Benefit Calculation, Monetization, and Resiliency Tab

Attachment 1: Model Assumptions

Attach description and assumptions of with-project conditions for years 2030 and 2070, as defined in section 6004(a)(2) of the regulations, as well as a description of the with- and without-project current conditions. See also regulations section 6003(a)(1)(BB).

WSIP Application Instructions, March 2017

Sites Reservoir Project Description and Assumptions of with-Project Conditions for Years 2030 and 2070 plus with and without-Project Current Conditions

August 9, 2017

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Figures

Acronyms and Abbreviations

Authority	Sites Project Authority
CALFED	CALFED Bay-Delta Program
cfs	cubic feet per second
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
DCR	Delivery Capability Report
Delta	Sacramento-San Joaquin River Delta
DSM2	Delta Simulation Model
DWR	California Department of Water Resources
Funks Reservoir	Holthouse Reservoir
GCID	Glenn-Colusa Irrigation District
M&I	municipal and industrial
MAF	million acre-foot (feet)
NODOS	North-of-Delta Offstream Storage
Reclamation	Bureau of Reclamation
SRSC	Sacramento River Settlement Contractor
SVI	Sacramento Valley 40-30-30 water year type index
SWP	State Water Project
SWRCB	State Water Resources Control Board
TAF	thousand acre-feet
T-C Canal	Tehama-Colusa Canal
TCCA	Tehama-Colusa Canal Authority
TRR	Terminal Regulating Reservoir
USACE	U.S. Army Corps of Engineers
USRDOM	Upper Sacramento River Daily Operations Model
VIC	Variable Infiltration Capacity

Introduction

This document provides descriptions and assumptions of the with-project conditions for the Sites Reservoir Project for years 2030 and 2070 as proposed by the Sites Project Authority (Authority). In addition, this document includes a description of the with- and without-project current conditions.

The with-project conditions include a 1.81-million-acre-foot (MAF) reservoir, which would be located in the Sacramento Valley west of the town of Maxwell, and associated conveyance facilities including use of existing Tehama-Colusa Canal (T-C Canal) and Glenn-Colusa Irrigation District (GCID) Main Canal diversion and conveyance facilities, plus a proposed new diversion and discharge pipeline. The proposed reservoir would be filled by diversion of excess Sacramento River water that originates from unregulated tributaries to the Sacramento River downstream from Keswick Dam. These flows are "excess" to those needed to meet current regulatory requirements or other water demands. Operation of the proposed reservoir would be in cooperation with the operations of existing Central Valley Project (CVP) and State Water Project (SWP) system facilities to facilitate and maximize the potential for a wide range of benefits. Detailed operating agreements would need to be developed that define a framework and procedures for cooperative operations among the Sites Project Authority (Authority), Central Valley Project (CVP), and State Water Project (SWP).

Approach

The with-project assumptions were developed through a series of meetings and coordination with Authority representatives including participating water district managers and county representatives, California Department of Water Resources (DWR), and Bureau of Reclamation (Reclamation). The with-project condition builds on previous work conducted under the CALFED Bay-Delta Program (CALFED) by DWR and Reclamation. Subsequent to CALFED, DWR has been the lead on technical studies in coordination with the Authority as part of the North-of-Delta Offstream Storage (NODOS) Project and associated investigations.

The analyses conducted for the Sites Reservoir Project utilized the model products and assumptions described in section 6004(a)(1) of the code of regulations. This includes the 2030 and 2070 future conditions CALSIM II and DSM2 models provided by the California Water Commission on November 2, 2016. The models provided by the commission were modified to include the facilities and operation of the Sites Project as described below in the Project Description and Assumptions section. There were no modifications to existing CVP and SWP operating criteria.

The with- and without-project Current Conditions analyses were based on the DWR State Water Project Final Delivery Capability Report 2015 (DWR 2015) – base scenario. Similar to above, the DCR 2015 base scenario, provided by DWR, was modified to include the facilities and operation of the Sites Project. The project description and assumptions for the with-project current condition is the same as described for the 2030 and 2070 with-project conditions.

The CALSIM II model is based on a monthly time step and, therefore, does not incorporate all the detailed decision processes that occur in actual daily operations of the CVP and SWP systems. To evaluate naturally occurring storm event flows, supplemental modeling was conducted on a daily time step to assess availability of excess Sacramento River flows.

Table 1 (located at the end of this document) shows the range of potential beneficiary operations under drought and other hydrologic conditions, and priorities assumed for various seasonal operations. It is intended that storage and associated releases could be adaptively managed to support operational actions found to produce the greatest benefits over time.

The analyses included the use of other analytical tools that were updated for future 2030 and 2070 conditions. These tools include:

- USRDOM – Upper Sacramento River Daily Operations Model
- Sacramento River HEC5Q model
- SALMOD
- American River CE-QUAL Model
- CWEST
- SWAP
- LTGEN
- SWP Power
- NODOS Power

The analytical framework, tools, and analyses were formulated for evaluating the benefits and impacts of the Project. The framework provides for iteratively refining operations criteria to minimize both the systemwide and localized impacts on various resources while maximizing the benefits.

The primary model in the framework is CALSIM II with inputs describing the hydrology, facilities, water management, regulatory standards, and operational criteria assumptions. CALSIM II outputs regarding system operation decisions including deliveries, flows and storages are then used by every other model in the analytical framework. CALSIM II operations were informed based on the reporting metrics from various models that simulate river temperatures, anadromous fish survival, Delta water quality, hydropower generation and economics.

Upper Sacramento River Daily Operations Model (USRDOM) uses the CALSIM II outputs regarding the operational controls and reservoir releases to simulate daily reservoir operations and daily river flows for the upper Sacramento River from Shasta Dam to Knights Landing. For evaluating Project operations, CALSIM II and USRDOM were simulated iteratively to determine potential Reservoir diversions based on flow conditions in Sacramento River.

Delta Simulation Model (DSM2) was used to simulate hydrodynamics (flow, velocity and water levels) and water quality (salinity) in the Sacramento-San Joaquin Delta. The Upper Sacramento River HEC5Q model was used to simulate reservoir and river temperatures in the upper Sacramento River, from Shasta Lake to Knights Landing. The Folsom CE-QUAL-W2 model was used to simulate reservoir and river temperatures on the American River. The SALMOD model was used to simulate benefits to anadromous fish in the Sacramento River. The LTGEN, SWP Power, and NODOS Power were used to study the power production and use. The SWAP and CWEST economic modeling tools were used to study the benefits to agricultural water supply and urban water supply. The interrelationships between the models are shown in the analytical framework in Figure 1.

Descriptions of the models used in the analytical framework are included in the following attachments.

- CALSIM II and DSM2 Modeling Assumptions
- HEC5Q Modeling for the Sites Project
- SALMOD Salmon Modeling of the Sacramento River
- Upper Sacramento River Daily Flow and Operations Modeling
- Power Modeling of the Sites Reservoir Project
- Economic Modeling of the Sites Reservoir Project
- Folsom Reservoir CE-QUAL-W2 Temperature Modeling

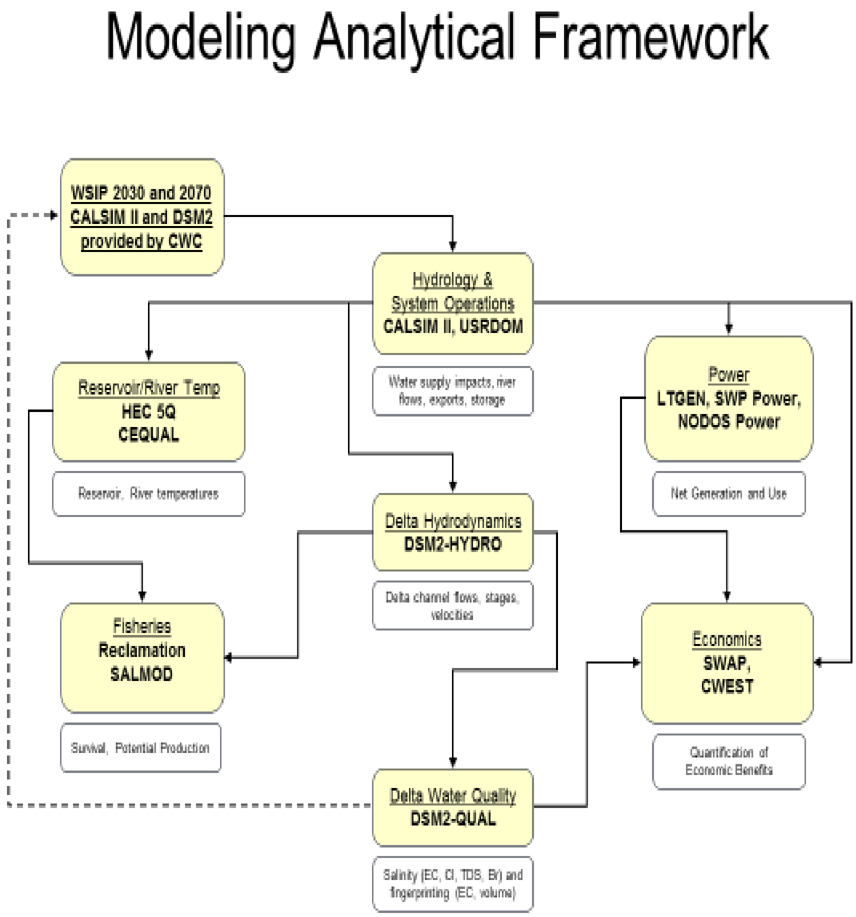


Figure 1. Modeling Analytical Framework

Project Description and Assumptions

Sites Reservoir would be filled by diversion of excess Sacramento River flows that originate from unregulated tributaries to the Sacramento River downstream from Keswick Dam. As described below, diversions are assumed to potentially occur in any month or water year type, but would likely be greatest in the winter months with wetter conditions (depending on storage conditions and annual flows and events). The Sites Reservoir Project could operate in cooperation with CVP and SWP system facilities to facilitate a wide range of benefits. Sites Reservoir would provide water through four primary mechanisms:

- Water stored in Sites Reservoir could be released directly to Colusa Basin users,
- Water could be released to the Sacramento River
- Water could be released through the Colusa-Basin Drain and Knights Landing Ridge Cut
- Water stored in Sites Reservoir could be exchanged for water stored in Shasta Lake or other CVP and SWP system reservoirs.

This last mechanism could be used to significantly increase upstream north-of-Delta storage and operational flexibility to support multiple water supply and ecosystem benefits.

The project employs a strategy to maximize the potential benefits of Sites Reservoir while not adversely affecting the CVP and SWP's ability to meet existing system regulatory requirements including the following:

- Water rights
- Instream flow requirements
- Biological opinions
- Delta water quality requirements
- CVP and SWP requirements
- Central Valley Project Improvement Act (CVPIA)

The following sections describe the proposed Sites Reservoir Project infrastructure, Sacramento River diversion criteria and assumptions, public benefits, and water supply benefits.

Project Infrastructure

The primary facilities include a 1.81-MAF Sites Reservoir that would rely on the existing T-C Canal and GCID Main Canal for diversion and conveyance purposes, as well as a new proposed Delevan Pipeline and intake to divert and convey water to and from the reservoir. Figure 1 shows the location of the proposed reservoir and associated conveyance facilities. A description of existing and proposed new conveyance facilities and their proposed operation follows.

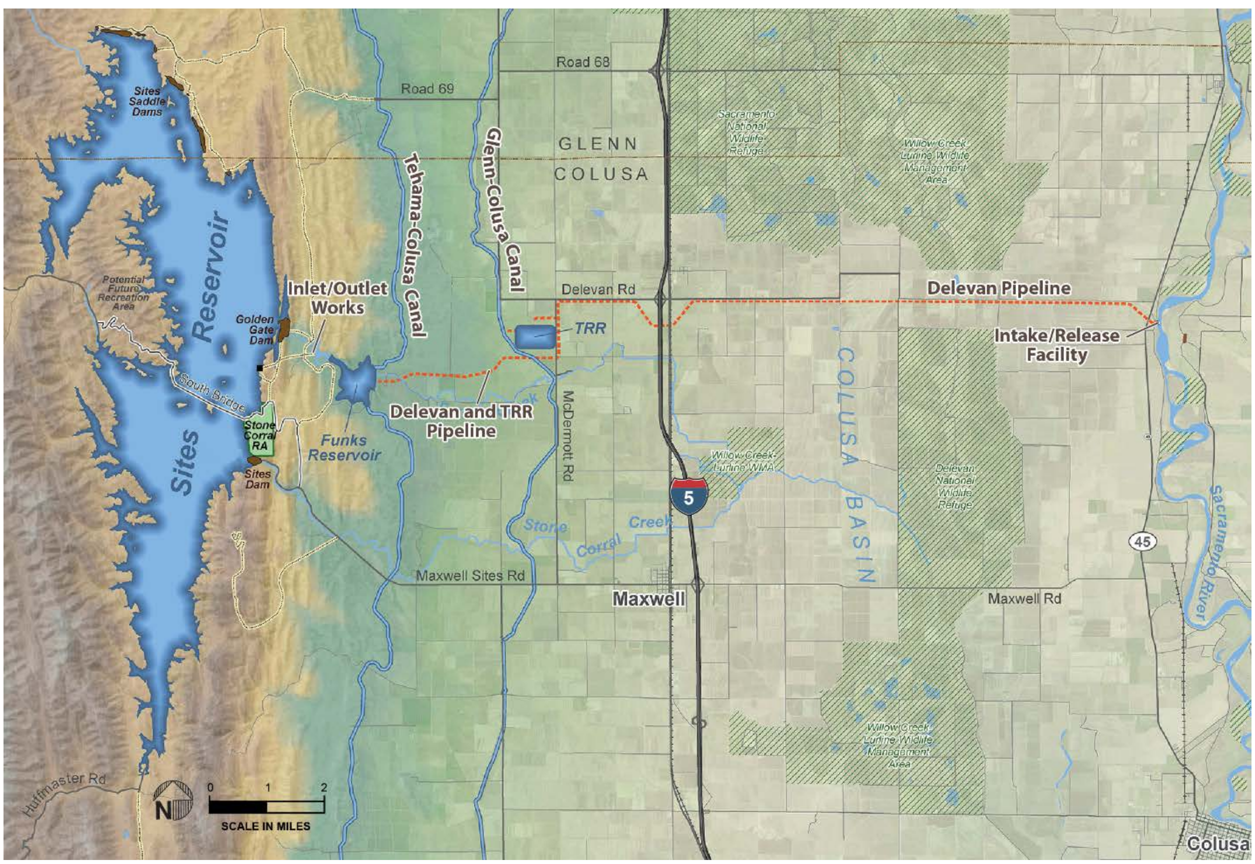


Figure 2. Sites Reservoir and Proposed Facilities

Tehama-Colusa Canal and Red Bluff Pumping Plant Facilities and Capacity

The existing Tehama-Colusa Canal Authority's (TCCA) T-C Canal through the TCCA service area and Red Bluff Pumping Plant located on the Sacramento River near Red Bluff would be used to divert and convey water to the proposed Sites Reservoir. Operating agreements among the Authority, TCCA, and Reclamation would need to be developed to define Sites Reservoir Project operations and cooperation among the parties.

Red Bluff Pumping Plant has an existing pumping capacity of 2,000 cubic feet per second (cfs), which is used to meet current agricultural water demand. The project would include installation of one additional pump (250 cfs) to the existing pump grouping, which would increase the overall pumping capacity to 2,250 cfs to fully use the 2,100-cfs capacity for diversion of water through T-C Canal to Sites Reservoir. The total conveyance capacity of T-C Canal is assumed to be 2,250 cfs at the upstream end of the canal and 2,100 cfs at Holthouse Reservoir. Any unused capacity remaining after meeting existing agricultural demands could be used as necessary to convey water to fill Sites Reservoir. Approximately 50 to 60 cfs of the T-C Canal capacity is assumed to be used for existing winter operations, based on communication with TCCA representatives.

No dedicated period for maintenance was assumed for T-C Canal on the basis of current canal capacity and projected Sites Reservoir diversion amounts. Discussions with TCCA representatives revealed operations and maintenance could be scheduled around proposed Sites Reservoir Project operations.

Glenn-Colusa Irrigation District Main Canal and Hamilton City Pumping Facilities and Capacity

Similar to T-C Canal, GCID Main Canal would be used to convey water pumped from the existing Hamilton City pumping facility to divert and convey Sacramento River water to the proposed Sites Reservoir. Operating agreements between the Authority and GCID would need to be developed to define Sites Reservoir Project operations and cooperation between the parties. The Hamilton City pumping facility has a 3,000 cfs diversion capacity at the Sacramento River intake, and the capacity of GCID Main Canal is 1,800 cfs at TRR. Any unused capacity remaining after existing agricultural operations could be used to convey water to the proposed Sites Reservoir. The following flows are assumed to occupy capacity in the canal during existing winter operations of GCID Main Canal (values in cfs).

October	November	December	January	February	March
513	534	389	235	56	48

A dedicated annual maintenance shutdown period was assumed from January 7 through February 21.

Proposed Delevan Pipeline and Intake Diversion and Release Capacities

The proposed Delevan Pipeline would extend east/west across the GCID service area located west of the existing Maxwell Irrigation District intake facility. The proposed intake and discharge facility would include a fish screen and pump station intake to divert up to 2,000 cfs from the Sacramento River to Sites Reservoir when excess Sacramento River water is available for diversion. The pipeline would also have the ability to convey up to 2,500 cfs by gravity from the Sites Reservoir back to the Sacramento River for downstream uses.

A dedicated annual maintenance shutdown period sometime between April 1 and May 31 is assumed for the pipeline, intake, and fish screen facility in wet, above-normal, and below-normal water year types in accordance with the Sacramento Valley 40-30-30 index. During the maintenance, both diversion and release operations at Delevan would be shut down. No maintenance would be scheduled in dry and critical water year types.

Existing Tehama-Colusa Canal and Glenn-Colusa Irrigation District Main Canal Intertie

The existing T-C Canal and GCID Main Canal intertie provides flexibility in routing flows of up to 285 cfs from the T-C Canal to the GCID Main Canal.

Williams Outlet

The Williams Outlet provides flexibility in routing water of up to 65 cfs from the T-C Canal to the GCID Main Canal.

Holthouse (Funks) Reservoir

The existing Funks Reservoir includes a storage capacity of 2,250 acre-feet and serves as a re-regulating reservoir to stabilize flows in T-C Canal as diverters come on line and off line. The existing Funks Reservoir would be expanded to form Holthouse Reservoir by constructing a new dam (Holthouse Dam) and reservoir to the east of Funks Reservoir, with an enlarged active storage capacity of approximately 6,500 acre-feet and a surface area of approximately 450 acres.

Terminal Regulating Reservoir and Pipeline

TRR would be a 1,200-acre-foot regulating reservoir constructed adjacent to GCID Main Canal, approximately 3 miles northeast of Holthouse Reservoir. TRR would be composed of an earthen embankment dam, concrete emergency overflow weir, outfall standpipe, and an approximate 4,000-foot-long underground 60-inch-diameter overflow outlet pipe to Funks Creek.

Water conveyed down GCID Main Canal would be directed into the proposed TRR. A new pump station (the proposed TRR pumping and generating plant) would then convey the water from TRR via the proposed TRR pipeline to the proposed Holthouse Reservoir. TRR would be required to provide operational storage for the TRR pumping and generating plant to balance normal and emergency flow variations between the upstream GCID Main Canal pump station, the 40 miles of connecting canal, and the TRR pumping and generating plant.

The proposed TRR pipeline would be bidirectional, allowing water to be pumped from TRR to Holthouse (Funks) Reservoir for storage, and allowing water to flow by gravity from Holthouse Reservoir for release to TRR and GCID Main Canal. The pipeline would have a capacity of 1,800 cfs to convey water pumped from TRR to Holthouse Reservoir. The capacity of the pipeline to convey water by gravity flow from Holthouse Reservoir to TRR would be 900 cfs.

Diversions to Sites Reservoir

The proposed Sites Reservoir would be filled through the diversion of excess Sacramento River water that originates from unregulated tributaries to the Sacramento River downstream from Keswick Dam. Less than 1 percent of diversions to Sites Reservoir are assumed to be provided by flood releases or spills that flow through Lake Shasta. Sacramento River water would be diverted at the three locations on the river as described above. Excess flows are defined as river flows in addition to those required to meet the following:

- Senior downstream water rights, existing CVP and SWP and other water rights diversions including SWP Article 21 (interruptible supply), and other more senior excess flow priorities (diversions associated with Freeport Regional Water Project and existing Los Vaqueros Reservoir)
- Existing regulatory requirements including State Water Resources Control Board (SWRCB) D-1641, CVPIA 3406(b)(2), the 2008 U.S. Fish and Wildlife Service biological opinion, and the 2009 National Marine Fisheries Service biological opinion and other instream flow requirements
- Bypass flow conditions needed to maintain and protect anadromous fish survival and Delta water quality

The Authority would need to obtain a water right permit to allow the intended operations. Operations would be consistent with the terms and conditions contained in the water right permit approved by SWRCB. The permit would describe the points and methods of diversion, diversion season, purposes of use, and places of use.

A description of proposed minimum bypass flow requirements and pulse flow criteria to protect existing and future water uses are provided below.

Sites Reservoir Diversion Bypass Flow Protection

Excess Sacramento River flow diversions to Sites Reservoir would only take place when flow monitoring indicates that bypass flows are present in the river due to storm event flows. Several existing and additional proposed bypass flow criteria were assumed at specified locations. These flow criteria are designed to make certain only excess water would be diverted into Sites Reservoir to maintain and protect existing downstream water uses, as follows.

- A bypass flow of 3,250 cfs downstream from Red Bluff Diversion Dam must be present to maintain flows in the upper Sacramento River that are required in SWRCB WR 90-5 to prevent dewatering salmonid redds and maintain water temperatures. Diversions at Red Bluff Pumping Plant for filling Sites Reservoir would only be allowed when flows in the river were above the 3,250-cfs bypass flow criteria.
- Diversions at the Hamilton City intake for GCID Main Canal currently require a bypass flow of 4,000 cfs to prevent fish entrainment. Diversions at Red Bluff Pumping Plant and GCID Main Canal intake for filling Sites Reservoir would only be allowed when flows in the river were above the 4,000-cfs bypass flow requirement downstream from Hamilton City.
- Diversions for filling Sites Reservoir would only be allowed when flows below Wilkins Slough were above 5,000 cfs given the current minimum flow requirements. Wilkins Slough Navigation Control Point minimum flows currently range from 3,250 to 5,000 cfs depending on hydrologic conditions.
- Diversions for filling Sites Reservoir would only be allowed when a Sacramento River flow of 15,000 cfs is present at Freeport in January, 13,000 cfs in December and February through June, and 11,000 cfs in all other months. This flow threshold was designed to protect and maintain existing downstream water uses and water quality in the Delta.

Pulse Flow Protection Diversion Assumptions

Operations modeling of the proposed Project included restrictions on diversions to limit impacts on out-migrating juvenile fish as a “surrogate” for likely permit conditions. Based on recent literature and the proposed permit conditions for other diversion projects, operations modeling for the proposed Project diversions were assumed to be restricted to minimize impacts to fish passage associated with pulse flow events that stimulate the observed spike in juvenile salmon outmigration. Actual operations are anticipated to be informed by real-time monitoring of fish movement.

The assumed limits on diversions during naturally occurring, storm-induced pulse flow events in the Sacramento River were based on a recent study by del Rosario et al. (2013), which found an abrupt and substantial spike in winter-run Chinook salmon arrivals at Knights Landing in association with the first storm event producing a flow of 400 cubic meters per second (14,126 cfs) at Wilkins Slough. This spike was followed shortly by passage of up to the 50th percentile of cumulative migration. This relationship was apparent for a wide range of water year types based on catch data collected between 1999 and 2007.

Accordingly, an assumed pulse protection period was developed that would extend from October through May to address out-migration of juvenile winter-, spring-, fall- and late-fall-run Chinook salmon, as well as steelhead. Pulse flows during this period would provide flow continuity between the upper and lower Sacramento River to support fish migration. It is recognized that research regarding the benefits of pulse flows is ongoing, and further research and adaptive management would be required to develop and refine a pulse flow protection strategy for fish migration and, as such, this assumption was used for modeling and informational purposes only.

For proposed Sites Reservoir operations, pulse flows are defined by extended peak river flows at Bend Bridge that originate primarily from storm event tributary inflows downstream from Keswick Dam. For the purposes of operations modeling, a naturally occurring pulse event was considered initiated when the 3-day running average flow below Bend Bridge exceeded 15,000 cfs. Such an event would need to continue for at least a 7-day duration to be considered a qualified storm event for the simulation process. Diversions to Sites Reservoir would not be allowed during the 7-day period that flow was greater than 15,000 cfs. The duration of a pulse flow event would be considered terminated under the following conditions: 1) the 3-day running average discharge flow remained greater than 15,000 cfs for 7 days after initiation, 2) the 3-day running average discharge flow dropped below 15,000 cfs before reaching the 7-day duration, or 3) the 3-day running average discharge flow exceeded 25,000 cfs before reaching the 7-day duration.

Given that del Rosario et al. (2013) indicate that the first storm event was associated with a spike in salmon arrivals at Knights Landing, diversions to Sites Reservoir would not be allowed during the first 7-day qualified pulse period, when flows reach 15,000 cfs during the out-migration season. For evaluation of Sites Project Reservoir operations, it was assumed that up to one qualified 7-day pulse event would occur each month during the pulse protection period from October through May, to encourage and support salmonid out-migration and minimize potential diversion impacts. Therefore, for operations modeling, diversions to Sites Reservoir storage would be restricted under the following conditions: 1) if pulse conditions exist at Bend Bridge, and a qualified pulse event has not already occurred within the given month, and 2) if Bend Bridge flows are less than 25,000 cfs during the pulse event. Diversions are allowed when flows exceed 25,000 cfs because flows of this magnitude are considered to provide lesser benefits to fish migration, as shown in Figure 2.

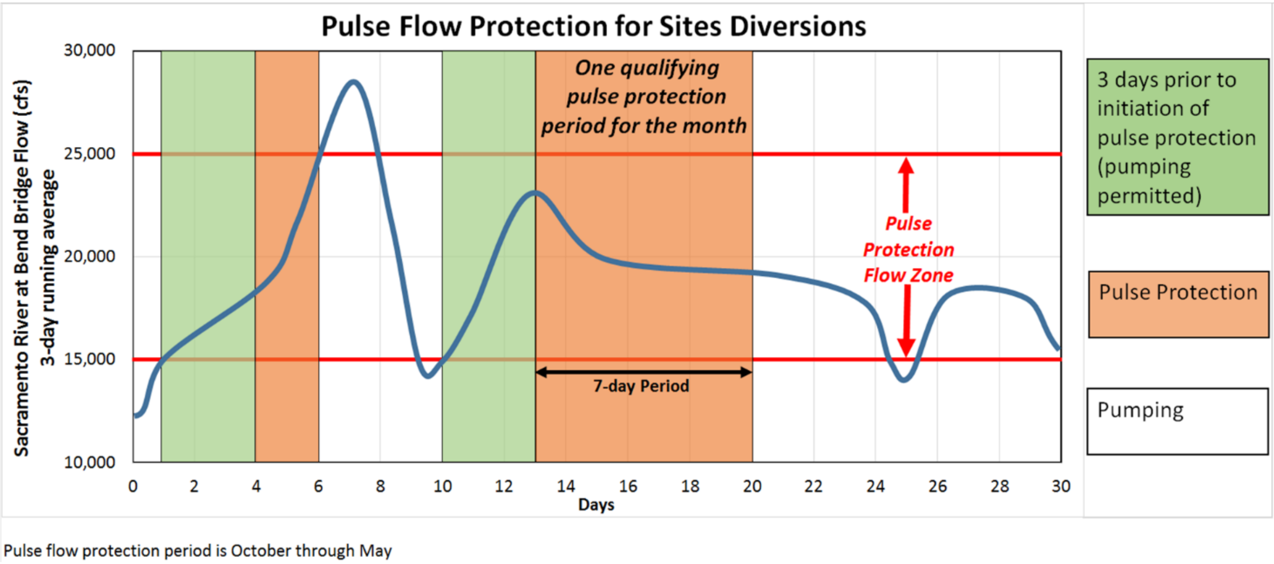


Figure 3. Pulse Flow Protection for Sites Diversions

Diversions to Fill Sites Reservoir Storage

Diversions of excess Sacramento River water to Sites Reservoir using existing T-C Canal and GCID Main Canal conveyance facilities could occur at any time during the year, given the flow conditions described above are present in the river. Deliveries for TCCA and GCID service areas have first priority at the existing T-C Canal and GCID intakes, with diversions to Sites Reservoir using the unused capacities of the two canals.

Diversions through the proposed Delevan Pipeline could also occur at any time of the year assuming Sacramento River flow conditions are above the bypass and pulse flow criteria described above. In summer months, preference would generally be given to Sites Reservoir releases to the river, resulting in limited diversions to storage because the pipeline could only convey flows in one direction at a time.

Sites Reservoir Evaporation

In the absence of available evaporation data, Sites Reservoir "net-evaporation" rates were estimated using evaporation and precipitation data from existing nearby reservoirs. Net-evaporation is the difference between evaporation and precipitation. Positive values indicate higher rates of evaporation than precipitation while negative values indicate lower rates of evaporation than precipitation. Evaporation and precipitation data have been collected for three nearby reservoirs along Stony Creek including: (1) East Park Reservoir, (2) Stony Gorge Reservoir, and (3) Black Butte Lake.

The evaporation data was taken from Reclamation's Stony Creek model (Yaworsky, 2006), which makes monthly estimates based on historical data from DWR, Reclamation, and U.S. Army Corps of Engineers (USACE). These evaporation rates are consistent with the data used as inputs in the DCR 2015, WSIP 2030, and WSIP 2070 CALSIM II models.

The data consists of six historical time series ranging from October 1922 to September 2003 at a monthly time-step. The average annual evaporation rates at East Park Reservoir, Stony Gorge Reservoir, and Black Butte Lake are 6.5 TAF, 4.7 TAF, and 12.2 TAF, respectively. The precipitation data has been provided by the Variable Infiltration Capacity (VIC) model (Liang et al., 1994), a large-scale, semi-distributed hydrologic model originally developed by Xu Liang at the University of Washington.

The net-evaporation rates for East Park Reservoir, Stony Gorge Reservoir, and Black Butte Reservoir were computed by subtracting each reservoir's precipitation rates from its evaporation rates. The monthly net-evaporation of the three reservoirs was averaged and used as the input for Sites Reservoir net-evaporation. Using this method, the average annual net-evaporation for Sites Reservoir equates to 33.3 TAF.

Consistent with all other evaporation inputs in CALSIM II, the Sites Reservoir net-evaporation rates are unchanged under 2030 and 2070 future climate conditions.

Reservoir Operations Assumptions

The primary operational criteria include the following:

- A defined ecosystem enhancement storage account would be established in Sites Reservoir to be managed by the State to provide water for ecosystem and water quality purposes.
- Each of the participating Authority members would be allocated a defined storage account in the Sites Reservoir Project to manage their water, as well as store water from other potential sources of supply.
- It is assumed that a water market of some form would be facilitated by the Authority to promote efficient use and exchange of water in Sites Reservoir storage.
- All storage accounts would receive an equal proportional share of new water diversions into Sites Reservoir storage.
- Any water in storage beyond designated member account volumes would be "at risk" and would be "spilled" if the reservoir fills to capacity.
- A set of operating guidelines and rules would be developed to promote efficient water management for operations of Sites Reservoir and associated facilities.
- All water stored in Sites Reservoir storage accounts are subject to evaporation and other losses.

Public Benefits

The operation of Sites Reservoir Project would allow for the development and administration of an ecosystem enhancement storage account that could be managed by the State to provide water for ecosystem and water quality purposes. Such an account would provide a pool of dedicated storage to manage in cooperation with existing operations to improve coldwater conservation storage, stabilize river flows during critical fisheries periods, increase flows through certain watercourses and/or facilities (such as, Yolo Bypass), improve water quality, and/or enhance habitat restoration.

Sites Reservoir Project would be operated in cooperation with CVP and SWP operations to coordinate releases from Trinity Lake, Shasta Lake, Lake Oroville, and Folsom Lake. Releases from Sites Reservoir would allow reduced releases from other reservoirs while still meeting requirements for minimum instream flow objectives, Sacramento River temperature requirements, and Delta salinity control assigned to CVP and SWP. Through this reduction in releases, storage could be conserved in Trinity Lake, Shasta Lake, Lake Oroville, and Folsom Lake to significantly increase operational flexibility to improve river water temperatures for fish survival, Delta water quality, flood control, and recreation.

The following summarizes the anticipated primary benefits that could be realized through the provision of Sites Reservoir Project water beyond that required to meet Authority member needs. The priorities and amount of water potentially allocated to achieving the benefits listed below will be subject to the participation of the California Water Commission Water Storage Investment Program. Sites Reservoir Project operations would achieve multiple benefits over a wide range of hydrologic conditions.

In drought conditions, Sites Reservoir Project could:

- Increase coldwater pool conservation in Trinity Lake, Shasta Lake, Lake Oroville, and Folsom Lake
- Help regulate Sacramento River summer flows for best use of cold water for control of temperature conditions adverse to anadromous fish

In non-drought hydrologic conditions, Sites Reservoir Project water could:

- Stabilize Sacramento River fall flows for improving spawning and rearing success of anadromous fish
- Provide water to the Yolo Bypass to support salmon migration and summer food production for delta smelt
- Provide water for Incremental Level 4 refuge deliveries per CVPIA
- Provide (via upstream actions) incidental Delta water quality improvements in the summer and fall

More detailed descriptions of potential actions that could be implemented in cooperation with the CVP and SWP operations are provided below.

Shasta Lake Coldwater Pool and Sacramento River Temperature Control

Maximum benefits could be realized assuming Sites Reservoir and Shasta Lake were operated in cooperation to increase Shasta Lake storage and preserve a greater volume of coldwater pool storage. This additional cold water would improve operational flexibility to provide releases to maintain appropriate water temperatures in the Sacramento River during summer months and in drought years.

Through releases from Sites Reservoir to meet TCCA and GCID irrigation diversions and equivalent reductions in CVP Shasta Lake releases, demands on Shasta Lake storage could be reduced and the coldwater pool maintained for a longer time at higher levels than are currently achievable. Shasta Lake release patterns could be shifted in season and between adjacent years to improve coldwater storage and flow management for salmon and other species using the portion of the Sacramento River between Keswick Dam and the Red Bluff Diversion Dam as habitat.

Stabilize Upper Sacramento River Fall Flows

Additional storage in Shasta Lake could be used to stabilize fall flows between Keswick Dam and Red Bluff to avoid abrupt flow reductions due to changes in local tributary inflows as a results of storm events. This would reduce adverse conditions for spawning fall-run Chinook salmon (such as, dewatering of redds and scour damage).

Sacramento River Diversion Reductions at Red Bluff and Hamilton City

The Sites Reservoir Project could allow Shasta Lake to provide increased Sacramento River flows in spring through fall by reducing Sacramento River diversions into T-C Canal and GCID Main Canal during the irrigation season. This would be achieved through exchange with releases from Sites Reservoir to meet CVP T-C Canal and GCID Main Canal contract demands, and could provide multiple benefits to anadromous fish and estuarine-dependent species by providing or augmenting transport flows, increasing habitat availability, increasing productivity, and improving nutrient transport and food availability.

Folsom Lake Coldwater Pool Improvement and Supply Reliability

Sites Reservoir Project operations in cooperation with Folsom Lake could improve the reliability of coldwater carryover storage at Folsom Lake, stabilize flows in the American River, and help maintain suitable water temperatures in the lower American River. Additional summer releases from Sites Reservoir could reduce the need for releases from Folsom Lake, resulting in increased carryover storage. Sites Reservoir releases could also provide additional Delta outflow and reduce short-term emergency flow reliance on Folsom Lake releases to maintain Delta water quality.

Yolo Bypass and Delta Outflow Improvement

Sites Reservoir releases through the Colusa Basin Drain and Knights Landing Ridge Cut into the Yolo Bypass would help increase productivity in in the lower Cache Slough and lower Sacramento River areas to increase desirable food sources for Delta smelt and other key fish species in the late summer and early fall.

Lake Oroville Coldwater Pool Improvement

Sites Reservoir releases could increase the reliability of coldwater pool storage in Lake Oroville to reduce lower Feather River water temperatures for juvenile steelhead and spring-run Chinook salmon over-summer rearing, and fall-run Chinook salmon. Higher and more stables flows in the lower Feather River at critical times could also minimize redd dewatering, juvenile stranding, and isolation of anadromous salmonids.

Water Supply

The Sites Reservoir Project could provide a substantial amount of water to potential Sites Reservoir Project participants including agricultural and municipal and industrial (M&I) users. Sites Reservoir water would be released to meet demands and supplement existing allocations to CVP contractors in the Colusa Basin and released for other water users in the Sacramento Valley.

The South-of-Delta CVP and SWP contractors that receive water from the Sites Reservoir Project have contract provisions for the conveyance of extra water through SWP of CVP facilities above their SWP or CVP allocations. These water users may opt to have their Sites Reservoir Project water conveyed as either “project” water or “non-project” depending on the conveyance agreements they develop with DWR or Reclamation. If the water is conveyed as project water, then it has a more flexible timeframe for its conveyance and the releases of their water from Sites via the Delevan Pipeline. If the water is conveyed as non-project water, then the water would likely be released from Sites Reservoir and conveyed south or west of the Delta during the “water transfer window” in the biological opinions for the operation on the CVP/SWP in the Delta, provided there is capacity to convey this non-project water.

Works Cited

California Department of Water Resources (DWR), 2015. The State Water Project Final Delivery Capability Report 2015. July.

del Rosario, R. B., Y. J. Redler, K. Newman, P. L. Brandes, T. Sommer, K. Reece, R. Vincik. 2013. “Migration Patterns of Juvenile winter-run-sized Chinook Salmon (*Oncorhynchus tshawytscha*) through the Sacramento–San Joaquin Delta.” *San Francisco Estuary and Watershed Science*. Vol. 11(1).

Liang, X., 1994. A Two-Layer Variable Infiltration Capacity Land Surface Representation for General Circulation Models, *Water Resource. Series*, **TR140**, 208 pp., Univ. of Washington, Seattle.

U. S. Bureau of Reclamation, 2006. Colusa Basin Hydrology Project, Appendix H Reclamation Stony Creek Model, March 2004.

Yaworsky, 2006. Stony Creek evaporation model. Prepared for Reclamation.

CALSIM II and DSM2 Modeling Assumptions

CALSIM II and DSM2 Modeling Assumptions

Introduction

This attachment provides a description of the assumptions for the CALSIM II and DSM2 modeling of the Current Conditions, WSIP 2030, and WSIP 2070 without project scenarios.

The with- and without-project Current Conditions analyses were based on the DWR State Water Project Delivery Capability Report 2015 (DCR 2015) – base scenario. The DCR 2015 base scenario was modified to include the facilities and operation of the Sites Project.

The 2030 and 2070 future conditions CALSIM II and DSM2 models provided by the California Water Commission on November 2, 2016 were modified to include the facilities and operation of the Sites Project.

Assumptions for DCR 2015, WSIP 2030, and WSIP 2070 Model Without Project Simulations

This section documents the assumptions used in the CALSIM II and DSM2 model simulations for the baseline model (Without Project) simulations used in the Sites Reservoir Project evaluation. The DCR 2015, WSIP 2030 Without Project, and WSIP 2070 Without Project models are identical except for hydrologic inflows and sea level rise due to climate change.

The Without Project assumptions include implementation of water operations components of the Reasonable and Prudent Alternatives (RPA) specified in the 2008 Fish and Wildlife Service (FWS) and 2009 National Marine Fisheries Service (NMFS) Biological Opinions (BiOps). The specific assumptions and implementation in the CALSIM II and DSM2 models were developed by a multiagency team comprised of fisheries and modeling experts from the DWR, Department of Fish and Game (DFG), Reclamation, USFWS, and NMFS.

The description of CALSIM II assumptions refers to the DCR 2015 scenario. However, these assumptions are applicable to the WSIP 2030 Without Project and WSIP 2070 Without Project scenarios also. A summary of the CALSIM II model assumptions in the DWR State Water Project Delivery Capability Report 2015 – base scenario is provided in Table 1.

CALSIM II Assumptions for Current Conditions (DCR 2015)

<u>Hydrology</u>

Inflows/Supplies

CALSIM II model includes the historical hydrology with projected 2030 modifications for the operations upstream of the rim reservoirs. Reservoir inflows, stream gains, diversion requirements, irrigation efficiencies, return flows and groundwater operation are all components of the hydrology for CALSIM II.

Level of Development

CALSIM II input hydrology is based on 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 (hydrology serial number 2020D09E). However, the San Joaquin Valley hydrology reflects draft 2030 land use assumptions developed by Reclamation. Where appropriate Year 2030 projections of demands associated with water rights and SWP and CVP water service contracts have been included. Specifically, projections of full build out are used to describe the American River region demands for water rights and CVP contract supplies and California Aqueduct and the Delta Mendota Canal SWP/CVP contractor demands are set to full contract amounts.

Demands, Water Rights, CVP/SWP Contracts

CALSIM II demand inputs are preprocessed monthly time series for a specified level of development (e.g. 2030) and per hydrologic conditions. Demands are classified as CVP project, SWP project, local project or non-project (e.g. pre-1914 water rights, in-Delta consumptive use etc.). 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 OCAP Biological Assessment Appendix D (Reclamation 2008a). Non-project demands within each Depletion Study Area (DSA) are based on the proportion of the acreage served by the projects versus the total acreage, for each land-use type. Non-project demands are satisfied from sources other than project storage and project conveyance facilities and are reduced as a function of water availability in the absence of project operations.

DCR 2015 assumes demands north of the Delta at the future level of development assuming full build-out of facilities and increases associated with water rights and CVP and SWP service contracts. This is primarily an increase in CVP M&I service contracts (253 TAF/Yr) and water rights (184 TAF/Yr) related to urban municipal and industrial (M&I) use, especially in the communities in El Dorado, Placer, and Sacramento counties.

DCR 2015 also assumes full contract amounts for demands associated with SWP contracts, south of the Delta at the future level of development, in all hydrologic conditions.

Facilities

CALSIM II includes representation of all the existing CVP and SWP storage and conveyance facilities. Key storage facilities including Shasta Lake, Trinity Lake, Whiskeytown Lake, Lake Oroville, Folsom Lake, Los Vaqueros Reservoir, San Luis Reservoir and Millerton Lake are represented in CALSIM II. Regulating reservoirs such as Lewiston, Keswick, Thermalito and Nimbus are also included in CALSIM II.

CALSIM II also represents existing conveyance facilities in the Colusa Basin region. Red Bluff Diversion Dam, Tehama-Colusa Canal (TCC) and its intake on the Sacramento River, Corning Canal, Glenn Colusa Canal (GCC) and its intake on the Sacramento River, Stony Creek – TCC intertie, TCC – GCC intertie, and Colusa Basin Drain are some of the key facilities included in the model.

CALSIM II also represents the flood control weirs along the Sacramento River such as Ord Ferry, Moulton Weir, Colusa Weir and Tisdale Weir, which bypass flood flows into Sutter Bypass. USRDOM was used to model the weir spills into the Sutter Bypass for the simulations. In addition, CALSIM II also represents the flood control weirs such as Fremont Weir and Sacramento Weir, which spill flood flows from the Sacramento River into Yolo Bypass.

Freeport Regional Water Project, located along the Sacramento River near Freeport, is assumed to be operational under the DCR 2015. Similarly, 30 mgd capacity, City of Stockton Delta Water Supply Project is assumed to be operational under the DCR 2015. Delta-Mendota Canal–California Aqueduct Intertie is assumed to be operational under the DCR 2015. Contra Costa Water District Alternative Intake Project and Los Vaqueros expanded storage capacity of 160 TAF, are included in the DCR 2015 along with the South Bay Aqueduct rehabilitation, to 430 cfs capacity, from junction with California Aqueduct to Alameda County FC&WSD Zone 7.

Red Bluff Pumping Plant

The permanent TCC Pumping Plant and intake facilities are in place and the Red Bluff Diversion Dam is operated with gates out of the water all year as required in the NMFS BO Action I.3.1 providing unimpeded upstream and downstream fish passage.

Tehama Colusa Canal Capacity

Fish Passage Improvements at Red Bluff Pumping Plant and Fish Screen are included in the DCR 2015 allowing for a pumping capacity of 2,000 cfs into TCC.

Glenn Colusa Canal Capacity

3,000 cfs of total diversion capacity is assumed at the Sacramento River intake near Hamilton City into GCC.

Existing TCC-GCC Intertie

The existing TCC-GCC intertie provides flexibility in routing flows of up to 285 cfs, between TCC and GCC.

Williams Outlet

The Williams Outlet provides flexibility in routing flows of up to 65 cfs, between TCC and GCC.

Funks Reservoir

The existing Funks Reservoir includes a storage capacity of 2,250 acre-foot and is part of the TCC system. Funks Reservoir serves as a re-regulating reservoir to stabilize flows in the TCC downstream of Funks Reservoir as diverters come on line and off line. Funks Reservoir is not modeled explicitly in CALSIM II.

The Delta serves as a natural system of channels to transport river flows and reservoir storage to the CVP and SWP facilities in the south Delta, which export water to the projects' contractors through two pumping plants: SWP's Harvey O. Banks Pumping Plant and CVP's C.W. Jones Pumping Plant. Banks and Jones Pumping Plants supply water to agricultural and urban users throughout parts of the San Joaquin Valley, South Lahontan, Southern California, Central Coast, and South San Francisco Bay Area regions.

The Contra Costa Canal and the North Bay Aqueduct supply water to users in the northeastern San Francisco Bay and Napa Valley areas.

SWP Banks Pumping Plant Capacity

SWP Banks pumping plant has an installed capacity of about 10,668 cfs (two units of 375 cfs, five units of 1,130 cfs, and four units of 1,067 cfs). The SWP water rights for diversions specify a maximum of 10,350 cfs, but the U. S. Army Corps' of Engineers (ACOE) permit for SWP Banks Pumping Plant allows a maximum pumping of 6680 cfs. With additional diversions depending on Vernalis flows the total diversion can go up to 8,500 cfs during December 15th – March 15th. Additional capacity of 500 cfs (pumping limit up to 7,180 cfs) is allowed to reduce impact of NMFS BO Action 4.2.1 on SWP.

CVP C.W. Bill Jones Pumping Plant (Tracy PP) Capacity

The Jones Pumping Plant consists of six pumps including one rated at 800 cfs, two at 850 cfs, and three at 950 cfs. DMC-California Aqueduct Intertie that allows 400 cfs additional DMC capacity is assumed to be in place; therefore, pumping capacity is 4,600 cfs in all months.

CCWD Intakes

The Contra Costa Canal originates at Rock Slough, about four miles southeast of Oakley, and terminates after 47.7 miles at Martinez Reservoir. The canal and associated facilities are part of the CVP, but are operated and maintained by the Contra Costa Water District (CCWD). CCWD also operates a diversion on Old River. CCWD can divert water to the Los Vaqueros Reservoir to store good quality water when available and supply to its customers. In addition to the Rock Slough and Old River diversions, CCWD's Middle River Intake and Pump Station (previously known as the Alternative Intake Project) is included in the DCR 2015. The Alternative Intake Project is a new drinking water intake at Victoria Canal, about 2.5 miles east of Contra Costa Water District's (CCWD) existing intake on the Old River.

Regulatory Standards

Major regulatory standards that govern the operations of the CVP and SWP facilities are briefly described below. Specific assumptions related to key regulatory standards are also outlined below.

D-1641 Operations

The SWRCB Water Quality Control Plan (WQCP) and other applicable water rights decisions, as well as other agreements are important factors in determining the operations of both the Central Valley Project (CVP) and the State Water Project (SWP).

The December 1994 Accord committed the CVP and SWP to a set of Delta habitat protective objectives that were incorporated into the 1995 WQCP and later, were implemented by D-1641. Significant elements in the D-1641 standards include X2 standards, export/inflow (E/I) ratios, Delta water quality standards, real-time Delta Cross Channel operation, and San Joaquin flow standards.

Coordinated Operations Agreement (COA)

The CVP and SWP use a common water supply in the Central Valley of California. The DWR and Reclamation have built water conservation and water delivery facilities in the Central Valley in order to deliver water supplies to project contractors. The water rights of the projects are conditioned by the SWRCB to protect the beneficial uses of water within each respective project and jointly for the protection of beneficial uses in the Sacramento Valley and the Sacramento-San Joaquin Delta Estuary. The agencies coordinate and operate the CVP and SWP to meet the joint water right requirements in the Delta.

The Coordinated Operations Agreement (COA), signed in 1986, defines the project facilities and their water supplies, sets forth procedures for coordination of operations, identifies formulas for sharing joint responsibilities for meeting Delta standards, as the standards existed in SWRCB Decision 1485 (D-1485), and other legal uses of water, identifies how unstored flow will be shared, sets up a framework for exchange of water and services between the Projects, and provides for periodic review of the agreement.

CVPIA (b)(2) Assumptions

The previous 2008 Operations Criteria and Plan (OCAP) Biological Assessment (BA) modeling included a dynamic representation of Central Valley Project Improvement Act (CVPIA) 3406(b)(2) water allocation, management and related actions (B2). The selection of discretionary actions for use of B2 water in each year was based on a May 2003 Department of the Interior policy decision. The use of B2 water is assumed to continue in conjunction with the USFWS and NMFS BO RPA actions. The CALSIM II implementation does not explicitly account for the use of (b)(2) water, but rather assumes pre-determined USFWS BO upstream fish objectives for Clear Creek and Sacramento River below Keswick Dam in addition to USFWS and NMFS BO RPA actions for the American River, Stanislaus River, and Delta export restrictions.

USFWS Delta Smelt BO Actions

The USFWS Delta Smelt BO was released on December 15, 2008, in response to Reclamation's request for formal consultation with the USFWS on the coordinated operations of the Central Valley Project (CVP) and State Water Project (SWP) in California. To develop CALSIM II modeling assumptions for the RPA documented in this BO, the Department led a series of meetings that involved members of fisheries and project agencies. This group has prepared the assumptions and CALSIM II implementations to represent the RPA in DCR 2015 CALSIM II simulation. The following actions of the USFWS BO RPA have been included in the DCR 2015 CALSIM II simulations:

- Action 1: Adult Delta smelt migration and entrainment (RPA Component 1, Action 1 – First Flush)
- Action 2: Adult Delta smelt migration and entrainment (RPA Component 1, Action 2)
- Action 3: Entrainment protection of larval and juvenile Delta smelt (RPA Component 2)
- Action 4: Estuarine habitat during Fall (RPA Component 3)
- Action 5: Temporary spring head of Old River barrier and the Temporary Barrier Project (RPA Component 2)

NMFS BO Salmon Actions

The NMFS Salmon BO on long-term actions of the CVP and SWP was released on June 4, 2009. To develop CALSIM II modeling assumptions for the RPA documented in this BO, the Department led a series of meetings that involved members of fisheries and project agencies. The following NMFS BO RPA have been included in the DCR 2015 CALSIM II simulations:

- Action I.1.1: Clear Creek spring attraction flows
- Action I.3.1: Operations after May 14, 2012: Operate RBDD with Gates Out
- Action I.4: Wilkins Slough operations
- Action II.1: Lower American River flow management
- Action III.1.3: Stanislaus River flows below Goodwin Dam
- Action IV.1.2: Delta Cross Channel gate operations
- Action IV.2.1: San Joaquin River flow requirements at Vernalis and Delta export restrictions
- Action IV.2.3: Old and Middle River flow management

For Action I.2.1, which calls for a percentage of years that meet certain specified end-of-September and end-of-April storage and temperature criteria resulting from the operation of Lake Shasta, no specific CALSIM II modeling code is implemented to simulate the performance measures identified.

Water Transfers

Lower Yuba River Accord (LYRA)

Lower Yuba River Accord (LYRA) Component 1 water is assumed to be transferred to South of Delta (SOD) State Water Project (SWP) contractors to help mitigate the impact of the NMFS BO on SWP exports during April and May. An additional 500 cfs of capacity is permitted at Banks Pumping Plant from July through September to export this water.

Phase 8 transfers

Phase 8 transfers are not included.

Short-term or Temporary Water Transfers

Short term or temporary transfers such as Sacramento Valley acquisitions conveyed through Banks PP are not included.

Specific Regulatory Assumptions

Upstream Reservoir Operations

Minimum flow below Lewiston Dam

The volume of the Trinity River instream flow requirement below Lewiston Dam ranges from 369 – 815 TAF/year, based on the Trinity EIS Preferred Alternative. The minimum flow volume is determined based on the Trinity River water year classification. The flow schedules from the Trinity Sites Reservoir Project were assumed for each water year type.

Trinity Lake End-of-September Minimum Storage

Based on the Trinity EIS Preferred Alternative, a minimum end-of-September carryover storage objective of 600 TAF at Trinity Reservoir was assumed to help provide coldwater resource protection. This objective may not be fully accomplished in extended drought periods.

Minimum flow below Whiskeytown Dam

Whiskeytown Dam is operated to meet the downstream water rights in the Clear Creek and 1963 Reclamation Proposal to USFWS and National Park Service (NPS). It is also operated to meet the predetermined CVPIA 3406(b)(2) flows, and the flow requirements identified under NMFS BO Action I.1.1.

Shasta Lake End-of-September Minimum Storage

Shasta Lake is operated such that the end-of-September carryover storage is 1900 TAF in non-critically dry years per the NMFS 2004 Winter-run Biological Opinion.

2009 NMFS BO Action 1.2.1 requires certain storage to be met at certain percentile of all years. A post-process of operations is used to determine whether or not these requirements are met.

Minimum flow below Keswick Dam

Keswick Dam is operated to meet the release schedule under SWRCB WR 90-5, which maintains 3,250 cfs in the Sacramento River. It is also operated to meet predetermined CVPIA 3406(b)(2) flows. NMFS BO Action I.2.2 includes actions that call for minimum flows to protect temperatures.

Flow Objective for Navigation at Wilkins Slough

NMFS BO Action 1.4 requires that to conserve cold water pool in Shasta Lake, Wilkins Slough is operated at a flow ranging from 3,500 cfs to 5,000 cfs based on the CVP water supply condition.

Minimum flow below Thermalito Diversion Dam

Thermalito diversion dam is operated to meet a minimum flow requirement of 700 cfs or 800 cfs in the Feather River low flow channel based on the 2006 Oroville Relicensing Settlement Agreement.

Minimum flow below Thermalito Afterbay Outlet

1983 DWR – DFG Agreement requires a minimum flow in the Feather River below Thermalito Afterbay Outlet to be between 750 cfs and 1,700 cfs, depending on the Oroville storage condition and the forecasted Feather River runoff condition.

Flow at Mouth of the Feather River

During the Feather River Service Area (FRSA) diversion season from April through September, a minimum flow of 2,800 cfs is maintained at the mouth of the Feather River depending on Lake Oroville inflow and FRSA allocation.

Minimum flow below Nimbus Dam

Nimbus Dam is operated to meet a minimum flow requirement based on the American River Flow Management under the NMFS BO Action II.1. Minimum release requirements range from 800 to 2,000 cfs based on a sequence of seasonal indices and adjustments.

American River Minimum flow at H Street Bridge

The minimum allowable flows in the Lower American River are defined by SWRCB Decision 893 (D-893) which states that, in the interest of fish conservation, releases should not ordinarily fall below 250 cfs between January 1 and September 15 or below 500 cfs at other times.

Minimum flow near Rio Vista

The minimum flow required on the Sacramento River at Rio Vista under the WQCP, SWRCB D-1641 is included. During September through December months, the flow requirement ranges from 3,000 cfs to 4,500 cfs, depending on the month and D-1641 40-30-30 index water year type.

Delta Outflow Index (Flow and Salinity)

SWRCB D-1641:

All flow based Delta outflow requirements per SWRCB D-1641 are included in the DCR 2015 simulation. Similarly, for the February through June period X2 standard is included.

USFWS BO (December, 2008) Action 4:

USFWS BO Action 4 requires additional Delta outflow to manage X2 in the fall months following the wet and above normal years to maintain average X2 for September and October no greater (more eastward) than 74 kilometers in the fall following wet years and 81 kilometers in the fall following above normal years.

Combined Old and Middle River Flows

USFWS BO restricts south Delta pumping to preserve certain OMR flows in three of its Actions: Action 1 to protect pre-spawning adult Delta smelt from entrainment during the first flush, Action 2 to protect pre-spawning adults from entrainment and from adverse hydrodynamic conditions, and Action 3 to protect larval Delta smelt from entrainment. CALSIM II simulates these actions to a limited extent.

Brief description of USFWS BO Actions 1-3 implementations in CALSIM is as follows: Action 1 is onset based on a turbidity trigger that takes place during or after December. This action requires limit on exports so that the average daily OMR flow is no more negative than -2,000 cfs for a total duration of 14 days, with a 5-day running average no more negative than 2,500 cfs (within 25 percent of the monthly criteria). Action 1 ends after 14 days of duration or when Action 3 is triggered based on a temperature criterion. Action 2 starts immediately after Action 1 and requires range of net daily OMR flows to be no more negative than -1,250 to -5,000 cfs (with a 5-day running average within 25 percent of the monthly criteria). The Action continues until Action 3 is triggered. Action 3 also requires net daily OMR flow to be no more negative than -1,250 to -5,000 cfs based on a 14 day running average (with a simultaneous 5-day running average within 25 percent). Although the range is similar to Action 2, the Action implementation is different. Action 3 continues until June 30 or when water temperature reaches a certain threshold.

NMFS BO Action 4.2.3 requires OMR flow management to protect emigrating juvenile winter-run, yearling spring-run, and Central Valley steelhead within the lower Sacramento and San Joaquin rivers from entrainment into south Delta channels and at the export facilities in the south Delta. This action requires reducing exports from January 1 through June 15 to limit negative OMR flows to -2,500 to -5,000 cfs. CALSIM II assumes OMR flows required in NMFS BO are covered by OMR flow requirements developed for actions 1 through 3 of the USFWS BO.

South Delta Export-San Joaquin River Inflow Ratio

NMFS BO Action 4.2.1 requires exports to be capped at a certain fraction of San Joaquin River flow at Vernalis during April and May while maintaining a health and safety pumping of 1,500 cfs. This export constraint is included.

Exports at the South Delta Intakes

Exports at Jones and Banks Pumping Plant are restricted to their permitted capacities per SWRCB D-1641 requirements. In addition, the south Delta exports are subjected Vernalis flow based export limits during April and May as required Action 4.2.1. Additional 500 cfs pumping is allowed to reduce impact of NMFS BO Action 4.2.1 on SWP during July through September period.

D-1641 1:1 CVP/SWP export limit based on the Vernalis flow from April 15 – May 15, is also included.

Under D-1641 the combined export of the CVP Tracy Pumping Plant and SWP Banks Pumping Plant is limited to a percentage of Delta inflow. The percentages range from 35% to 45% during February depending on the January eight river index and 35% during March through June months. For rest of the months 65% of the Delta inflow is allowed to be exported.

Delta Water Quality

The DCR 2015 simulation includes compliance with the SWRCB D-1641 salinity requirements. However, not all salinity requirements are included as CALSIM II is not capable of predicting salinities in the Delta. Instead, empirically based equations and models are used to relate interior salinity conditions with the flow conditions. DWR's Artificial Neural Network (ANN) trained for salinity is used to predict and interpret salinity conditions at Emmaton, Jersey Point, Rock Slough and Collinsville stations. Emmaton and Jersey Point standards are for protecting water quality conditions for agricultural use in the western Delta and they are in effect from April 1st to August 15th. The EC requirement at Emmaton varies from 0.45 mmhos/cm to 2.78 mmhos/cm, depending on the water year type. The EC requirement at Jersey Point varies from 0.45 mmhos/cm to 2.20 mmhos/cm, depending on the water year type. Rock Slough standard of 250 mg/L chloride is for protecting water quality conditions for M&I use for water through the Contra Costa Canal. It is a year-round standard. D-1641 also requires a certain number of days in a year with chloride concentration less than 150 mg/L. The number of days required is dependent upon the water year type. A pre-processed fixed number of days is used as input to CALSIM II to comply with 150 mg/L chloride standard at Rock Slough. Collinsville standard is applied during October through May months to protect the water quality conditions for the migrating fish species, and it varies between 12.5 mmhos/cm in May and 19.0 mmhos/cm in October.

Operations Criteria

Delta Cross Channel Gate Operations

SWRCB D-1641 DCC standards provide for closure of the DCC gates for fisheries protection at certain times of the year. From November through January, the DCC may be closed for up to 45 days for fishery protection purposes. From February 1 through May 20, the gates are closed for fishery protection purposes. The gates may also be closed for 14 days for fishery protection purposes during the May 21 through June 15 time period. Reclamation determines the timing and duration of the closures after discussion with USFWS, DFG, and NMFS.

NMFS BO Action 4.1.2 requires gates to be operated as described in the BO based on presence of salmonids and water quality from October 1 through December 14; and gates to be closed from

December 15 to January 31, except short-term operations to maintain water quality. CALSIM II includes NMFS BO DCC gate operations in addition to the D-1641 gate operations. When the daily flows in the Sacramento River at Wilkins Slough exceeds 7,500 cfs (flow assumed to flush salmon into the Delta), DCC is closed for a certain number of days per month.

Allocation Decisions

CALSIM II includes allocation logic for determining deliveries to north-of-Delta and south-of-Delta CVP and SWP contractors. The delivery logic uses runoff forecast information, which incorporates uncertainty in the hydrology and standardized rule curves (i.e. Water Supply Index versus Demand Index Curve). The rule curves relate forecasted water supplies to deliverable "demand," and then use deliverable "demand" to assign subsequent delivery levels to estimate the water available for delivery and carryover storage. Updates of delivery levels occur monthly from January 1 through May 1 for the SWP and March 1 through May 1 for the CVP as runoff forecasts become more certain. The south-of-Delta SWP delivery is determined based on water supply parameters and operational constraints. The CVP system wide delivery and south-of-Delta delivery are determined similarly upon water supply parameters and operational constraints with specific consideration for export constraints.

San Luis Operations

CALSIM II sets targets for San Luis storage each month that are dependent on the current South-of-Delta allocation and upstream reservoir storage. When upstream reservoir storage is high, allocations and San Luis fill targets are increased. During a prolonged drought when upstream storage is low, allocations and fill targets are correspondingly low. The San Luis rule curve is managed to minimize situations in which shortages may occur due to lack of storage or exports.

CALSIM II Assumptions for WSIP 2030

The WSIP 2030 without project CALSIM II model was provided by the CWC. The assumptions and operating criteria are identical to DCR 2015 assumptions except for hydrologic inflows and sea level rise due to climate change.

CALSIM II Assumptions for WSIP 2070

The WSIP 2070 without project CALSIM II model was provided by the CWC. The assumptions and operating criteria are identical to DCR 2015 except for hydrologic inflows and sea level rise due to climate change.

DSM2 Assumptions for Current Conditions

The Current Conditions DSM2 model was developed from the baseline WSIP 2030 study. The boundary conditions and dispersion factors in the CWC model representing 2030 conditions were removed to create the current conditions DSM2 study. Model input data from DWR's Bay Delta Office Modeling Support Branch Delta Modeling Section was incorporated to represent Current Conditions. All other data used in the Current Conditions study is consistent with the CWC 2030 DSM2 model.

River Flows

For the Current Conditions (DCR 2015) DSM2 simulation, the river flows at the DSM2 boundaries are based on the monthly flow time series from DWR CALSIM II DCR 2015 model results.

Tidal Boundary

The tidal boundary condition at Martinez is provided by an adjusted astronomical tide normalized for sea level rise (Ateljevich and Yu, 2007).

Water Quality

Martinez EC

Martinez EC boundary condition is estimated using the G-model based on the net Delta outflow simulated in CALSIM II and the pure astronomical tide (Ateljevich, 2001).

Vernalis EC

For the Current Condition DSM2 simulation, the Vernalis EC boundary condition is based on the monthly San Joaquin EC time series estimated in the DWR DCR 2015 CALSIM II model results.

Morphological Changes

No additional morphological changes were assumed as part of the Current Condition simulation. DSM2 model and grid developed as part of the 2009 recalibration effort (CH2M HILL, 2009) was used as part of the modeling.

DSM2 Assumptions for WSIP 2030 and WSIP 2070

The WSIP Baseline DSM2 without project models for 2030 and 2070 conditions were provided by the CWC.

Table 1
CALSIM II Model Assumptions

CALSIM II Modeling Assumptions from DWR State Water Project Delivery Capability Report 2015

	Existing Condition[1]
Planning Horizon	2015
Period of Simulation	82 years (1922-2003)
HYDROLOGY	
Level of Development (land use)	2030 Level[2]
DEMANDS	
North of Delta (excluding the American River)	
CVP	Land-use based, full build-out of contract amounts[3]
SWP (FRSA)	Land-use based, limited by contract amounts[4, 7]
Non-project	Land-use based, limited by water rights and SWRCB Decisions for Existing Facilities
Antioch Water Works	Pre-1914 water right
Federal refuges	Firm Level 2 water needs[5]
American River Basin	
Water rights	Year 2025, full water rights[6]
CVP	Year 2025, full contracts, including Freeport Regional Water Project[6]
San Joaquin River Basin[8]	
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[9, 17]	Land-use based, based on New Melones Interim Operations Plan, up to full CVP Contractor deliveries (155 TAF/yr) depending on New Melones Index
South of Delta	
CVP	Demand based on contract amounts[3]
Federal refuges	Firm Level 2 water needs[5]
CCWD	195 TAF/yr CVP contract supply and water rights[10]
SWP [4, 11]	Demand based on full Table A amounts (4.13 MAF/yr)
Article 56	Based on 2001-2008 contractor requests
Article 21	MWD demand up to 200 TAF/month (December-March) subject to conveyance capacity, KCWA demand up to 180 TAF/month, and other contractor demands up to 34 TAF/month, subject to conveyance capacity
North Bay Aqueduct	77 TAF/yr 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 [15]

	Existing Condition[1]
FACILITIES	
System-wide	Existing facilities
Sacramento Valley	
Shasta Lake	Existing, 4,552 TAF capacity
Red Bluff Diversion Dam	Diversion dam operated with gates out all year, NMFS BO (Jun 2009) Action I.3.1[17];assume permanent facilities in place
Colusa Basin	Existing conveyance and storage facilities
Lower American River	Hodge criteria for diversion at Fairbairn
Upper American River	PCWA American River pump station
Lower Sacramento River	Freeport Regional Water Project
Fremont Weir	Existing Weir
Delta Export Conveyance	
SWP Banks Pumping Plant (South Delta)	Physical capacity is 10,300 cfs, permitted capacity is 6,680 cfs in all months and up to 8,500 cfs during Dec 15th - Mar 15th depending on Vernalis flow conditions[18]; additional capacity of 500 cfs (up to 7,180 cfs) allowed Jul–Sep for reducing impact of NMFS BO (Jun 2009) Action IV.2.1[17] on SWP[19]
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 Delta-Mendota Canal Capacity	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[13]
San Joaquin River	
Millerton Lake (Friant Dam)	Existing, 520 TAF capacity
Lower San Joaquin River	City of Stockton Delta Water Supply Project, 30 mgd capacity
South of Delta (CVP/SWP project facilities)	
South Bay Aqueduct	SBA rehabilitation, 430 cfs capacity from junction with California Aqueduct to Alameda County FC&WSD Zone 7 point
California Aqueduct East Branch	Existing capacity
REGULATORY STANDARDS	
Trinity River	
Minimum Flow below Lewiston Dam	Trinity EIS Preferred Alternative (369-815 TAF/yr)
Trinity Reservoir end-of-September minimum storage	Trinity EIS Preferred Alternative (600 TAF/yr as able)

	Existing Condition[1]
Clear Creek	
Minimum flow below Whiskeytown Dam	Downstream water rights, 1963 Reclamation proposal to USFWS and NPS, predetermined Central Valley Protection Improvement Act 3406(b)(2) flows[20], and NMFS BO (Jun 2009) Action I.1.1[17]
Upper Sacramento River	
Shasta Lake end-of-September minimum storage	NMFS 2004 Winter-run Biological Opinion (1,900 TAF in non-critical dry years), and NMFS BO (Jun 2009) Action I.2.1[17]
Minimum flow below Keswick Dam	Flows for the SWRCB Water Rights Order 90-5, predetermined Central Valley Protection Improvement Act 3406(b)(2) flows, and NMFS BO (Jun 2009) Action I.2.2[17]
Feather River	
Minimum flow below Thermalito Diversion Dam	2006 Settlement Agreement (700 / 800 cfs)
Minimum flow below Thermalito Afterbay outlet	1983 DWR, DFG agreement (750 – 1,700 cfs)
Yuba River	
Minimum flow below Daguerre Point Dam	D-1644 Operations (Lower Yuba River Accord)[14]
American River	
Minimum flow below Nimbus Dam	American River Flow Management as required by NMFS BO (Jun 2009) Action II.1[17]
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	Federal Energy Regulatory Commission 2916-029[12], 1996 (Joint Settlement Agreement) (100 – 325 cfs)
Minimum flow below Woodbridge Diversion Dam	Federal Energy Regulatory Commission 2916-029, 1996 (Joint Settlement Agreement) (25 – 300 cfs)
Stanislaus River	
Minimum flow below Goodwin Dam	1987 Reclamation, DFG agreement, and flows required for NMFS BO (Jun 2009) Action III.1.2 and III.1.3[17]
Minimum dissolved oxygen	SWRCB D-1422

	Existing Condition1
Merced River	
Minimum flow below Crocker- Huffman Diversion Dam	Davis-Grunsky (180 – 220 cfs, Nov – Mar), and Cowell Agreement
Minimum flow at Shaffer Bridge	Federal Energy Regulatory Commission 2179 (25 – 100 cfs)
Tuolumne River	
Minimum flow at Lagrange Bridge	Federal Energy Regulatory Commission 2299-024, 1995 (Settlement Agreement) (94 – 301 TAF/yr)
Updated Tuolumne River	New Don Pedro operations
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 D1641. VAMP is turned off since the San Joaquin River Agreement has expired.[16] NMFS BO (Jun 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 FWS BO (Dec 2008) Action 4[17]
Delta Cross Channel gate operation	SWRCB D-1641 with additional days closed from Oct 1-Jan 31 based on NMFS BO (Jun 2009) Action IV.1.2[17] (closed during flushing flows from Oct 1-Dec 14 unless adverse water quality conditions)
South Delta exports (Jones PP and Banks PP)	SWRCB D-1641 export limits as required by NMFS BO (June 2009) Action IV.2.1 Phase II[17] (additional 500 cfs allowed for Jul-Sep for reducing impact on SWP)[19]
Combined Flow in Old and Middle River (OMR)	FWS BO (Dec 2008) Actions 1-3 and NMFS BO (Jun 2009) Action IV.2.3[17]
OPERATIONS CRITERIA: RIVER-SPECIFIC	
Upper Sacramento River	
Flow objective for navigation (Wilkins Slough)	NMFS BO (Jun 2009) Action I.4[17]; 3,250 – 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 the DFG/DWR flow target of 2,800 cfs for Apr - Sep dependent on Oroville inflow and FRSA allocation
Stanislaus River	
Flow below Goodwin Dam	Revised Operations Plan and NMFS BO (Jun 2009) Action III.1.2 and III.1.3[17]

	Existing Condition[1]
San Joaquin River	
Salinity at Vernalis	Grasslands 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, FWS BO (Dec 2008), and NMFS BO (Jun 2009) export restrictions[17]
CVP municipal & industrial	100% - 50% based on supply. South-of-Delta allocations are additionally limited due to D-1641, FWS BO (Dec 2008), and NMFS BO (Jun 2009) export restrictions[17]
SWP Water Allocation	
North of Delta (FRSA)	Contract-specific NOD Allocation Settlement Agreement terms for Butte and Yuba [15]
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, FWS BO (Dec 2008), and NMFS BO (Jun 2009) export restrictions[17] NOD Allocation Settlement Agreement terms for Napa and Solano [15]
CVP/SWP Coordinated Operations	
Sharing of responsibility for in-basin use	1986 Coordinated Operations Agreement (FRWP and EBMUD 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, FWS BO (Dec 2008), and NMFS BO (Jun 2009) export restrictions[17]
Water transfers	Acquisitions by SWP contractors are wheeled at priority in Banks Pumping Plant over non-SWP users; LYRA included for SWP contractors[19]
Sharing of export capacity for lesser priority and wheeling-related pumping	Cross Valley Canal wheeling (max of 128 TAF/yr), 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
CVPIA 3406(b)(2)	
Policy decision	Per May 2003 Department of Interior decision
Allocation	800 TAF/yr, 700 TAF/yr in 40-30-30 dry years, and 600 TAF/yr in 40-30-30 critical years
Actions	Pre-determined non-discretionary FWS BO (Dec 2008) upstream fish flow objectives (Oct-Jan) for Clear Creek and Keswick Dam, non-discretionary NMFS BO

	Existing Condition[1]
	(Jun 2009) actions for the American and Stanislaus Rivers, and NMFS BO (Jun 2009) actions leading to export restrictions[17]
Accounting adjustments	No discretion assumed under FWS BO (Dec 2008) and NMFS BO (Jun 2009)[17], no accounting
WATER MANAGEMENT ACTIONS	
Water Transfer Supplies (long term programs)	
Lower Yuba River Accord[19]	Yuba River acquisitions for reducing impact of NMFS BO export restrictions[17] on SWP
Phase 8	None
Water Transfers (short term or temporary programs)	
Sacramento Valley acquisitions conveyed through Banks PP[21]	Post analysis of available capacity

Notes:

1 These assumptions have been developed under the direction of the Department of Water Resources and Bureau of Reclamation management team for the BDCP HCP and EIR/EIS. Additional modifications were made by Reclamation for its October 2014 NEPA NAA baselines and by DWR for the 2015 DCR.

2 The Sacramento Valley hydrology used in the Existing Condition CALSIM II model 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. Assumptions regarding CVP agricultural and M&I service contracts and Settlement Contract amounts are documented in the Delivery Specifications attachments to the BDCP CALSIM assumptions document.

4 SWP contract amounts have been updated as appropriate based on recent Table A transfers/agreements. Assumptions regarding SWP agricultural and M&I contract amounts are documented in the Delivery Specifications attachments to the BDCP CALSIM assumptions document.

5 Water needs for Federal refuges have been reviewed and updated, as appropriate. Assumptions regarding firm Level 2 refuge water needs are documented in the Delivery Specifications attachments to the BDCP CALSIM assumptions document. Refuge Level 4 (and incremental Level 4) water is not included.

6 Assumptions regarding American River water rights and CVP contracts are documented in the Delivery Specifications attachments to the BDCP CALSIM assumptions document. The Sacramento Area Water Forum agreement, its dry year diversion reductions, Middle Fork Project operations and “mitigation” water is not included.

7 Demand for rice straw decomposition water from Thermalito Afterbay was added to the model and updated to reflect historical diversion from Thermalito in the October through January period.

8 The new CALSIM II representation of the San Joaquin River has been included in this model package (CALSIM II San Joaquin River Model, Reclamation, 2005). Updates to the San Joaquin River have been included since the preliminary model release in August 2005. The model reflects the difficulties of on-going 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

9 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 (Jun 2009) Action III.1.3.

10 The actual amount diverted is reduced because of supplies from the Los Vaqueros project. The existing Los Vaqueros storage capacity is 100 TAF, and future storage capacity is 160 TAF. Associated water rights for Delta excess flows are included.

11 Under DCR 2015 and 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 Mokelumne River flows reflect EBMUD supplies associated with the Freeport Regional Water Project.

13 The CCWD Alternate Intake Project, an intake at Victoria Canal, which operates as an alternate Delta diversion for Los Vaqueros Reservoir.

14 D-1644 and the Lower Yuba River Accord are assumed to be implemented for Existing baselines. The Yuba River is not dynamically modeled in CALSIM II. Yuba River hydrology and availability of water acquisitions under the Lower Yuba River Accord are based on modeling performed and provided by the Lower Yuba River Accord EIS/EIR study team.

15 This includes draft logic for the updated Allocation Settlement Agreement for four NOD contractors: Butte, Yuba, Napa and Solano.

16 It is assumed that D-1641 requirements will be in place in 2030, and VAMP is turned off.

17 In cooperation with Reclamation, National Marine Fisheries Service, Fish and Wildlife Service, and CA Department of Fish and Game, the CA Department of Water Resources has developed assumptions for implementation of the FWS BO (Dec 15th 2008) and NMFS BO (June 4th 2009) in CALSIM II.

18 Current ACOE permit for Banks PP 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 during Dec 15th – Mar 15th up to a maximum diversion of 8,500 cfs, if Vernalis flow exceeds 1,000 cfs.

19 Acquisitions of Component 1 water under the Lower Yuba River Accord, and use of 500 cfs dedicated capacity at Banks PP during Jul-Sep, are assumed to be used to reduce as much of the impact of the Apr-May Delta export actions on SWP contractors as possible.

20 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 Old and Middle River Flow and Delta Export restrictions under the FWS BO (Dec 15th 2008) and the NMFS BO (June 4th 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 pre-determined

based on CVPIA 3406(b)(2) based operations from the Aug 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.

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

References

Atejlevich, E. (2001). "Chapter 11 – Improving Estimates of Salinity at the Martinez Boundary". Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh. 22nd Annual Progress Report to the State Water Resources Control Board. Sacramento, CA.

Atejlevich, E. and Yu, M. (2007). "Chapter 4: Extended 82-year Martinez Planning Tide". Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh. 28th Annual Progress Report to the State Water Resources Control Board. Sacramento, CA.

California Department of Water Resources, 2015. The State Water Project Final Delivery Capability Report 2015. July.

CH2M HILL, 2009. DSM2 Recalibration. Prepared for California Department of Water Resources, October, 2009.

National Marine Fisheries Service (NMFS), 2009. Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project.

SWRCB, 2000. Revised Water Right Decision 1641, March 15, 2000.

U. S. Bureau of Reclamation (Reclamation), 2008. Central Valley Project and State Water Project Operations Criteria and Plan Biological Assessment, Appendix D CALSIM-II Model, May 2008.

U. S. Bureau of Reclamation (Reclamation), 2008. Central Valley Project and State Water Project Operations Criteria and Plan Biological Assessment, Appendix F DSM2 Model, May 2008.

U. S. Fish and Wildlife Service, 2008. Formal Endangered Species Act Consultation on the Proposed Coordinated Operations of the Central Valley Project (CVP) and State Water Project (SWP).

HEC5Q Modeling for the Sites Reservoir Project

Development of WSIP Climate Scenarios for Use in HEC5Q

The section describes the updates to HEC5Q that were necessary for performing temperature benefits analysis to support the Water Storage Investment Program (WSIP) application.

Background

HEC5Q Model Background and Limitations

Over the last 15 years, the US Bureau of Reclamation (Reclamation) has developed applications of the US Army Corps of Engineers HEC5Q model for evaluation of water temperatures on the Sacramento River, American River, and Stanislaus Rivers. Reclamation made substantial revisions to these models for use in their NEPA EIS analysis of the Coordinate Long-Term Operations of the Central Valley Project and State Water Project (LTO EIS) (Reclamation, 2015). The HEC5Q model was designed to work with the model results of the CALSIM II model and was calibrated for historical meteorological conditions. For the LTO EIS analysis, procedures were established to incorporate operational assumptions related to selective withdrawal features at Shasta Lake (temperature control device). HEC5Q is listed in Table 4-14 of the WSIP Technical Reference document as one of the applicable water quality models that can be used to quantify physical changes in water temperatures.

The regulations for the WSIP require that the models used in the evaluation of the Project incorporate changes associated with the WSIP 2030 and 2070 climate conditions. This required establishing Without Project versions of the HEC5Q models that reflected the change in temperatures associated with the WSIP 2030 and 2070 climate conditions. The LTO EIS HEC5Q model for the Sacramento River was modified to adjust for increases in temperature associated with each climate condition. Further, the operational assumptions related to selective withdrawal features at Shasta Lake were adjusted to consider the effects of each climate condition on the management of reservoir release temperatures and the extent to which water temperature objectives could be achieved within the critical reaches downstream of these reservoirs.

The HEC5Q models calculate the change over time in water temperatures in reservoirs and rivers based on estimates of equilibrium water temperature and the rate at which heat exchange in the water will change as it approaches equilibrium. These estimates are based on meteorological and environmental information associate with the geographic location being studied. Based on temperature information included in the WSIP statewide gridded monthly data products (CWC, 2016) model inputs for equilibrium temperatures were adjusted for the WSIP climate scenarios.

In applying the HEC5Q models, water temperature objectives downstream of Shasta Lake are required for the model to select what elevation to withdrawal releases from. The temperature of water varies with depth in a reservoir depending on the degree to which the profile is stratified (due to temperature and density variation). Warmer water is less dense than cooler water and will move to the top of the reservoir. Much of the warming of a reservoir over the spring and early summer months comes from solar radiation through the surface of the lake. To meet temperature objectives downstream of the reservoir, water is selectively withdrawn at an elevation that provides water cool enough to meet the downstream objective. The Shasta Lake schedule is varied each year of simulation based on reservoir storage and inflow conditions and expected changes in water temperature that occur between the reservoirs and the objective locations in the rivers. Based on reiterative analysis, schedules of temperature objectives are modified to reflect the effects of the WSIP climate conditions.

The HEC5Q model provides a projection of how the water temperature trends with changes in storage and flows in the water resources system. The model does not provide a prediction of what future water temperatures will be. This model is intended for use in comparative analysis and demonstration of potential effects in the setting of hydrologic information considering historical variability and the effects of climate change. It should be recognized that the HEC5Q model is a simplified and generalized representation of complex hydrodynamic and thermodynamic processes in the riverine environment. While the HEC5Q model can provide 6-hour to daily timestep information at any location within the model domain, evaluation of the model results should consider the limitations of the information used to calibrate the model and the inputs to the model for the specific conditions being evaluated. Because the CALSIM II model results used are subject to specific location and monthly timestep limitations, care must be used in drawing any conclusion from the HEC5Q model results that is finer in spatial and temporal resolution than the CALSIM II model used. Nevertheless, HEC5Q is the best available tool for this evaluation of system effects related to the Project.

Approach

HEC5Q Changes

Updates were made to the Trinity-Sacramento River Reclamation HEC5Q models used for the Coordinated Long-Term Operations of the Central Valley Project and State Water Project Environmental Impact Study (LTO EIS) to support temperature modeling for the WSIP Application process. The following changes were made to better simulate water temperatures at Current Conditions, and in the 2030 and 2070 climate scenarios developed by the California Water Commission (CWC) for the WSIP Application process: 1) increasing the equilibrium temperatures based on the calculated increase in air temperature for the WSIP 2030 and 2070 climate scenarios, and 2) adjusting the Shasta release temperature schedule assumptions in the Trinity-Sacramento HEC5Q model.

Equilibrium Temperature Adjustment

Changes in climate can have a myriad of potential and unpredictable effects on water temperatures. However, several studies indicate that increasing air temperatures result in increased water temperatures, regardless of climate scenario (Webb and Walsh 2004, Cushing 1997, Isaak et al. 2012). Since air temperatures are predicted to increase under the WSIP 2030 and 2070 climate scenarios, an increase in water temperature is assumed.

With the limited data provided, equilibrium temperatures were increased based on the increased air temperature in the WSIP 2030 and 2070 climate scenarios. This approach was supported with an analysis between observed air temperature data from the Gerber and Nicolaus CIMIS stations and the calculated equilibrium temperatures at those two stations. The equilibrium temperatures were developed as part of the Sacramento River Water Quality Extension effort conducted by Reclamation (Smith et al. 2013). The period of record of the observed air temperature data was 01Jan2001 to 31Dec2011. The observed air temperature was averaged by month and then plotted against the calculated current climate equilibrium temperature as shown in Figures 1 and 2. Two linear regressions were performed on the data, one regression for the fall and winter months (October-March) and one regression for the spring and summer months (April-September). Regressions at Gerber indicate a 1:1 ratio of air temperature to equilibrium temperature during fall and winter months and 1:0.8 ratio of air temperature to equilibrium temperature in spring and summer months. Regressions at Nicolaus indicate a 1:1 ratio, year-round. The calculation of the climate adjusted equilibrium temperature, based on these regressions, is described in the next section.

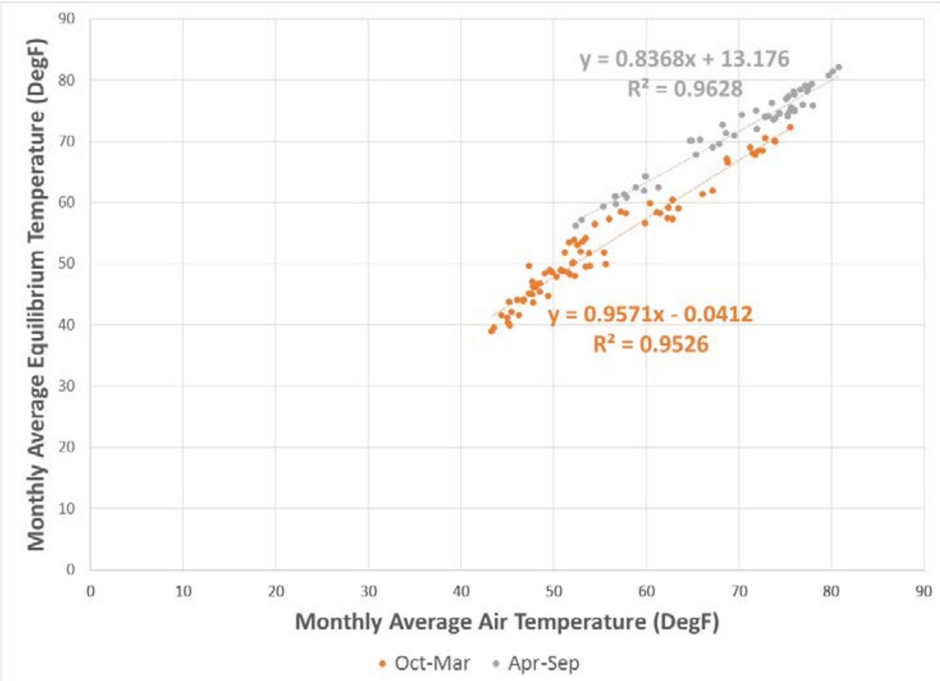


Figure 1: Gerber CIMIS Station Monthly Average Observed Air Temperature vs. Monthly Average Calculated Equilibrium Temperature

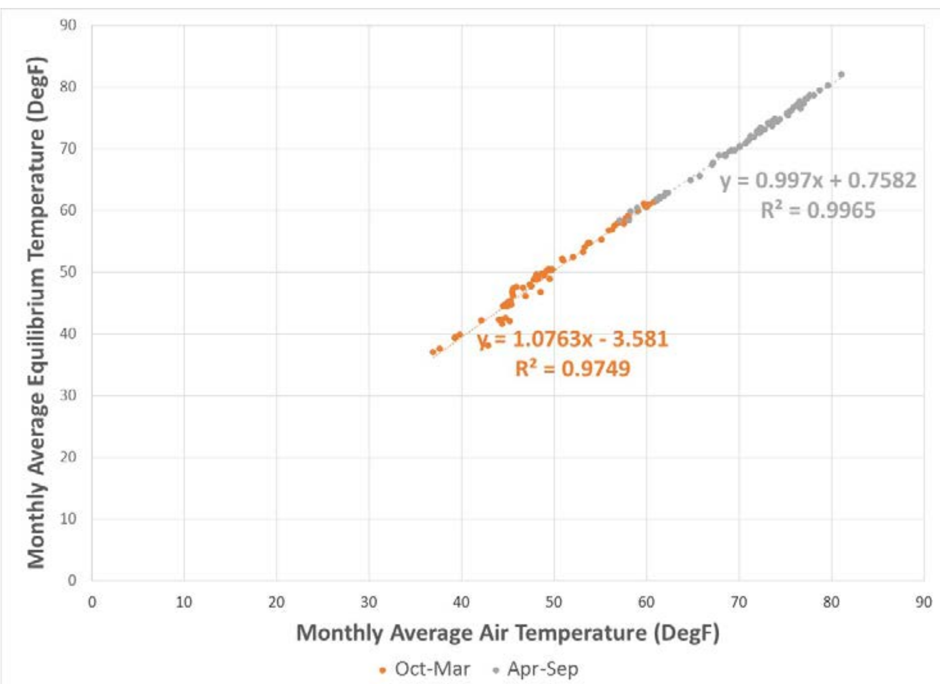


Figure 2: Nicolaus CIMIS Station Monthly Average Observed Air Temperature vs. Monthly Average Calculated Equilibrium Temperature

After performing the regressions to determine the seasonal adjustment factor, the following process was used to calculate the climate scenario adjusted equilibrium temperatures. The WSIP climate scenario data was obtained from the CWC website (Water Commission 2016). The data comes in files that correspond to grid cells with different latitude and longitudes. In order to perform the equilibrium temperature adjustments, the latitude and longitude coordinates of the Gerber and Nicolaus California Irrigation Management Information System (CIMIS) stations the meteorology data is based from were obtained and then matched with the closest WSIP climate scenario grid cell (Table 1). The climate scenario data that corresponded to that grid cell was then retrieved for the two CIMIS stations.

Table 1: CIMIS Station Latitude and Longitude coordinates and the corresponding WSIP grid cell coordinates

Station	**CIMIS**		**WSIP**	
	Latitude	*Longitude*	*Latitude*	*Longitude*
Gerber	40.05	122.16	40.03125	122.15625
Nicolaus	38.87	121.55	38.84375	121.53125

After retrieving the data, the maximum and minimum monthly air temperatures (Tmax & Tmin) in the WSIP climate scenario data were converted to Fahrenheit from Celsius to match the units of the HEC5Q model. For each WSIP climate scenario, the average monthly air temperature (Tavg) was calculated by averaging the maximum and minimum monthly air temperatures (Tmax + Tmin)/2. Then, the monthly average temperature shifts from Current Climate to WSIP 2030 and 2070 were calculated by subtracting the WSIP Current Climate Tavg from the 2030 Tavg and the 2070 Tavg, respectively. Gerber temperature shifts for April to September were multiplied by 0.8 to reflect the equilibrium temperature ratio described earlier. This difference was added to the existing HEC5Q Current Climate Equilibrium Temperature time series (described earlier) to calculate the climate adjusted equilibrium temperature for 2030 and 2070. Figures A1 to A6 in Appendix A show the 2030 and 2070 temperature shifts for each of the Gerber and Nicolaus CIMIS stations.

It should be noted that the WSIP Current Climate and the LTO EIS HEC5Q Current Climate are based on different climate analyses that do not reflect the same set of assumptions. However, for the WSIP climate updates, it was assumed that both represent the same current climate. In addition, the California Department of Water Resources 2015 Delivery Capability Report (DCR 2015) CALSIM II model was used to analyze the benefits of Sites reservoir under current climate conditions. The WaterFix HEC5Q Current Climate inputs are used for DCR 2015. See Figure 3 for a schematic of the climate adjustment process and climate scenarios used. With project and without project refer to without or with Sites Reservoir.

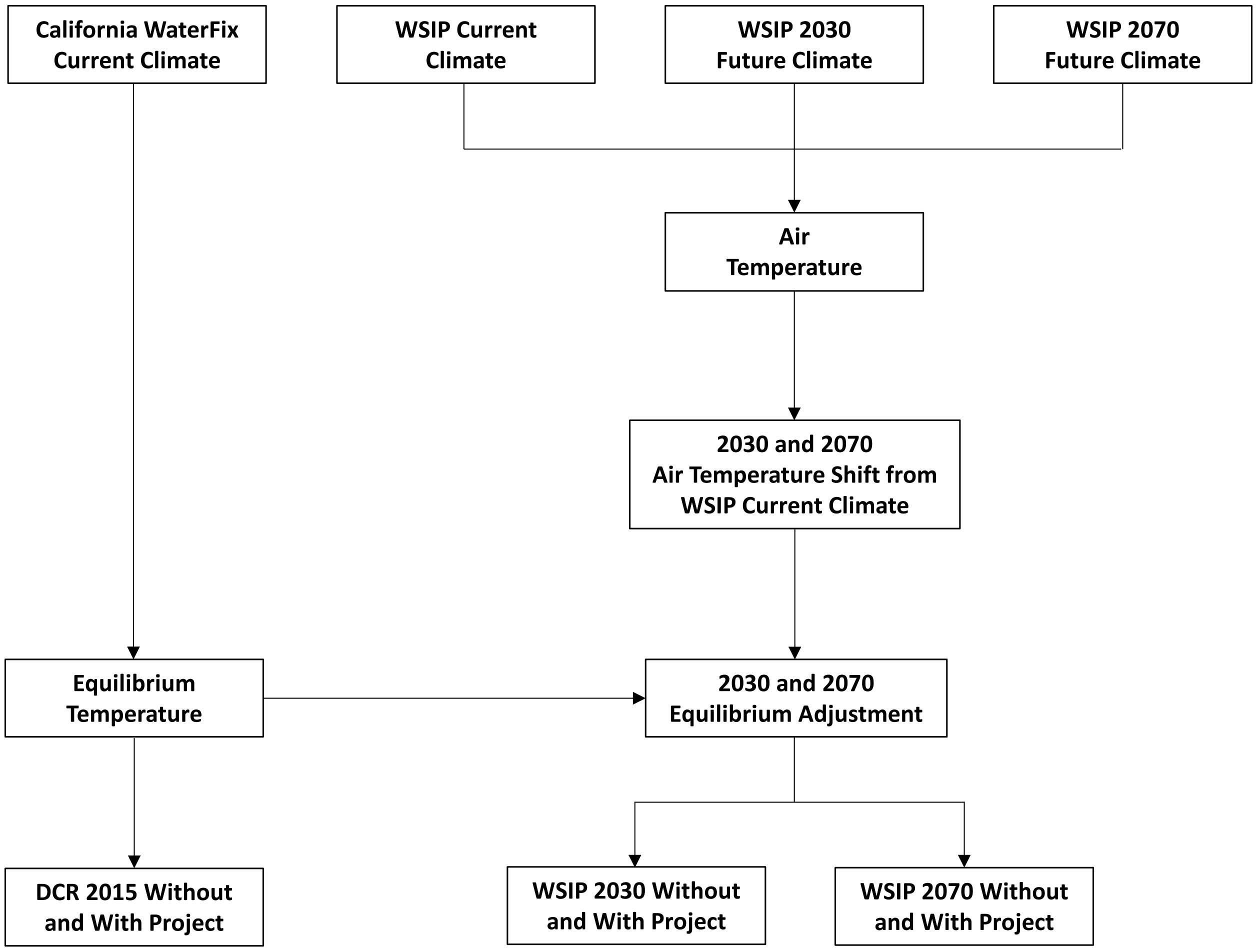


Figure 3: Climate scenarios and climate update process used to update equilibrium temperature for the Sites Reservoir WSIP Application.

Shasta Release Temperature Targeting Adjustments

The HEC5Q model simulates the Shasta Temperature Control Device (Shasta TCD) to manage temperature downstream at the following four temperature compliance locations: Clear Creek at Bonnyview Bridge, Balls Ferry, Jelly's Ferry, and Bend Bridge. The Shasta TCD modeling code requires a temperature release target for Shasta to operate to. These temperature target schedules are developed as a series of annual temperature target schedules in a pre-processing spreadsheet tool for each temperature compliance location. For the Sites WSIP Application, two adjustments were made to the assumptions of the temperature target spreadsheet tool to demonstrate the Sacramento River temperature benefits of the changed operations at Shasta due to the operational flexibility provided by Sites Reservoir. These adjustments are described below.

Storage Tier Adjustments

For the Sites WSIP Application, the maximum of April and May end-of-month storage was used to specify that year's compliance location. This adjustment was made because End-of-May is greater than End-of-April storage in some years. Allowing flexibility between End-of-April and End-of-May storage gives a more complete picture of how much cold water pool is available for the temperature management season than if just End-of-April storage was used as the indicator of available cold water pool.

Second, the storage tiers were adjusted due to the change in inflows and air temperatures in the WSIP 2030 and 2070 climate scenarios. The changes in climate variables requires a greater volume of water to meet temperature compliance at the targeted compliance location (e.g. it will take more storage volume to meet temperature compliance at Balls Ferry throughout the year).

An iterative approach was used to adjust the storage levels for both the WSIP 2030 and 2070 climate scenarios. An initial HEC5Q run was completed that utilizes the Maximum End-of-April or May Shasta Storage levels (see Table 2). After the run was completed, temperature outputs for the four compliance locations were loaded into the spreadsheet along with Shasta storage data from CALSIM II. The average of July and August temperature for each year of the 81 year period of record was calculated for each compliance location. The average between July and August was used because it represents the two months with the highest expected temperatures. The furthest downstream location that had a July-August temperature below 56 degrees was the compliance location that was met for that year. For example, if the July-August temperature is 54.5, 55, 55.8, and 56.2 for Bonnyview, Balls Ferry, Jellys Ferry, and Bend Bridge respectively, then the compliance location that was met was Jellys Ferry, since it is the most downstream location that is below 56 degrees. The compliance location based on the Maximum End-of-April or May Shasta storage was also calculated. The number of years where the compliance location was different between the July-August average temperature and the Maximum End-of-April or May Shasta storage was tabulated. The Maximum End-of-April or May Shasta storage levels were then adjusted until the smallest difference was achieved.

The Shasta temperature target schedules were then recomputed for each year and the HEC5Q model was then rerun. The new temperature results at the compliance locations were loaded into the spreadsheet and the same process of changing the Maximum End-of-April or May Shasta storage levels was performed. The final Maximum End-of-April or May Shasta storage levels were settled upon after the third iteration for the WSIP 2030 and WSIP 2070 climate scenarios, as shown in Table 2 below. The values in the table show the maximum storage necessary for each compliance location.

Table 2: Adjusted End-of-April Shasta Storage Levels

Compliance Location	**Maximum End-of-April or May Shasta Storage**		
	Current Conditions	*2030*	*2070*
Bend Bridge	9999	9999	9999
Jelly's Ferry	4425	4500	4500
Balls Ferry	4000	4300	4400
Below Clear Creek	3600	3600	4000
None	2000	2000	2000

Temperature Target Adjustments

A temperature schedule was developed for each temperature compliance location. These temperature schedules are Shasta release temperatures that are calculated based on the amount of warming that will occur between Shasta and the four compliance locations. The amount of warming that occurs was calculated using an exceedance based approach. With the change in operations to Shasta with Sites Reservoir in place, these exceedance percentages were adjusted in order to demonstrate the potential amount of temperature benefit Sites Reservoir can provide. The June to October exceedance percentages were lowered, which calculates a higher warming that occurs between Shasta and the compliance locations for which Shasta has to adjust to by lowering its release temperature target. Lowering the release temperature targets means Shasta uses more of the cold water pool that is available. The exceedance percentages were adjusted to save cold water in the cold water pool for August and September. See Table 3 for the June to September exceedance percentages used for the without project scenarios and the adjusted exceedance percentages used to characterize warming in the river for the with-project scenarios in the Sites WSIP Application.

Table 3: June to October exceedance percentages used to characterize warming between Shasta and the temperature compliance locations on the Sacramento River

Compliance Location	Exceedance Percentages							
	June		*July*		*August*		*September*	
	W/O Sites	W Sites	W/O Sites	W Sites	W/O Sites	W Sites	W/O Sites	W Sites
Clear Creek	75%	5%	50%	5%	15%	5%	5%	5%
Balls Ferry	75%	10%	50%	10%	15%	5%	5%	5%
Jellys Ferry	75%	15%	50%	15%	15%	5%	5%	5%
Bend Bridge	75%	25%	50%	25%	15%	5%	5%	5%

After setting the exceedance percentages, the HEC5Q model was run three times in order to settle in on the Shasta release temperatures based on these new exceedances. This process was done for the three climate scenarios. See Attachment B for the final Shasta Release temperature schedules for the three climate scenarios.

Results

After making the necessary adjustments to the climate updates described above, the Without-Project CALSIM II models for each of the three climate scenarios provided by the California Water Commission were run through the updated Trinity-Sacramento River HEC5Q models to quantify the river temperatures on the Sacramento River under the Without Project condition. This established the river temperature baselines for the three climate scenarios that river temperature benefits of the With-Project conditions would be quantified from. Attachment D shows river temperature results on the Sacramento River at Jellys Ferry. The results for both the Sacramento River show that river temperatures increase between the Current Conditions climate, the WSIP 2030 climate scenario, and the WSIP 2070 climate scenario. There are two major factors for this change, the shift in equilibrium temperature based on the increased air temperature and the change in operations based on the change in hydrologic conditions between the climate scenarios.

References

California Water Commission (CWC). 2016. Application Resources (data and model products), Water Storage Investment Program. California Water Commission. Sacramento CA. November, 2016. (https://cwc.ca.gov/Pages/ApplicationResources.aspx)

California Water Commission (CWC). 2016. Regulation filed with Office of Administrative Law, Water Storage Investment Program. California Water Commission. Sacramento CA. November, 2016. (https://cwc.ca.gov/Documents/2017/WSIP/2017-0123-03S_App.pdf)

California Water Commission (CWC). 2016. Technical Reference, Water Storage Investment Program. California Water Commission. Sacramento CA. November, 2016. (https://cwc.ca.gov/Documents/2017/WSIP/TechnicalReference.pdf)

California Water Commission (CWC). 2016. Water Storage Investment Program Climate Change and Sea Level Rise Data and Model Products Update. California Water Commission. (https://cwc.ca.gov/Documents/2017/WSIP/WSIP_Data_and_Model_Product_Description_2-22-17.pdf)

Cushing, C. 1997. Freshwater Ecosystems and Climate Change in North America. A Regional Assessment. Advances in Hydrological Processes.

Edinger, J., Brady, D., Geyer, J. 1974. Heat Exchange and Transport in the Environment. Electric Power Research Institute.

Isaak, D. Wollrab, S., Horan, D., Chandler, G. 2012. Climate Change Effects on Stream and River Temperatures Across the Northwest US from 1980-2009 and Implications for Salmonid Fishes. Climatic Change.

National Marine Fisheries Service (NMFS). 2009. Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project. June 4. Southwest Region. Long Beach, CA.

U.S. Bureau of Reclamation (Reclamation). 1990. U.S. Bureau of Reclamation Monthly Temperature Model Sacramento River Basin. United States Bureau of Reclamation.

U.S. Bureau of Reclamation (Reclamation). 2015. Coordinated Long-Term Operations of the Central Valley Project and State Water Project. Final Environmental Impact Statement. Mid-Pacific Region. Sacramento, California. November, 2015. (http://www.usbr.gov/mp/BayDeltaOffice/coordinated-long-term.html)

University of Washington. 2017. Washington State Water Temperature Projections. https://cig.uw.edu/datasets/washington-state-water-temperature-projections/

Webb, B., Walsh, A. 2004. Changing UK River Temperatures and Their Impact on Fish Populations. Hydrology: Science & Practice for the 21st Century. Volume II. British Hydrological Society.

Attachment A – Equilibrium Temperature Shifts

This attachment shows the results of the equilibrium temperature shifts for the Gerber, and Nicolaus CIMIS stations described in the Equilibrium Temperature Adjustment section.

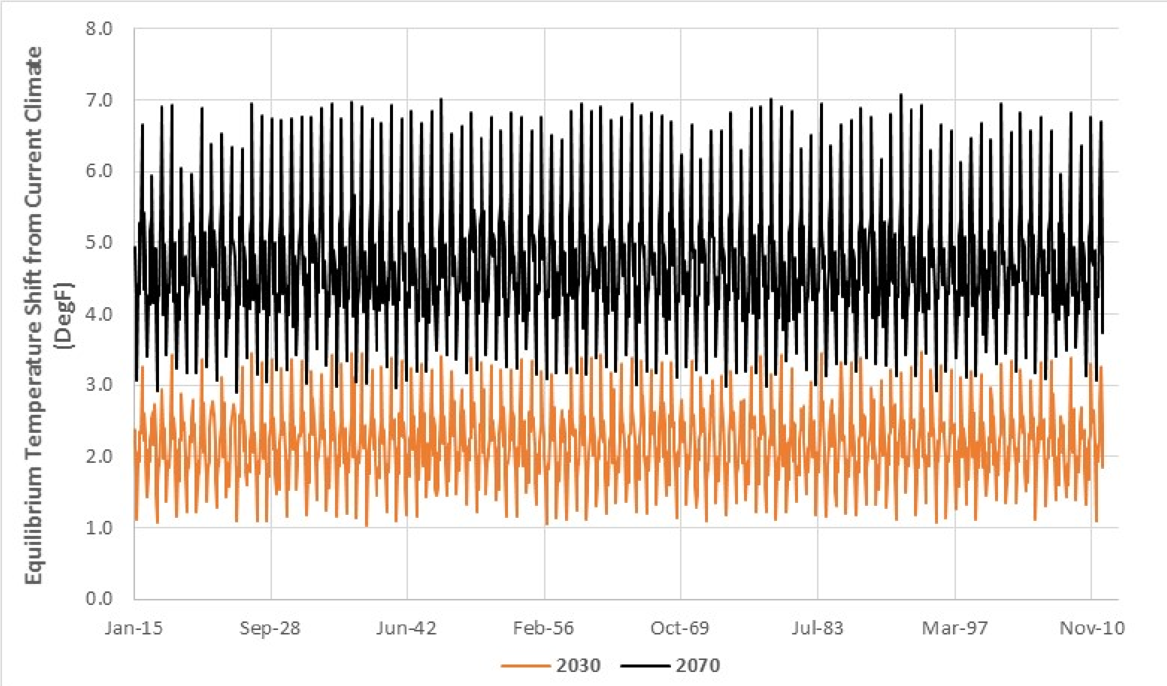


Figure A1: Gerber CIMIS station equilibrium temperature shifts for 2030 and 2070 climate scenarios.

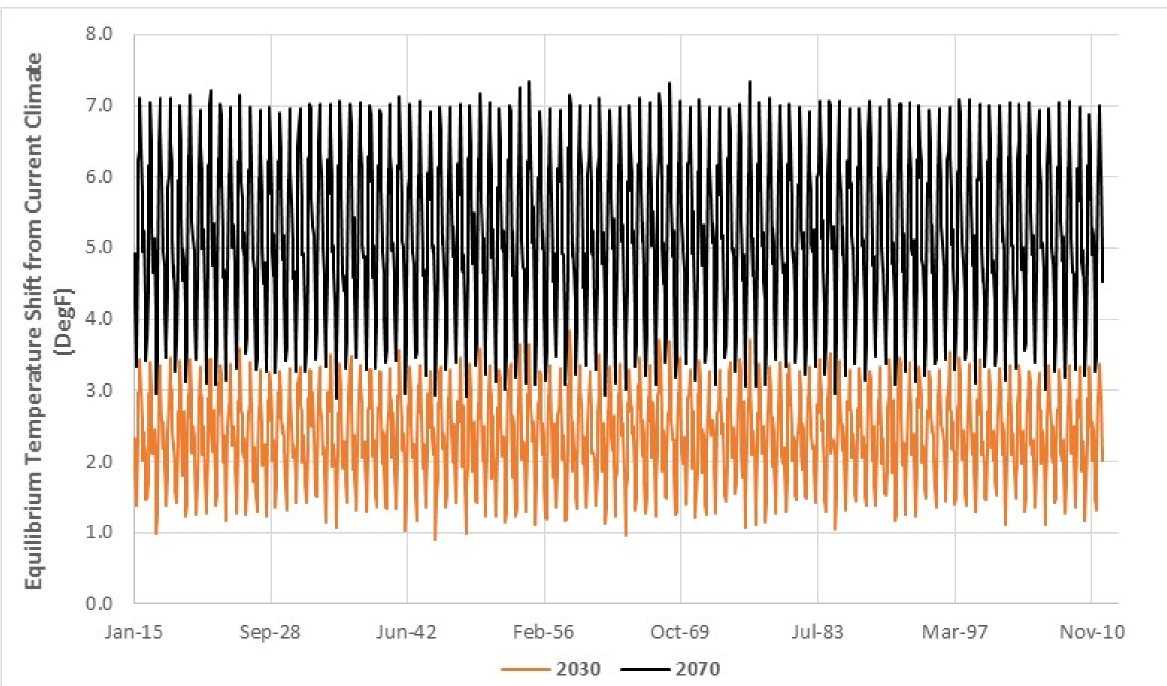


Figure A2: Nicolaus CIMIS station equilibrium temperature shifts for 2030 and 2070 climate scenarios.

Attachment B – Shasta Release Temperature Schedules

This attachment shows the final Shasta release temperature schedules that were developed for the Sacramento River HEC5Q model for Current Conditions, WSIP 2030, and WSIP 2070 climate scenarios.

Table B1: Shasta Release Temperature Schedules for Current Conditions.

Location	Max EO-Apr or May Storage	Temperature (F) Schedules for Shasta Dam Release											
		This table is for temperature target with Percent Exceedances											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0	*60.8*	*60.8*	*60.8*	*53.6*	*53.6*	*52.0*	*51.6*	*51.2*	*49.9*	*55.0*	*56.2*	*56.4*
None	2000	60.8	60.8	60.8	53.6	53.6	52.0	51.6	51.2	49.9	55.0	56.2	56.4
Clear Creek	3600	60.8	60.8	60.8	53.6	53.6	52.0	51.6	51.2	49.9	55.0	56.2	56.4
Balls Ferry	4000	60.8	60.8	60.8	53.6	53.6	50.1	50.5	49.8	48.4	54.5	56.6	57.2
Jellys Ferry	4425	60.8	60.8	60.8	53.6	53.6	47.9	48.8	48.2	46.7	54.1	56.9	58.0
Bend Bridge	9999	60.8	60.8	60.8	53.6	53.6	47.5	47.9	47.0	45.5	53.7	57.2	58.5

Table B2: Shasta Release Temperature Schedules for WSIP 2030.

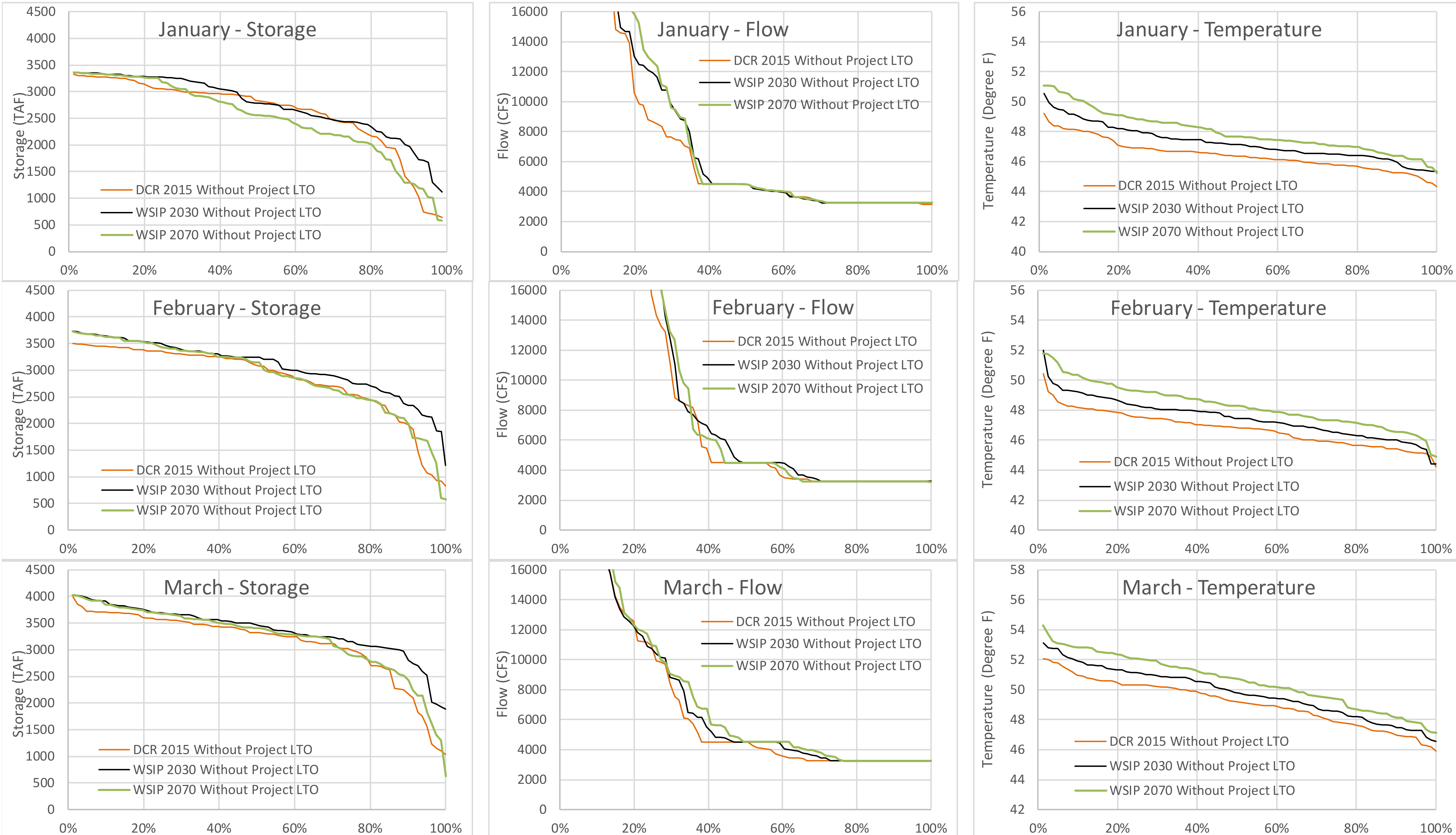
Location	Max EO-Apr or May Storage	Temperature (F) Schedules for Shasta Dam Release											
		This table is for temperature target with Percent Exceedances											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0	*60.8*	*60.8*	*60.8*	*53.6*	*53.6*	*52.5*	*52.6*	*51.6*	*50.9*	*54.8*	*56.2*	*56.2*
None	2000	60.8	60.8	60.8	53.6	53.6	52.5	52.6	51.6	50.9	54.8	56.2	56.2
Clear Creek	3600	60.8	60.8	60.8	53.6	53.6	52.5	52.6	51.6	50.9	54.8	56.2	56.2
Balls Ferry	4300	60.8	60.8	60.8	53.6	53.6	50.2	50.9	49.6	48.9	54.1	56.7	57.5
Jellys Ferry	4500	60.8	60.8	60.8	53.6	53.6	48.4	49.3	48.0	47.2	53.5	57.1	58.4
Bend Bridge	9999	60.8	60.8	60.8	53.6	53.6	47.7	48.8	46.7	46.0	53.2	57.4	58.9

Table B3: Shasta Release Temperature Schedules for WSIP 2070.

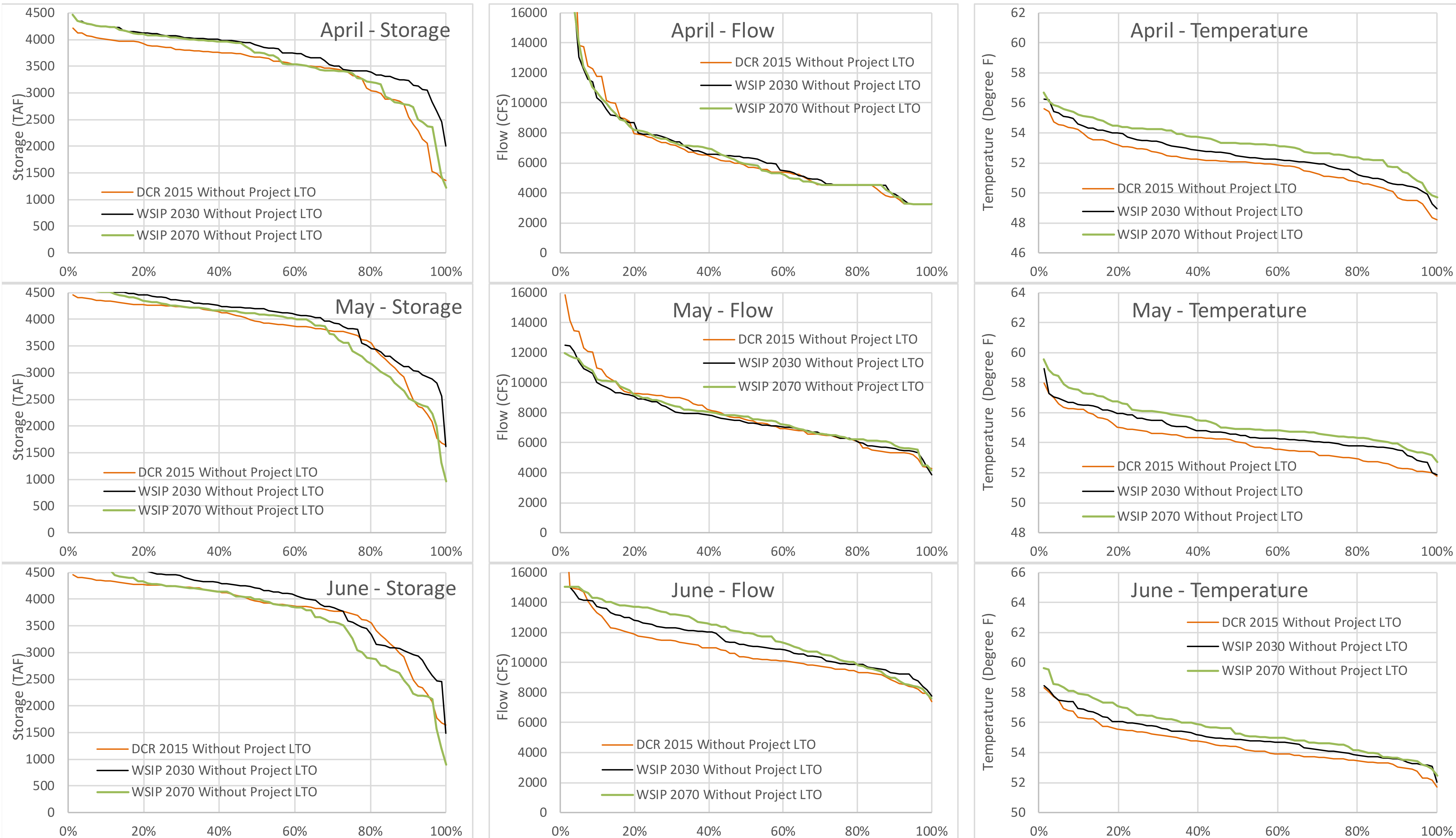
Location	Max EO-Apr or May Storage	Temperature (F) Schedules for Shasta Dam Release											
		This table is for temperature target with Percent Exceedances											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0	60.8	60.8	60.8	53.6	53.6	*51.4*	*51.4*	*50.5*	*49.4*	*54.1*	*56.1*	*56.5*
None	2000	60.8	60.8	60.8	53.6	53.6	51.4	51.4	50.5	49.4	54.1	56.1	56.5
Clear Creek	4000	60.8	60.8	60.8	53.6	53.6	51.4	51.4	50.5	49.4	54.1	56.1	56.5
Balls Ferry	4400	60.8	60.8	60.8	53.6	53.6	50.0	50.4	48.8	47.8	53.4	56.5	57.6
Jellys Ferry	4500	60.8	60.8	60.8	53.6	53.6	48.4	49.0	46.8	45.9	52.8	56.8	58.6
Bend Bridge	9999	60.8	60.8	60.8	53.6	53.6	47.7	48.3	45.5	44.4	52.4	57.2	59.2

Attachment C – Sacramento River at Jellys Ferry Without Project Climate Scenario Temperature Comparisons

Shasta Lake Storage (Beginning of Month) | **Keswick Dam Flow** | **Jelly's Ferry Temperature**

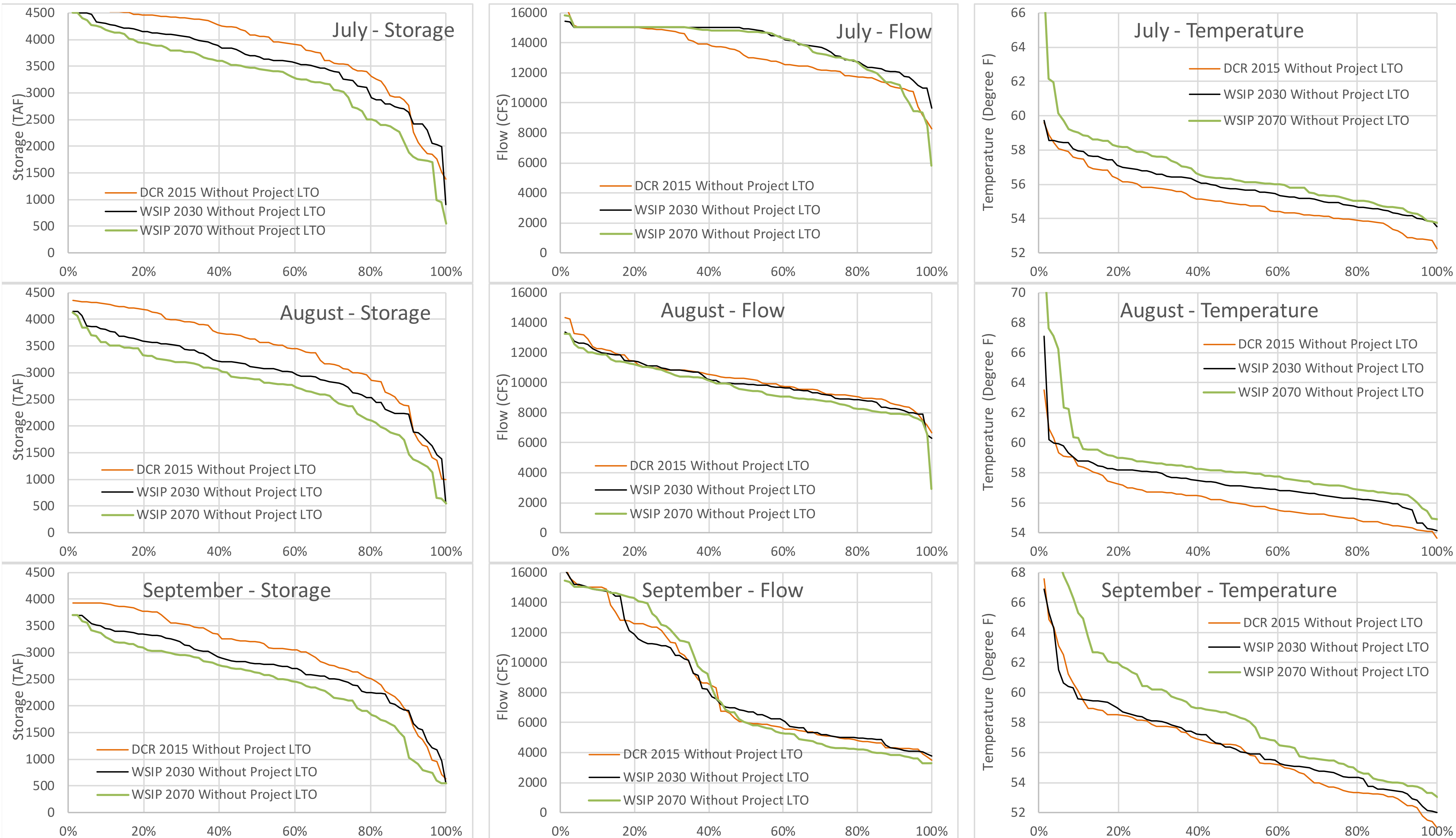


Shasta Lake Storage (Beginning of Month) | **Keswick Dam Flow** | **Jelly's Ferry Temperature**



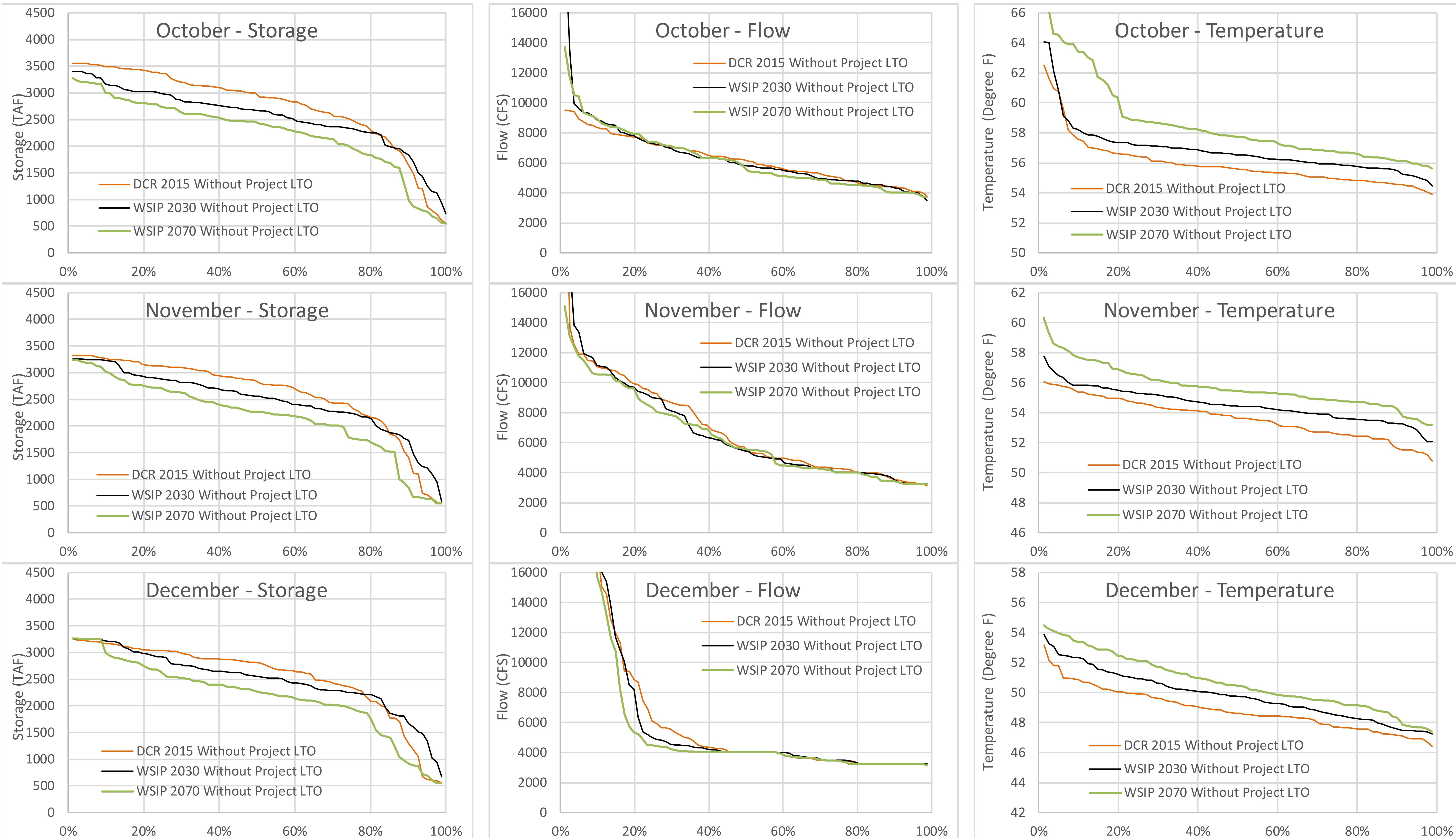
STATUS:	FINAL	PREPARER:	R LEAF	PHASE:	1	VERSION:	C
PURPOSE:	BENEFIT CALCULATION, MONETIZATION, AND RESILIENCY A1	CHECKER:	R TULL	DATE:	2017 AUGUST		
CAVEAT:		QA/QC:		REF/FILE #:	WSIP APPLICATION		
NOTES:				PAGE:	52	OF	84

Shasta Lake Storage (Beginning of Month) | **Keswick Dam Flow** | **Jelly's Ferry Temperature**



STATUS:	FINAL	PREPARER:	R LEAF	PHASE:	1	VERSION:	C
PURPOSE:	BENEFIT CALCULATION, MONETIZATION, AND RESILIENCY A1	CHECKER:	R TULL	DATE:	2017 AUGUST		
CAVEAT:		QA/QC:		REF/FILE #:	WSIP APPLICATION		
NOTES:				PAGE:	53	OF	84

Shasta Lake Storage (Beginning of Month) | **Keswick Dam Flow** | **Jelly's Ferry Temperature**



SALMOD Salmon Modeling of the Sacramento River

SALMOD Salmon Modeling of the Sacramento River for the Sites Reservoir Project

This attachment provides a summary of the SALMOD model used to simulate the annual production potential for each run of Chinook salmon in the Sacramento River for the Sites Reservoir Water Storage Investment Program Application. It includes a description of the SALMOD model and assumptions.

SALMOD Overview

SALMOD simulates the population dynamics of the freshwater life stages of anadromous Chinook salmon. Model processes include spawning (egg deposition), egg and alevin development and growth, mortality, and movement (due to habitat limitation, freshets, and seasonal stimuli). Pre-smolts do not graduate to the smolt stage within the model. Instead, they exit the study area and the population is reinitialized with survey estimates of spawning adults each biological year. SALMOD is a spatially explicit model in which habitat quality and carrying capacity are characterized by the hydraulic and thermal properties of individual mesohabitats, which serve as spatial computational units in the model. SALMOD is organized around events occurring during a biological year beginning with spawning and typically concluding with fish that are physiologically "ready" (e.g., pre-smolts), swimming downstream toward the ocean. It operates on a weekly timestep for one or more biological years. Input variables (e.g., streamflow, water temperature, number and distribution of adult spawners) are represented by their weekly average values. SALMOD tracks a population of spatially distinct cohorts that originate as eggs and grow from one life stage to another as a function of local water temperature. The biological characteristics of fish within a cohort are the same. Fish cohorts are tracked by life stage and size class within the spatial computational units. SALMOD uses the weekly averages of the daily flow outputs from the CALSIM II model and the daily temperature outputs from the Trinity-Sacramento HEC5Q model.

The 2008 Central Valley Project and State Water Project Operations Criteria and Plan Biological Assessment (OCAP BA) Technical Appendix P (Reclamation, 2008) describes the SALMOD model in detail including the development history, model formulation, input assumptions, use of outputs, and limitations of the model.

SALMOD Assumptions for Returning Chinook Salmon Spawners

This section presents the assumptions used for returning Chinook salmon spawners used in SALMOD modeling for evaluation of the alternatives. The Chinook salmon runs considered in SALMOD include winter, spring, fall, and late fall.

Based on spatial distribution of surveyed redds on various segments of the Sacramento River, a distribution of spawners is assumed for the reach segments in the SALMOD model. Assumptions of the spawning distributions were based on average 2003–2014 redd survey data, provided by David Swank at NMFS in April 2015.

The total number of returning adults assumed for each of the four runs is shown in Table 1. The numbers of returning adults assumed for each run summarized in Table 1 are approximate maximums of values assumed in recent applications of the SALMOD model. The ratios of spawning females to total number of returning adults are also included in Table 1. References are unavailable for these ratios. The fractional distribution of returning adults, for each reach segment, for each salmon run, are summarized in Table 2. Each segment is identified by locations along the Sacramento River. Using the fractional distribution of spawners shown in Table 2, the number of returning adults was apportioned to the reach segments in the model.

SALMOD modeled production potential is assumed to vary across alternatives and within each alternative across each biological year according to variations in water temperatures, flows, and the resultant habitat available for Chinook salmon. The assumed number and distribution of returning female spawners is not varied by biological year. The high value was assumed for the number of returning female spawners so as to describe the potential available habitat under a wide range of flow and temperature conditions (value based on maximums of values assumed in recent applications of the SALMOD model). Therefore, the SALMOD results are not intended to estimate a specific number of Chinook salmon produced, but rather to provide an index of available habitat assuming that the number of returning female spawners is not limited.

Table 1: Number of Returning Chinook Salmon Adults, and Ratio of Spawning Females to All Returning Adults, on the Sacramento River

Chinook Salmon Run	Returning Adults (High Curve)	Ratio of Spawning Adults to Non-spawning Adults
Winter	8,500	0.48
Spring	999	0.48
Fall	65,000	0.48
Late Fall	14,000	0.48

Table 2: Distribution of Returning Chinook Salmon Adults in Eight Spawning Segments of the Sacramento River

Cumulative Distance from Keswick Dam (meters)	Location of Sacramento River Segment	Fraction of Returning Chinook Salmon Adults (percentage)			
		Winter-Run	Spring-Run	Fall-Run	Late Fall-Run
5791	Keswick Dam to Anderson-Cottonwood Irrigation District (ACID) Dam	45.10	12.83	19.50	71.30
9025	ACID Dam to Highway 44 Bridge	42.10	33.97	6.60	5.20
28810	Highway 44 Bridge to Airport Road Bridge	12.20	29.76	14.70	3.90
41411	Airport Road Bridge to Balls Ferry Bridge	0.30	11.12	19.40	8.90
49207	Balls Ferry Bridge to Battle Creek	0.10	7.41	12.50	5.90
56538	Battle Creek to Jellys Ferry	0.10	1.50	15.20	3.10
71413	Jellys Ferry Bridge to Bend Bridge	0.10	2.61	8.00	1.20
84828	Bend Bridge to just upstream of the Red Bluff Diversion Dam	0.00	0.80	4.20	0.60

References

U.S. Bureau of Reclamation (Reclamation). 2008. 2008 Central Valley Project and State Water Project Operations Criteria and Plan Biological Assessment. Technical Appendix P SALMOD Model. May 2008. U.S. Bureau of Reclamation, Mid-Pacific Region, Sacramento, California. Accessible at http://www.usbr.gov/mp/cvo/OCAP/sep08_docs/Appendix_P.pdf

Upper Sacramento River Daily River Flow and Operations Modeling

Upper Sacramento River Daily River Flow and Operations Modeling

This attachment provides the summary of modeling performed to simulate daily flow and operations in the reservoirs, rivers and other conveyance features that are part of the Central Valley Project (CVP) and the Sites Reservoir Project (Project). It includes a description of the Upper Sacramento River Daily Operations Model (USRDOM) and results used in the detailed evaluation of alternatives.

USRDOM Overview

USRDOM simulates daily flow and storage conditions in the upper Sacramento River including Trinity basin, Sacramento River from Shasta Lake to Knights Landing and Colusa Basin including the Project conveyance and storage features. USRDOM utilizes results from CALSIM II to evaluate the impacts of changing diversion, in-basin use and Delta operations under projected conditions within current or future regulatory and operational regimes. It couples the downstream monthly operational decisions in CALSIM II to a simulation of the associated sub-monthly operational response at Lake Shasta depending on the inflows. It is particularly useful in verifying the CALSIM II simulated river conditions and the availability of excess flows to fill the Sites Reservoir under the capacity and operational constraints of the three intakes at the Red Bluff, Hamilton City and Delevan locations.

Development of the USRDOM, calibration and verification, its use in planning simulations and its application to the Sites Reservoir Project is documented in detail in the final USRDOM Development, Calibration, and Application report prepared by CH2M HILL for Reclamation (CH2M HILL, 2011).

Objective

USRDOM is used in several ways as part of modeling of the operations of the Sites Reservoir Project. It was used to test and finalize the CALSIM II operations for the Project alternatives. The main objective of using USRDOM was to simulate daily flows to inform CALSIM II (monthly) about the potential restrictions on the diversions due to pulse flow conditions. It was also used to evaluate storage conditions in Lake Shasta and Sites Reservoir, flow conditions on a daily-weekly time scale along the Sacramento River from Keswick Dam to Knights Landing and in the Colusa Basin conveyance. The results from USRDOM are used for input into temperature, biological and flow regime models to evaluate the Project.

Project Intake Operations Assumptions

This section briefly describes the key operational assumptions used in the USRDOM model for evaluating the Project.

The operational assumptions governing the diversions at the three Project intakes, namely existing Tehama Colusa Canal (TCC) Intake, Glenn Colusa Canal (GCC) Intake and the Delevan Pipeline Intake include:

- Restrictions based on the available channel conveyance capacities at various locations along the TCC and GCC. Further, restrictions based on the dedicated annual maintenance periods for TCC, GCC, and Delevan pipeline.
- Restrictions based on meeting the specified bypass flow requirements downstream of each of the three intakes. In addition, diversions are restricted based on the seasonal bypass flow requirements specified for Sacramento River near Hood.

- Restrictions based on the occurrence of pulse flows in the Sacramento River, which provide key biological cues for the outmigrating juvenile winter-, spring-, fall, and late fall-run Chinook salmon, as well as a portion of the steelhead juvenile fish. Therefore, diversions are restricted for up to one pulse event recognized in each month of the October through May period. Bend Bridge flow was used to identify pulse signals as part of the modeling.

Overview of the Planning Analysis

CALSIM II simulates CVP and State Water Project (SWP) operations on a monthly timestep from WY 1922 through WY 2003. Therefore, for the USRDOM projected conditions simulation, the inputs are taken from CALSIM II for a consistent analysis. Because USRDOM requires inputs on a daily timestep, the monthly inputs and outputs of the CALSIM II model are downscaled to a daily timestep using the CAL2DOM utility. CAL2DOM utility translates monthly CALSIM II operations data to a daily time step. It uses the inputs and outputs from CALSIM II, USRDOM hydrology inputs, and other datasets to compute inflows, diversions, and evaporation rates for using as inputs in the USRDOM.

Analysis of the Project

CALSIM II was the core model used to simulate Project operations. However, the assumptions related to the intake operations require daily flow data in determining the diversions allowed at the intakes, in turn affecting the system-wide operations. Since CALSIM II is a monthly timestep model, USRDOM results were used to enforce the intake operations on a sub-monthly scale. Due to the complexity in the intake operational rules, a spreadsheet tool was developed to implement the operational constraints using the daily results from the USRDOM. Further, the models were iterated to ensure all the intake operations assumptions were simulated accurately. Figure 1 shows the schematic of the modeling process used to simulate Project operations.

In the first iteration, CALSIM II and USRDOM models are simulated for the Project to determine the days requiring the pulse protection. A draft CALSIM II simulation was run with all the physical, regulatory and operational assumptions for the Project alternative. The results from this “draft” CALSIM II simulation were used to run the USRDOM model. The USRDOM setup included Project assumptions consistent with the draft CALSIM II. Since this USRDOM run is used to estimate daily flows in the river to determine the days requiring pulse protection, the diversions at the TCC, GCC, and Delevan intakes are restricted to meet the agricultural demands and other local uses in Colusa Basin region. The CAL2DOM logic was altered to estimate the diversions at the three intake locations without including the diversions for filling Sites Reservoir in this USRDOM run (called as, draft USRDOM No Fills Run). The results from the draft USRDOM No Fills run are used in a spreadsheet tool to determine the number of days under pulse protection in each month, over the 82-year period.

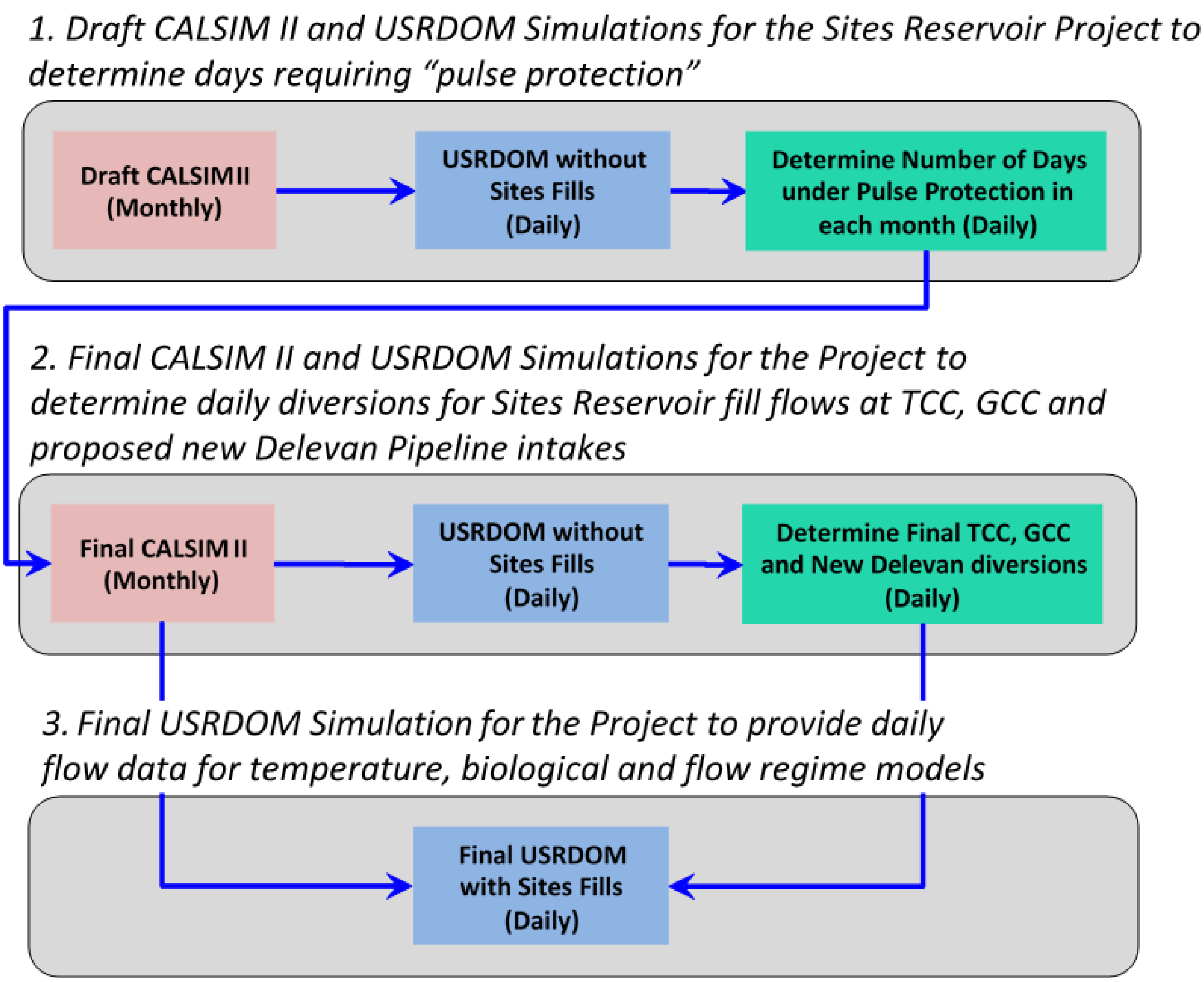


Figure 1 - Operations Modeling Process used for the Project Alternatives Evaluation

In the second iteration, the draft CALSIM II from the first iteration is re-run with the pulse protection data, to simulate the final monthly operations for the Project. The goal of this iteration is to determine the daily diversion amounts at the TCC, GCC, and Delevan pipeline intakes. Since the complexity involved in simulating capacity and maintenance constraints, bypass flow requirements and pulse protection restrictions simultaneously, the existing CAL2DOM logic to determine the daily diversions at the three intakes is insufficient. Therefore, the results from the final CALSIM II simulation are used to run another USRDOM simulation without including the diversions needed to fill the Sites Reservoir at the three intake locations (called as, final USRDOM No Fills Run). The purpose of this final USRDOM No Fills run is to determine the daily flows in the Sacramento River at key control points. This data is used in a spreadsheet tool to determine the daily diversions required to fill Sites Reservoir at the three intakes while complying with all the operational rules.

The daily diversions for the Sites fills at the three intakes are determined in three steps in the spreadsheet tool. In the first step the available diversion capacity is determined based on the capacity and maintenance constraints described above. In addition, based on the daily USRDOM flow the available flow to meet the monthly average diversion for fill (from CALSIM II) is determined at each intake, while meeting the bypass flow requirements. If there are no pulse flow restrictions for a given day, then the diversion at each intake is estimated as the minimum of available capacity and the available flow for diversion.

If the total diversion volumes at each intake from the first step for each month are less than the amount determined in CALSIM II, additional diversions needed to make up the difference are estimated in the second step. In this step, the additional diversions are made up at any of the three intakes depending on the available diversion capacity and the available flow for the diversion. First TCC intake is checked, then the GCC intake and finally the Delevan pipeline intake for any available diversion capacity for each month.

Based on the diversions from the second step, the months with volumes continue to be short of the CALSIM II values are flagged in the third and final step. These shortages are carried forward to the next months in which the diversion capacity and the flow for the diversion are available. This carrying forward of the shortages is only allowed in November through May months, which generally is the Sites Reservoir filling period. The availability of the flow for the diversion is estimated as the Wilkins Slough flow in excess of the minimum flow requirement at Knights Landing (estimated in CAL2DOM).

In this process, a few reasonable simplifying assumptions were made for modeling purposes, mainly because CALSIM II determines the diversions at the three intakes on a monthly timestep without knowing the daily constraints due to the intake operations assumptions and the daily variability in the unregulated flows. It is assumed that based on the available real-time monitoring, there is enough flexibility in TCC, GCC, and Delevan pipeline operations and in the interoperability among the three conveyance systems such that the diversions to fill Sites Reservoir can be made up through the following:

- Diversions at any of the three intake locations while meeting all the intake operations assumptions at each intake
- Diversions in any of the months during the fill season of November through May if usable diversion capacity and divertible flow is available

In the third iteration a final USRDOM run is simulated using the final CALSIM II results and the daily diversions for fills from the final step of the spreadsheet tool. CAL2DOM is modified to combine the diversions for the fills and the diversions for meeting local Colusa Basin demands to determine the total daily diversions at each of the three intakes.

Limitations

In using the USRDOM results for the Sites Reservoir Project evaluation following limitations should be noted:

The USRDOM calibration for Clear Creek flows below Whiskeytown Dam is significantly weaker than for other flows in the Trinity and Sacramento River systems. It is recommended that the CALSIM II model alone be used as the basis for impact assessment on Clear Creek flows.

In the downscaling of CALSIM II boundary condition flows for use in the USRDOM simulations, diversions at Red Bluff, Hamilton City and the Delevan Pipeline (Project alternatives) are smoothed from monthly to daily timestep. In this smoothing operation, in order to conserve volume and have a gradual change in diversion flows (as opposed to sharp changes at monthly or other time scale boundaries), there are some days in which diversions are represented in the model at flow rates that may exceed the sustainable rate of the physical capacity of these facilities. It is recommended that any assessment of flows or other parameters linked to the peak flow rate of these diversions use monthly average values rather than daily or other sub-monthly average values.

The CALSIM II model is used to establish system operational conditions and USRDOM is used to interpret these on a daily time-step; all residuals and inconsistencies between the CALSIM II and USRDOM models accumulate in storage facilities modeled, including Sites Reservoir; the Sites Reservoir storage in the USRDOM sometimes exceeds physical capacity slightly due to this inconsistency between the models.

References

CH2M HILL. 2011. Final USRDOM Development, Calibration, and Application. Prepared for Bureau of Reclamation, Mid-Pacific Region.

Power Modeling of the Sites Reservoir Project

Sites Reservoir Power Analysis – Planning Level Assumptions and Modeling Approach

This section describes the planning level modeling approach to estimate power impacts of proposed Sites Reservoir facilities.

Sites Reservoir Power Model Overview

The Sites Reservoir power analysis tool is a spreadsheet post-processor that evaluates power impacts of flow scenarios from CALSIM II operations studies. The tool estimates average annual energy generation and use at proposed Sites Reservoir generation and pumping facilities, including existing facilities that would be operated differently if Sites Reservoir is built. For generation facilities, the tool estimates average annual energy generation and average annual peaking power capacity. For pumping facilities, the tool estimates average annual power requirements. The tool also checks to determine whether off-peak energy use targets are being met. Transmission losses are estimated for both pumping and generation facilities.

In addition, the tool estimates the economic benefits and costs of power generation and use at the proposed Sites Reservoir generation and pumping facilities.

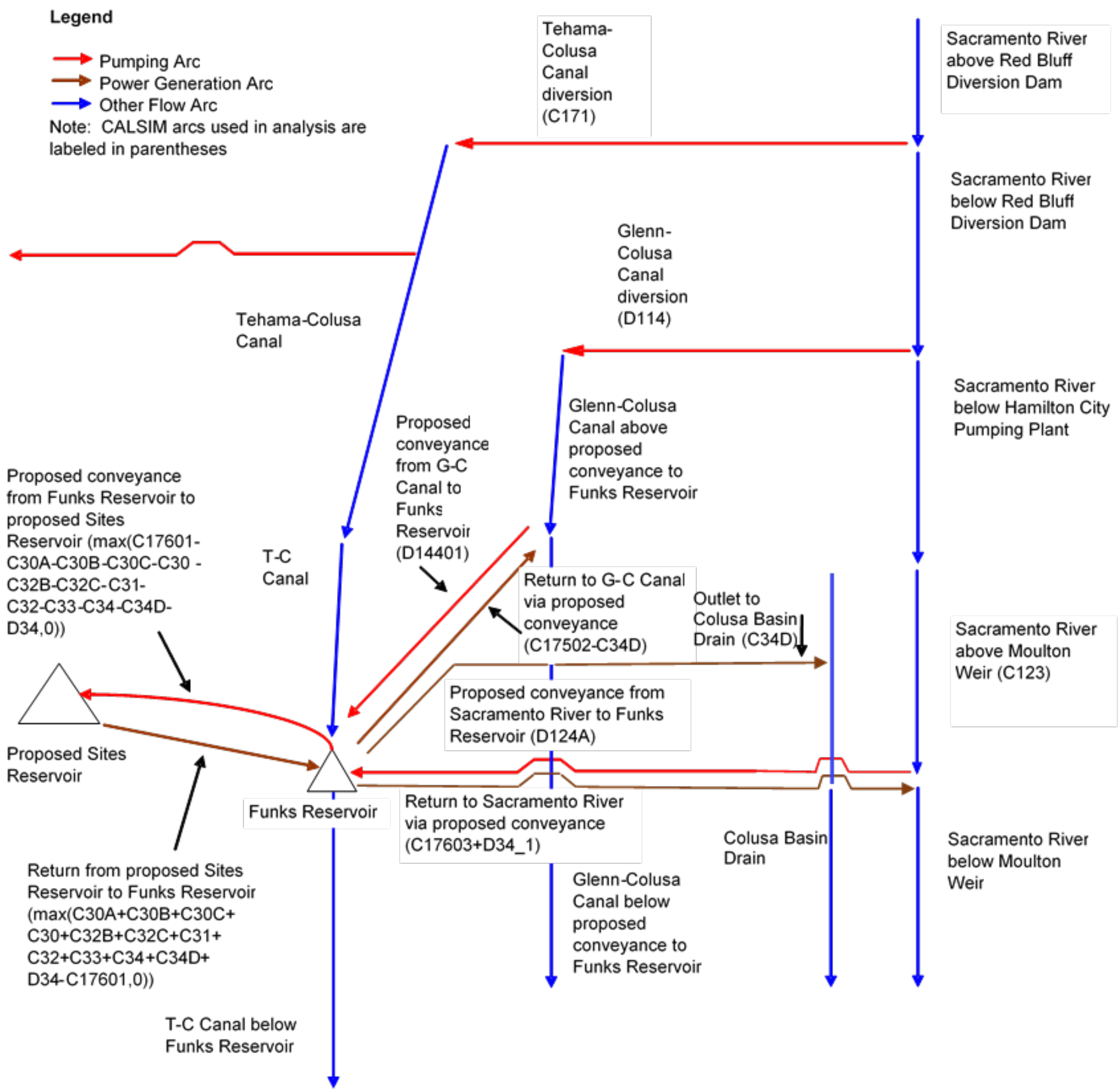
Flow and storage levels used in the power analysis tool are taken from CALSIM II studies. The analysis period is for 82 years, based on the projected level hydrologic and land use assumptions associated with the CALSIM II analysis used.

Figure 1 shows pumping and power generation facilities that are included in the power analysis tool (CALSIM II output parameter names are included in the figure).

A total of five pumping facilities and three generation facilities are included in the analysis.

- Pumping facilities:
  - Sacramento River diversion to Tehama-Colusa Canal (existing pumping facility)
  - Sacramento River diversion to Glenn-Colusa Canal (existing pumping facility)
  - Conveyance from Glenn-Colusa Canal Terminal Regulating Reservoir to Funks Reservoir (proposed conveyance with pumping facilities)
  - Conveyance from Sacramento River to Funks Reservoir (proposed conveyance with pumping facilities)
  - Conveyance from Funks Reservoir to Sites Reservoir (proposed conveyance with pumping facilities)

FIGURE 1
Facilities Included in the Sites Reservoir Power Analysis



Generation facilities:

- Conveyance from Sites Reservoir to Funks Reservoir (proposed conveyance with power generation facilities)
- Conveyance from Funks Reservoir to the Sacramento River (proposed conveyance with power generation facilities)
- Conveyance from Funks Reservoir to Glenn-Colusa Canal Terminal Regulating Reservoir (proposed conveyance with power generation facilities)

Approach

This section documents the approach that is used to estimate energy use, generation, peaking power capacity, and transmission losses.

Energy Use at Pumping Facilities

The approach used to estimate energy use at pumping facilities assumes that pumping plant energy use is a function of flow and total head. Energy use is estimated using the following equation:

Energy Use (MWh) =

$$0.7457\frac{kW}{hp}*62.4\frac{lbs}{ft\text{^}3}*\frac{1MW}{1000kW}*\frac{1hp}{550\frac{lb*ft}{s}}*t\frac{hrs}{month}*\frac{1}{\eta}*\text{head}(ft)*\text{Q}\frac{ft\text{^}3}{s}$$

The tool also estimates whether user-defined off-peak energy use targets can be met. For example, if it is desired that 90% of required pumping energy use during a particular month occur during off-peak hours, the tool determines whether this is feasible given power and flow capacity limits.

Energy Generation

The approach used to estimate energy generation at power facilities assumes that power plant generation is a function of flow and total head. Energy generation is estimated using the following equation:

Energy Generation (MWh) =

$$0.7457\frac{kW}{hp}*62.4\frac{lbs}{ft\text{^}3}*\frac{1MW}{1000kW}*\frac{1hp}{550\frac{lb*ft}{s}}*t\frac{hrs}{month}*\eta*\text{head}(ft)*\text{Q}\frac{ft\text{^}3}{s}$$

Power Capacity

The approach used to estimate power capacity assumes that peak capacity is a function of total head and average power plant flow. Power capacity is estimated using the following equation:

Power Capacity (MW) =

$$0.7457\frac{kW}{hp}*62.4\frac{lbs}{ft\text{^}3}*\frac{1MW}{1000kW}*\frac{1hp}{550\frac{lb*ft}{s}}*\eta*\text{head}(ft)*$$

$$\text{Avg. power plant flow rate}(\frac{ft\text{^}3}{s})$$

The above approach may underestimate peak power capacity. The approach uses average monthly power plant flows, while generation facilities may release at levels considerable higher than average monthly flows during peak demand periods. This approach should be revised if the use of average monthly flows is determined to be too conservative.

Transmission Losses

Transmission losses are estimated to estimate energy use and generation at load center. Transmission losses are estimated as a percentage of energy use or generation.

Economic Benefits and Costs

The economic benefits and costs of power generation and use at each facility is estimated using year 2025 forecasted monthly on-peak and off-peak power prices for Northern California.

Assumptions

Tables 1-A through 1-E list assumptions that are used to estimate energy use and transmission losses at proposed Sites Reservoir pumping facilities.

Tables 2-A through 2-C list assumptions that are used to estimate energy generation, power capacity, and transmission losses at proposed Sites Reservoir generation facilities.

Table 3 shows the 2025 forecasted on-peak and off-peak power prices that are used to estimate economic costs and benefits.

TABLE 1-A
Assumptions for Tehama-Colusa Canal Diversion Pumping Facility

Plant Characteristics	Units	Modeling Assumptions	Basis for Assumption
Max Q Plant	cfs	2,000	Fish Passage Improvement Project at the Red Bluff Diversion Dam: Design Development Report, November 2009, CH2M HILL
Efficiency		85%	Based on conversation with Dinh Nguyen, Design Engineer, DWR
Transmission Losses		2%	Discussion with DWR staff, 2/8/07
Percent Eng Off Peak			No off-peak pumping target
Dynamic Head	ft	12	Discussion with DWR staff, 2/8/07
Power Rating	MW	6.00	Red Bluff Pumping Plant and Fish Screen October 2009 - Contract #4 Conformed Drawings USBR and CH2M HILL

TABLE 1-B
Assumptions for Pumping from GC Canal Terminal Regulating Reservoir (TRR) to Funks Reservoir

Plant Characteristics	Units	Modeling Assumptions	Basis for Assumption
Max Q Plant	cfs	1,800	From pg 17 of DWR Conveyance Report
Num Pipes		2	From pg 17 of DWR Conveyance Report
Max Q Pipe	cfs	900	From pg 17 of DWR Conveyance Report
Roughness	ft	0.003	Based on pre-cast concrete pipe (pg 20, DWR Conveyance Report)
Diameter	ft	12	Based on pre-cast concrete pipe (pg 20, DWR Conveyance Report)
Length	ft	14,400	From Alternative 3, Appendix D of DWR Conveyance Report
Efficiency		82%	March 15, 2011 project team meeting
Off-/on-peak objective			No off-peak pumping target
Transmission Losses		2%	Discussion with DWR staff, 2/8/07
Elevation 1	ft	111.5	Assumes TRR WS is constant; from pg 17 of DWR Conveyance Report
Elevation 2	ft	203	Assumes Funks WS is constant; from pg 6 of Appurtenant Facilities report
Power Rating	MW	19.68	Table A, NODOS Feasibility Study (DWR, Sep 2010)

TABLE 1-C
Assumptions for Pumping from Sacramento River to Funks Reservoir

Plant Characteristics	Units	Modeling Assumptions	Basis for Assumption
Max Q Plant	cfs	2,000	Discussion with DWR staff, 2/8/07
Num Pipes/Pumps		2	Discussion with DWR staff, 2/8/07
Max Q Pipe	cfs	1,000	Discussion with DWR staff, 2/8/07
Roughness	ft	0.003	Based on pre-cast concrete pipe (pg 20, DWR Conveyance Report)
Diameter	ft	12	From pg 16 of DWR Conveyance Report
Length	ft	70,000	From pg 9 of DWR Conveyance Report
Efficiency		82%	March 15, 2011 project team meeting
Off-/on-peak objective			No off-peak pumping target
Transmission Losses		0.02	Discussion with DWR staff, 2/8/07
Elevation 1	ft	Sac Stage	From Sac Rating Curve
Elevation 2	ft	203	Assumes Funks WS is constant; from pg 6 of Appurtenant Facilities report
Power Rating	MW	65.65	Table A, NODOS Feasibility Study (DWR, Sep 2010)

TABLE 1-D
Assumptions for Pumping from Funks Reservoir to Sites Reservoir

Plant Characteristics	Units	Modeling Assumptions	Basis for Assumption
Tunnel		1	From DWR Appurtenant Facilities report
Max Q Pipe	cfs	5,900	March 15, 2011 project team meeting
$Roughness_{concrete}$	ft	0.003	Based on concrete lining (pg 23, DWR Appurtenant Facilities report)
$Roughness_{steel}$	ft	0.0002	Discussion with DWR staff, 2/8/07
Diameter	ft	30	From Appendix A (pg 23) of DWR Appurtenant Facilities report
$Length_{concrete}$	ft	3,031	From Figures 4-1 & 4-2 of DWR Appurtenant Facilities report
$Length_{steel}$	ft	1,000	From Figures 4-1 & 4-2 of DWR Appurtenant Facilities report
Efficiency		82%	March 15, 2011 project team meeting
Off-/on-peak objective			Maximize off-peak pumping
Transmission Losses		0.02	Discussion with DWR staff, 2/8/07
Elevation 1	ft	203	Assumes Funks WS is constant; from pg 6 of Appurtenant Facilities report
Elevation 2	ft	Sites WS	From Sites Elevation-Capacity curve
Power Rating	MW	181.35	Table A, NODOS Feasibility Study (DWR, Sep 2010)

TABLE 1-E
Assumptions for Glenn-Colusa Canal Diversion Pumping Plant

Plant Characteristics	Units	Modeling Assumptions	Basis for Assumption
Max Q Plant	cfs	3,000	CALSIM II maximum flow for GC Canal
Efficiency		85%	Based on conversation with Dinh Nguyen, Design Engineer, DWR
Transmission Losses		2%	Discussion with DWR staff, 2/8/07
Off-/on-peak objective			No off-peak pumping target
Dynamic Head	ft	10	Discussion with DWR staff, 2/8/07
Power Rating	MW	3.39	Derived from Table 2-3 (pg 2-6) in GCID Feasibility Report.

TABLE 2-A
Assumptions for Funks Reservoir Generating Plant

Plant Characteristics	Units	Modeling Assumptions	Basis for Assumption
Tunnel		1	Same as Funks (P) above
Max Q Pipe	cfs	5,100	March 15, 2011 project team meeting
$Roughness_{concrete}$	ft	0.003	Same as Funks (P) above
$Roughness_{steel}$	ft	0.0002	Same as Funks (P) above
Diameter	ft	30	Same as Funks (P) above
$Length_{concrete}$	ft	3,031	Same as Funks (P) above
$Length_{steel}$	ft	1,000	Same as Funks (P) above
Efficiency		85%	March 15, 2011 project team meeting
Off-/on-peak objective			Maximize on-peak generation
Transmission Losses		0.02	Discussion with DWR staff, 2/8/07
Elevation 1	ft	Sites WS	From Sites Elevation-Capacity curve
Elevation 2	ft	203	Assumes Funks WS is constant; from pg 6 of Appurtenant Facilities report
Power Rating	MW	123.0	Table A, NODOS Feasibility Study (DWR, Sep 2010)

TABLE 2-B
Assumptions for Glenn-Colusa Canal Terminal Regulating Reservoir Generating Plant

Plant Characteristics	Units	Modeling Assumptions	Basis for Assumption
Max Q Plant	cfs	1,500	March 15, 2011 project team meeting
Num Pipes		2	From pg 17 of DWR Conveyance Report
Max Q Pipe	cfs	750	March 15, 2011 project team meeting
Roughness	ft	0.003	Based on pre-cast concrete pipe (pg 20, DWR Conveyance Report)
Diameter	ft	12	Based on pre-cast concrete pipe (pg 20, DWR Conveyance Report)
Length	ft	14,400	From Alternative 3, Appendix D of DWR Conveyance Report
Efficiency		85%	March 15, 2011 project team meeting
Off-/on-peak objective			No on-peak generation target
Transmission Losses		2%	Discussion with DWR staff, 2/8/07
Elevation 1	ft	203	Assumes Funks WS is constant; from pg 6 of Appurtenant Facilities report
Elevation 2	ft	111.5	Assumes TRR WS is constant; from pg 17 of DWR Conveyance Report
Power Rating	MW	9.8	Table A, Sites Feasibility Study (DWR, Sep 2010)

TABLE 2-C
Assumptions for Sacramento River Generating Plant

Plant Characteristics	Units	Modeling Assumptions	Basis for Assumption
Max Q Plant	cfs	1,500	Pg. 3, DWR Pumping-Generating Plants Feasibility Study
Num Pipes/Pumps		2	Discussion with DWR staff, 2/8/07
Max Q Pipe	cfs	750	Pg. 3, DWR Pumping-Generating Plants Feasibility Study
Roughness	ft	0.003	Based on pre-cast concrete pipe (pg 20, DWR Conveyance Report)
Diameter	ft	12	From pg 16 of DWR Conveyance Report
Length	ft	70,000	From pg 9 of DWR Conveyance Report
Efficiency		85%	March 15, 2011 project team meeting
Off-/on-peak objective			Maximize on-peak generation
Transmission Losses		2%	Discussion with DWR staff, 2/8/07
Elevation 1	ft	203	Assumes Funks WS is constant; from pg 6 of Appurtenant Facilities report
Elevation 2	ft	Sac Stage	From Sac Rating Curve
Power Rating	MW	10.8	Table A, NODOS Feasibility Study (DWR, Sep 2010)

TABLE 3

Forecasted Year 2025 On-Peak and Off-Peak Power Prices

Source: Prices are forward prices developed by DWR power portfolio section; date of forecast: 08/25/09

Month	On-Peak	Off-Peak
October	$82.81	$67.87
November	$83.69	$69.89
December	$86.29	$72.33
January	$83.25	$70.59
February	$82.22	$71.67
March	$79.50	$67.48
April	$75.45	$61.76
May	$76.95	$57.78
June	$79.19	$58.07
July	$92.57	$65.79
August	$87.50	$66.90
September	$84.59	$66.31

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Economic Modeling

Economic Modeling of the Sites Reservoir Project

This attachment includes the assumptions and approaches used to estimate hydropower benefits from the Sites Reservoir Project. The California Water Commission (CWC) requirements and recommendations for water supply and Hydropower benefits estimation provided in the Technical Reference document are incorporated and detailed in this document. Section 1 covers two approaches that provide M&I water supply benefits at 2030 and 2070 conditions in average annual value (2015 dollars):

1. Unit Value Approach using California Water Commission (CWC) provided $/Acre-Foot benefit of water supply cited in the Technical Reference Document
2. Economic Model Approach:
    a. M&I Water Supply: California Water Economics Spreadsheet Tool (CWEST)
    b. Agricultural Water Supply: Statewide Agricultural Production Model (SWAP)

Section 2 covers the estimation of hydropower benefits and conveyance costs using Long Term Generation (LTGen), State Water Project (SWP) Power, and North of Delta Off-Stream Storage (NODOS) Power.

Section 3 provides additional comments on the CWC Water Storage Investment Program (WSIP) Technical Reference document (CWC, 2016).

Section 1. Water Supply Benefits Estimation

Quantifying Private Water Availability and Uses

Sites Project Participants are both agricultural (Ag) and municipal and industrial (M&I) agencies. Table X1 provides a list of Sites Project Participants and beneficial use of Sites water supply. Figure X1 maps the location of the Sites Project Participants.

Table X1. Sites Project Participants (Ag/M&I)

Sacramento Valley Sites Project Participants (Ag)	
Colusa County	Glenn-Colusa Irrigation District
Colusa County Water District	Orland-Artois Water District
Cortina Water District	Proberta Water District
Davis Water District	Reclamation District 108
Dunnigan Water District	Westside Water District
La Grande Water District	
South of Delta Sites Project Participants (M&I)	
American Canyon, City of	San Bernardino Valley Municipal Water District
Antelope Valley-East Kern Water Agency	San Gorgonio Pass Water Agency
Castaic Lake Water Agency	Santa Clara Valley Water District
Coachella Valley Water District	Zone 7 Water Agency
Desert Water Agency	
South of Delta Sites Project Participants (Ag)	
Wheeler Ridge-Maricopa Water Storage District	

Figure X1 Sites Project Participants

The WSIP 2030 and 2070 without Project CALSIM II model runs were compared to the WSIP 2030 and 2070 with Project CALSIM II model runs to quantify the annual deliveries to Sites Project Participants. Table X2 provides the annual delivery by water year type and long-term average that were used in the water supply and hydropower benefit estimation. Delivery is the calculated quantity at the location of each Sites Project Participant after accounting for conveyance losses, consistent with section 4.12.3 Location at Which Supply is Measured of the CWC Technical Reference document (CWC, 2016).

Table X2. Delivery[1] by Water Year Types[2] (TAF/year)

	Year of Analysis - 2030	Year of Analysis -2070
Sacramento Valley Sites Project Participants (Ag)		
Long-Term Average	111	137

Wet	62	110
Above Normal	86	146
Below Normal	125	152
Dry	157	161
Critical	153	133
South of Delta Sites Project Participants (M&I)		
Long-Term Average	107	117
Wet	15	15
Above Normal	52	72
Below Normal	121	116
Dry	213	257
Critical	185	145
South of Delta Sites Project Participants (Ag)		
Long-Term Average	27	30
Wet	5	5
Above Normal	6	12
Below Normal	28	26
Dry	56	69
Critical	53	41
Sites Project Participants Total		
Long-Term Average	244	285
Wet	82	130
Above Normal	144	230
Below Normal	273	294
Dry	426	488
Critical	391	319

[1] Increases from the No Action Alternative. Accounts for 18% deduction for carriage water for Delta Export

[2] Water Year types are the 2030 and 2070 Sacramento Valley 40-30-30 index and the 2030 and 2070 San Joaquin Valley 60-20-20 index

Approach 1 Unit Values Estimation

Approach 1 applies a dollar value per acre-foot ($/AF) values for water by region, water year type, and future condition. Table D-6 "Unit Values of Water for WSIP, by Year Type, Future Condition, and Region" of the WSIP Technical Reference (CWC, 2016) unit values were applied to deliveries by region and water year type for 2030 and 2070 conditions. Conveyance costs were included in the benefit calculation. For more information on estimated conveyance costs, see Section 2 Hydropower and Conveyance Cost Estimation.

Approach 2 Economics Models

M&I Water Supply Benefit: CWEST

CWEST was developed for the US Bureau of Reclamation's Coordinated Long Term Operation of the Central Valley Project and State Water Project Environmental Impact Statement (LTO EIS) Environmental Consequences analysis. Appendix 19A of the LTO EIS details the history, methodology, and assumptions (Reclamation, 2015). CWEST was selected to estimate M&I water supply benefits in the WSIP application through the list of criteria in Technical Reference document Section 4.12 Water Supply Analysis (CWC, 2016). CWEST was updated for the Sites WSIP analysis to evaluate nine M&I Sites Project Participants. The updates to CWEST include 2030 and 2070 analysis using 2015 UWMP data, inclusion of only Sites Project Participants, and all relevant assumptions outlined in the CWC Technical Reference document.

Methodology

CWEST quantifies M&I water supply benefit by simulating the decisions made at the district or agency level. The model's objective is to select each Sites Project Participant's set of management actions that meet the annual water demand at the lowest cost. The difference in cost between the water supply conditions with and without Sites delivery provides the M&I water supply benefit.

Data Update for Prop 1 WSIP Application

The major update to CWEST was removing non- Sites Project Participants from the model and including any Sites Project Participants that were not including in the existing version on the model. CWEST updates for the WSIP application allows for analysis at 2030 and 2070 and is in 2015 dollars. The main data source for the update was individual Sites Project Participants Urban Water Management Plans (UWMPs). Table X3 lists the major model updates relevant Technical Reference document requirements and data sources.

Table X3. CWEST Key Assumptions, Updates, and Sources

Variables	Notes	Sources
Retail Water Price	Retail water prices are in 2015 dollars and were provided by the Raftelis 2015 California-Nevada Water and Wastewater Rate Survey. For Sites Project Participants not included in this study, retail water rates were gathered from individual Site Project Participant documents. Retail water prices were escalated to 2030 based on a retail water price escalation within CWEST (USBR, 2015).	(American Canyon, 2017), (AVEK, 2015), (City of Banning, 2010), (Desert Water Agency, 2017), (Raftelis, 2015), (USBR, 2015)
Conveyance Costs	Conveyance Costs calculations are described in Section 2	
Groundwater Pumping Costs	The existing CWEST Groundwater pumping cost estimates (USBR, 2015) are applicable to only Sites Project Participants with groundwater as a supply in their 2015 UWMP. The cost ($/AF) is the sum of a representative cost by region plus a groundwater replenishment charge assumed to be the same as the conveyance cost. Inclusion of the groundwater replenishment charge is consistent with Section 5.4.1.1 of the Technical reference document.	(USBR, 2015), UWMPs for each Sites Project Participant (See reference list)
Shortage Cost	The default M&I demand elasticity in CWEST is -0.1 as published in the LTO EIS (USBR, 2015) and is determined applicable for the WSIP application. In CWEST, long-term conservation is a decision variable for M&I Sites Project Participants. With adoption of additional long-term conservation by Sites Project Participants in our analysis, a shortage caused welfare loss needs to be measured under this heightened level of conservation. The CWEST update for the WSIP application relies on 2030	(USBR, 2015), (MCubed and RMann, 2016)

Table X3. CWEST Key Assumptions, Updates, and Sources		
Variables	**Notes**	**Sources**
	conservation and demand levels for the nine M&I Sites Project Participants provided in their 2015 UWMPs. Calculating welfare loss at a level of conservation greater than the UWMP stated conservation and demand levels supports the use of a more inelastic response. The default M&I demand elasticity in CWEST results in a welfare loss per AF similar in magnitude to the values provided in previous studies. Across the nine M&I Sites Project Participants, 2030 welfare loss per AF is in a range of $300 to $2,300 with an average value of $1,100 per AF. MCubed and RMann Economics, 2016 study calculated welfare loss per AF across California in a range of $500 to $2,600 with an average value of $1,500 per AF. Therefore, the use of the default M&I demand elasticity in CWEST is reasonable.	
Transfer Quantities and Costs	Annual transfers were available for the Sites Project Participants with transfers as a 2030 supply in their UWMP. The stated quantity is the annual limit for below normal or above or dry/critical water year types if that information was available. The $/AF cost of transfer water is based on the Technical Reference document provided unit values by region and water year type plus the conveyance charge.	(CWC, 2016), UWMPs for each Sites Project Participant (See reference list)
2030, 2070 Water Demands	2030 water demands were gathered from 2015 UWMPs. 2070 followed Technical reference document provided methods in section 2.7.1 Future Population Levels and Section 2.7.3 Future M&I Water Demand Levels using Department of Finance population projections and gallons per capita per day estimates from 2015 UWMPs	Technical Reference document (CWC, 2016) section 2.7.1 Future Population Levels method using Department of Finance population projects and UWMPs for each Sites Project Participant (See reference list)
2030, 2070 Water Supplies	2030 water supply data for preliminary Sites M&I participants was gathered from 2015 UWMPs. 2030 water supplies were held consistent through 2070, with no modifications based on future climate, environmental, or physical conditions due to data availability.	UWMPs for each Sites Project Participant (See reference list)
Alternative Supply Costs	Alternative Supply costs and available quantities were extrapolated from LCPSIM v97 input values. The four categories of alternative supply costs are: Indoor Conservation, Outdoor Conservation, Recycling, and Desalination. Costs were converted to 2015 dollars and escalated to 2024 based on the Technical Reference document section 5.2.7 Real	(DWR, 2010)

Table X3. CWEST Key Assumptions, Updates, and Sources		
Variables	**Notes**	**Sources**
	Energy Price Escalation.	
Accounting for Potential Reuse	Section 4.12.7 Accounting for Potential Reuse discusses reuse of new supply. This analysis does not include additional benefit from the reuse of Sites deliveries	

Other Relevant Information

M&I groundwater pumping is modeled in CWEST for Sites Project Participants if their 2015 UWMP includes groundwater as a water supply in 2030. M&I groundwater pumping is used to meet annual demand under variable surface water deliveries. When available, annual put and take limits, storage capacity, losses, and pumping costs are modeled in CWEST as managed storage facilities. Otherwise, the UWMP stated 2030 groundwater pumping quantity constrains the maximum annual pumping quantity. For more information on groundwater in CWEST see Reclamation, 2015. Potential SGMA pumping limits were not incorporated into 2030 or 2070 conditions due to data availability. M&I groundwater basins are generally adjudicated or not identified as medium to high priority. Therefore, groundwater use stated in UWMPs is likely to be consistent with future Groundwater Sustainability Plans. Nevertheless, CWEST does not allow annual groundwater pumping to exceed UWMP stated 2030 quantities, annual take limits, or cumulative take greater than the UWMP stated groundwater storage capacity.

The distinction between wholesale and retail electricity prices is relevant to private water supply and hydropower benefits estimation. The Technical Reference document did not make this distinction in section 5.2.7 Real Energy Prices for Future Project Costs. For the Hydropower benefits estimation, proprietary wholesale electricity prices were used. In the M&I water supply benefits estimation, the Technical Reference document provided escalation rates to 2024 were used where applicable. This included the escalation of alternative supply costs and groundwater pumping costs. Retail water price escalation used a retail water price escalation to 2030. Following the Technical Reference document section 5.2.7, 2024 or 2030 were held constant thereafter for the 2070 analysis.

Agricultural Water Supply Benefit: SWAP

The CWC provided a SWAP model to estimate the benefit to ag Sites Project Participants. This CWC version of SWAP was applied to ensure consistency between the Sites agricultural benefit analysis and the CWC unit value analysis (CWC, 2016).

Methodology

See *Statewide Agricultural Production (SWAP) Model Update and Application to Federal Feasibility Analysis* (Reclamation, 2012) for a comprehensive report on the SWAP model.

Data Update for Prop 1 WSIP Application

The Sites SWAP analysis used the CWC provided SWAP model without any modifications to the model code or baseline data.

Section 2. Hydropower and Conveyance Cost Estimation

Methodology

Hydropower benefits estimation follows the requirements of section 4.13 Hydropower Analysis in the Technical Reference document (CWC, 2016). Pumping costs and generation revenue for all major SWP, CVP, and Sites facilities is calculated based on three hydropower models: SWP Power, LTgen, and NODOS Power, respectively. SWP Power and LTgen are publicly available models and are referenced in Section 4.13.3.1 Energy Generation of the CWC Technical Reference document (CWC, 2016).

Data Update for Prop 1 WSIP Application

Electricity prices provided by CA DWR in an email correspondence were used to updated all three of the hydropower models. The DWR provided data is proprietary and will not be published in this documentation. The 2030 NP-15 wholesale electricity prices were used in both 2030 and 2070 conditions. Forecasts are not available for 2070 and per the direction of the CWC Technical Reference document, 2030 prices were applied to the 2070 analysis. No changes were made to SWP Power and LTgen from the Sites EIR/EIS or feasibility study. NODOS power was updated to be consistent with the project proposal.

Conveyance Cost Estimation

Technical Reference document Section 6.5.1 requires all water "be assigned a water delivery cost per acre-foot be based on variable costs" (CWC, 2016). Conveyance costs for each Sites Project Participant were twofold – A north of delta operations power cost plus the conveyance charge to respective location and delivery quantity after conveyance losses.

1. North of Delta Operations Hydropower Cost: A $/AF north of delta operations hydropower cost was calculated by dividing the total long-term average annual net costs north of delta by the total long-term average annual AF through Holthouse. Annual net cost is the total hydropower generation revenue minus the total pumping costs over one year. The water balance accounting at Holthouse can be used to allocate the north of delta operations hydropower cost across the private and public accounts. The net north of delta operations hydropower cost includes Sites net pumping/generation costs and any other with-project effects measured in other north of delta facilities. The SWP/CVP facilities included in the calculation had net effects measured between the No Action and With-Project CALSIM runs. The effects on these facilities were generally reductions in pumping costs or increases in generation revenue. The net north of delta operations hydropower cost was calculated at $16/AF.

2. A unique $/AF conveyance cost for each Sites Project Participant is added to the $16/AF cost from #1. The unique $/AF conveyance cost is the sum of representative unit costs of facilities (pumping and generation) used to get the delivered water to each Site Project Participant location. The unit cost for each facility was calculated from LTgen and SWP power model analyzed with the WSIP 2030 and 2070 with Project CALSIM II runs. This $/AF was applied to the delivered water to estimate the total hydropower cost. The calculated conveyance costs are similar to the SWP conveyance charges provided in Bulletin 132-10 (DWR, 2013).

Section 3. Additional Comments on Private Water Supply Benefit and Hydropower Costs Estimation

Comments	
2030 and 2070 With and Without-project Future Conditions for M&I, Ag, and Hydropower benefits estimation	2030 and 2070 With and without-project future conditions are identical in these benefit estimation categories. With and without-project hydrology is the only difference in future conditions. Future hydrology used in these analyses were the CWC provided WSIP 2030 without Project CALSIM II modelling runs were compared to the Sites WSIP 2030 with Project modelling runs.
Consistency with existing Sites Feasibility study and EIR/EIS for M&I benefits estimation	The M&I benefits estimation in the Feasibility Study and EIR/EIS use LCPSIM and OMWEM. Due to the difference in participant beneficiaries in the WSIP application, CWEST was determined to be a more suitable model. The evaluation methods of M&I benefits in CWEST is generally consistent with LCPSIM and OMWEM
Consistency with existing Sites Feasibility study and EIR/EIS for Ag benefits estimation	The Ag benefits estimation in the Feasibility Study and EIR/EIS use SWAP, albeit a previous version. Due to the availability of a newer version through the CWC for the WSIP application, the CWC model was selected to evaluate ag benefits in the WSIP application. In addition, use of the CWC SWAP model in the Sites WSIP application provides consistent analysis with the CWC unit values estimation in the Technical Reference document.
Consistency with existing Sites Feasibility study and EIR/EIS for Hyrdopower benefits estimation	The Hydropower benefits estimation in the Feasibility Study and EIR/EIS use LTgen, SWP power, and NODOS power models, albeit with different future wholesale electricity prices. Due to the availability of a newer forecasted future wholesale electricity prices, these models were updated for the WSIP application.

References

American Canyon, City of. (2016). 2015 Urban Water Management Plan for City of American Canyon. American Canyon, CA.

American Canyon, City of. (2017). Rate Schedule Effective 2017. American Canyon, CA.

Antelope Valley-East Kern (AVEK) Water Agency. (2015). Resolution NO. R-15-11 Wholesale Water Rates and Charges. Palmdale, CA.

Antelope Valley-East Kern (AVEK) Water Agency. (2016). 2015 Urban Water Management Plan. Palmdale, CA.

California Department of Water Resources (DWR). (2010). Least Cost Planning Simulation Model. Sacramento, CA. http://www.water.ca.gov/economics/downloads/Models/LCPSIM_Model_Ray.pdf

California Department of Water Resources (DWR). (2013). Management of the California State Water Project Bulletin 132-10. Sacramento, CA.

California Water Commission. (2016). Water Storage Investment Program Technical Reference. Sacramento, CA.

Castaic Lake Water Agency (CLWA) et. al. (2016). 2015 Urban Water Management Plan for Santa Clarita Valley. Santa Clarita, CA.

City of Banning. (2010). Ordinance 1428 Water Rate Schedule. Banning, Ca.

Coachella Valley Water District. (2016). 2015 Urban Water Management Plan. Coachella, CA.

Desert Water Agency. (2016). 2015 Urban Water Management Plan. Palm Springs, CA.

Desert Water Agency. (2017). Water Rates & Charges, Residential and Commercial, Effective January 1, 2017. Palm Springs, CA.

MCubed and RMann Economics. (2016). Proposed Regulatory Framework for Extended Emergency Regulation for Urban Water Conservation Fiscal and Economic Impact Analysis.

Raftelis. (2015). 2015 California-Nevada Water and Wastewater Rate Survey. Published by Raftelis Financial Consultants, Inc. and California-Nevada Section of the American Water Works Association

San Bernardino Valley Municipal Water District. (2016). 2015 San Bernardino Valley Regional Urban Water Management Plan. San Bernardino, CA.

San Gorgonio Pass Water Agency. (2017). 2015 Urban Water Management Plan for San Gorgonio Pass Water Agency. Beaumont, CA.

Santa Clara Valley Water District. (2016). 2015 Urban Water Management Plan. San Jose, CA.

U.S. Bureau of Reclamation (Reclamation). (2012). Statewide Agricultural Production (SWAP) Model Update and Application to Federal Feasibility Analysis. Sacramento, CA.

U.S. Bureau of Reclamation (Reclamation). (2015). Draft Coordinated Long Term Operation of the CVP and SWP Environmental Impact Statement (LTO EIS) Environmental Consequence Analysis, Appendix 19A – California Water Economics Spreadsheet Tool (CWEST) Documentation. Sacramento, CA.

Zone 7 Water Agency. (2016). 2015 Urban Water Management Plan. Livermore, CA.

Folsom Reservoir
CE-QUAL-W2 Temperature Model

Folsom Reservoir CE-QUAL-W2 Temperature Modeling

This attachment discusses the CE-QUAL-W2 water temperature modeling tool (PCWA 2015), which was applied to evaluate temperature benefits on the American River. The model was developed for Placer County Water Agency's (PCWA) American River Water Rights Extension (ARWRE) Project (PCWA 2015).

CE-QUAL-W2 Overview

The CE-QUAL-W2 model was developed to test the ability of alternative hydrology and reservoir operations scenarios to meet regulatory water temperature requirements (or targets if the requirement cannot be met) in the lower American River at Watt Avenue. The water temperature targets are based on the Automated Temperature Selection Procedure (ATSP) schedules developed as part of the Water Forum Flow Management Standard (FMS). The primary water temperature management objective for the lower American River is to meet the best possible temperature schedule each year for Central Valley steelhead (summer rearing) and fall-run Chinook salmon spawning (fall months) given Folsom Reservoir inflows, available reservoir volume, and Folsom Reservoir outflows. The model simulates temperatures in Folsom Lake and temperatures on the American River downstream of Folsom to the confluence with the Sacramento River. The model has the capability of simulating the City of Folsom Temperature Control Device and the Folsom Dam Shutters For planning analyses, the CE-QUAL-W2 temperature model represents the best available planning model for the American River.

Similar to the Sacramento River HEC5Q model, the input climate data to the CE-QUAL-W2 model was updated to incorporate the WSIP 2030 and 2070 climate scenarios. The process for updating climate in the CE-QUAL-W2 model was different than the climate updates that were performed for HEC5Q.

The CE-QUAL-W2 model uses climate data based on the Folsom/Fair Oaks CIMIS station. As described in the HEC5Q climate updates section, the WSIP climate change data is based on grid cells and the closest grid cell to the Folsom/Fair Oaks CIMIS station was 38.65625 degrees latitude and -121.15625 degrees longitude. Climate data for 1995, 2030, and 2070 were downloaded from the data file corresponding to that grid cell. The monthly average air temperature was then calculated by summing the min and max air temperature and dividing by two. The difference between the 1995 average air temperature and the 2030 and 2070 air temperatures was then calculated. The air temperature difference calculated was then added to the original hourly climate data of the model. The difference was added at the midpoint of each month and then difference to each subsequent hour was added based on linear interpolation between the midpoints of each month. For instance, if the difference for June was 2 degrees and for July was 3 degrees, the difference for 6/25 was interpolated between 6/15 and 7/15. In addition to updating the air temperature, the relative humidity was also adjusted using a formula that links air temperature, dew point, and relative humidity based on the adjusted 2030 and 2070 air temperatures.

References

Placer County Water Agency (PCWA) American River Water Rights Extension Project (ARWRE). 2015. Folsom Reservoir CE-QUAL-W2 Temperature Model Report. November.