Spencer Kenner (SBN 148930)
James E. Mizell (SBN 232698)
DEPARTMENT OF WATER RESOURCES
Office of the Chief Counsel
1416 9th St.
Sacramento, CA 95814
Telephone: +1 916 653 5966
E-mail: jmizell@water.ca.gov

Attorneys for California Department of Water Resources

BEFORE THE

CALIFORNIA STATE WATER RESOURCES CONTROL BOARD

HEARING IN THE MATTER OF CALIFORNIA DEPARTMENT OF WATER RESOURCES AND UNITED STATES BUREAU OF RECLAMATION REQUEST FOR A CHANGE IN POINT OF DIVERSION FOR CALIFORNIA WATER FIX	TESTIMONY OF ARMIN MUNĖVAR

I, Armin Munévar, do hereby declare:

I. INTRODUCTION

I am a Senior Engineer employed at CH2M. I received a Bachelor of Science degree in Civil Engineering from the University of California at Los Angeles (1991) and a Master of Science degree in Civil and Environmental Engineering from the University of California at Davis (1997). I am a registered Civil Engineer in the State of California. I have 22 years of experience in water resource systems modeling for complex water systems in California and the western United States. My experience includes the development and application of the CalSim II model, and application of the DSM2 model, for a range of Central Valley and Sacramento-San Joaquin Delta water resource management projects since 1998.

My responsibilities at CH2M include serving as the global technology lead for Integrated Water Resource Management, providing technical expertise on various water resource management projects, and directing staff to conduct technical studies. For the

California Water Fix (CWF), I have provided technical support on the CWF alternatives development and water resources modeling since 2007. A copy of my statement of qualifications has been submitted as Exhibit DWR-30.

In my testimony, I provide an overview of the models and modeling methodology used to analyze the CWF. More specifically, this testimony, in conjunction with Dr. Nader-Tehrani's separate testimony, is provided to present the modeling results from the CalSim II and DSM2 models used to evaluate projected changes in water supply, water quality, and water levels with the CWF that may affect legal users of water. The focus of this testimony is on potential changes in water supply. The focus of Dr. Nader-Tehrani's testimony is on changes in water quality and water levels.

II. OVERVIEW OF TESTIMONY

This testimony provides an overview of the computer modeling performed to evaluate changes in the water supply, water quality, and water levels in the Delta associated with the CWF Alternative 4A, the preferred alternative from the Recirculated Draft Environmental Impact Report/Supplemental Draft Environmental Impact Statement (RDEIR/SDEIS). Alternative 4A is described by initial operational criteria referred to as scenarios H3 and H4. Specific initial operational criteria will be set at the time of Project approval. Further, the operational criteria could subsequently change based on adaptive management. To ensure that any operations considered within this change petition proceeding have been evaluated with regard to effects on legal users of water, the modeling uses a boundary analysis; specifically Boundary 1 and Boundary 2, representing the outer range of regulatory and operational conditions within which the CWF could conceivably operate in the future. In addition, modeling results using the initial operational range of the CWF, as represented through scenarios H3 and H4, are shown. These scenarios are consistent with and included in the range of alternatives evaluated in the Environmental Impact Report/Environmental Impact Statement (EIR/EIS). These scenarios are evaluated considering climate change and sea level rise effects at about year 2025.

The modeling results are compared between the CWF scenarios and the No Action

Alternative (NAA).[1] This declaration describes the results of the scenario modeling, showing changes in reservoir storage and water deliveries to CVP and SWP contractors. In separate testimony, Dr. Nader-Tehrani will describe results related to Delta water quality and water levels.

III. OVERVIEW OF MODELS AND TOOLS

Several models and analytical methods were used to characterize and analyze the changes in water operations in the SWP and CVP systems under each alternative. The primary models used in the CWF analyses are the CalSim II and DSM2 models. These models represent the best available technical tools for purposes of evaluating the CWF water operations. The overall flow of information between the CalSim II and DSM2 models and the general application and use of outputs for the resource evaluations are shown in Figure 1. (Exhibit DWR-514, p. 1.) The models were used to compare and contrast the effects among various operating scenarios. The models incorporate a set of base assumptions[2]; the assumptions were then modified to reflect the operations associated with each of the scenarios. The output of the models is used to show the comparative difference in the conditions among the different scenarios.

In general, CalSim II is used to simulate the operations of the SWP and CVP, resulting in information on projected storage conditions, river flows, exports, deliveries, and delta inflows, and outflows. The output of this model is then used by the DSM2 model to simulate the hydrodynamics, water quality, and particle tracking within the Delta. With the information generated from these models, the water deliveries, flows, water quality, and water levels can be compared under different operating scenarios.

A. CALSIM II Model

CalSim II is a mathematical model[3] developed jointly by the Department of Water Resources ("DWR") and the Bureau of Reclamation ("Reclamation") to evaluate SWP/CVP

[1] Based on CalSim II 2015 version modeling.
[2] The base assumptions are all non- project-specific assumptions.
[3] A systematic description of an object or phenomenon that shares important characteristics with the object or phenomenon. A simplified representation used to explain the workings of a real world system or event.

operations. CalSim II is the best available planning tool to evaluate SWP/CVP system operations and other water-related projects in California since May, 2002.

CalSim II is a monthly model that uses historical hydrologic information from October 1922 to September 2003 to simulate CVP-SWP operations, including reservoir storage, water flows in the Delta, water exports, and water deliveries. The results from the model are used to evaluate various water project operations under the 82 year historic hydrology.

Inputs to CalSim II include water diversion requirements (demands), stream accretions and depletions, rim basin inflows, irrigation efficiencies, return flows, non-recoverable losses, and groundwater operations. Central Valley and tributary rim-basin hydrologic inputs are developed using a process designed to adjust the historical sequence of monthly stream flows over an 82- year period (1922 to 2003) to represent a sequence of flows at a future level of development. Adjustments to historical water supplies are determined by imposing future level land use on historical meteorological and hydrologic conditions. The resulting hydrology represents the water supply available from Central Valley streams to the SWP and CVP at a future level of development.

CalSim II uses pre-defined or generalized “rules” to approximate regulatory requirements, like D-1641. The rules are often specified as a function of water-year type or prior month’s simulated storage or flow condition. The generalized rules have been developed based on historical operational trends and on extensive CVP/SWP operator input to provide a reasonable representation of the project operations over the simulated hydrologic conditions. However, the CalSim II model is not able to adjust these rules to respond to specific events that may have occurred historically, e.g., levee failures, fluctuations in barometric pressure that may have affected Delta tides and salinities, facility outages. CalSim II results should not be expected to exactly match actual operations in a specific month or year within the simulation period since operational decisions are evolving and informed by numerous real-time operational considerations. CalSim II results should only be used comparatively, evaluating relative changes from a common reference point.

i. D-1641 Water Quality Standards Incorporated Into CalSim II

In CalSim II, the reservoirs and SWP/CVP facilities are operated to assure the flow and water quality requirements for these systems are met. Meeting regulatory requirements, including Delta water quality objectives, is the highest operational priority in CalSim II.

The CalSim II model uses an Artificial Neural Network (ANN)[4] to approximate the complex flow-salinity relationships in the Delta. ANN models are commonly used to model complex relationships between inputs and outputs. The ANNs in CalSim II determine the flows (combination of Delta flows and exports) required to meet the salinity-related Delta standards. The ANNs in CalSim II emulate flow-salinity relationships derived from DSM2. Since the ANN is built to emulate the flow-salinity relationships from DSM2, CalSim II is capable of simulating future scenarios with significant changes to the Delta, for example sea level change. The ANN simulates salinity at five of the locations that have D-1641 standards for salinity. The five locations are identified in Exhibit DWR-514, p. 2, Table 1 and CalSim II also adjusts the operations of the New Melones Reservoir to meet D-1641 at San Joaquin River at Vernalis for those locations.

Since CalSim II is a model with a monthly time-step and a number of daily D-1641 objectives are active during only portions of a month (e.g. April 1 to June 20 and June 20 to August 15), D-1641 objectives are calculated as a monthly weighted average.

ii. Customization of the CalSim II Model Network

The modeling for the CWF required customization of the CalSim II model network to include the proposed north delta diversion (NDD) along the Sacramento River and the Fremont Weir modification.[5] The NDD intakes and associated conveyance allow for SWP/CVP diversions on the Sacramento River between Clarksburg and Courtland.

[4] In machine learning and cognitive science, artificial neural networks (ANNs) are a family of models inspired by biological neural networks (the central nervous systems of animals, in particular the brain) which are used to estimate or approximate functions that can depend on a large number of inputs and are generally unknown. Artificial neural networks are generally presented as systems of interconnected "neurons" which exchange messages between each other. The connections have numeric weights that can be tuned based on experience, making neural nets adaptive to inputs and capable of learning.

[5] For the 2010 modeling, modification of Fremont Weir including the daily patterning was included in the CalSim II customization. For the 2015 modeling, modification of Fremont Weir was included in the base assumptions.

iii. Incorporation of Sacramento River Daily Variability

The operation of the modified Fremont Weir and the NDD are sensitive to the daily variability of flows. Short duration, highly variable storms are likely to cause Fremont Weir spills. However, if flows are averaged for the month, as is done in a purely monthly model, it is possible that flows may have not indicated a spill. Similarly, the NDD bypass rules associated with operation of the north Delta intakes include variable bypass flow (flow remaining in the river downstream of the proposed intakes) requirements and pulse protection criteria. Storms as described above may permit significant diversions but only for short periods of time. Initial comparisons of monthly versus daily operations at these facilities indicated that weir spills were likely underestimated and north Delta diversion potential was likely overstated using a monthly time step.[6]

To better represent the sub-monthly flow variability, particularly in early winter, this analysis uses a monthly-to-daily flow mapping technique that is applied directly in CalSim II for the Fremont and Sacramento Weirs and the NDD intakes. This analysis applies historical daily patterns based on the year's hydrology to transform the monthly volumes into daily flows. In all cases, this analysis preserves the monthly volumes when converting the monthly to daily flows.

The daily Sacramento River flows are computed for each month in the 82-year hydrologic record by: 1) utilizing CalSim II simulated monthly Sacramento River flow volume, 2) determining historical daily volume fractions (fraction of daily flow volume to monthly volume), and then, 3) multiplying the CalSim II monthly flow volume by the daily flow fractions. The result is a daily flow sequence that preserves the monthly volume and includes realistic daily variability. From the daily flow sequence, a daily operation of the Fremont Weir, Sacramento Weir, and NDD diversion is simulated.

CalSim II hydrology is derived from historical monthly gauged flows for the period of 1922-2003. This is the source of the data for monthly and annual flow variability. In this

[6] See footnote 5 above.

analysis, DAYFLOW data for water years 1956-2003 were used as the basis for daily flow volume fractions. For each year in the period 1922-1955 daily pattern data was developed by selecting a reference water year from the 1956-2003 DAYFLOW dataset that had a similar volume of total annual unimpaired Delta inflow. The pattern for the reference year was then utilized as the daily flow volume fractions for the current year.

iv. Review and Development of CALSIM II

CalSim II is a public access model, meaning that it is publicly available for use by interested members of the public. In 2004 a modeling workgroup was formed to establish a common modeling framework for evaluating future projects' "common assumptions." As a result of the interaction between DWR, Reclamation and the modeling work group, CalSim II has been updated and improved over time.

CalSim II is the state of the art model for the purposes of comparing various CWF scenarios. It is a well-accepted model and has been used in multiple planning and regulatory processes, including but not limited to, the 2008 Fish and Wildlife Service and 2009 National Marine Fisheries Service Endangered Species Act consultation on coordinated operations of the CVP and SWP ("2008 FWS BiOp" and "2009 NMFS BiOp"), and the related federal litigation. CalSim II was also used in the Reclamation's National Environmental Policy Act Environmental Impact Statement ("EIS") for the Coordinated Long-Term Operation of the Central Valley Project and State Water Project (2015).

CalSim II has informed the State Water Resources Control Board (State Water Board) during many proceedings, including as part of its triannual reviews of the Bay-Delta Water Quality Control Plan. DWR and the State Water Board also have an agreement whereby DWR completes CalSim II and other modeling runs at the request of the State Water Board staff in support of the Water Boards planning and regulatory decision-making processes.

DWR submits annual reports to the State Water Board updating the State Water Board on DWR's progress in further refining CalSim II, as well as its other modeling tools. (See http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/AR2014/AR-2014-All.pdf.)

CalSim II has been subject to peer review. In 2003, the California Bay Delta Authority Science Program sponsored a peer review panel that issued a report titled, "A Strategic review of CalSim II and its Use for Water planning, Management, and Operations in Central California." (Available at: http://baydeltaoffice.water.ca.gov/modeling/hydrology/CalSimII/.) DWR responded to the peer review in a 2004 report titled "Peer Review Response, A Report by DWR/Reclamation in Reply to the Peer Review of the CalSim II Model Sponsored by the CALFED Science Program" in December 2003. (Available at: http://baydeltaoffice.water.ca.gov/modeling/hydrology/CalSimII/.)

In its 2004 peer review response at p. 27, DWR highlighted the following remarks from the California Bay Delta Authority Science Program:

> We believe the use of an optimization engine for simulating the hydrology and for making allocation decisions is an appropriate approach and is in fact the approach many serious efforts of this kind are using.

And,

> CalSim II represents a state-of-the art modeling system that is similar in general concept, while differing in specific details, to other data-driven river basin modeling systems such as ARSP, MODSIM, OASIS, REALM, RiverWare, and WEAP.

In its 2004 peer review response at p. 27, DWR concluded:

> DWR and Reclamation believe that CalSim-II is an adequate model for planning studies for new storage and conveyance facilities in the CVP & SWP systems….

CalSim II has also been peer reviewed as part of the publication of the model. See, Draper, A.J., Munévar, A., Arora, S. K., Reyes, E., Parker, N.L., Chung, F.I., Peterson, L.E. 2004. CALSIM: Generalized Model for Reservoir System Analysis, Journal of Water Resources Planning and Management, 130:6(480). DWR completed a quasi-validation of the CALSIM II model in 2003. See, CalSim II Simulation of Historical SWP/CVP Operations, Technical Memorandum Report, November 2003 ("CALSIM II Simulation Study"). The CalSim II Simulation Study showed that CalSim II could approximate historic trends suggesting that CALSIM II was a reasonable tool for water resource planning.

The CalSim II Simulation Study results that are summarized in Exhibit DWR-514, p.3, Table 2 show that simulated SWP Table A and CVP south-of-Delta deliveries during the drought (1987-1992) were within 5 percent of historical values, suggesting a close fit between simulated and actual values.

A comparison of Sacramento Valley inflow to the Delta (flow at Freeport) is a good measure of how well Sacramento Valley hydrology is simulated by CalSim II. Exhibit DWR-514, p. 3, Table 2 shows that for this quasi-validation run CalSim II simulated Delta inflows were 0.3 percent greater than historical, a reasonably close fit between simulated and actual values.

Comparison of the Net Delta Outflow Index, a measure of how well the Sacramento-San Joaquin Delta is represented by CalSim II, also show a close fit between simulated and actual. Exhibit DWR-514, p. 3, Table 2 shows simulated values are 3.5 percent less than historical during the 1987-1992 time-period. This exhibit also shows that simulated long-term (1975-1998) average deliveries compare quite well and are within 7 percent of historical values, suggesting a reasonably close fit between simulated and actual values. DWR and Reclamation have continued to improve CalSim II since 2003.

i. Comparison of CALSIM II 2010 and 2015

In an effort to maintain consistency while developing the CWF EIR/EIS, DWR used the CalSim II 2010 version throughout the multiple-year development of the Draft EIR/EIS and the RDEIR/EIS. At the request of the state and federal fisheries agencies, the CalSim II 2015 version was used for the draft biological assessment. This same model version is also used for the presentation of evidence in support of this petition. The specific updates to CalSim II that were included in the 2015 version are described in Exhibit DWR-514, p. 4, Table 3.

A comparison between the CalSim II 2010 and CalSim II 2015 update model results show similar system-wide operations and leads to similar conclusions in terms of the overall changes in water supply and Delta water quality associated with CWF scenarios in comparison with the NAA.

B. DSM2

DSM2 is a one-dimensional hydrodynamic and water quality simulation model used to simulate hydrodynamics and water quality in the Delta. DSM2 represents the best available planning model for Delta tidal hydrodynamics and salinity modeling. It is appropriate for describing the existing conditions in the Delta, as well as performing simulations for the assessment of incremental changes caused by future facilities and operations. The DSM2 HYDRO simulates velocities and water surface elevations and its output provides the flow input for QUAL, a module that simulates fate and transport of conservative and non-conservative water quality constituents, including salts, given a flow field simulated by HYDRO.

Estimates for all the Delta river inflows and Delta diversions (including SWP/CVP) from CalSim II are used to drive the DSM2-Hydro and QUAL for estimating tidally-based flows, stage, velocity, and salt transport within the estuary. The results from CalSim II and DSM2 are used to inform the understanding of the overall effects of the CWF including changes in water supply, water quality and water levels in the Delta.

CalSim II uses ANN models to estimate salinity at selected compliance stations in the Delta estuary. The ANN models are used to describe simplified flow-salinity relationships to determine water operations suitable for operating to D-1641. The ANN models are calibrated based on detailed hydrodynamics and salinity modeling of the Delta using the DSM2. All operational scenarios modeled for purposes of this hearing make the same climate change assumptions. Because the assumptions are the same, climate change is not a variable that will be expected to affect the comparison of results.

C. APPROPRIATE USE OF MODELS

CalSim II and DSM2 results are appropriately used comparatively. Because CalSim II relies on generalized rules, a coarse representation of the project operations, adjusted hydrologic conditions to reflect future demands and land use, and no specific operations in response to extreme events, results should not be expected to exactly match what operators might do in a specific month or year within the simulation period. In reality, the operators would be informed by numerous real-time considerations such as salinity monitoring.

When comparing CalSim II results to historical information, it is important to note major changes to the system have occurred such as facilities coming on line, availability of Trinity Basin water, growth in demands, changes in land use, and changes in regulatory requirements such as the 2008 USFWS and 2009 NMFS BiOps. Any such comparisons should involve similar conditions. Even with similar facility, land use, demands, and regulatory conditions, differences would be expected due to specific actions in response to real-time events, such as levee failures, gate operations, Delta tides, and facility outages.

One noteworthy difference in the current modeling is that CalSim II results show that the September upstream reservoir releases are consistently lower in the drier years compared to the historical values. Although there are detailed model inputs and assumptions, the CalSim II results may differ from real-time operations given that not all of the regulatory requirements (e.g. upstream temperature requirements, reservoir release ramping rates, etc.) or real-time operational adjustments to Shasta operations are modeled in CalSim II.

The upstream reservoir releases in real-time are determined based on many factors such as available cold water pool within the reservoirs, In-Basin use including Delta flow requirements, forecasted hydrology, and unforeseen demands, among other factors. Many of the factors involve day-to-day decision-making by the SWP/CVP operators taking into account the recommendations from many of the decision-making/advisory teams such as the Sacramento River Temperature Task Group (SRTTG), Water Operations Management Team (WOMT), b2 interagency team (B2IT), and American River Operations Group, to name a few. These real time operations decisions based on the input and recommendations listed above do not follow a precise operation pattern that can be implemented into CalSim II. Therefore, CalSim II does not take into account all of the factors identified above given that it includes a generalized representation of the likely long-term operations.

Delta SWP/CVP diversions in CalSim II are a function of many factors including physical pumping capacities, health and safety pumping requirements, south-of-Delta allocations, monthly demand patterns, available SWP/CVP Delta diversion capacities considering regulatory and operational constraints, and the San Luis rule curve (rule curve). The rule curve is an input to CalSim II that provides a target storage each month that is dependent on south-of-Delta allocation and upstream reservoir storage. The rule curve allows CalSim II to emulate judgment of the operators in balancing the north-of-Delta and south-of-Delta storage conditions. The rule curve could differ depending on the available SWP/CVP Delta diversion capacity during winter and spring months and the need to protect upstream carryover storage in the fall months. In the absence of any other operating criteria controlling the upstream reservoir releases or the Delta SWP/CVP diversions, different rule curves can result in differences in upstream reservoir release patterns and SWP/CVP Delta diversions.

When system wide storage levels are at or near dead pool, also described as stressed water supply conditions, the CalSim II model results should only be an indicator of stressed water supply conditions and should not necessarily be understood to reflect actually what would occur in the future under a given scenario.

Appropriate use of model results is important. While there are certain components in the model that are downscaled to a daily time step (simulated or approximated hydrology), the results of those daily conditions are always averaged to a monthly time step. As an example, a certain number of days with and without the action is calculated and the monthly result is calculated using a day-weighted average based on the total number of days in that month. However, ultimately model operational decisions based on those components are made on a monthly basis. Therefore, the use of sub-monthly results of CalSim II should be used with caution.

Because it is a simulation, based on a combination of historical hydrology, the current regulatory environment and projected changes to the hydrology due to climate change, CalSim II cannot be calibrated and therefore, should not be used in a predictive manner. CalSim II results are intended to be used in a comparative manner, which allows for assessing the changes in the SWP/CVP system operations and resulting incremental effects between two scenarios. The model should be used with caution where absolute results are needed in instances such as determining effects based on a threshold, prescribing seasonal operations, or predicting flows or water deliveries for any real-time operations.

In summary, the CalSim II and DSM2 results should only be used comparatively. As explained in the RDEIR/SDEIS:

> Understanding the uncertainties and limitations in the modeling and assessment approach is important for interpreting the results and effects analysis, including assessment of compliance with water quality objectives. … In light of these limitations, the assessment of compliance is conducted in terms of assessing the overall direction and degree to which Delta chloride would be affected relative to a baseline, and discussion of compliance does not imply that the alternative would literally cause Delta chloride to be out of compliance a certain period of time. In other words, the model results are used in a comparative mode, not a predictive mode.

Executed on 27 day of May, 2016 in Sacramento, California.

(SWRCB-3, Appendix 8G.1, Chloride Methodology.) Because of the technical limitation of the models, they cannot reliably predict specific operations. The models should only be used to estimate trends in a comparative framework.

D. INCORPORATION OF THE EFFECTS OF CLIMATE CHANGE AND SEA LEVEL RISE

Climate and sea level changes are incorporated into the CalSim II model in two ways: changes to the input hydrology and changes to the ANNs to reflect a modified flow-salinity relationship in the Delta due to sea level rise. The application of climate information in the CWF modeling represents the best science available at the time, and the methods for application in CWF modeling were developed in conjunction with DWR, Reclamation, USFWS, and NOAA Fisheries technical staff. The input hydrology and sea level rise assumptions that represent 2025 climate change conditions are consistent with the methodology described in SWRCB-4, Appendix 5A. All operational scenarios modeled for purposes of this hearing make the same climate change assumptions. Because the assumptions are the same, climate change is not a variable that will be expected to affect the comparison of results.

II. MODELING SCENARIOS

In order to evaluate the effects of CWF under a range of operational and regulatory conditions, several modeling scenarios were prepared to inform decision-making and disclosure of effects. These include four CWF scenarios:

- Boundary 1
- Boundary 2
- H3 –Initial Project Operational Range
- H4 – Initial Project Operational Range

Each of the scenarios with the CWF facilities and operations is compared to the NAA base case to evaluate areas in which the project changes conditions and the seasonality and magnitude of such changes. The change in hydrologic response or system conditions is important information related to water-dependent resources in the Sacramento and San Joaquin River watersheds.

Each of the scenarios is briefly described below and key assumption differences are summarized in Exhibit DWR-515. Each of the CWF scenarios includes the 9,000 cfs north Delta diversion facility and associated operations.

A. NO ACTION ALTERNATIVE

The NAA simulation includes the existing infrastructure, existing regulatory restrictions including the recent Biological Opinions, future demands, climate, and sea level rise at about year 2025 and reasonably foreseeable facilities and operational rules. This base case model has a similar intent to the NEPA NAA in the EIR/EIS and it is being referred to as the NAA; however, this model has been updated since the original EIR/EIS NAA modeling in April 2010. Both scenarios incorporate the effects of climate change and sea level rise based upon an Early Long Term (ELT) climate scenario that was developed around projected future conditions for the year 2025. Modeling performed for the NAA shows how the current project facilities would perform in comparison to the CWF facilities with similar base assumptions.

B. CWF CHANGE IN POINT OF DIVERSION BOUNDARY SCENARIOS

As described in Ms. Pierre's Testimony, two boundary scenarios were developed for purposes of disclosing effects under a wide range of operational and regulatory assumptions. (Exhibit DWR-51.) These boundary scenarios should not be considered as the proposed operational range of the CWF, but reflect bookends to illustrate the effects on other legal uses of water.

Boundary 1 reflects a condition of less regulatory restriction on operations than the NAA. In this scenario, Delta outflow objectives are set per the D-1641 requirements. The Fall X2 and San Joaquin River inflow-export components from the Biological Opinions are not included in this scenario.

Conversely, Boundary 2 reflects a condition of significantly increased delta outflow targets and increased restrictions on south delta exports as compared to the NAA. The assumptions for this scenario were guided by SWRCB staff. In this scenario, Delta outflow targets are significantly increased throughout the year, but particularly during winter and spring. More restrictive requirements were set for Old and Middle River (OMR) flows throughout the year that limit south Delta pumping substantially during January through June, and also impose further restrictions during July through December. In addition, modeling for Boundary 2 includes a fully-closed Head of Old River Gate during spring months which further reduces the amount of San Joaquin River water entering Old and Middle Rivers.

C. CWF INITIAL OPERATIONAL RANGE SCENARIOS

The CWF includes a range of initial operational criteria known as H3 and H4. These scenarios include similar or more restrictive operational assumptions for Delta outflow and OMR flows than the NAA. In both H3 and H4 scenarios, the San Joaquin River inflow-export component of the NMFS Biological Opinion is replaced with more restrictive OMR flow requirements that have been developed in consultation with fishery agencies. Scenario H3 includes D-1641 and Fall X2 outflow requirements, while scenario H4 increases the Delta outflow requirements beyond those in H3 during March through May.

III. MODELING RESULTS

CalSim II modeling simulations were developed for the NAA and the four CWF scenarios. This testimony presents and describes the results of the CalSim II scenario modeling, showing changes in water deliveries to CVP and SWP contractors, delta exports, and reservoir storage.

A. WATER CONTRACTOR DELIVERIES

CalSim II simulates water deliveries to CVP, SWP, and other water right holders throughout the Sacramento and San Joaquin Valleys. Water deliveries to CVP Sacramento River Settlement Contractors and CVP north of Delta federal wildlife refuges are shown in Figure 2 and Figure 3, respectively. (Exhibit DWR-514, pp. 5-6.) As shown in the figures, these CVP water deliveries are essentially unchanged in the CWF scenarios compared to the NAA. Long-term average deliveries to these contractors are essentially identical to NAA. Critical year type deliveries differ by less than 1 percent.

Water deliveries to CVP Exchange Contractors and CVP south of Delta federal wildlife refuges (firm level 2 demand) are shown in Figure 4 and Figure 5, respectively. (Exhibit DWR-514, pp. 7-8.) As shown in the figures, these south of Delta water deliveries are essentially unchanged in the CWF scenarios compared to the NAA. Long-term average deliveries to these contractors are identical to NAA. Critical year type deliveries refuges differ by less than 0.5 percent.

Water deliveries to SWP Feather River Service Area contractors are shown in Figure 6. (Exhibit DWR-514, p. 9.) As shown in this figure, deliveries to these SWP contractors are similar in the CWF scenarios compared to the NAA. Long-term average deliveries to these contractors are equal or higher with critical year type increases of less than 5 percent.

The SWP and CVP also deliver project supply to agricultural and municipal and industrial water contractors both north and south of the Delta. The deliveries to these contractors vary considerably from year to year and are based on reservoir storage conditions, hydrology, regulatory conditions, and the operational capability of the SWP and CVP. Deliveries to these contractors are particularly sensitive to changes in facility operations and/or regulatory requirements placed on the SWP or CVP.

Figures 7 and 8 show the deliveries to CVP north of Delta Agricultural Water Service and Municipal and Industrial Water Service contractors, respectively. (Exhibit DWR-514, pp. 10-11.) As shown in these figures, long-term average deliveries to CVP north of Delta water service contractors is increased under all CWF scenarios as compared to the NAA. Deliveries to these contractors are increased for all water year types under the Boundary 1, H3, and H4 scenarios. Under the high outflow Boundary 2 scenario, deliveries to these contractors are reduced in dry and critical years, as compared to the NAA, by less than 5 percent.

Figure 9 shows the deliveries to SWP north of Delta contractors. (Exhibit DWR-514, p. 12.) As shown in this figure, long-term average deliveries and dry and critical year type deliveries to SWP north of Delta contractors are increased under all CWF scenarios as compared to the NAA. Under the Boundary 1 scenario, deliveries to these contractors are improved for all water year types. Under H4 and, to a lesser extent, Boundary 2, deliveries to these contractors are reduced in wet, above normal, and below normal year types by less than 4 percent due to increased releases for Delta outflow from Lake Oroville.

The majority of the project water service deliveries of the SWP and CVP are to contractors south of the Delta. Annual south of Delta SWP and CVP demands exceed 6 million acre-feet. However, full delivery to these contractors has rarely been provided historically, and under the current regulatory assumptions in the NAA full contract delivery will be increasingly unlikely. Figure 10 shows the simulated combined SWP and CVP deliveries to south of Delta water service contractors. (Exhibit DWR-514, p. 13.) As shown in the figure, deliveries to these contractors are highly sensitive to operational and regulatory assumptions. Simulated long-term average deliveries range from approximately 1,100,000 acre-feet higher (a 34 percent increase) under the Boundary 1 scenario to 1,100,000 acre-feet lower (a 33 percent decrease) under the Boundary 2 scenario, as compared to the NAA. For all year types, scenarios H3 and H4 fall between Boundary 1 and Boundary 2 scenarios.

B. SWP AND CVP DELTA EXPORTS

Delta exports is a useful metric to evaluate broad changes in SWP and CVP water delivery capability or reliability. CalSim II simulates delta exports as a function of upstream releases, water entering the delta, delta outflow requirements, export limits, water quality requirements, gate operations, south of delta storage levels, demands, and other operational considerations. Under high outflow requirements, restrictive OMR flow requirements, and other export restrictions, SWP and CVP delta exports are reduced. Conversely, under more flexible operations that permit upstream releases or surplus supplies to be transferred to San Luis Reservoir or south of delta demands, SWP and CVP delta exports are increased.

Figure 11 shows the simulated SWP and CVP delta exports for all years as an exceedance plot. (Exhibit DWR-514, p. 14.) The boundary scenarios, Boundary 1 and 2, provide a broad range of delta exports ranging from an export reduction (in Boundary 2) of about 1,100,000 acre-feet per year (24 percent decrease) to about 1,200,000 acre-feet per year (in Boundary 1) higher exports (25 percent increase) as compared to the NAA. The CWF proposed operational range scenarios, H3 and H4, reflect a more modest range of roughly equivalent to the NAA to about 500,000 acre-feet per year increase (10 percent increase) as compared to the NAA. Under scenarios H3 and H4, delta export increases occur primarily during wetter year types and wet hydrologic conditions.

C. SWP AND CVP RESERVOIR STORAGE

End of September SWP and CVP reservoir storage is another useful metric to evaluate changes in SWP and CVP operations. CalSim II simulates storage in the major SWP and CVP reservoirs as a function of instream flow requirements, upstream water rights, water service contractor allocations, delta flow and salinity requirements, reservoir rule curves, south of delta storage levels, and other operational considerations. CalSim II modeling attempts to maintain minimum end of year storage levels in each major reservoir based on operator input. However, under the most extreme (dry) hydrologic conditions, these levels are not always attainable in CalSim II modeling due to competing water right or regulatory flow needs downstream of these reservoirs. Under real-time operations, operators have greater flexibility than that included in the modeling. As such, the appropriate use of the modeling is to compare storage volume outcomes across the scenarios.

End of September (EOS) storage volumes are shown for Shasta, Oroville, Folsom, and Trinity Reservoirs in Figures 12 through 15. (Exhibit DWR-514, pp. 15-18.) Simulated EOS storage conditions at Shasta, Oroville, and Trinity Reservoirs under the CWF scenarios are similar or higher than the NAA conditions across the entire range of hydrologic conditions. Boundary 1 and Boundary 2 scenarios result in the highest carryover storage levels due to greater flexibility in operations (Boundary 1) and substantially reduced export capability (Boundary 2), while scenarios H3 and H4 are more similar to NAA. Scenarios H3 and H4 are similar to NAA primarily due to similar Delta outflow requirements. Simulated EOS storage conditions at Folsom Reservoir are similar or higher than the NAA for the lower half of years (reflected in the left half of Figure 14, and below 450,000 acre-feet carryover storage). (Exhibit DWR-514, p. 17.) Higher EOS storage occurs in the Boundary 1 scenario for the entire range of hydrologic conditions due to the lower fall outflow needs and greater operational flexibility in this scenario. At EOS storage levels greater than 500,000 acre-feet, scenarios Boundary 2, H3, and H4 result in slightly decreased carryover storage.

IV. CALSIM II MODELING CONCLUSIONS

CalSim II modeling was performed for a range of CWF scenarios to characterize and analyze the operational changes in water operations in the SWP and CVP systems under a range of conditions. CalSim II represents the best available model of SWP and CVP operations and comprehensive hydrology of the Central Valley. The model and results presented in this testimony reflect the outcome of the recent refinements of the CalSim II and DSM2 models. While the models reflect the best available analytical tools for this evaluation, the models are necessarily mathematical simplifications of the physical system and operational decisions. Therefore, the appropriate use of the CALSIM II and DSM2 models is through comparison of one or more model simulations to a reference simulation. The results for water deliveries, SWP and CVP exports, and reservoir storage have been presented four CWF scenarios and compared to the NAA scenario.

The results from the CalSim II modeling suggest the following conclusions:

- Water deliveries to CVP and SWP contractors, including Settlement Contractors, Exchange Contractors, Refuge Level 2, and Feather River Service Area Contractors, are provided at the same level as the NAA under all CWF scenarios. There were no substantial differences in the simulated long-term average deliveries to these contractors, and maximum decreases in critical years were less than 1 percent.
- Simulated long-term average deliveries to CVP and SWP north of Delta water service contractors were similar or higher than NAA under most CWF scenarios. Reduced deliveries to these contractors did result under the Boundary 2 and H4 scenarios for some year types due to changing Delta outflow objectives under these scenarios. Year type reductions were always less than 5 percent.
- Model simulations suggest significant changes in south of Delta deliveries to SWP and CVP water service contractors. The boundary scenarios reflect a range of a 34 percent increase to a 33 percent decrease in deliveries to these contractors.
- CalSim II modeling suggests a broad range of changes in long-term average SWP and CVP delta exports under the boundary scenarios; roughly 1,200,000 acre-feet per year increase to 1,100,000 acre-feet per year decrease. Simulated SWP and CVP delta export increases under the CWF initial project operational range is from essentially from no change compared to NAA to a 10 percent increase over NAA.

- Simulated reservoir EOS storage levels in major SWP and CVP reservoirs are similar or higher than the NAA under CWF scenarios for the range of storage levels of concern. Slightly lower storage levels are simulated at Folsom Reservoir for EOS volumes above 500,000 acre-feet.

Modeling results for delta salinity and water levels simulated from the DSM2 model are included in Dr. Nader-Tehrani's separate testimony.

Executed on this 31 day of May, 2016 in Sacramento, California.

Armin Munévar