases to benefit the lower Klamath River, particularly because the addition of language to section 2(a)(1)(A) implied that the Act's focus was broader than just the Trinity River basin.

Section 4 of the 1984 Act, which was amended by the 1995 Act, included an authorization of appropriations for design and construction under the management program to be formulated under section 2 "to remain available until October 1, 1995," and an authorization of appropriations for operations, maintenance, and monitoring under the management program for each of the fiscal years in the 10-year period beginning on October 1, 1985. The 1995 Act extended the authorization in section 4(a) to October 1, 1998, and extended the authorization for operations, maintenance and monitoring for an additional 3 years, or a total of 13 years after the period beginning in 1985.

The 1995 Act also added an additional subsection (i) to section 4 to the 1995 TRD Act, stating:

> *(i) Beginning in the fiscal year immediately following the year the restoration effort is completed and annually thereafter, the Secretary is authorized to seek appropriations as necessary to monitor, evaluate, and maintain program investments and fish and wildlife populations in the Trinity River Basin for the purpose of achieving long-term fish and wildlife restoration goals.*

The program authorization set forth in section 2 is long-term, or permanent, general grant of authority despite the established expiration term for the authorization for appropriations and provides in general authority "[s]uch other activities as the Secretary determines to be necessary to achieve the long-term goal of the program" which include actions to restore habitat in the lower Klamath River such as the proposed fall flow releases.

The Fish and Wildlife Coordination Act

The Fish and Wildlife Coordination Act (FWCA) provides the Secretary with broad authority "to provide assistance to, and cooperate with, Federal, State, and public or private agencies and organizations" to take actions for the "protection, rearing, and stocking of all species of wildlife, resources thereof and their habitat, in controlling losses of the same from disease or other causes." 16 U.S.C. § 661. The Bureau of Reclamation has been delegated authority under the FWCA to take "actions, directly or by providing financial assistance… regarding the construction and/or continued operation and maintenance of any Federal reclamation project" to among other things "improve instream habitat." Departmental Manual, 255 DM 1.

The FWCA provides authority for Reclamation to take actions that result in habitat improvements such as releases of water to improve habitat for the fish in the lower Klamath River below its confluence with the Trinity River. This authority is discretionary. The delegation of authority to Reclamation under the FWCA specifies that any actions taken under this delegation must be related to habitat that is affected by a Reclamation Project. (Reclamation is authorized to conduct activities for the improvement of fish and wildlife habitat associated with water systems or water supplies affected by Reclamation projects, including but not limited to fish passage and screening facilities at any non-Federal water diversion or storage project within the region; Reclamation Manual 6.f.(2) [from 255 DM 1.1.B.)

The action alternatives are authorized by the FWCA because the construction and operation of the Trinity River Division affected the average annual flow in the Trinity River and the Klamath River below its confluence. The flow augmentation improves that habitat.

Central Valley Project Improvement Act

CVPIA§3406(b)(1) provides that the Secretary shall make all reasonable efforts to address "other identified adverse environmental impacts of the CVP not otherwise specifically enumerated in [3406(b)]." Reclamation could conclude that the CVP has adversely impacted the lower Klamath River. Since the TRD is part of the CVP, this section applies to the Trinity River.

Tribal Trust Obligation

The trust responsibility to protect the tribal fishing rights provides a supplementary authority for the action.

Water Rights

Reclamation holds eight water right permits for the operation of the TRD (Permits 11966, 11967, 11968, 11969, 11970, 11971, 11972, 11973). Three permits (11966, 11970, 11972) are for power generation; the other five allow appropriation of water for multiple purposes, including Fish and Wildlife Enhancement. The current water rights permits for the Trinity Division include terms providing for release of water consistent with Proviso 1 and Proviso 2 of the 1955 Act.

However, the lower Trinity River, and the lower Klamath River below Weitchpec, are not included in the water rights place of use for the five permits mentioned above. The State Water Resources Control Board (SWRCB), in a letter dated August 12, 2012 responding to a temporary urgency change petition filed by Reclamation to add the lower Trinity and Klamath Rivers to the place of use for these permits, stated “As the operator of Trinity Dam, Reclamation may bypass water without a change approval, and may release water for various purposes that do not require State Water Board approval. Examples of these purposes include releases for dam safety or maintenance, releases made to satisfy nonconsumptive cultural resource needs, or releases made to improve instream conditions for the benefit of aquatic resources.” However, the SWRCB went on to say that “(A)bsent a transfer or other change approved by the State Water Board, the Division cannot consider the bypass and/or release of water for such purposes as a beneficial use unless Reclamation's permitted place of use includes the streams where the water is bypassed and/or released. If Reclamation is concerned that its Trinity River permits do not cover the place of use for the planned salmonid protection activities, in addition to a Water Code section 1707 Petition, Reclamation should consider filing a Petition for Change of Place of Use pursuant to Water Code section 1701.” The SWRCB added “(A) decision to not divert water or failure to put water to beneficial use for a period of five years may result in reversion of the water to the public and result in partial or total revocation of the water right. (Water Code, § 1241.)”

The SWRCB’s discussion of the release of water from Trinity Reservoir applies equally to releases made as part of the Trinity River Restoration Program (the so-called “Record of Decision (ROD) Flows”). As part of its ongoing review of Central Valley Project water rights, and as part of a separate action from this Long Term Plan, Reclamation will evaluate whether to petition the SWRCB to protect releases made for the Long-Term Plan to Protect Adult Salmon in the Lower Klamath River, as well as the ROD Flows, from possible revocation and unauthorized diversion, and if so, when to seek such an action from the SWRCB.