Long-Term Operation – Biological Assessment

Appendix AB-E – Exploratory Modeling

July 2024

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Appendix E Exploratory Modeling

E.1 Introduction

This exploratory modeling appendix establishes an analytical foundation for the following.

1. Support a common understanding of the U.S. Department of the Interior, Bureau of Reclamation (Reclamation) and California Department of Water Resources (DWR) operational constraints and opportunities to inform potential alternatives and a Preferred Alternative/Proposed Action for consultation on the Long-Term Operation (LTO) of the Central Valley Project (CVP) and State Water Project (SWP),
2. Identify potential systemwide capabilities and impacts from related processes such as the update to the Bay-Delta Water Quality Control Plan and proposed infrastructure development.

The CVP and SWP facilities were designed and constructed in the 1940s through 1960s, primarily to meet flood protection and water supply needs to the extent those needs were understood at that time. Over the decades following construction of facilities, these needs have evolved and not only expanded in terms of increased water demands, but also expanded in the form of the needs. An understanding of environmental needs emerged and evolved. With each regulatory milestone, new operational rules have been layered on top of the existing set of rules. Current primary operational rules are State Water Resources Control Board (Water Board) Decision 1641 (D-1641), the 2019 National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (USFWS) Biological Opinions (implemented through the 2020 Record of Decision [ROD]), and the 2020 Incidental Take Permit (ITP) (which only applies to the SWP). These requirements are complex and overlapping. Figure E-1 provides a summary of the actions and timing of the D-1641 requirements. A summary of the actions in the 2019 Biological Opinions and their timing is included in Figure E-2, and a summary of the SWP actions under the 2020 ITP and their timing is included in Figure E-3.

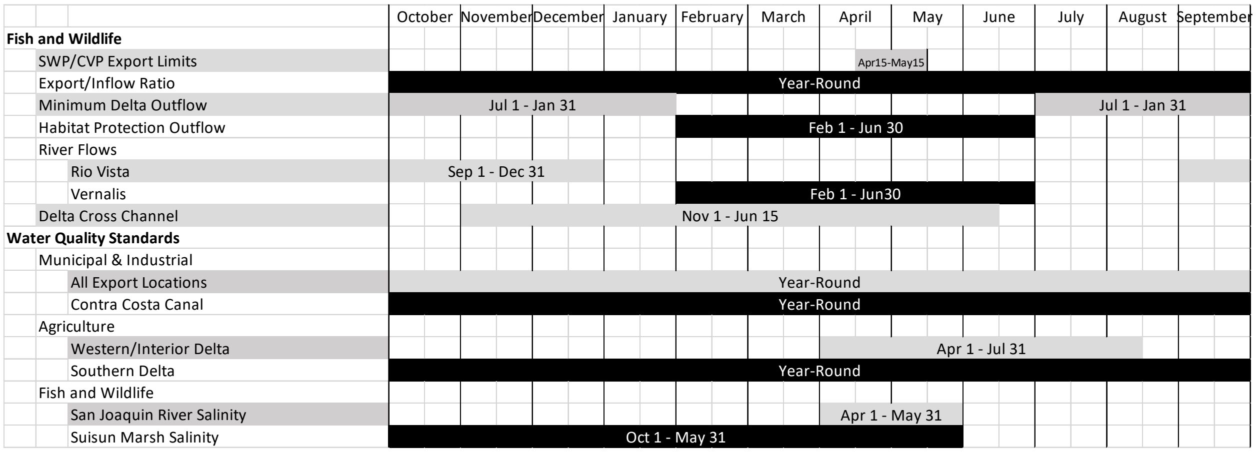
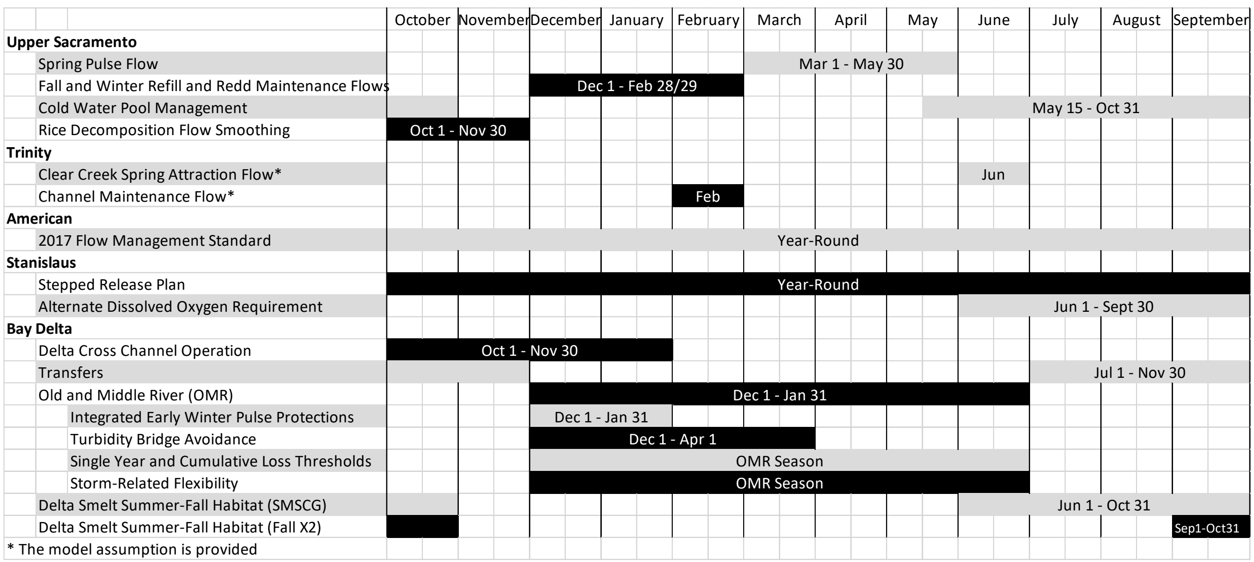


Figure E-1. D-1641 Actions



SMSCG = Suisun Marsh Salinity Control Gates

Figure E-2. 2019 Biological Opinions Actions

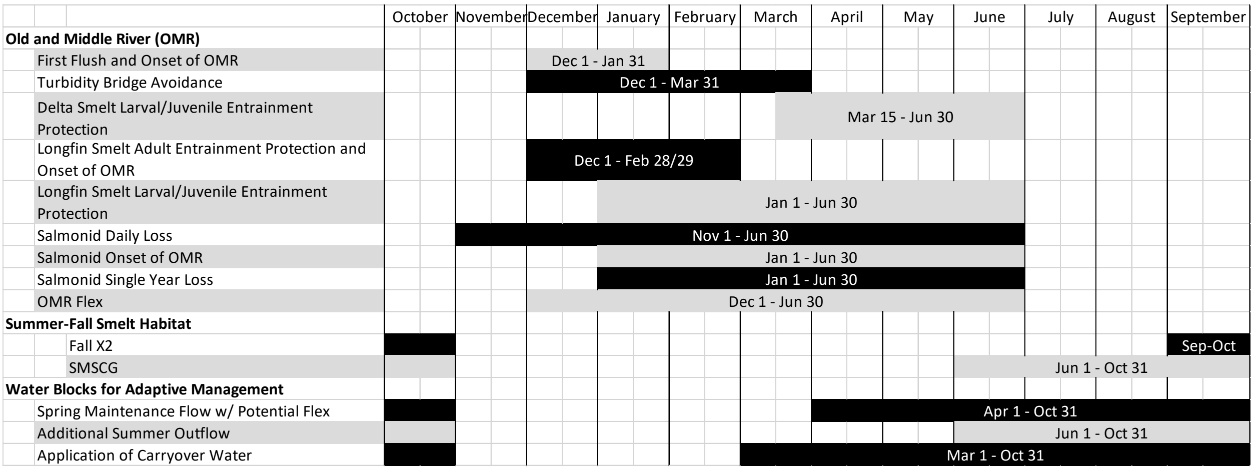


Figure E-3. 2020 ITP Actions

In addition to the evolving regulatory environment, the hydrology continued to change, with a prominent warming trend that affected the fills and releases from the reservoirs. Given these conditions, for the general audience, it has become increasingly more difficult to understand how the CVP and SWP are altering flow patterns and for what reason at any given time.

To facilitate discussions for the 2021 LTO, Reclamation developed an analytical framework to support common understanding of operational requirements and how Reclamation and DWR can operate project facilities to meet requirements. These models and their results were shared with interested parties in a series of recurring meetings, and Reclamation sought feedback on scenarios to consider. These models are also utilized to inform development of several components of the initial alternatives. Analyses that helped inform initial alternatives are documented in the respective appendices of those components.

Reclamation operates the CVP and DWR operates the SWP under the 1986 Coordinated Operation Agreement (COA), as amended in 2018, authorized by Public Law 99-546. The CVP and SWP operate under overlapping statutory, regulatory, and contractual requirements. Reclamation and DWR must comply with the federal Endangered Species Act (ESA) by consulting with USFWS and NMFS on operations. Operations must comply with the terms of water rights issued for the CVP and SWP by the Water Board, including their water quality control plans. DWR must comply with the California Endangered Species Act (CESA) and has an ITP from the California Department of Fish and Wildlife (CDFW). The CVP and SWP deliver water for fish and wildlife, agriculture, and municipal and industrial uses under the terms of various contracts and agreements. Water operations modeling simulates the outcomes for how Reclamation and DWR may operate the CVP and SWP to meet these requirements.

These exploratory modeling efforts develop operational scenarios that may assist in discussions with USFWS, NMFS, CDFW, Water Board, and interested parties regarding how to meet operational requirements. The layering of permits and programs on hydrology results in tradeoffs on the availability of water within a year and with subsequent years. The information from these models and the tradeoffs they illustrate is to be used to facilitate alternatives development; the exploratory models do not reflect any proposed operation of the CVP and SWP, and the models are not intended to be alternatives.

E.2 Background

Fish species native to the state of California evolved under California's hydrology in an unaltered landscape, but now face a different environment. Elements of natural flow regimes can provide a basis for the conditions that may best support species viability (State Water Resources Control Board 2017); however, achieving environmental objectives under an altered landscape and balancing multiple competing demands for water resources may require different operational actions. Reclamation and DWR can operate facilities to manage the water provided from each year's hydrology within the limitations of facilities and legal requirements.

The operational aspects of any LTO Proposed Action move water spatially from where water supplies are developed to where they are put to beneficial use, and consist of the following.

1. Storing water runoff from the impaired watersheds upstream of CVP and SWP dams.
2. Releasing stored water to augment flows in the system and moving flows in time:
    a. From the winter and spring to the summer and fall, or
3. From wetter years to meet needs in drier years;
4. Diverting water for beneficial uses (e.g., public health and safety, Central Valley Project Improvements Act [CVPIA] wildlife refuges, water service contracts).
5. Routing of flows and fish through operating gates and barriers.
6. Blending withdrawals from reservoir levels to provide cold water for temperature-sensitive endangered/threatened species while generating and/or bypassing power plants.

Section 8 of the Reclamation Act of 1902 addresses the control, appropriation, use, and distribution of water by states and territories, provided those laws are not inconsistent with clear congressional directives. While some riparian rights exist in the state, California implements a priority system based on seniority; therefore, the CVP and SWP satisfy senior water rights before operating to meet CVP and SWP obligations. Some of these senior water rights are represented by Settlement, Exchange, and/or other types of agreements, such as the Sacramento River Settlement Contracts, Feather River Settlement Contracts (SWP), Friant Dam Riparian Holding Contracts, San Joaquin River Exchange Contract, and San Joaquin River Settlement Contracts. Reclamation and DWR satisfy these senior water rights in accordance with the specific agreements. Senior water right contracts are different than the contracts and agreements for water service and repayment (water service contracts). Water service contracts form the basis for the construction, operation, maintenance, and repayment of the CVP.

Reclamation also operates the CVP consistent with the hierarchy of purposes established by Section 2 of the 1937 Act, as amended and supplemented, specifically Section 3406 of the CVPIA. This hierarchy includes the following.

1. River regulation, improvement of navigation, and flood control.
2. Irrigation and domestic uses and fish and wildlife mitigation, protection, and restoration purposes.
3. Power and fish and wildlife enhancement.

Within that framework, Reclamation operates the CVP to meet senior water rights that predate the CVP's water rights, applicable federal law and regulations, applicable state law and regulations through Section 8 of the Reclamation Act, and other obligations, such as contracts and agreements. In general, Reclamation implements water operations in the following overall priority system.

- Senior Water Rights that Predate the CVP's Water Rights:
    - CVPIA(b)(23) flows, which reflect federal tribal trust responsibilities to protect fishery resources that predate the CVP and the state of California
    - CVPIA Level 1 Refuge Water supplies, binding obligations in Settlement Contract sand Agreements executed with the United States, including releases from Friant Dam for the Exchange Contractors, if required
    - Navigation and Flood Control:
    - Flood Control and Safety of Dams: Section 2 of 1937 Act implemented through U.S. Army Corps of Engineers flood control diagrams and regulations
    - Navigation: Section 2 of the 1937 Act
- Irrigation, Domestic, and Fish and Wildlife Mitigation, Protection and Restoration:
    - ESA under Biological Opinions issued under Section 7 of the ESA
    - CVPIA Level 2 Refuge Water Supply and Exchange Contractor deliveries from the Sacramento–San Joaquin Delta (Delta)
    - CVPIA Section 3406(b)(2), which dedicates up to 800,000 acre-feet of CVP yield for fish and wildlife purposes including measures under (b)(1)(B) and others
    - Municipal and Industrial water supply contracts
    - Irrigation water supply contracts
- Power and Fish and Wildlife Enhancement:
    - Power Marketing with Western Area Power Administration and their Power Contractors
    - CVPIA Level 4 Refuge Water supplies, which comes from acquired water
    - Flow Agreements

Reclamation and DWR must comply with applicable federal laws, and DWR must comply with applicable state laws. Both senior water right contracts and water service contracts have various provisions that impose binding obligations. A shortage of water supply under those contracts must be implemented in accordance with the terms of the contracts.

This effort focuses on water operations modeling. Water operations analyses may be later supplemented by hydraulic and temperature models to evaluate selective withdrawals from reservoirs for cold water pool management, and biological models for the routing flows and fish to determine growth and survival.

E.3 Methodology

E.3.1 Tools

DWR and Reclamation developed the computer model CalSim to simulate operation of the water resources infrastructure in the Central Valley of California and the Delta region and coordinated operation of the CVP and SWP, over a range of hydrologic conditions, regulatory frameworks, and with existing and proposed infrastructure. Although CalSim is primarily intended for comparative analysis of water management alternatives analyzed in environmental compliance documents, Reclamation has expanded the model application to explore the boundaries or limits of the water resources and facilities managed by Reclamation and DWR.

For exploratory modeling purposes, Reclamation's CalSim II model with 2035_CT hydrology and operational rules that represent the 2020 ROD and 2020 ITP was used as the starting model to develop the exploratory layers. Additional information on the 2035_CT climate development and modeling approach and the 15-centimeter sea level rise can be found in Appendix F2, *Additional Climate Scenario Sensitivity Analysis*, Section F2.3, *Climate Changes Projections Development,* of Reclamation's 2019 *Reinitiation of Consultation on the Coordinated Long-Term Operation of the Central Valley Project and State Water Project* (Bureau of Reclamation 2019a).

E.3.1.1 Flow Tracker

The FlowTracker is a post processor tool that tracks "flow types" of water (such as pass-through inflow or stored water release from a particular reservoir) through the system, so that the user can track what flow type is contributing to meeting specific flow requirements or deliveries.

The FlowTracker takes as input the merged inputs and outputs of a CalSim II run. The FlowTracker determines what flow types are for each channel and delivery arc in the system by following just two principles: (1) that every channel or diversion arc is the sum of its flow types and (2) that mass balance of each flow type at each node must be maintained. Storage nodes need specific logic, depending on their characteristics, to assign flow types to evaporation, delivery, and release.

The user determines the disposition of flow types throughout the system through weights assigned to each flow type for each diversion. This enables the tool to be used for a wide variety of purposes in CVP/SWP system analysis.

For this application, a weight structure was used in the FlowTracker to prioritize the use of Shasta releases farther up in the system, minimizing the amount of Shasta releases traveling to the Delta so as to not overstate the role played by Shasta in meeting Delta requirements.

E.3.2 Layers

The approach for exploratory modeling layers high-level operational objectives on scenarios for different system requirements. Looking at each operational layer provides information on what drives different capabilities. Different scenarios explore different constraints. Chapter 6, *Title*, Section 6.1, *Attachment 1 – CalSim II Modeling Assumptions Callouts*, documents the assumptions in detail.

Initially, the exploratory modeling consisted of five layers, which were later refined to answer a broader range of questions.

- Layer 1 – Run of the River
- Layer 2 – Maximum Storage: The only releases are to pass-through inflow to meet senior water rights, minimum instream flows, and D-1641 requirements. Originally, Layer 2 met obligations upstream to downstream, often resulting in deliveries being met before downstream flows or Delta outflow. This was then expanded into two scenarios.
    - EXP2A prioritizes pass-through inflow for delivery to senior water rights
    - EXP2B prioritizes pass-through inflow for meeting minimum flow and D-1641 requirements

  In both scenarios, any inflow that was not needed to meet the priority can be released to meet the other objective; any inflow not used for senior water rights and minimum flow and D-1641 requirements is stored unless it evaporates or needs to be released to meet flood control.
- Layer 3 – Releases stored water to meet senior water rights and minimum flow and D-1641 requirements that were unmet through pass-through inflow. Finer resolution was requested, and a Layer 2.5 (between 2 and 3), was developed
    - Layer 2.5 uses pass-through inflow for senior water rights and minimum flow and D-1641 requirements, but then releases stored water to meet any minimum flow and D-1641 requirements that could not be met through pass-through inflow. Like Layer 2, Layer 2.5 has the following.
        - 2.5A that prioritizes pass-through inflow for delivery to senior water rights
        - 2.5B that prioritizes pass-through inflow for meeting minimum flow and D-1641 requirements
- Layer 4 – Allows for the delivery (including export) of water that would otherwise be excess Delta outflow to project water service contractors. Three versions of this layer explored different ways that delivery of exported water could be prioritized.
    - Only delivering to Exchange Contractors and Refuges

  - Delivering to all CVP contractors
  - Delivering to all CVP contractors after reserving water for the Exchange Contractors and Refuges

  These three versions were each run with and without Old and Middle River (OMR) requirements.

- Layer 5 – Implements most operations (Biological Opinions regulations and delivery of stored water). For finer resolution, the following were included.
  - Layer 4.95 was developed, which simulates current regulations, but limits exports and delivery to water service contractors to excess water except for deliveries for minimum public health and safety
  - Layer 5P was included to add some specialized programs that were not included in the exploratory modeling: the Lower Yuba River Accord transfers and delivery of Article 21 and Section 215 water

Layer 1 – Run of the River (EXP1): This layer identifies hydrologic conditions in the absence of the operation of the CVP and SWP and provides a basis of comparison to hydrologic impairment by factors other than the operation of the CVP and SWP. The following principles are included.

1. The CVP and SWP will not store water. Inflow to project reservoirs will be released at the earliest opportunity; however, the CVP and SWP will limit releases to downstream channel capacities (for flood control and dam safety purposes).
2. Senior water right holders, with or without contracts with the CVP and SWP, including wildlife refuges with Level 1 supplies, would continue to divert when water is available for their diversion.
3. No diversions or rerouting of flows would occur at CVP or SWP facilities, including no exports at Jones Pumping Plant and Banks Pumping Plant.

This layer is expected to show shortfalls, if they occur, to Settlement Contracts and other types of senior water right agreements, D-1641 requirements, minimum instream flow requirements, and anticipated water temperature requirements.

This layer informs agreement on hydrologic conditions and alterations not attributable to operation of the CVP and SWP.

Layer 2 – Maximum Storage (EXP2): This layer begins to incorporate aspects of project operations by allowing reservoirs to store water. Reclamation and DWR have an operational objective to store water in upstream reservoirs as it provides the greatest flexibility to meet the obligations of the CVP and SWP. The ability to store water is limited by releases required for the following.

1. Flood conservation and safety of dams

2. Bypassing inflow for downstream senior water rights (e.g., Sacramento River Settlement Contractors, Exchange Contract, Refuge Level 1)
3. Bypassing inflow for navigation and minimum instream flow agreements (e.g., CDFW, the Federal Energy Regulatory Commission) and/or required by CVPIA
4. Bypassing inflow for D-1641 Water Quality Control Plan

Reclamation and DWR would have some discretion, after meeting D-1641 to the extent possible by bypassing inflow, to select among storing water in Shasta, Oroville, or Folsom reservoirs (or a combination of the reservoirs). Under this layer, Friant and New Melones dams are not operated for D-1641 Delta requirements (New Melones can contribute bypassed inflow to the Vernalis flow and water quality standards). Under this layer, the ability to store water would be allocated based on minimizing the risk of spill (e.g., Reclamation would not make releases from Shasta Reservoir to store water in Folsom Reservoir if water in Folsom Reservoir is likely to later spill). Reclamation and DWR do not divert at project facilities under this layer. Reclamation and DWR only release stored water for flood control purposes. In this layer, Reclamation and DWR are exercising discretion to store water, but bypassing some inflow given the requirements of other parties, e.g., senior water right holders and the Water Board. Different scenarios may explore changes to those requirements.

This layer is expected to show shortfalls, if they occur, similar to the Run of the River layer.

This layer informs how much water Reclamation and DWR can potentially have available in storage to meet obligations. It may also inform how Settlement, Exchange, Refuge, and D-1641 requirements influence the availability of storage. It may inform potential unimpaired flow comparisons by showing when, for how long, and if, reservoirs refill. This information starts to demonstrate the sustainability of in-year and multi-year protections for species and health and safety.

Layer 2 was run in two ways.

- EXP2A: This version prioritizes the use of the bypassed inflow for downstream senior water rights
- EXP2B: This version prioritizes the use of the bypassed inflow to meet flow and D-1641 standards

Layer 2.5 – Maximize Storage – Release Stored Water for Unmet for Flow and D-1641 Standards (EXP2.5): The requirements in D-1641 and other (non-ESA) flow requirements commit Reclamation and DWR to use stored water in the absence of other intervening factors (e.g., Congressional Directive, Temporary Urgency Change Petitions, Voluntary Programs, Board Order, Shortage Provisions). In this layer, Reclamation and DWR will continue to bypass inflow to meet the releases as required in Layer 2 and will make releases from reservoir storage where the flows otherwise in the system are insufficient to meet navigation and minimum instream flow requirements and D-1641.

Facility capabilities and other limitations may still prevent meeting obligations (e.g., lake levels for hydropower generation, municipal and industrial intakes), and there continues to be no south of Delta exports.

Reclamation and DWR may have some discretion in how obligations are met, but the obligations in and of themselves are non-discretionary. Certain obligations are limited based on which facilities can provide water, e.g., releases on American River cannot meet demands on the Sacramento River that are upstream of the confluence. Where there is a possibility for either Shasta or Folsom to meet a downstream obligation, CalSim II determines the source of water through rules that attempt to match the reservoir balancing under historical operations. Reservoir balancing rules do not often control CalSim II operations.

This layer is expected to inform the demands on storage to meet instream flows and water quality standards.

Layer 2.5 was run in two ways.

- EXP2.5A: This version prioritizes the use of the bypassed inflow for downstream senior water rights
- EXP2.5B: This version prioritizes the use of the bypassed inflow to meet flow and D-1641 standards

Layer 3 – Minimum Releases from Storage (EXP3): The agreements and requirements in Settlement Contracts and Exchange Contracts also commit Reclamation and DWR to use stored water in the absence of other intervening factors (e.g., Congressional Directive, Temporary Urgency Change Petitions, Voluntary Programs, Board Order, Shortage Provisions). In this layer, Reclamation and DWR make releases from reservoir storage where the flows otherwise in the system are insufficient to meet the following.

1. Navigation and minimum instream flow requirements
2. Downstream senior water rights
3. Exchange Contract and Refuge Level 2
4. D-1641

Facility capabilities and other limitations may still prevent meeting obligations (e.g., lake levels for hydropower generation, municipal and industrial intakes) and there continues to be no south of Delta exports.

Reclamation and DWR may have some discretion in how obligations are met, but the obligations in and of themselves are non-discretionary. Certain obligations are limited based on which facilities can provide water, e.g., releases on American River cannot meet demands on the Sacramento River that are upstream of the confluence. Where there is a possibility for either Shasta or Folsom to meet a downstream obligation, CalSim II determines the source of water through rules that attempt to match the reservoir balancing under historical operations. Reservoir balancing rules do not often control CalSim II operations.

This layer is expected to inform the demands on storage to meet instream flows, senior water right settlement diversions, and water quality standards.

Layer 4 – Excess Flow Diversions (EXP4): This layer begins to operate to meet project water supply functions. The model will divert water that cannot be stored and is not required for other purposes. Reclamation and DWR have an operational objective to divert excess flows to meet obligations without relying upon stored water. Preserving stored water preserves the flexibility to meet obligations of the CVP and SWP at other times. The model accomplishes the following.

1. Meets north of Delta (NOD) project deliveries as possible with water that otherwise would have gone to surplus Delta outflow
2. Enables export of remaining Delta surplus, sharing available water in the Delta between the CVP and SWP according to COA conditions for unstored water for export and suspended COA
3. For CVP, first meets CVP Refuge Level 2 and Exchange Contract requirements from Delta Exports
4. Delivers to Friant contracts if Exchange Contract and refuge demands are met

This layer reveals the potential for project operations without using stored water. It provides for deliveries based on diversion of water in the system and water previously stored in San Luis Reservoir. Meeting water service contract demands through use of excess flows reduces the demands for stored water described in the next layer.

Layer 4 was developed in experimental steps, as described below. Versions 3 and 6 were subsequently used and displayed as the most useful to the exploratory analysis.

- EXP4v1 – Does not include OMR restrictions on exports. Exports are delivered to Exchange Contractors and Refuge Level 2 and then stored in CVP San Luis. No deliveries are allowed to CVP service contracts. This version is the simplest way to meet senior CVP contractors with excess flow and full use of San Luis off-stream storage.
- EXP4v2 – Does not include OMR restrictions on exports. Exports are delivered to all water users and then stored in CVP San Luis. This version demonstrates the maximum amount of Delta excess that could be exported and delivered, but delivery patterns are unrealistic and water supply is depleted early.
- EXP4v3 – Does not include OMR restrictions on exports. Based on the results from EXP4v1, reserve exports and CVP San Luis storage to meet Exchange Contractors and Refuge Level 2; CVP agriculture (Ag) and municipal and industrial (M&I) can take exports and water stored in CVP San Luis that is not needed for Exchange Contractors and Refuge Level 2. This version attempted to strike a middle ground between versions 1 and 2 – senior water user demands are met first, but patterns of delivery to CVP service contractors reflect the "as available" basis.
- EXP4v4 – EXP4v1, but with OMR limits on exports.
- EXP4v5 – EXP4v2, but with OMR limits on exports.

- EXP4v6 – EXP4v3, but with OMR limits on exports.

Layer 4.95 (EXP4.95) – This layer fully operates the CVP and SWP to potentially make use of stored water for temperature benefits within a year, releases for fisheries such as pulse flows, or carryover for drought protection in a subsequent year by implementing the actions from the 2019 Biological Opinions and 2020 ITP. This is the first layer to include imports from the Trinity River. Deliveries to project contractors above a minimal health and safety level are limited to water that would have otherwise gone to excess Delta outflow.

Layer 5 – Storage Management (EXP5): This layer operates the CVP and SWP to make use of stored water for temperature benefits within a year, releases for fisheries such as pulse flows, carryover for drought protection in a subsequent year, and/or deliveries to project contractors. Differences in results relative to EXP4.95 may shed light on the use of stored water for project delivery and exports beyond public health and safety levels. Modeling assumptions for this layer assume stored water can be delivered to water service contracts after satisfying other operational criteria including those from the 2019 Biological Opinions and 2020 ITP.

Layer 5P – Placeholder for Additional Actions (EXP5P): Actions not considered in the above conditions that may be excluded from the models for the purpose of exploratory modeling, but provide an important component of operating the CVP and SWP. Examples include the following.

- Water Transfers and the Lower Yuba River Accord use of Banks Pumping in July and August
- Article 21/Section 215
- New Storage and Conveyance Projects

Exploratory modeling may provide a platform for analyzing these actions under alternative LTO operations.

E.3.3 Model Limitations

E.3.3.1 CalSim

CalSim II was used to develop the suite of scenarios for exploratory modeling, and the limitations of the exploratory modeling are either inherent in CalSim II or arise from the alterations or application of the exploratory modeling. CalSim II was designed to represent the full operations of the CVP and SWP system in a current or hypothetical regulatory environment and accommodate potential operational alternatives. The first layer of exploratory modeling completely removes the CVP's and SWP's operational capabilities, and then, additional requirements and operational capabilities are added on for each progressive layer. CalSim II was not designed for scenarios with severely limited operational capabilities, and it cannot account for how water users or regulatory agencies would adjust to the CVP and SWP having severely limited to no operational capabilities.

CalSim II has a monthly time step, which does not capture daily variability in the system. While there are certain components in the model that are downscaled to a daily time step (simulated or approximated hydrology), such as an air-temperature–based trigger for a fisheries action, the results of those daily conditions are always averaged to a monthly time step. Any reporting or use of sub-monthly results from CalSim II should include disaggregation methods that are appropriate for the given application, report, or subsequent model.

In addition, the Artificial Neural Network (ANN) developed to determine the flows necessary to meet Delta water quality requirements was trained on full operations of the CVP and SWP. DSM2 simulations of the entire exploratory modeling suite were analyzed to examine whether the ANN was appropriate for use in the exploratory modeling. It was found that, for the layers where reservoirs were operated to meet D-1641 Delta water quality requirements, those reservoirs met those requirements as often or more than the full operations study, indicating that the ANN is appropriately depicting water quality in these scenarios.

Additional details on the limitations of CalSim II can be*,* Appendix F, Attachment 2-7, *Model Limitations*, of Reclamation's 2019 *Reinitiation of Consultation on the Coordinated Long-Term Operation of the Central Valley Project and State Water Project* (Bureau of Reclamation 2019b). Despite the limitations of the exploratory modeling, its narrow purpose of analyzing the limitations of the CVP and SWP to inform a consultation makes the analysis valuable.

Given the wide range of operations in the exploratory modeling, stream-groundwater interactions were fixed to EXP5 levels. Fixing the stream-groundwater allows the exploratory modeling to focus on the changing operations, without the additional complexity of varying stream-groundwater interactions.

The Water Balance Tool was used to review the results from the exploratory modeling suite. The Water Balance Tool aggregates inputs, outputs, and reservoir storage changes for different segments of the model (like Upper Sacramento River above Red Bluff, the American River). The output of the Water Balance Tool was used to ensure the model was operating correctly under the exploratory modeling scenarios and to investigate whether the models have used problematic methods to achieve mass balance. Mass balance was sustained in all regions in the Water Balance Tool for EXP1, EXP2, EXP3, EXP5, and EXP5P. The results also highlighted how changes in river flows, diversions, storage changes, etc., relate to each other between scenarios.

E.3.4 Appropriate Use of Model Results

E.3.4.1 CalSim

The exploratory modeling suites are meant to inform on water availability under different layers of regulatory conditions. The Run of the River scenario, specifically, is built to show a scenario that is close to a more natural hydrograph, with the understanding that it will be different from a full natural flow or unimpaired flow. Reclamation did not try to depict what would have happened if the CVP and SWP were not in place as there might have been different outcomes and different facilities built to meet needs in any of the system sub-basins.

All of the exploratory models have their shortfalls and are merely offered to help understand water availability for actions of the CVP and SWP. Any specific action that may become a part of the Proposed Action or a National Environmental Policy Act (NEPA) alternative in the 2021 LTO process will be fully simulated and analyzed using CalSim 3.

E.3.4.2 Flow Tracker

As the name implies, the Flow Tracker keeps a running tally of where streamflow at any particular location originally came from. At diversion locations, the user must make decisions about what kind of water to divert for each category of demand. Different applications may use unique weight structures that produce different results for uses of storage release versus other kinds of flow. The use of the Flow Tracker for exploratory modeling was intended to help clarify the ultimate destination of storage releases, for Shasta in particular. Shasta releases were used as high up in the system as possible in an effort to not overstate the need for Shasta release to meet Delta criteria.

This perspective can lend an impression of explicit purpose for releases that enter the Delta that is not a factor in actual operations. If Shasta releases water for flood control, including normal ramp-down operations in wetter years, remaining release entering the Delta would be assigned by the Flow Tracker to go to exports while other flow types meet required Delta outflow. It would be equally reasonable in this context to assign the Shasta release to required Delta outflow. These perspectives are important to keep in mind when reviewing results.

E.4 Exploratory Modeling Results

Each layer of the exploratory modeling suite changes the responsibilities and capabilities of the CVP and SWP, and therefore each layer is expected to alter elements of the Sacramento-San Joaquin Delta water system. These elements include but are not limited to reservoir storage, deliveries, river flows, exports, and Delta outflow. Table E-1 lays out the study expectations for each model in the exploratory modeling suite in each of these elements.

Table E-1. Exploratory Modeling Study Expectations within the Sacramento-San Joaquin Delta

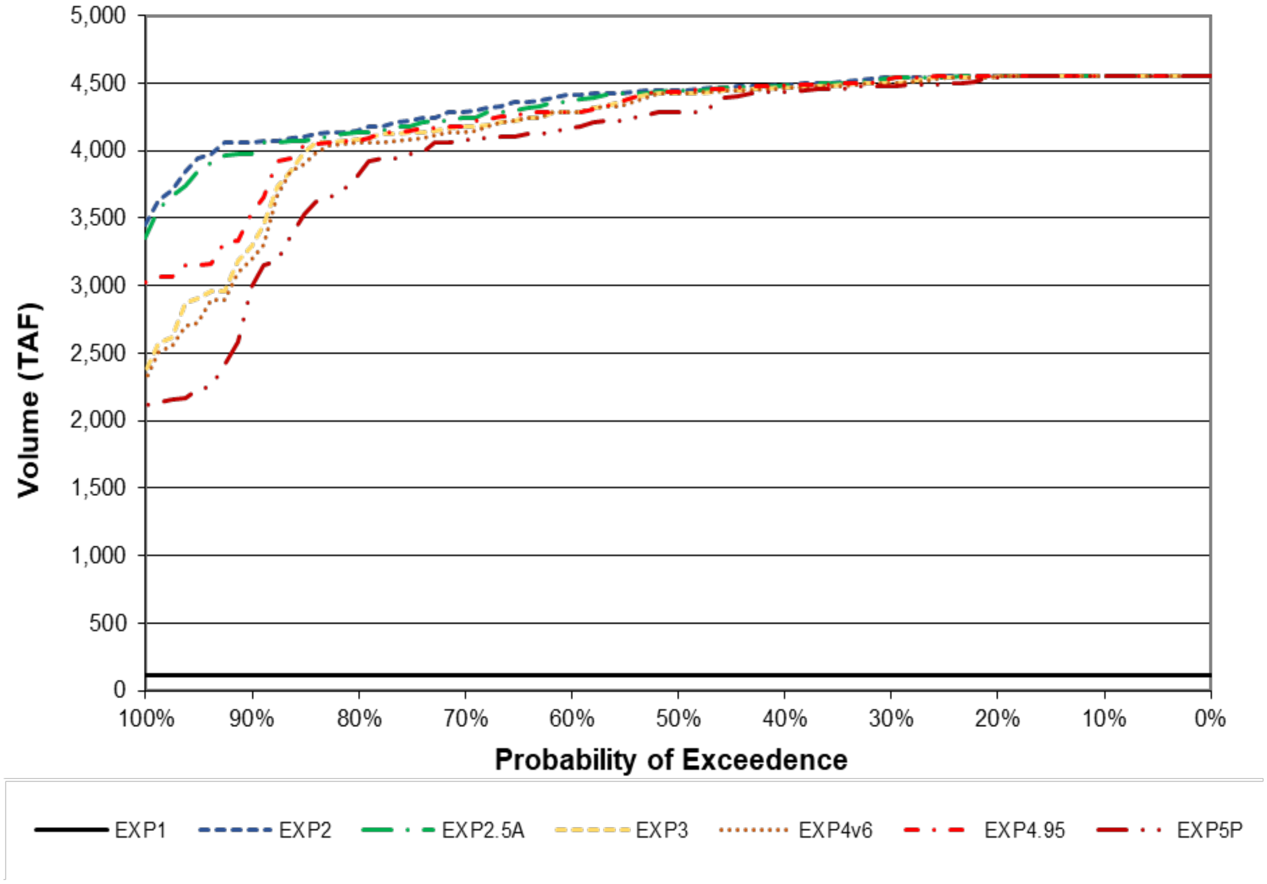
Runs	Storage	Deliveries	River Flows	Exports	Delta Outflow
EXP1	Dead pool	Senior water right deliveries limited by available flows	Reflect hydrologic mass balance	None	Reflects hydrologic mass balance
EXP2	Maximized up to flood limits	Similar to EXP1	Reduced flows aside from flood control releases and pass-through inflow	None	Reduced outflow aside from flood control releases
EXP2.5A	Storage affected by releases for D-1641 and minimum flows	Senior water right deliveries increase with stored water released for minimum flows	Increased river flows in summer due to stored water releases for D-1641 and minimum flows	None	Delta outflow reflects stored water releases for D-1641 and minimum flows

Runs	Storage	Deliveries	River Flows	Exports	Delta Outflow
EXP3	Storage affected by releases for all non-discretionary uses	Senior water rights met by stored water releases	Increased river flows in summer due to stored water releases for non-discretionary uses	None	Delta outflow reflects stored water releases for non-discretionary uses
EXP4	Storage may reflect additional releases for Delta water quality due to use of excess water	Project deliveries from excess water enabled	Reflect delivery of excess water upstream to downstream	Export Excess water	Reduced due to delivery and export of excess water
EXP5P	Managed storage	Project deliveries increase with stored water releases and full exports	Reflect full project operations	Exports	Delta outflow reflects full project operations

The differences between layers had similar trends across all CVP and SWP reservoirs and the watersheds below those reservoirs. The results shown focus on Shasta Reservoir, the Sacramento River, the Delta, and exports to south of Delta (SOD). However, notable differences in other reservoirs and watersheds from that of Shasta and the Sacramento River are also described.

E.4.1 Reservoir Storage

Each subsequent layer adds responsibilities that the CVP and SWP attempt to meet, which affects reservoir storage, either by passing through inflow instead of storing it or by releasing previously stored water, when able and necessary. In general, the result is lower storage in the reservoirs as the layers progress. During the fill season (from October through the end of April), the differences between the layers are minimal in all but the driest years.



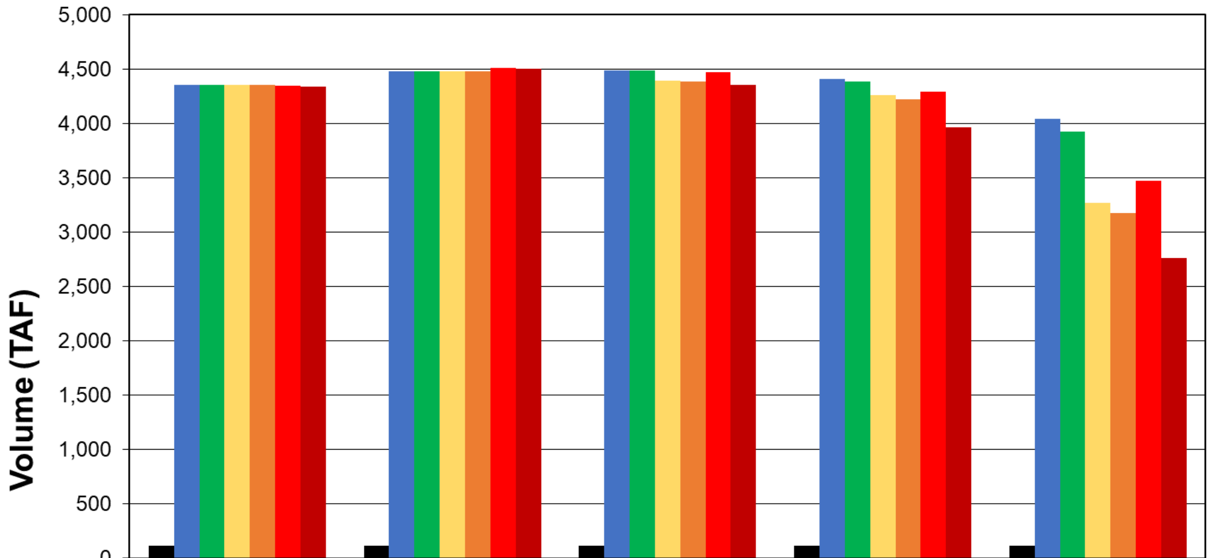
TAF = thousand acre-feet

Figure E-4. End of April Exceedance for Shasta Storage

Figure E-4 shows an exceedance of Shasta storage at the end of April (EoApr) which is the end of the fill season. In EXP1, storage remains at dead pool because all inflow is passed, except when there are downstream capacity constraints. Reservoir storage in EXP2 represents the maximum possible storage. In this scenario, only inflow that passes through the reservoir is used to meet non-discretionary requirements, and previously stored water is only released for flood control. In EXP3, the reservoirs are operated to meet non-discretionary requirements by releasing previously stored water. Therefore, the difference between the EoApr Shasta storage in EXP2 versus EXP3 represents the volume of storage Shasta must release to meet non-discretionary requirements during the fill season. Note that even while meeting only non-discretionary regulations and limited senior water rights, EXP3 fill can be less than some commonly stated objectives. Fill is lower than 3.5 million acre-feet 11% of the time, and lower than 3.9 million acre-feet 15% of the time. (Dry and critical years comprise 35% of years in the period of record.)

In EXP4v6, excess water can be used for discretionary purposes such as project deliveries and exports. Despite only using excess water, there is an additional Delta water quality cost when excess water that could have helped decrease the salinity in the Delta is used for discretionary purposes instead (the change in Delta outflow can impact salinity for several subsequent months). The difference between the EoApr Shasta storage in EXP3 versus EXP4v6 represents the additional volume of storage Shasta must release to meet the additional Delta water quality cost. The introduction of Trinity imports in EXP4.95 takes some responsibility off of Shasta and results in higher Shasta storage, especially in the driest years.

In EXP5P, the reservoirs are operated to meet all non-discretionary requirements and previously stored water can be released for discretionary purposes. The difference between the EoApr Shasta storage in EXP3 and EXP5P represents the overall effect of discretionary purposes on Shasta fill, including the year-over-year effects of drought, carryover, and differences in non-discretionary costs incurred by project operations.



	Wet	Above Normal	Below Normal	Dry	Critically Dry
EXP1	116	116	116	116	116
EXP2	4,351	4,477	4,487	4,411	4,039
EXP2.5A	4,351	4,477	4,487	4,386	3,925
EXP3	4,351	4,477	4,396	4,257	3,266
EXP4v6	4,351	4,477	4,387	4,224	3,175
EXP4.95	4,344	4,507	4,471	4,293	3,469
EXP5P	4341	4499	4351	3964	2762

EXP1 EXP2 EXP2.5A EXP3 EXP4v6 EXP4.95 EXP5P

Figure E-5. Average End of April Shasta Storage by Water Year Type

Looking at Figure E-4, the additional burden on Shasta storage from each subsequent layer of the exploratory modeling suite is most visible in the driest 15%-20% of years. Figure E-5 shows Average EoApr Shasta storage by water year type. It reinforces that there is very little difference in fill between the scenarios in wet, above normal, and below normal years; some noticeable difference in dry years; and significant differences in critically dry years.

The need for releases, in all scenarios, is typically higher during the management season (from May through September) than during the filling season. Differences in end of September storage between the EXP scenarios are therefore more pronounced than end of April fill differences.

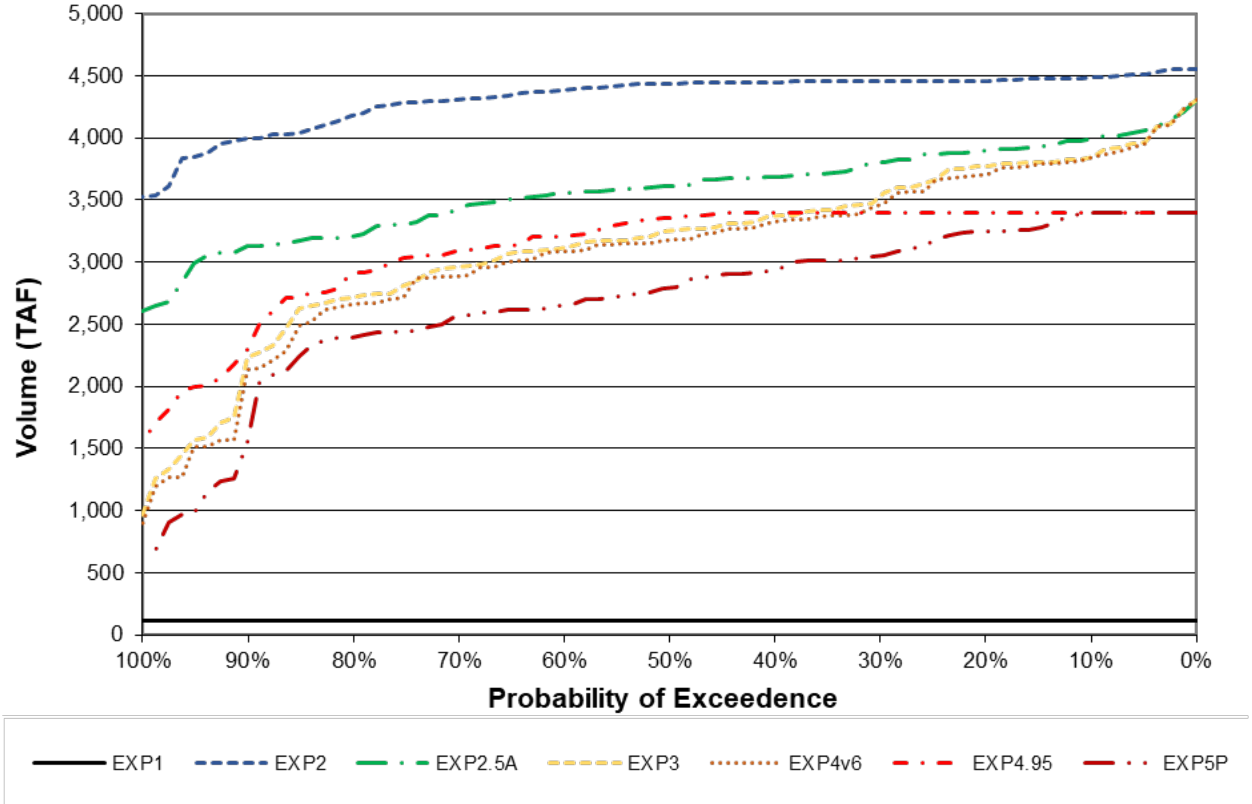
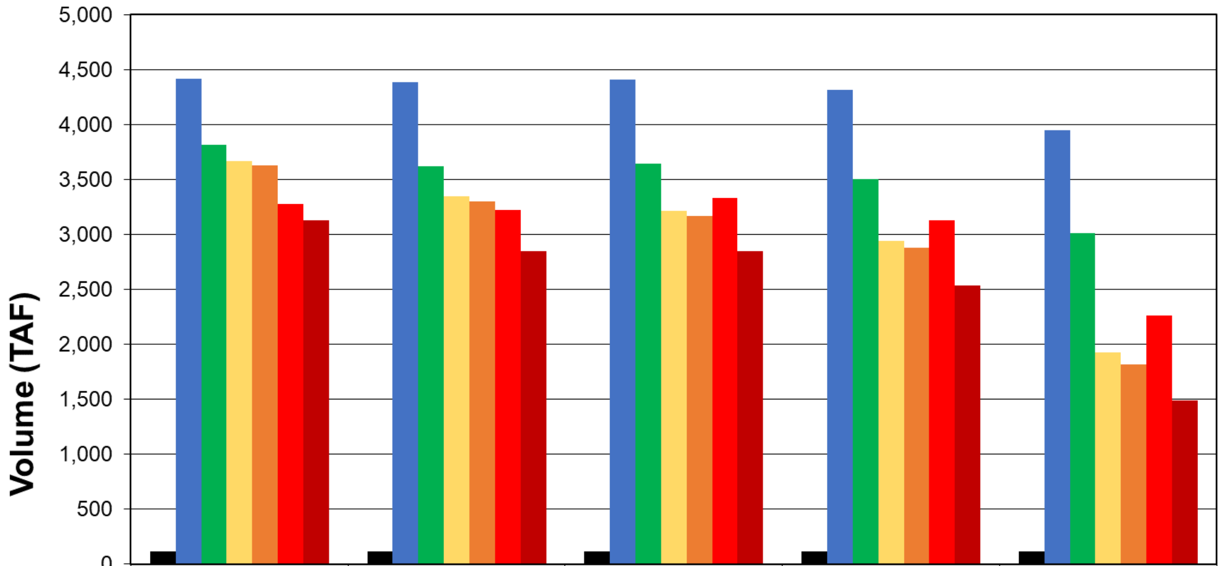


Figure E-6. End of September Exceedance of Shasta Storage

Figure E-6 shows the exceedance of end of September (EoSep) Shasta storage. In EXP2.5A, previously stored water is released from Shasta to meet D-1641 requirements and minimum instream flows after pass-through inflow is prioritized for deliveries to senior water rights. The difference between EoSep Shasta storage in EXP2 and EXP2.5A represents the volume of storage that must be released to meet D-1641 and minimum instream flow requirements. The difference between EoSep Shasta storage in EXP2.5A versus EXP3 represents the additional storage that must be released to meet senior water right demands that were not met by pass-through inflow.

Looking at Figure E-6, the difference in EoSep Shasta storage is much larger between EXP2 and EXP3 than it is between EXP3 and EXP5P, indicating that the burden of non-discretionary requirements on Shasta storage is larger than the costs of discretionary uses. While Trinity imports in EXP5P assume some of the burden of meeting the flow requirements, the bulk of the non-discretionary cost still falls to Shasta.



	Wet	Above Normal	Below Normal	Dry	Critically Dry
EXP1	116	116	116	116	116
EXP2	4,416	4,387	4,411	4,315	3,948
EXP2.5A	3,819	3,620	3,645	3,500	3,009
EXP3	3,667	3,350	3,217	2,938	1,924
EXP4v6	3,628	3,304	3,170	2,876	1,817
EXP4.95	3,281	3,220	3,334	3,130	2,260
EXP5P	3129	2847	2847	2536	1488

EXP1 EXP2 EXP2.5A EXP3 EXP4v6 EXP4.95 EXP5P

Figure E-7. Average End of September Shasta Storage by Water Year Type

This is especially true in the driest years. Looking at Figure E-7 the difference in EoSep Shasta storage between EXP2 and EXP3 is 749 thousand acre-feet (TAF) in wet years while the difference is 2,024 TAF in critically dry years. On the other hand, the difference in EoSep Shasta storage between EXP3 and EXP5P is 538 TAF in wet years while the difference is 436 TAF in critically dry years. This shows that in the driest years, the increase of the cost on Shasta storage is primarily because of non-discretionary requirements, while additional Shasta storage that is used for discretionary purposes decreases in drier years.

The fill and carryover trends described for Shasta Reservoir are generally true for Folsom Lake and Lake Oroville. Shasta plays an outsized role in meeting non-discretionary actions due to the scale of releases for non-discretionary mainstem Sacramento River flow standards and deliveries, while full operations under EXP5P tend to have a larger impact on Folsom and Oroville. These facilities are discussed further in Section 6.2, *Attachment 2 – Model Results*.

E.4.2 River Flows

River flows downstream of the reservoirs are directly affected by hydrological inputs and reservoir operations, which cause changes across the exploratory modeling suite. Below Keswick Dam, on the Sacramento River, the flows are affected by both releases from Shasta Reservoir and water that is released from Trinity Reservoir and imported to the Sacramento River.

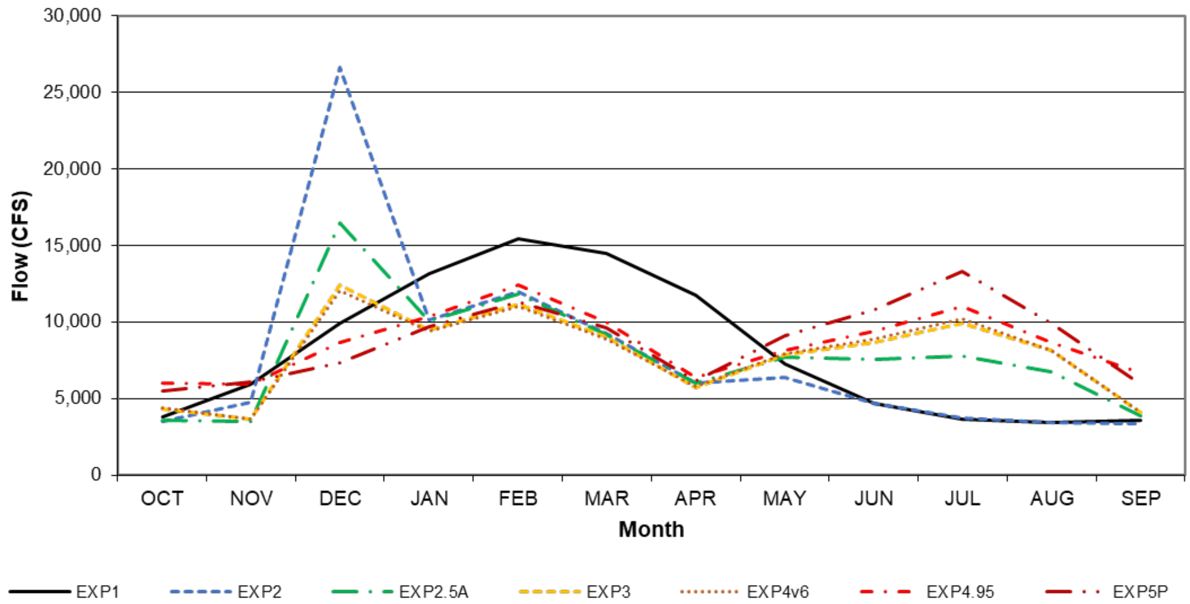
Table E-2. Average Annual Total Keswick Releases by Source and Release Type[a]

Water Source	EXP1	EXP2	EXP2.5A	EXP3	EXP4V6	EXP4.95	EXP5P
Shasta pass-through inflow	5,796	4,575	4,432	4,295	4,275	4,387	4,133
Shasta stored water releases for flood control	0	1,092	282	313	297	328	100
Shasta stored water releases	34	0	971	1,084	1,121	976	1,471
Trinity pass-through inflow	0	0	0	0	0	274	250
Trinity stored water releases for flood control	0	0	0	0	0	28	19
Trinity stored water releases	0	0	0	0	0	255	342

[a] In thousands of acre-feet.

Table E-2 shows the average annual total of different sources of water flowing below Keswick Dam. This includes pass-through inflow, releases for flood control, and releases of previously stored water from both Shasta and Trinity reservoirs. The operational capability to import Trinity water is not available until EXP4.95, and so, in all earlier models in the exploratory modeling suite, all the flow below Keswick Dam comes from Shasta releases.

In general, Shasta pass-through inflow and releases for flood control decrease and stored water releases increase for each subsequent layer of the exploratory modeling suite. In EXP1, water is not purposefully stored, but downstream channel capacities can back up water into the reservoirs which is later released as previously stored water. Flood control releases are higher in EXP3 and EXP4v6 than in EXP2.5A due to an oversight in a handful of years of input data for those two studies, which caused fall drawdown ahead of the December onset of formal flood control.



CFS = cubic feet per second

Figure E-8. Monthly Pattern of Sacramento River Flow Below Keswick Dam

Figure E-8 shows the monthly pattern of average flows below Keswick Dam. Additional operational capabilities and responsibilities in each subsequent layer cause the CVP and SWP to store more water in the fill season (from October until the end of April) and release more of that water in the management season (from May until the end of September). Flows below Keswick in EXP1 reflect the inflows into Shasta Reservoir. In EXP2, previously stored water is only released for flood control, and this is what causes the high spike of flows below Keswick Dam. Subsequent exploratory modeling layers require less December release because stored water is used, particularly during summer months, to meet incremental levels of responsibilities. EXP4.95 and EXP5P further introduce summer and fall drawdown rules that ramp storage down to December flood control levels to avoid the sudden flow spike. After the December flood control releases, storing water during the fill season causes flow below Keswick in all scenarios to be lower than Run of the River. Upon the start of the management season in May, the progressively increased CVP responsibility in each subsequent layer causes progressively more releases for those responsibilities in the management season, which results in increased flows below Keswick Dam. In EXP3, Shasta releases water for non-discretionary requirements. Additional releases are needed to meet Delta water quality requirements due to the delivery and export of excess water in EXP4v6, and in EXP4.95 and EXP5P, there is full operations, including Trinity imports.

The trends described for Shasta Reservoir are generally true for flows below Folsom and Oroville; however, the large EXP2 releases for flood control at Folsom occur in November. Detailed results for these facilities are contained in Section 6.2, *Attachment 2 – Model Results*.

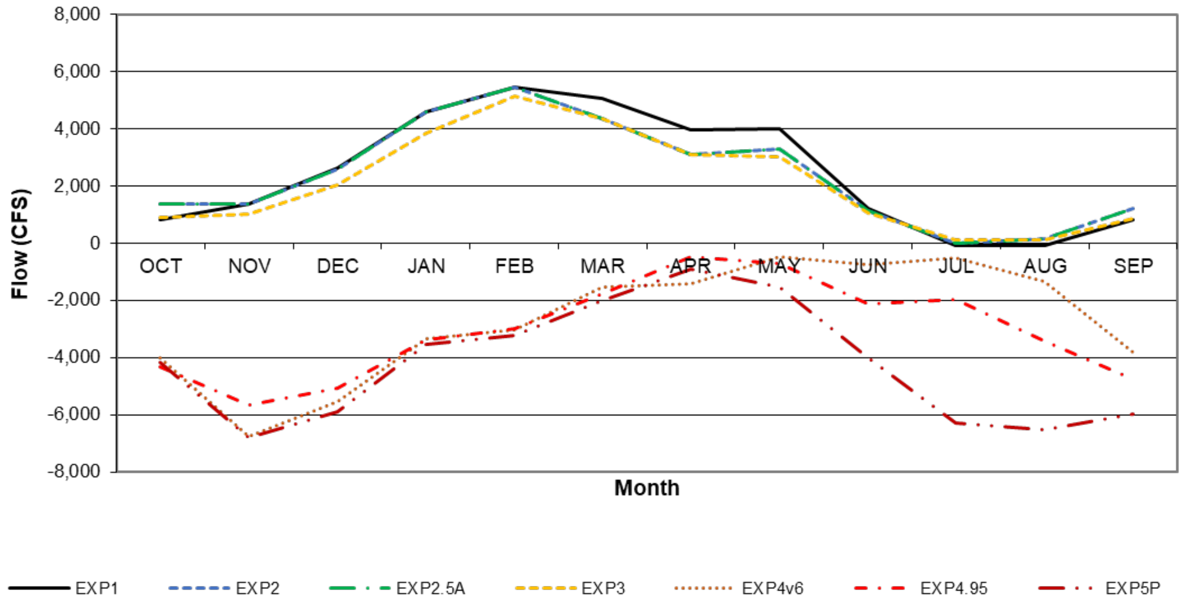


Figure E-9. Monthly Pattern of Flow in the Old and Middle River

As a result of exports starting in EXP4v6, flow in the OMR is affected by pumping at Jones and Banks pumping plants. Figure E-9 clearly shows that operations of the pumps in EXP4v6 and EXP5P reverse the flow in the OMR, while flows are similar across all the other exploratory models that do not include operations of Jones and Banks pumping plants. It is important to note that even in scenarios when the pumps are not operational, negative flows still sometimes occur during June and August due to south Delta consumptive use.

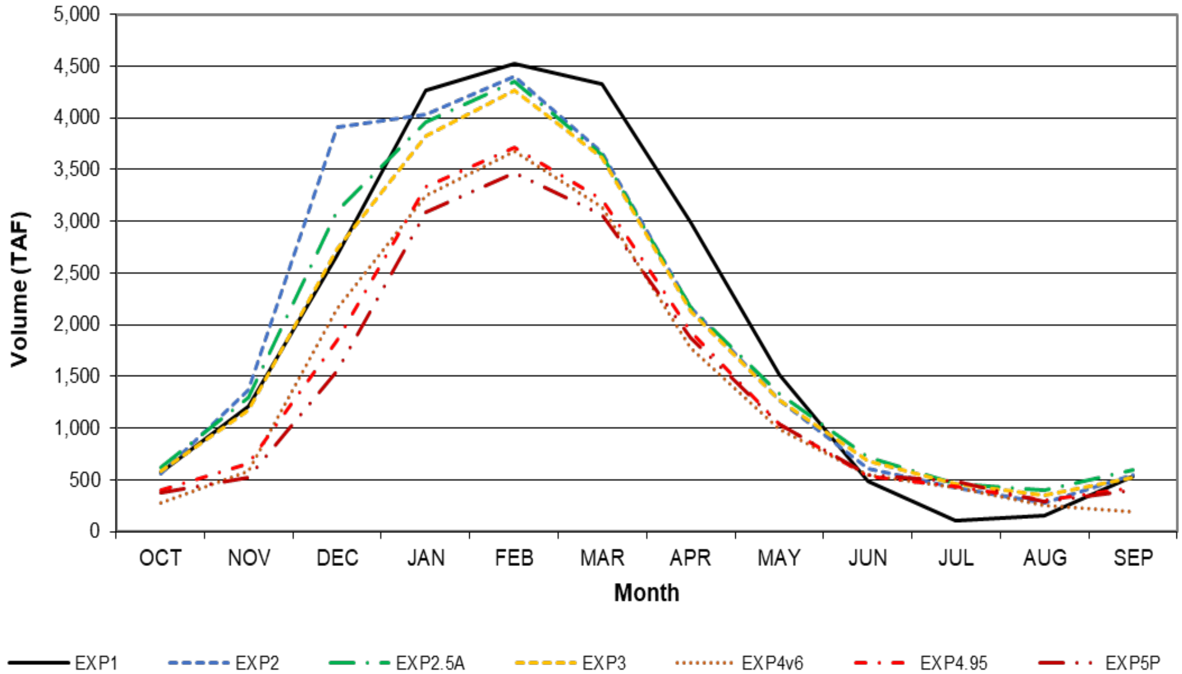
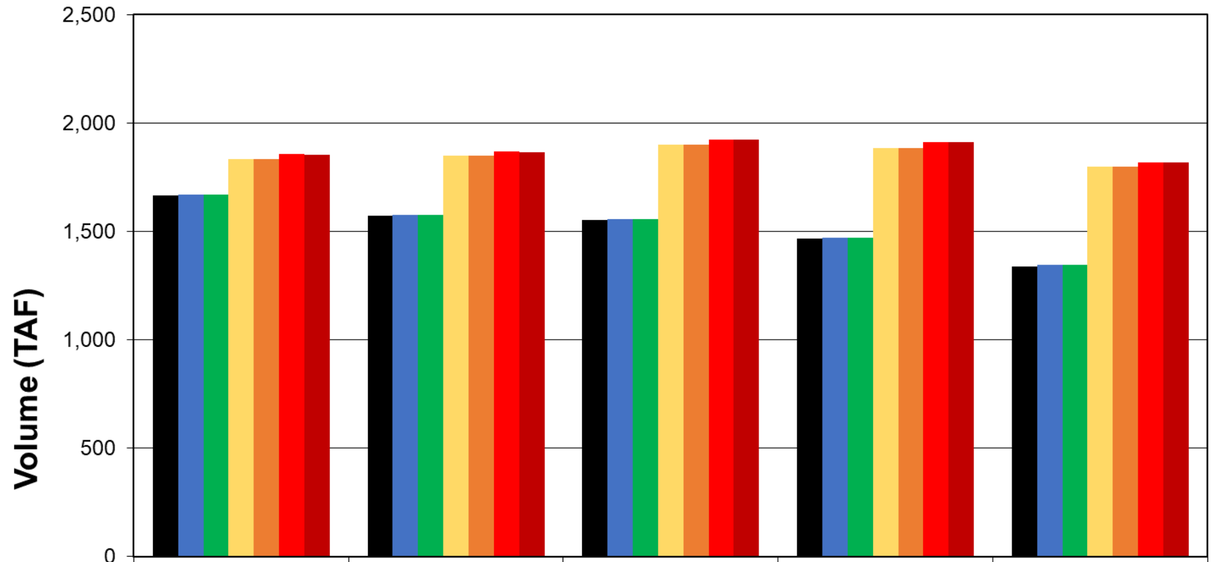


Figure E-10. Monthly Pattern of Delta Outflow

Figure E-10 shows the average monthly pattern of Delta outflow. The trends described for flows below Keswick Dam are similar but muted for Delta outflow. EXP1 reflects the inflows into the system. The signal from December flood control releases is noticeable but decreased in EXP2 and EXP2.5A. When comparing EXP4v6 to EXP3, there is significantly less Delta outflow during the fill season because water that would be excess Delta outflow in EXP3 is exported instead in EXP4v6.

E.4.3 Deliveries and Exports

The operational capability to deliver and export water is one of the primary differences between the layers of the exploratory modeling suite. In EXP1, EXP2, and both versions of EXP2.5, water can only be delivered to senior water rights as is hydrologically available. In EXP3, the reservoirs are operated to meet senior water right demands. In EXP4v6 and EXP4.95, excess water can be exported and delivered to project demands, and in EXP5 and EXP5P, the reservoirs are operated to meet all project demands and export.

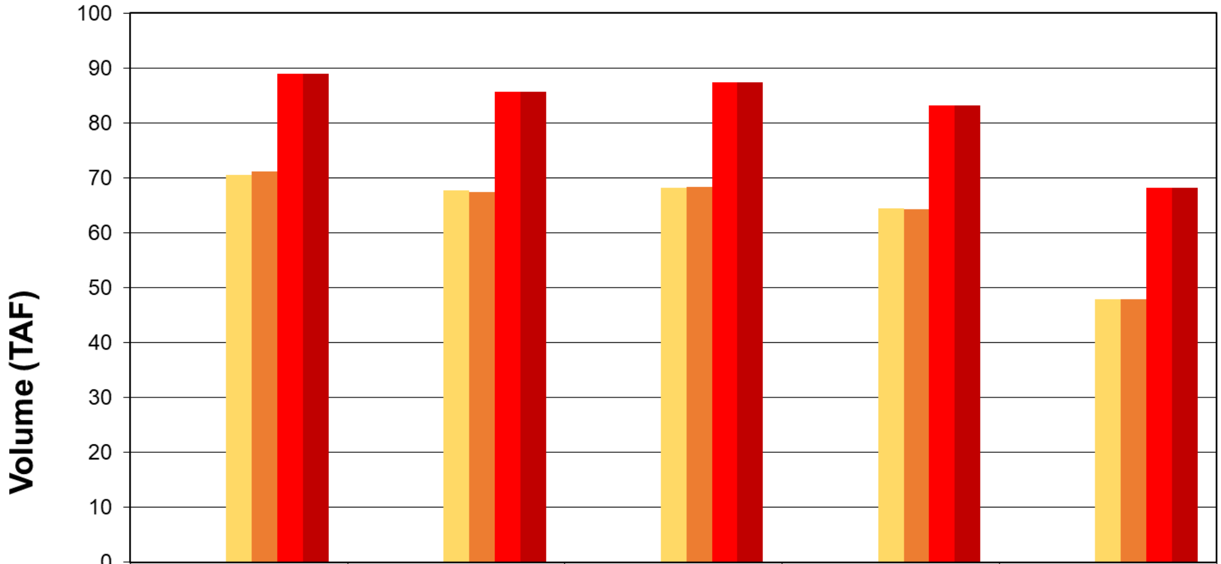


	Wet	Above Normal	Below Normal	Dry	Critically Dry
EXP1	1,667	1,573	1,553	1,466	1,339
EXP2	1,669	1,576	1,557	1,471	1,346
EXP2.5A	1,669	1,576	1,557	1,471	1,346
EXP3	1,835	1,848	1,899	1,884	1,797
EXP4v6	1,835	1,848	1,899	1,885	1,797
EXP4.95	1,855	1,868	1,925	1,911	1,819
EXP5P	1853	1865	1924	1911	1819

EXP1 EXP2 EXP2.5A EXP3 EXP4v6 EXP4.95 EXP5P

Figure E-11. Average Annual Total Settlement Contract Deliveries by Water Year Type

Figure E-11 shows average annual deliveries to Settlement Contracts by water year type. EXP1, EXP2, and EXP2.5A deliver water as is hydrologically available, and, therefore, Settlement Contract demands are often not met in the management season when storage releases are needed to satisfy those demands. The CVP and SWP in EXP3, EXP4v6, EXP4.95, and EXP5P can operate the reservoirs to meet those demands and, therefore, rarely short those demands. The difference between these two groups of exploratory models increases in drier water year types because there is less water hydrologically available in drier years.

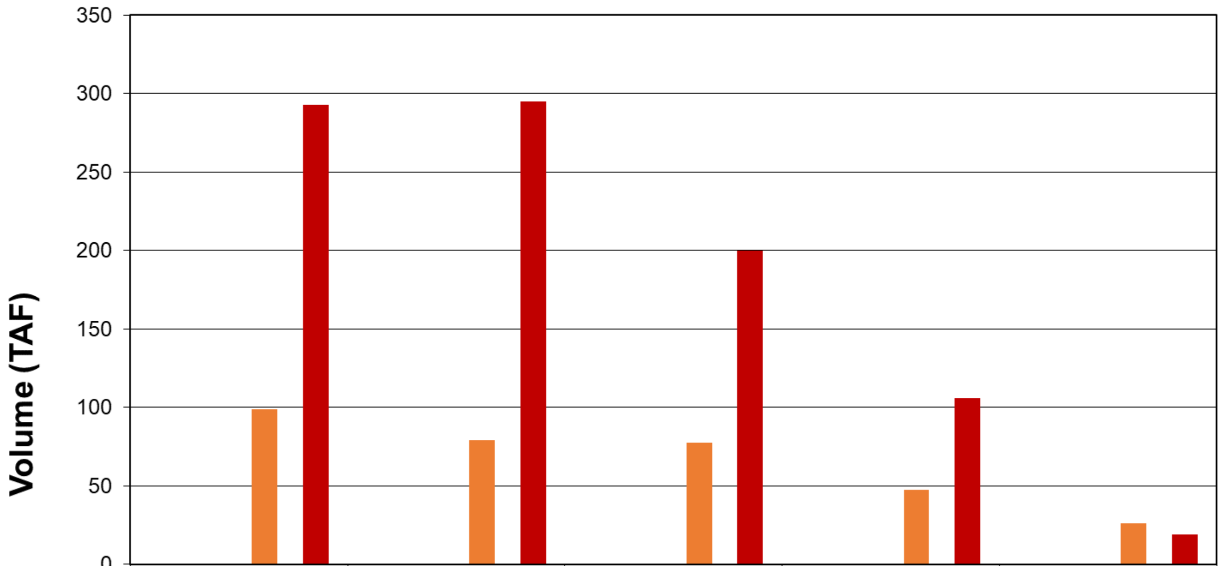


	Wet	Above Normal	Below Normal	Dry	Critically Dry
EXP1	0	0	0	0	0
EXP2	0	0	0	0	0
EXP2.5A	0	0	0	0	0
EXP3	71	68	68	64	48
EXP4v6	71	67	68	64	48
EXP4.95	89	86	87	83	68
EXP5P	89	86	87	83	68

EXP1 EXP2 EXP2.5A EXP3 EXP4v6 EXP4.95 EXP5P

Figure E-12. Average Annual Total NOD Refuge Deliveries by Water Year Type

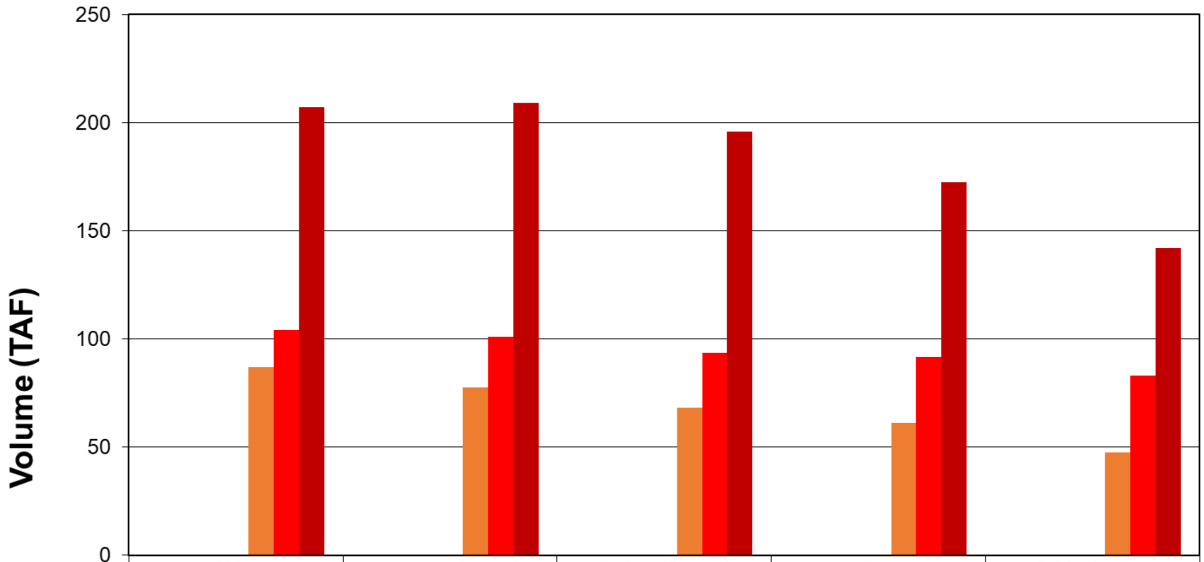
In EXP1, EXP2, and EXP2.5A, the CVP only makes deliveries to Level 1 refuge demands as is hydrologically possible, but north of the Delta, the Level 1 refuge demands are 0 TAF. As shown in Figure E-12, refuge demands are increased to Level 2 in EXP3, and stored water releases are made to meet those demands. The discrepancies between EXP3/EXP4v6 and EXP4.95/EXP5P are due to weighting issues in the model and an unintended outcome of the exploratory modeling.



	Wet	Above Normal	Below Normal	Dry	Critically Dry
EXP1	0	0	0	0	0
EXP2	0	0	0	0	0
EXP2.5A	0	0	0	0	0
EXP3	0	0	0	0	0
EXP4v6	99	79	78	47	26
EXP4.95	0	0	0	0	0
EXP5P	293	295	200	106	19

EXP1 EXP2 EXP2.5A EXP3 EXP4v6 EXP4.95 EXP5P

Figure E-13. Average Annual Total CVP NOD Ag Deliveries by Water Year Type

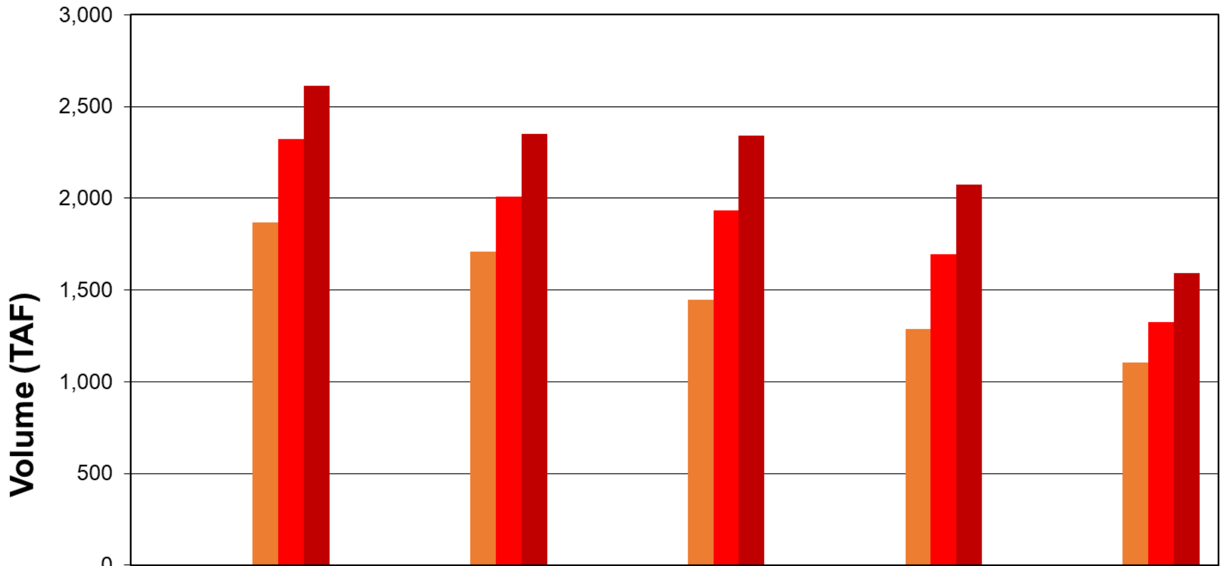


	Wet	Above Normal	Below Normal	Dry	Critically Dry
EXP1	0	0	0	0	0
EXP2	0	0	0	0	0
EXP2.5A	0	0	0	0	0
EXP3	0	0	0	0	0
EXP4v6	87	78	68	61	48
EXP4.95	104	101	93	92	83
EXP5P	207	209	196	173	142

EXP1 EXP2 EXP2.5A EXP3 EXP4v6 EXP4.95 EXP5P

Figure E-14. Average Annual Total CVP NOD M&I Deliveries by Water Year Type

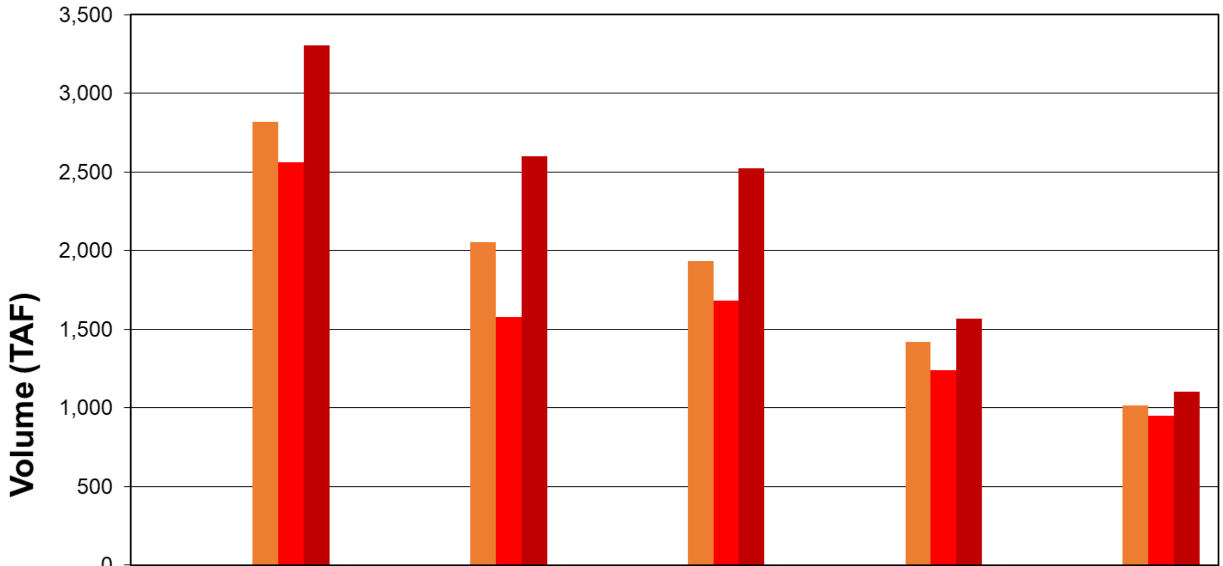
Project deliveries are only made in EXP4v6 and beyond, with access to varying levels of resources. EXP4 versions are able to deliver and export only Delta excess. EXP4.95 can export Delta surplus and meet health and safety requirements from storage releases, but does not deliver to CVP NOD Ag (due to model development schedule constraints). EXP5P operates to deliver available water to all project users. Figure E-13 and Figure E-14 show average annual CVP NOD Ag and NOD M&I deliveries by water year type.



	Wet	Above Normal	Below Normal	Dry	Critically Dry
EXP1	0	0	0	0	0
EXP2	0	0	0	0	0
EXP2.5A	0	0	0	0	0
EXP3	0	0	0	0	0
EXP4v6	1,867	1,708	1,444	1,289	1,107
EXP4.95	2,320	2,008	1,935	1,693	1,325
EXP5P	2611	2349	2341	2075	1590

EXP1 EXP2 EXP2.5A EXP3 EXP4v6 EXP4.95 EXP5P

Figure E-15. Average Annual Total Jones Pumping Plant by Water Year Type

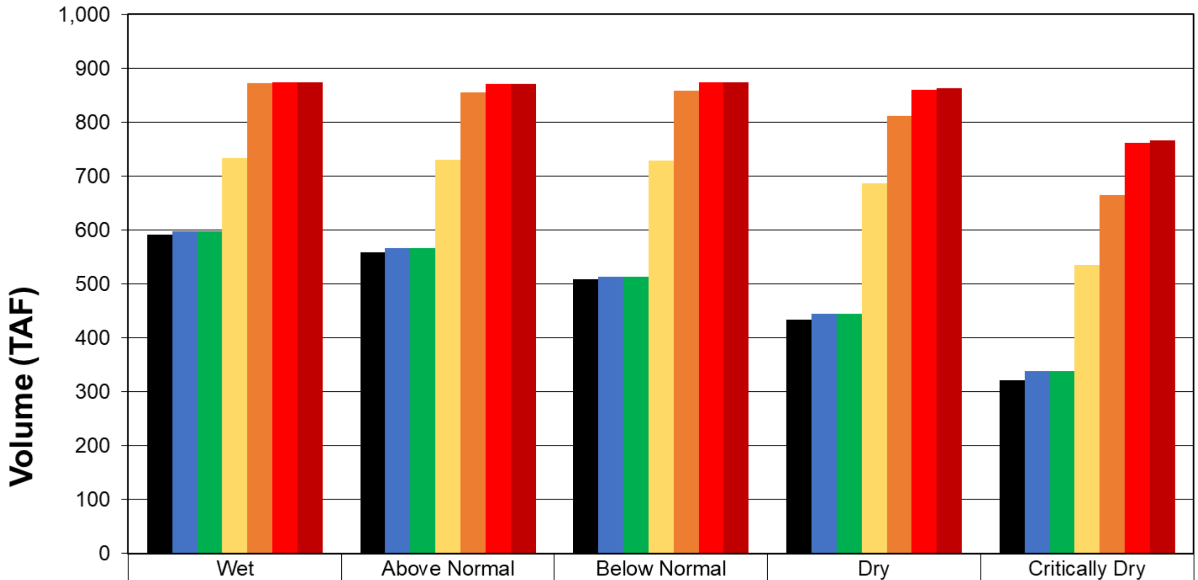


	Wet	Above Normal	Below Normal	Dry	Critically Dry
EXP1	0	0	0	0	0
EXP2	0	0	0	0	0
EXP2.5A	0	0	0	0	0
EXP3	0	0	0	0	0
EXP4v6	2,818	2,056	1,931	1,419	1,015
EXP4.95	2,561	1,579	1,685	1,237	947
EXP5P	3303	2599	2526	1568	1101

■EXP1 ■EXP2 ■EXP2.5A ■EXP3 ■EXP4v6 ■EXP4.95 ■EXP5P

Figure E-16. Average Annual Total Banks Pumping Plant by Water Year Type

Figure E-15 and Figure E-16 show average annual Jones and Banks exports by water year type, respectively. Jones exports increase from EXP4v6 to EXP4.95 due to exports for M&I and availability of Trinity imports, which result in more water coming into the Delta. EXP5P allows export to the full extent that storage releases and regulatory criteria will support. The reduction in exports at Banks in EXP4.95 is due to the limit on delivery to health and safety levels, while EXP5P exports reflect full SWP operations under all regulatory criteria with storage releases for export.

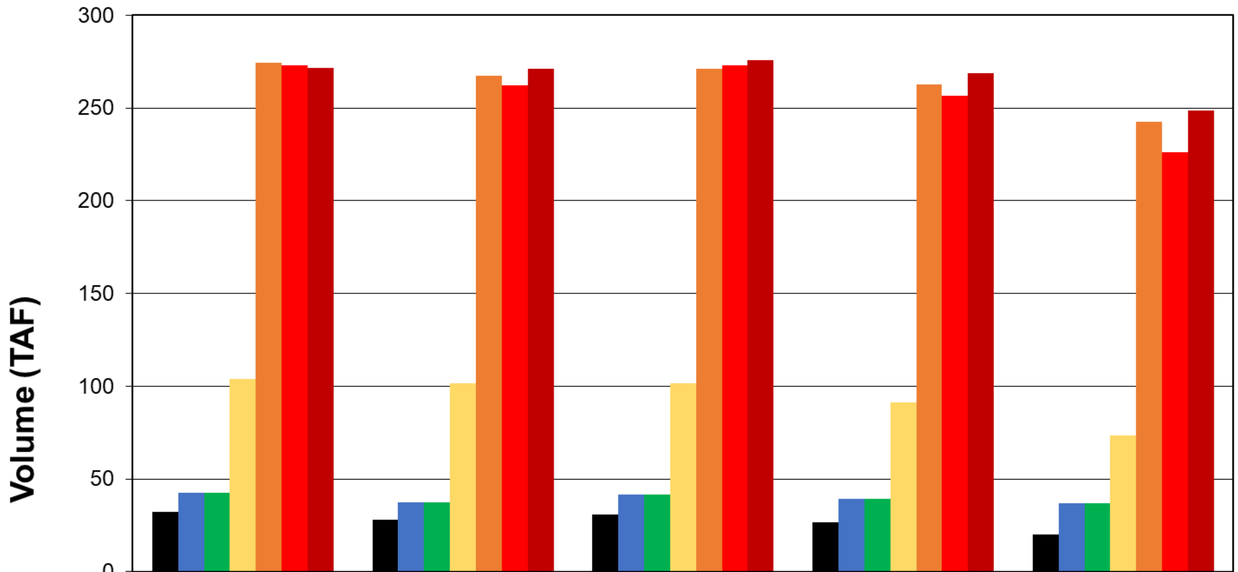


	Wet	Above Normal	Below Normal	Dry	Critically Dry
EXP1	592	559	508	433	322
EXP2	597	567	514	444	338
EXP2.5A	597	567	514	444	338
EXP3	733	730	728	686	535
EXP4v6	872	856	859	811	664
EXP4.95	874	871	873	860	762
EXP5P	874	871	873	862	766

EXP1 EXP2 EXP2.5A EXP3 EXP4v6 EXP4.95 EXP5P

Figure E-17. Average Annual Total SOD Exchange Contract Deliveries by Water Year Type

Figure E-17 shows average annual Exchange Contract deliveries by water year type. In EXP1, EXP2, and EXP2.5A, deliveries are made as hydrologically available from the San Joaquin River, which results in shortages during the management season when there are less inflows. In EXP3, Friant is operated to meet Exchange Contractor demands. However, there are still some shortages during the management season. The CVP can export excess water in EXP4v6 and EXP4.95, decreasing shortages and reducing the reliance on inflows and SOD storage, and finally, in EXP5P full exports allow for full Exchange Contractor deliveries without the use of inflows and SOD storage.



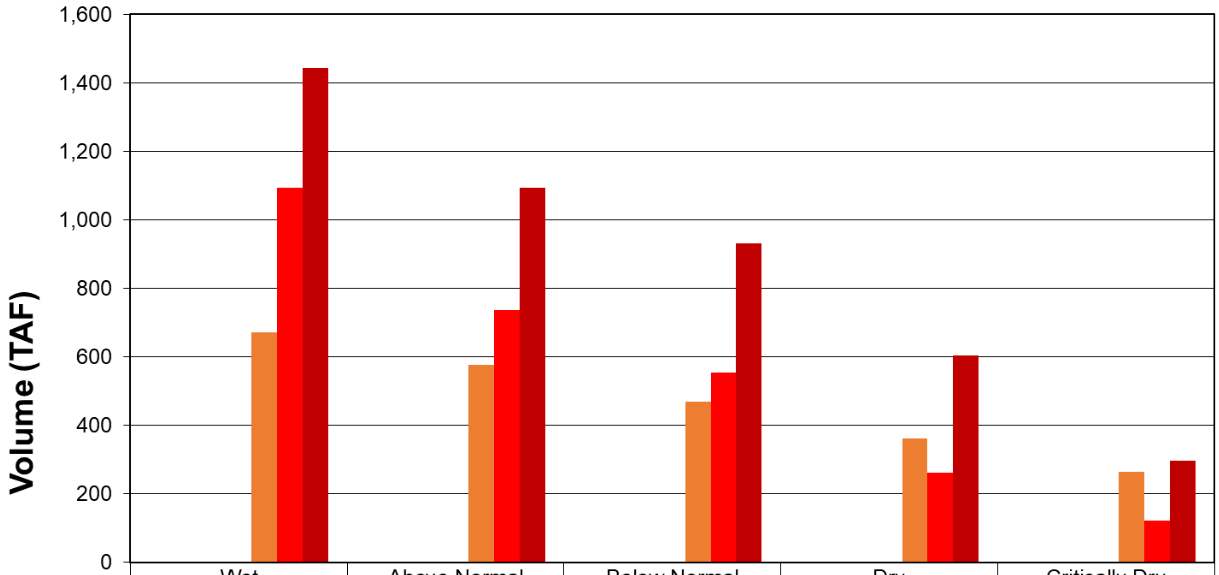
	Wet	Above Normal	Below Normal	Dry	Critically Dry
EXP1	32	28	31	27	20
EXP2	42	38	41	39	37
EXP2.5A	42	38	41	39	37
EXP3	104	101	101	91	73
EXP4v6	275	267	271	263	243
EXP4.95	273	262	273	257	226
EXP5P	272	271	276	269	249

EXP1 EXP2 EXP2.5A EXP3 EXP4v6 EXP4.95 EXP5P

Figure E-18. Average Annual Total SOD Refuge Deliveries by Water Year Type

Figure E-18 shows that SOD refuge deliveries are similar to Exchange Contract deliveries. Deliveries are made as hydrologically available in EXP1, EXP2, and EXP2.5A. In EXP3, Friant stored water releases are made to meet refuge demands, and starting in EXP4v6, the addition of exports minimize shortages to refuges.

Figure E-19 show the average annual total CVP SOD agriculture deliveries by water year type.

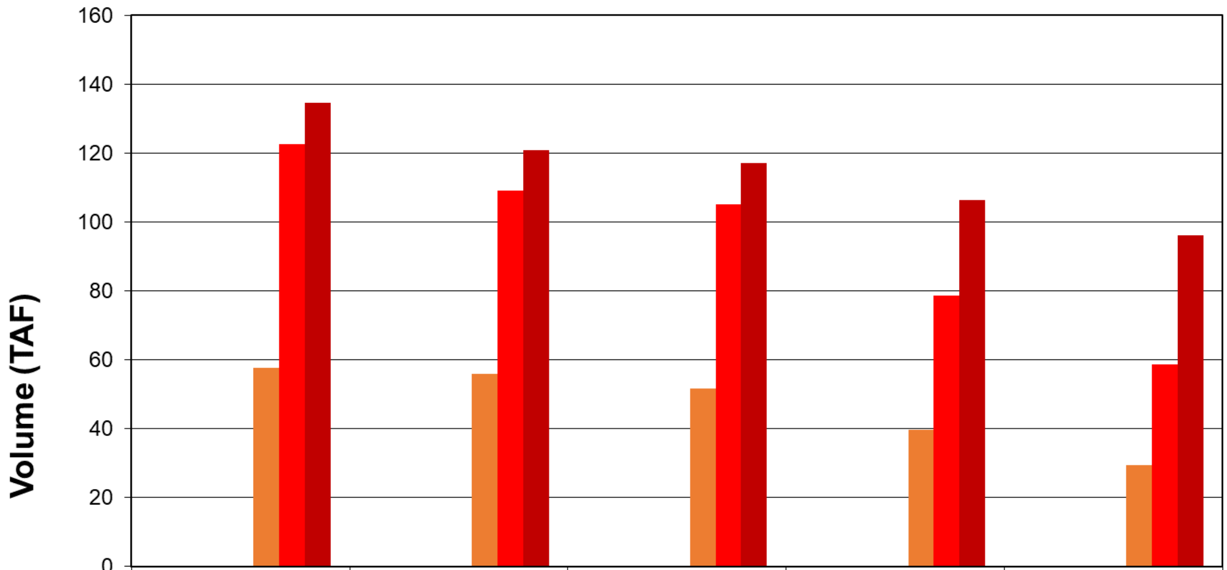


	Wet	Above Normal	Below Normal	Dry	Critically Dry
EXP1	0	0	0	0	0
EXP2	0	0	0	0	0
EXP2.5A	0	0	0	0	0
EXP3	0	0	0	0	0
EXP4v6	671	576	469	361	263
EXP4.95	1,093	735	554	262	121
EXP5P	1443	1094	930	604	297

EXP1 EXP2 EXP2.5A EXP3 EXP4v6 EXP4.95 EXP5P

Figure E-19. Average Annual Total CVP SOD Agriculture Deliveries by Water Year Type

Figure E-19 shows the average annual total CVP SOD M&I deliveries by water year type.



	Wet	Above Normal	Below Normal	Dry	Critically Dry
EXP1	0	0	0	0	0
EXP2	0	0	0	0	0
EXP2.5A	0	0	0	0	0
EXP3	0	0	0	0	0
EXP4v6	58	56	52	40	29
EXP4.95	123	109	105	79	59
EXP5P	135	121	117	106	96

EXP1 EXP2 EXP2.5A EXP3 EXP4v6 EXP4.95 EXP5P

Figure E-20. Average Annual Total CVP SOD M&I Deliveries by Water Year Type

Similar to NOD, SOD project deliveries are not made until EXP4v6. Figure E-17 shows the effects of successive layers of operations. EXP4v6 opportunistically delivers exports of Delta surplus that are not reserved for senior SOD water users, limited only by OMR constraints. EXP4.95 exports are also limited to Delta surplus after minimal exports are made to meet Health and Safety deliveries, but are limited by allocation logic. The availability of Trinity imports in this scenario does affect water supply available for export. EXP5P meets all demands as possible under full operations and water supply conditions.

E.5 Discussion

Project storage operations, deliveries, and exports will be key topics in the LTO 2021 Consultation. The exploratory modeling documented here provides insight to the capabilities and limits of project storage facilities to operate to successive layers of regulatory and contractual obligations. EXP2 captures the hydrologic feasibility of meeting core regulations and senior water rights and provides perspective on the maximum storage volumes that could be available for operations not covered by local inflow. EXP3 demonstrates the storage cost of legal and contractual obligations by making releases from storage reserves for these elements when local inflow is not sufficient. EXP4 added the storage responsibility for covering water quality costs of exporting Delta surplus, and illuminates remaining storage reserves available to enhance water supply delivery. EXP4.95 is the penultimate steppingstone, demonstrating the storage cost of full regulatory criteria and public health and safety deliveries while leaving out storage releases for additional discretionary delivery and export. EXP5P is the operation for all project obligations. Trinity imports in EXP4.95 and EXP5P add flexibility to meet both regulatory costs and deliveries.

This appendix, along with the Shasta Operations Analysis in Appendix AB-L, *Shasta Coldwater Pool Management*, Attachment L.1, *Sacramento River Water Temperature Analysis*, provides background on feasible combinations of flow, storage, delivery, and export. Uncertainty in forecasted inflow, variability in regulatory cost, and facility limitations should illuminate potential tradeoffs among project purposes and inform action proposals. Exploratory model layers have the freedom to use systemwide flexibility in collectively managing CVP storage resources. Actions specific to any particular tributary would reduce this systemwide flexibility and should be carefully analyzed to avoid potential unintended consequences.

E.6 References

Bureau of Reclamation. 2019a. *Additional Climate Scenario Sensitivity Analysis*, Appendix F2 of *Reinitiation of Consultation on the Coordinated Long-Term Operation of 1 the Central Valley Project and State Water Project*. Available: https://www.usbr.gov/mp/nepa/includes/documentShow.php?Doc_ID=41745. Accessed: December 5, 2023.

Bureau of Reclamation. 2019b. *Model Limitations*, Appendix F Attachment 2-7 of *Reinitiation of Consultation on the Coordinated Long-Term Operation of 1 the Central Valley Project and State Water Project*. Available: https://www.usbr.gov/mp/nepa/includes/documentShow.php?Doc_ID=41744. Accessed: December 5, 2023.