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STATE WATER RESOURCES CONTROL BOARD

PUBLIC WORKSHOPS AND REQUEST FOR INFORMATION: COMPREHENSIVE (PHASE 2) REVIEW AND UPDATE TO THE BAY-DELTA PLAN

Workshop 1: Ecosystem Changes and the Low Salinity Zone

Written Submittal of Walter Bourez, MBK Engineers

On behalf of Sacramento Valley Water Users And Northern California Water Association

1. I am a civil engineer registered in the State of California (California registration no. 54794). I am a principal with the firm MBK Engineers ("MBK"). The focus of my practice is surface water modeling within the watersheds tributary to the Bay-Delta. I have worked extensively with the CalSim II model and its predecessors. A fundamental aspect of my practice is interpreting and analyzing data concerning the Bay-Delta watershed's hydrology. A true and correct copy of my resume is attached hereto as Exhibit 1.

2. I participated in the proceedings that preceded State Water Board's issuance of the August 3, 2010 report entitled "Development of Flow Criteria for the Sacramento-San Joaquin Delta Ecosystem" ("2010 Delta Flow Criteria Report"). Following issuance of that report, I prepared two additional analyses: (a) Memorandum dated December 15, 2011 Relating Delta Smelt Index to X2 Position, Delta Flows, and Water Use ("December 2011 MBK Memo"); and (b) Report dated April 25, 2012 entitled "Evaluation of Potential State Water Resources Control Board Unimpaired Flow Objectives" ("April 2012 MBK Report"). The December 2011 MBK Memo is attached hereto as Exhibit 2 and the April 2012 MBK Report is Exhibit 3. (The

Sacramento Valley Water Users also submitted these reports with the group's April 25, 2012 scoping comments.)

3. The State Water Board's Notice of Public Workshops dated June 22, 2012 at page 4 identifies two key issues for Workshop 1. The focus of my presentation for Workshop 1 is on the following portions of the questions that the State Water Board identified as key issues for this Workshop:

> What additional scientific and technical information should the State Water Board consider to inform potential changes to the Bay-Delta Plan relating to ecosystem changes and the low salinity zone that was not addressed in the 2009 Staff Report and the 2010 Delta Flow Criteria Report? . . . What is the level of scientific certainty or uncertainty regarding the foregoing information?

Specifically, my presentation will address the following key points:

- To the extent there is a relationship between the health of pelagic fish in the Delta and the location of the low salinity zone, it is highly uncertain whether the location of the low salinity zone can be positioned with sufficient precision through modification of Sacramento River flow objectives in order to generate specific benefits for Delta pelagic fish. This uncertainty stems in large part from the strong influence of the tides on Delta flows and water quality and the general variability of Delta hydrology. (See paragraphs 4 through 14 below.) Given the risks to many other beneficial uses associated with new Delta flow objectives, the State Board should be very cautious in setting objectives intended to position the low salinity zone in specific locations.

- There is no correlation between water use in the Sacramento Valley and the recent decline in pelagic fish populations in the Delta. (See paragraphs 15 through 17 below.)
- Post-2010 hydrologic modeling shows that adoption of new water quality objectives for the Bay-Delta based on percentages of unimpaired flow would cause severe hydrologic and ecosystem impacts. (See paragraphs 18 through 22 below.)
- In considering new water quality objectives for the Bay-Delta, the State Water Board should focus on how to manage the system as a whole for the maximum benefit of all beneficial uses. The State Water Board should not develop new flow objectives based solely on the needs of fish in the Delta and then seek to determine the impacts of such objectives on other beneficial uses. Instead, the State Water Board should carefully consider the mutually-dependent ecosystem and water-supply benefits that are created by existing irrigation water use in the Sacramento Valley and the potential impacts of new water quality objectives on the beneficial uses that currently are supported by that irrigation water use. (See paragraphs 22 through 27 below.)

There Is A High Degree of Uncertainty About the Precision With Which The Low Salinity Zone Can be Positioned To Achieve Specific Fishery Benefits.

4. The first part of my presentation concerns the high degree of uncertainty involved in attempting to use Delta streamflow requirements to position the low salinity zone to generate specific benefits for pelagic fish.

5. Hydrodynamic and water quality conditions in the Delta are heavily influenced by the tides. The daily tidal flow of water in the western Delta normally exceeds net Delta outflow by at least an order of magnitude. For example, the Department of Water Resources' 1995 Sacramento San Joaquin Delta Atlas indicates that the average flow of each of the two daily tides at Chipps Island is about 330,000 to 340,000 cubic feet per second (cfs), while summer Delta outflows generally average on the order of 5,000 to 10,000 cfs. Exhibit 4 is a copy of page 21 from that Atlas (available at http://baydeltaoffice.water.ca.gov/DeltaAtlas/03-Waterways.pdf) that depicts these tidal influences.

6. During Workshop 1, I will present a publicly-available computer-generated animation that graphically illustrates the point described in paragraph 5 above. (This animation is available at MBK's website in .avi format at ftp://ftp.mbkengineers.com/outgoing/SWRCB/tidalflows.avi. A copy of the animation also is being delivered to the State Water Board. Please contact me if assistance is necessary to view the animation.) This animation was developed by John DeGeorge of the consulting engineering firm RMA applying their RMA Bay Delta model that utilizes data from the United States Geological Survey and other generally accepted

sources. I have reviewed the animation and, in my opinion, it is an accurate depiction of the relative magnitudes of tidal flows in comparison to Delta net flows.

7. The Bay-Delta experiences two tides, of different magnitudes, each day. The times and amplitudes of Delta tides are influenced by the alignments of the sun and moon, and are different every day of the year. In the western Delta, the twice daily movement of water associated with the tides is approximately 9 km (5.5 miles). This tidal action causes a great deal of dispersion, or mixing, of salt water with fresh water.

8. To the extent there is a relationship between the health of pelagic fish in the Delta and the location of the low salinity zone, it is highly uncertain whether the location of the low salinity zone can be positioned with sufficient precision through modification of Sacramento River flow objectives in order to generate specific benefits for Delta pelagic fish. This uncertainty stems in large part from the strong influence of the tides on Delta flows and water quality and the general variability of Delta hydrology. Because of these factors, the precise location of X2 is not measured by any gage. Instead, X2 is estimated through: (a) regressions between estimated X2 locations and net Delta outflow; and (b) linear interpolation of data from water quality gages in the Delta. The data indicating X2's estimated location, as calculated through regression equations based on calculated Delta outflow, are available at: http://www.water.ca.gov/dayflow/output/. The California Data Exchange Center ("CDEC") data indicating the estimated location of X2 through interpolation of water quality data are available at: http://cdec.water.ca.gov/cgi-progs/queryDaily?s=cx2&d=today.

9. DAYFLOW is a commonly used data set for Delta flows and includes estimates of the position of X2 from water year 1996 through the present. In this data set, the estimated X2 location is based on an equation that attempts to relate calculated Delta outflow to X2 position. Many of the analyses performed that attempt to determine the relationship between X2 and habitat and fish populations use a value of X2 that is derived from this relationship of X2 with Delta outflow. For example, the U.S. Environmental Protection Agency used this type of X2 estimate in relating X2 position to the size of the low salinity zone on pages 52 through 56 of its February 2011 Unabridged Advanced Notice of Proposed Rulemaking for Water Quality Challenges in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (available at http://www.epa.gov/sfbay-delta/pdfs/BayDeltaANPR-fr_unabridged.pdf).

10. In 2007, the CDEC began posting X2 values that are based not on flow data, but rather that are calculated by linear interpolation of water quality data from different Delta sampling stations. I compared flow-based X2 values listed in DAYFLOW to the water quality-based values listed by CDEC and found significant differences. Exhibit 5 depicts daily flow-based and water quality-based estimates of X2 position from January 2007 through October 2011. The water quality-based X2 values vary significantly from the flow-based X2 values. The two estimates often are several kilometers apart and sometimes are up to 15 kilometers apart. These differences highlight the fact that the precise location of X2 is not known and can only be estimated. Moreover, due to the dynamic nature of the Delta, there is no reliable way to determine the precise location of X2 at any given point in time.

11. This fact is particularly important in light of the Delta’s changing physical characteristics. In recent decades, a great deal of sediment deposited in the Delta by upstream hydraulic mining in the 1800's has eroded away. (See, e.g., Cappiella et al., "Sedimentation and Bathymetry Changes in Suisun Bay: 1867-1990," USGS Open File Report 99-563 (http://geopubs.wr.usgs.gov/open-file/of99-563/of99-563.pdf); Hestier et al., "An Observed Step Change in River Delta Turbidity Following 1982-1983 El Nino Floods," American Geophysical Union, Fall Meeting 2010, abstract #H43E-1310 (http://www.cstars.ucdavis.edu/?page_id=2354).) As a result of outflows of this debris, the bathymetry of the Delta has changed in recent times. Specifically, the deep channels in Suisun Bay have deepened since the 1980’s and 1990’s. These changes, in turn, would have caused changes in the relationship between Delta outflow and salinity because physical changes in the Delta's channels affects how salt water under tidal influence flows in and out of the Delta. Flow-based estimates of X2’s location that do not account for physical changes in the Delta during the period to which the estimates apply do not accurately depict the Delta’s evolving hydrodynamics and have a high degree of uncertainty with respect to the actual location of the low salinity zone.

12. There have been significant differences in hydrology over the historical period of record during which pelagic fish populations have been measured. The 1956-1987 period, which is often used as a baseline for evaluating those populations, was a wet period with higher Delta outflows, particularly in comparison with the 1988-2010 dry period during which those populations declined. Based on information available in DWR's 2006 report *California Central Valley Unimpaired Flow Data, Fourth Edition*,

the difference in average spring unimpaired Delta outflows between the wet 1956-1987 period and the dry 1988-2010 period was approximately 1,500,000 acre-feet per year. Exhibit 6 is an exceedance chart comparing unimpaired Delta outflow for various periods and notes differences in these flows. In my opinion, it would be physically impossible to replicate 1956-1987 hydrologic and water quality conditions through regulatory requirements that attempt to replicate 1956-1987 average streamflows because water quality conditions such as turbidity that are created by high runoff would not be re-created by high reservoir releases that seek to mimic the same level of streamflows.

13. An additional level of uncertainty is added by the lack of a demonstrable relationship between the calculated position of X2 and pelagic fish populations. Publicly available data concerning the flow-based calculation of X2 and delta smelt populations do not indicate that there is any strong relationship between those two sets of data. These data are available at: http://www.water.ca.gov/dayflow/output/ and http://www.dfg.ca.gov/delta/data/fmwt/charts.asp. They indicate that low delta smelt populations have occurred in years with relatively high Delta outflows (i.e., low X2). These years are, among others, 1982 through 1984. Conversely, high delta smelt populations have occurred in years with relatively low Delta outflows (i.e., high X2). These years are, among others, 1993, 1999 and 2000. Based on publicly available data, Exhibit 7 depicts the average flow-based estimate of X2's position during the September-November period from 1930 through 2010 and the Delta smelt index for the period 1967 through 2010.

14. In summary, there is a high degree of uncertainty associated with any attempt to generate any fishery benefits by positioning the low salinity zone through modified flow objectives. In addition, publicly available data does not indicate a strong relationship between the calculated position of X2 and pelagic fish populations.

There is No Correlation Between Water Use in the Sacramento Valley And the Decline in Delta Pelagic Fish Populations.

15. The second category in my presentation concerns conditions in the Sacramento Valley that are related to the State Water Board's consideration of possible changes to the provisions of the Bay-Delta Plan concerning the low salinity zone that were not addressed in the 2010 Delta Flow Criteria Report.

16. Publicly available information indicates that, while the hydrology of the Delta watershed has varied over the last several decades, the percentage of unimpaired runoff that flows from the Sacramento Valley to the Delta during the January-June period has changed very little since the 1950's. Exhibit 8 shows the percentage of unimpaired Sacramento River flow that flowed to the Delta during the 1956-1968, 1969-1979, 1980-1989 and 1990-2003 periods. Exhibit 8 is based on data available in DWR's 2006 report *California Central Valley Unimpaired Flow Data, Fourth Edition*. As Exhibit 8 shows, the percentages of unimpaired Sacramento River flow to the Delta have changed very little from the 1950's and 1960's, when the Delta's pelagic fish populations generally were viewed as healthy, through the decades to the present.

17. Similarly, publicly available information indicates that there is little relationship between water use in the Sacramento Valley and populations of pelagic fish species in the Delta (delta smelt, longin smelt, splittail, threadfin shad and striped

bass). The relevant fishery data is publicly available at: http://www.dfg.ca.gov/delta/data/fmwt/charts.asp. Based on the 1967-2009 Delta Smelt Index data and data concerning irrigated acreage in the Sacramento basin available from DWR, the December 2011 MBK Memo demonstrates that the Sacramento Valley's irrigated acreage has been essentially constant since the late 1970s, while certain pelagic fish populations including delta smelt and longfin smelt have varied and declined dramatically over the same period. Exhibit 9 summarizes this information.

Adoption of New Flow Objectives Based on Unimpaired Flow Would Result In Severe Hydrologic and Ecosystem Impacts.

18. The third category in my presentation concerns the severe hydrologic and ecosystem impacts that would result from the State Water Board's adoption of water quality objectives for Delta flows based on percentages of unimpaired flow. Specifically, the April 2012 MBK Report (submitted as Exhibit 3) presents the results of modeling the hydrological impacts of implementing new Delta outflow and Sacramento River flow objectives based on: (a) 50% of unimpaired Delta outflow from January through June; and (b) 40% of unimpaired Delta outflow from January through June.

19. As the April 2012 MBK Report discusses in detail, the impacts of each of these scenarios on Central Valley Project and State Water Project reservoirs and operations would be severe, and would result in an inability to maintain viable operations. In lay terms, flow objectives of this magnitude would break the system, causing, among other impacts, significant reductions in the cold water pools in CVP

and SWP reservoirs that resource agencies have determined are key to maintaining appropriate conditions for the Sacramento Valley's salmon populations.

20. Understanding ongoing efforts in the Sacramento Valley to improve conditions for salmon and steelhead is crucial here. Since the decline in pelagic fish populations in the Delta that occurred in the early 2000's, the regulatory requirements for streamflows in the Sacramento Valley's major rivers have been revised to improve conditions for salmon and steelhead. These rivers are all governed by streamflow requirements, many of which have been implemented since 2006. The State Water Board itself has approved many of those requirements. Specifically:

- The upper Sacramento River is governed by, among other requirements, State Water Board Orders 90-5 and 91-01, and the 2008 USFWS biological opinion and the 2009 NMFS biological opinion;
- The Feather River is governed by the Clean Water Act section 401 water quality certification that the State Water Board adopted in 2010 in connection with the relicensing of the Oroville project (FERC Project No. 2100);
- The Yuba River is governed by the Yuba River Accord's streamflow requirements that the State Water Board adopted in its Corrected Order WR 2008-0014; and
- The American River is governed by the Water Forum flow management standard, as incorporated into the 2009 NMFS biological opinion.

21. Each of these sets of requirements includes measures intended to provide appropriate downstream water temperatures to support Chinook salmon and

steelhead. As discussed in more detail below, however, new Delta streamflow requirements based on percentages of unimpaired flow, if implemented, would adversely affect cold-water pool management in the Sacramento Valley's reservoirs and the operators' abilities to implement these instream flow requirements.

22. As detailed in the April 2012 MBK Report, the effects of implementing January through June minimum monthly Delta outflow requirements of 50% and 40% of unimpaired flows would be:

- Effects on CVP and SWP reservoirs and operations would be severe and would result in the inability of the CVP and the SWP to maintain viable operations.

- Based on CalSim II modeling, required increases in average annual Delta outflows would be: (i) 1,200,000 acre-feet for a 50% of unimpaired flows requirement; and (ii) 480,000 acre-feet for a 40% of unimpaired flows requirement. Exhibit 10 is based on the April 2012 MBK Report and depicts average annual changes in key system flows if a 50% of unimpaired flow were adopted.

- Based on CalSim II modeling, the following reductions and decreases in CVP and SWP reservoir carryover storage would occur: (i) significant reductions in cold water pools would occur under both the 50% and 40% of unimpaired flows scenarios; (ii) an average reduction of 2,200,000 acre-feet in reservoir carryover storage would occur under the 50% of unimpaired flow scenario; (iii) an average reduction of 1,000,000 acre-feet in reservoir carryover storage would occur under the 40% of unimpaired flows scenario. Exhibit 11 is based on the April 2012 MBK Report and contains charts showing effects on CVP and SWP reservoirs if a 50% of unimpaired flow were adopted. In particular, the cold-water pools in those CVP and SWP reservoirs often would be depleted, with such depletions occurring in multiple consecutive years during multi-year droughts. For example, under the 50% scenario, during a repeat of the 1987-1992 drought, Shasta Reservoir would be drawn down to dead pool in 1988, 1989, 1990, 1991 and 1992. Such a loss of cold-water storage would have very significant impacts on the Sacramento Valley's salmon and steelhead populations. The hydrologic analysis that Yuba County Water Agency submitted with its April 25, 2012 scoping comments indicates that similar results could occur in the Yuba basin.

- Reservoir storage is the key hydrologic factor that allows California to simultaneously (a) maintain cold water in Sacramento Valley rivers to, among other things, support salmon and steelhead; (b) make significant water-supply deliveries during California's annual dry season and its periodic multi-year droughts; and (c) generate hydroelectricity to meet peak summer and fall demands. The 40% and 50% of unimpaired flow scenarios, if implemented, would significantly reduce this stored water buffer in all years and eliminate it in many years.

- In contrast to other parts of the Central Valley, groundwater levels in the Sacramento Valley have been stable for many years because surface water has been available. In theory, substantial increases in Sacramento Valley groundwater pumping could occur to offset reductions in surface water deliveries within the valley. However, such increases in groundwater pumping actually are not realistic, given current pumping capacity and conveyance limitations. As discussed in the April 2012 MBK Report and summarized in Exhibit 10, in many critical years, there would need to be over 1,000,000 acre-feet of additional groundwater pumping to maintain current levels of water use, with that pumping reaching 1,600,000 acre-feet in some years and exceeding 1,000,000 acre-feet in multiple consecutive years in multi-year droughts. Because such levels of groundwater pumping in the Sacramento Valley are not feasible under current conditions, significant reductions in Sacramento Valley irrigated acreage would occur if either the 50% or 40% of unimpaired flows scenarios were implemented.

- Under both the 40% and 50% of unimpaired flow scenarios, there would be severe impacts to instream temperatures and habitats. As discussed in the April 2012 MBK Report, implementation of such percentages of unimpaired flows as regulatory requirements would shift significant amounts of streamflows from the summer and fall to the spring. Consequently, there would be regular and multiple violations of existing State Water Board water quality objectives and ESA Biological Opinion requirements. Based on the April 2012 MBK Report, Exhibit 12 summarizes the average changes in monthly flows at key locations in the water system that would occur if the State Water Board were to require that 50% of unimpaired flows flow through the Delta during the January-June period. Such reductions in summer and fall flows would cause reduction in salmon habitat and adverse effects to many beneficial uses of water.

- Under both the 40% and 50% of unimpaired flow scenarios, there would be severe water supply impacts including significant reductions in CVP and SWP deliveries, inability to meet public health and safety water requirements and reductions in water deliveries to wildlife refuges. These effects would all derive from the severe impacts that implementing such flow requirements would have on reservoir storage.

The State Water Board Should Seek to Build on Current Management Measures That Enable the Same Water to Serve Numerous Beneficial Uses Simultaneously.

22. The final category of my presentation concerns the functioning of the current hydrologic system, focusing on the multiple benefits provided by irrigation water use in the Sacramento Valley, and the importance of the State Water Board focusing on overall system management in considering new water quality objectives for the Bay-Delta.

23. Streamflow releases under current management measures often simultaneously serve multiple purposes. For example, summer releases from Shasta Reservoir's cold-water pool support the following beneficial uses:

- Providing cool water temperatures to support salmon present in the upper Sacramento River;
- Generating hydroelectricity that meets high summer demands;
- Meeting the Bureau of Reclamation's obligations under the CVP's Sacramento River settlement contracts and providing water supplies to CVP water-service contractors;
- Satisfying other downstream streamflow requirements, including Delta requirements; and
- Providing migratory bird habitat, particularly within the Pacific Flyway.

24. Some commenters have suggested that the ecosystem requirements of the Delta can be met if the State Water Board were to adopt a 75%, 50% or 40% of unimpaired flows scenario and the resulting water supply deficit were made up by

reducing water diversions in the Sacramento Valley. This suggestion rests on overly simplistic, and false, assumptions about how the hydrologic system in the Sacramento Valley functions. Flow requirements based on unimpaired flow generally would require higher flows during late winter and spring. Reservoirs, however, typically build storage during this period, so that reservoir storage releases can be increased to satisfy numerous beneficial uses during dry summer periods and possible future droughts. Because agricultural demands generally occur during summer months, it would not be possible to directly reduce agricultural diversions to satisfy flow requirements based on unimpaired flow. Instead, the only way to satisfy these requirements would be to reduce storage and forego development of cold water pools and supplies for drought conditions. I will discuss these issues in more detail during the State Water Board's Workshop 3. For Workshop 1, the key point is that the severe impacts that new Delta flow requirements could have on reservoir storage could not be reduced significantly simply by reducing diversions to Sacramento Valley agriculture.

25. Summertime releases from reservoir storage to the streams below the reservoirs are needed to maintain cool-water conditions that support salmon and steelhead. If reservoir releases for agricultural use were reduced in the summer period, then it would not be possible to create these favorable conditions in river reaches between the reservoirs and the diversions. Moreover, the benefits of the cool water that extends downstream of the diversions because of these releases from reservoir storage also would be lost.

26. As the system currently functions, agricultural water releases and diversions in the Sacramento Valley provide multiple benefits including benefits to

fish, waterfowl, ESA listed species (for example, the giant garter snake), hydropower, and agriculture. Reducing irrigated agriculture in the Sacramento Valley would seriously reduce these benefits while providing at most only relatively small Delta inflow and outflow benefits.

27. In my opinion, the State Water Board, in considering new water quality objectives for the Bay-Delta, should not focus solely on developing requirements for flows into and out of the Delta and then analyze the effects of such requirements on other beneficial uses merely as impacts of new Delta requirements. Instead, the State Water Board should focus on how to manage the system as a whole for the maximum benefit of all beneficial uses.

Exhibit 1

RESUME OF WALTER BOUREZ, III

EDUCATION

- California State University, Sacramento
  MS in Civil Engineering, 1995
- California State University, Sacramento
  BS in Civil Engineering, 1988

PROFESSIONAL LICENSES, SOCIETIES, and HONORS

- Registered Civil Engineer in California
- Member, American Society of Civil Engineers
- California Water and Environmental Modeling Forum, Hugo B. Fischer Award

PROFESSIONAL HISTORY

2003 - Present	Part-time faculty CSUS
2000 - Present	MBK Engineers, Sacramento, CA Principal
1996 - 1999	Surface Water Resources, Inc., Sacramento, CA Senior Water Resources Engineer
1989 - 1996	Water Resources Management, Inc., Sacramento, CA Water Resources Engineer
1987 - 1989	Boyle Engineering, Sacramento, CA Civil Engineer

PROJECT HISTORY

- Evaluation of State Water Resources Control Board Water Availability Analysis
  Completed evaluation for the State Water Resources Control Board (SWRCB) to review their method of Water Availability Analysis (WAA) for accuracy and defensibility. The SWRCB WAA is used to determine if water is available for diversion and to evaluate the potential environmental impacts due to additional appropriations. Natural flow must be determined when developing a WAA; and most streams where a WAA is needed are not gaged. Thus, natural flow is often determined using rainfall-runoff methods. This review focused on methods for estimating natural flow based on precipitation records for delineated watershed areas.

- Revising Colusa Basin and Sacramento River Representation in CalSim.
  Provide a revision to the CalSim model schematic to better represent the physical characteristics of the Colusa Basin, Stony Creek, and portions of the Sacramento River. The task included revising the model connectivity and logic that routes water through the system. A working version of the model was produced, with model development and refinement of model inputs in order to: 1. Revise depiction of agricultural demands; 2. Validate diversions and stream flows using recent historical data; 3. Revise accretions in Colusa Basin; 4. Revise representation of refuge operation.

- CVP/SWP Operations Modeling, Franks Tract EIR/EIS, DWR, Sacramento, CA.
  Developed methods to analyze how CVP/SWP operations would respond to changes in Delta salinity conditions that result from operation of a gate on Threemile Slough. Developed a water operations model to simulate changes in upstream reservoir operations, Delta exports, and south-of-Delta deliveries to support the evaluation of various project alternatives, selection of a preferred alternative, and development of environmental documentation.

- Documenting CalSim II.
  Work with USBR to design and create a document describing aspects of the CalSim II model hydrology. 1. The hydrology documentation is designed. 2. Information is incorporated into the document. 3. The documentation is enhanced. 4. The hydrology document is linked to CalSim.

- Hydrologic Support for Development of CalSim-III.
  Hydrologic analysis and support needed to improve and enhance the CalSim-II water resources planning model. The project goals are to: 1. Improve accuracy of representation of water supplies and water use; 2. Reconcile differences between CVGSM and CalSim; 3. Reduce development time for new hydrology inputs associated with new land use scenarios; 4. Represent groundwater sufficiently accurately for impact analysis and preliminary conjunctive use studies; 5. Be relatively simple, accessible, and well-documented. Performed water budgets for CalSim III to determine natural flows, water demands, and available water supply.

- Upper San Joaquin River Basin Storage Investigation.
  Served as an integral part of the team evaluating new storage in the upper San Joaquin River Basin watershed for Reclamation. Responsible for development of analytical tools and performing hydrologic analysis for reservoir operations and conjunctive management of Friant water supply. Evaluated effects of new storage on CVP/SWP water system using CalSim II.

- San Joaquin River Basin CalSim Model Development.
  Key developer of the CALSIM depiction of the San Joaquin Basin River Basin and reservoirs including New Hogan, New Melones, Don Pedro, New Exchequer, Eastman, Hensley, and Millerton Reservoirs; including operations of all water districts in the San Joaquin River Basin. Calculate stream accretions / depletion by estimating unimpaired precipitation runoff by stream reach.

- Sacramento River Basin-Wide Water Management Plan.
  Evaluation of current water use practices within the Sacramento Valley and identification of possible water management practices that could improve the overall water management. Development of a detailed evaluation of increased efficiency and associated water supply benefits within the CVP.

- Delta Risk Management Strategy.
  Developed reservoir operations model to simulate CVP/SWP system response to Delta levee breaches and changed Delta conditions. Integrated reservoir operations module with Delta hydrodynamic calculator to dynamically operate system reservoirs and revise water allocations in the CVP/SWP export area.

- Water Temperature Evaluations.
  Evaluated temperature impacts to the Sacramento, American, and Feather Rivers resulting from alternative Central Valley Project/State Water Project operations for several clients, including Sacramento County Water Agency, Sacramento Area Flood Control Agency, City of Sacramento, and the Sacramento Area Water Plan Forum. These evaluations utilized monthly output from CVP/SWP models (e.g., DWRSIM and PROSIM). Utilized temperature modeling results in Reclamation's Salmon Mortality Model to assess impacts to winter-run Chinook salmon in the Sacramento River, and Chinook salmon in the American River. Analyzed output from these model runs to determine compliance with applicable regulations and other flow, storage, and temperature criteria for the different river reaches. Also worked with clients to develop mitigation for any potential temperature impacts.

- CALFED Common Assumption.
  Assisted with development of the Common Assumptions Common Model Package being use by CALFED Surface Storage Investigation teams to complete Plan Formulation, Feasibility Study Reports, Environmental Impact Studies, Environmental Impact Reports, and other environmental documents.

- Folsom Dam and Reservoir Interim Reoperation Agreement - Sacramento Area Flood Control Agency (SAFCA).
  Performed hydrologic and temperature model simulations for the SAFCA Interim Reoperation of Folsom Dam and Reservoir Environmental Impact Report/Environmental Assessment. Primary hydrologic issues requiring consideration included changes in reservoir storage and river flows in the American River and Central Valley Project/State Water Project system. Provided technical assistance on all water supply, power analysis, and temperature studies for impact analyses.

- Sacramento Area Water Forum Plan Supplement and Environmental Impact Report - City-County Office of Metropolitan Water Planning.
  Developed modeling assumptions regarding reservoir operations and hydrologic data for all hydrologic and temperature analyses related to the Water Forum EIR. Performed all hydrologic, temperature, and salmon mortality modeling for the CVP and SWP system that was used as the basis of impact assessment for water supply, power, fisheries, riparian vegetation, recreation, and cultural resources.

- Hamilton City Pumping Plant Fish Screen Improvement Project EIR/EIS - Glenn-Colusa Irrigation District.
  Developed the water supply model to assess environmental impacts associated with project alternatives for the Hamilton City Pumping Plant Fish Screen Improvement Project. Performed the temperature and salmon mortality modeling for assessing impacts due to project alternatives.

- Long-Term Groundwater Stabilization Project EIR - Placer County Water Agency/ Northridge Water District.
  Developed hydrologic and temperature modeling assumptions and performed model simulations. Designed model simulations to investigate potential effects on fishery, riparian habitat, power supply, water-related recreation, and cultural resources along the American River and CVP system.

- Central Valley Project Water Supply Contracts EIS/EIR - Sacramento County Water Agency.
  Performed the hydrologic and water temperature modeling to determine potential impacts to the lower American River, Sacramento River, and the Delta that could result from diverting a portion of Central Valley Project Water Supply Contracts P.L. 101-514 water from Folsom Reservoir. Worked closely with SWRI fishery biologists to design the hydrologic modeling studies and to determine output needed to conduct the necessary environmental assessments.

- CALFED Bay/Delta Facilities Evaluation - California Department of Water Resources.
  Assisted the Department of Water Resources in the evaluation of potential Bay/Delta facilities, implemented either individually or in combination, as a part of the CALFED Program. Provided technical guidance by reviewing model results and evaluating changes to CVP/SWP operations including water supply, stream flow, Delta flow, groundwater and system storage.

- San Joaquin Area Simulation Model Development - U.S. Bureau of Reclamation.
  Participated in the development of the U.S. Bureau of Reclamation's San Joaquin Area Simulation Model. Researched the hydrology in the San Joaquin Valley to develop water demands, stream accretions and depletions, reservoir operation criteria, minimum stream flow requirements, and all data necessary as input to the simulation model.

- Republican River Depletion Study - Kansas Water Office.
  Participated in the Republican River Depletion Study in northern Kansas. Responsible for data and model development and selection of analytical methods. The analysis addressed the effect of increased irrigated acreage, land surface alteration for water conservation, and groundwater pumping within the basin.

- Water Operations Model Development - Eastern Irrigation District.
  Participated in the development of a water operations model for the Eastern Irrigation District in Alberta, Canada. Assisted in model development, data development, and created database interface for data manipulation and program execution.

- Central Valley Project/State Water Project Model.
  Developed the input data for Reclamation's Project Operations Model (PROSIM), and produced the first accepted base run of this model. Using PROSIM, analyzed various project alternatives for Reclamation, Sacramento County, Sacramento Area Flood Control Agency, Glenn-Colusa Irrigation District, Kern County Water Agency, State Water Contractors, Central Valley Project Water Association, and the Metropolitan Water District of Southern California.

- Central Valley Project/State Water Project Operations Alternative - Association of California Water Agencies Ag/Urban Technical Group.
  Assisted the Ag/Urban Technical Group in identifying a preferred CVP/SWP operations alternative for recommendation to CALFED. Using the DWRSIM model, prepared operation studies on multiple alternatives, including options for no new facilities, fully isolated canal water transfer facility, dual facility, and through Delta water transfer.

- Integrated Resource Planning Studies - Metropolitan Water District of Southern California.
  Performed numerous planning studies for the Metropolitan Water District of Southern California using the DWRSIM model.
  Study results were used in MWD's Integrated Resource Planning modeling effort for transfer analysis and by their State Water Project branch. DWRSIM was used to evaluate combinations of the following alternatives: South Delta Improvements, a Through-Delta Facility, Peripheral Canal, Los Banos Grandes, Kern Water Bank and others; under the following constraints: D-1485, National Marine Fisheries Service criteria for winter-run Chinook salmon, Delta smelt criteria, proposed D-1630 standards, and the December 1994 Water Quality Control Plan.

- Groundwater Model Development - California State Water Resources Control Board.
  Participated in the development of the Central Valley groundwater model for the State Water Resources Control Board. Responsible for the surface water input data and aided in the calibration and verification of the model.

- Water Transfer Analysis - Metropolitan Water District of Southern California.
  Assisted MWD by analyzing the water supply benefit and cost of potential water transfers. Analysis involved the development of a model that was used to determine probable yield and cost of potential transfers. The model was also used to provide information that aided MWD when negotiating potential transfers.

- Las Vegas Valley Water Supply Optimization Model - Southern Nevada Water Authority.
  Participated in the development of the Las Vegas Valley Water Supply Optimization Model. Responsible for all data development and network configuration and performed several training sessions for water purveyors in the use of the model. Assisted in negotiations between Las Vegas Valley water purveyors (Boulder City, Henderson, Las Vegas, North Las Vegas, the Big Bend Water District, Clark County Sanitation District, and the Las Vegas Valley Water District) which led to the formation of the Southern Nevada Water Authority.

MBK ENGINEERS
Water Resources • Flood Control • Water Rights

M E M O R A N D U M

DATE: December 15, 2011

TO: Northern California Water Association

FROM: Walter Bourez

SUBJECT: Relating Delta Smelt Index to X2 Position, Delta Flows, and Water Use

INTRODUCTION

There has recently been much interest in requiring higher instream flows through the Sacramento-San Joaquin River Delta (Delta) in an attempt to reverse the continuing decline of a number of fish species that reside in or migrate through the Delta. Last year, for instance, reports issued by the State Water Resources Control Board (SWRCB) and the California Department of Fish & Game (DFG) stated that additional flows in the form of increased Delta outflows would be needed to meet the needs of both pelagic and salmonid species. More recently, the United States Environmental Protection Agency (USEPA) issued an Advance Notice of Proposed Rulemaking, which also suggested that higher instream flows through the Delta may be necessary. These reports rely on the theory that, by increasing instream flows and restoring a more natural hydrograph, habitat conditions for the fish species in question will improve and, as a result, fish populations will also improve.

Examination of the data used in each of these reports, however, shows that there is little, if any, scientific basis for the claim that additional flows will enhance declining fish populations. Key findings are:

1. The data used to support the claim that additional flows will enhance fish populations compares a wetter period (1956-1987) with a drier period (1988-2003). This invalid comparison of periods with very different hydrology is a fundamental flaw in the claim that increasing flows through the Delta will result in increasing fish populations.

2. Moreover, the constantly changing nature of the operations of the federal Central Valley Project (CVP) and the State Water Project (SWP) during the period from 1988-2003, as well as the fact that Delta outflow requirements increased during that period, make it difficult to conclude that a lack of flows is responsible for the decline in Delta fisheries.

3. A comparison of Delta fish population with water use in the Sacramento Valley shows that there appears to be no relationship between that water use and fish populations.

Taken together, all of these factors suggest that the decline in Delta fisheries is the result of factors other than flow.

Both the SWRCB and the DFG reports advocate modifying instream flows in the Delta and its tributaries so as to more closely mimic the natural hydrograph (i.e. streamflows occurring prior to 1850). A "natural hydrograph" means that hydrology will mimic the variability that occurred prior to the construction of the CVP and SWP. This variability included both wet and dry years. Examination of the data discussed above, however, indicates that both reports are – in fact – advocating not a natural hydrograph but, rather, that the Delta and its tributaries be operated so that every year mimics a wet or above normal year. If the fundamental concept behind the "natural hydrograph" claim is correct, then it is likely that it is just as harmful to fish species for every year to be a wet year as it would be if every year were a dry year.

Lastly, examination of the hydrologic data for the Delta leads to the strong conclusion that hydrology is not destiny. The continuing decline in fish populations, notwithstanding continuing regulatory adjustments to project operations through increasing Delta outflow requirements, strongly suggest that there are other factors at play. Specifically, as described in depth by Dave Vogel in his April 2011 report entitled *Insights into the Problems, Progress and Potential Solutions for Sacramento River Basin Native Anadromous Fish Restoration*, it appears that predation (particularly by non-native species) and habitat degradation in the Delta is likely a major problem for Sacramento River basin anadromous fisheries. In addition, there may be alternative ocean harvest methods that could increase the reproductive capacity of Sacramento River basin anadromous fisheries. The data presented in this report make it clear; however, that increasing Delta outflow by means of X2 is not likely to reverse population declines in anadromous fisheries.

COMPARING HYDROLOGIC PERIODS DURING SPRING PERIODS

The SWRCB Delta Flow Report (at pages 104-106) compares average net Delta outflow for the January through June period from 1956-2009. The report then concludes that the "step-decline in the abundance X2 relationship that occurred after 1987 for many of these species . . . leads to uncertainty regarding the future response of these species to elevated flows." (p. 107). Notwithstanding this caution, the report concludes that such elevated flows "are necessary to protect public trust resources and that the current flow regime has harmed native species and benefited non-native species." (p. 108). Figure 1, below, contains "Figure 14, Net Delta Outflow Exceedance Plot – January through June" from page 106 of the SWRCB August 3, 2010 report titled: *Development of Flow Criteria for the Sacramento-San Joaquin Delta Ecosystem*, prepared pursuant to the Sacramento-San Joaquin Delta Reform Act of 2009. The line representing "Actual" flow for the 1956-1987 period is above the line representing the 1988-2009 period, indicating flow during the 1956-1987 period was greater. Average net Delta outflow during the 1988-2009 period was approximately 5,000 cfs less than during the 1956-87 period, which means that during the 1956-87 period there was approximately an additional 1.7 million acre-feet of net Delta outflow (5,000 cfs x 1.98 af/cfs x 180 days) than during the 1988-2009 period.

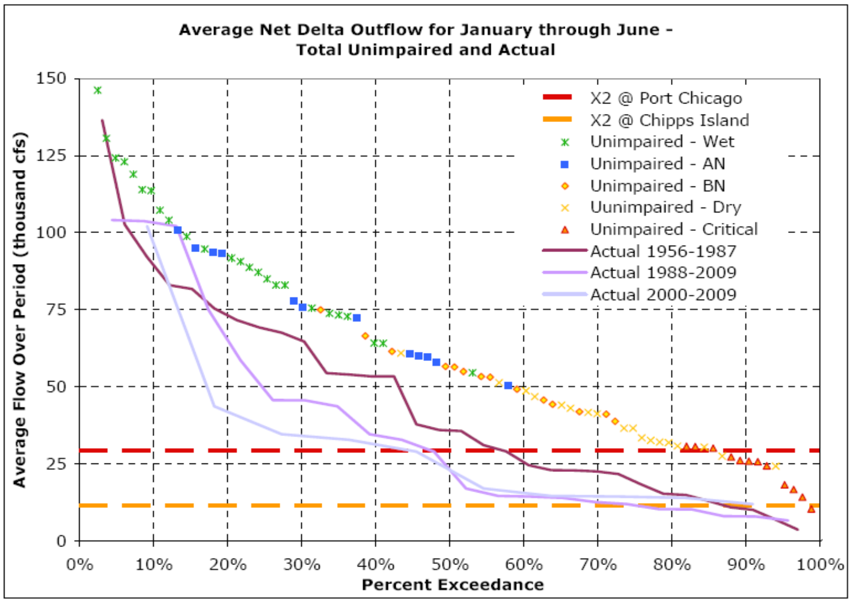


Figure 1 - Net Delta Outflow Exceedance Plot from SWRCB Report Page 106

Figure 2 shows probabilities of exceedance of historical ("actual") average Delta outflow for the DAYFLOW period of record (1930-2008) during January through June and the average Delta outflow for the periods 1930-1955, 1956-1987, 1988-2009, and 2000-2009. As in Figure 1, the 1988-2009 period is substantially drier than the 1956-1987 period.

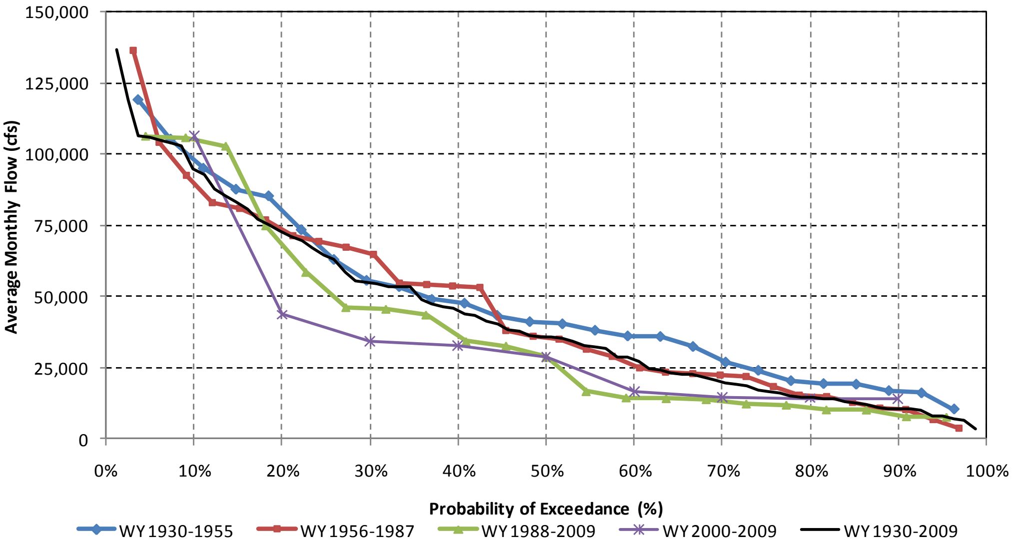


Figure 2 – Average January - June Historical Net Delta Outflow from 1930 - 2009

Figure 3 shows, for the January-June period, probabilities of exceedance of average unimpaired Delta outflow for the 1930-2003 period of record and the average unimpaired Delta outflow for those months during the component periods 1930-1955, 1956-1987 and 1988-2003. Unimpaired flow is runoff that would have occurred had water flow remained unaltered in rivers and streams instead of stored in reservoirs, imported, exported, or diverted. The data is a measure of the total water supply available for all uses after removing the impacts of most upstream alterations as they occurred over the years;

therefore, all variation in this data is due to natural causes. Although DWR has estimated unimpaired Delta outflow for the period of 1922-2003, this comparison uses the period after 1930 to be as consistent as possible with the DAYFLOW period.

Comparison of unimpaired flow for these various periods demonstrates variations due to hydrology alone, without human influence. Differences in the exceedance plots between the 1956-1987 and the 1988-2003 are solely due to natural variation in hydrology and cannot be attributed to project operations or water use.

As can be seen in the unimpaired flow chart in Figure 3, the 1956-1987 period was wetter than the average for the entire 1930-2003 period and was also generally wetter than the post-1988 period. On average, unimpaired Delta outflow during the January to June period during 1956-1987 seems generally to have been about 4,300 cfs greater than average January to June Delta Outflow during the period from 1988-2003. This means that, for the January-June period under unimpaired conditions, an average of about 1.5 million acre-feet more water would have flowed out of the Delta during the 1956-1987 period than during the 1988-2003 period. A flow difference of this magnitude can change X2 location and influence any conclusions based on this data. **Thus, the decline in the abundance-X2 relationship that occurred since 1987 is probably due, in significant part, to the fact that this period was substantially drier than the 1956-1987 period.**

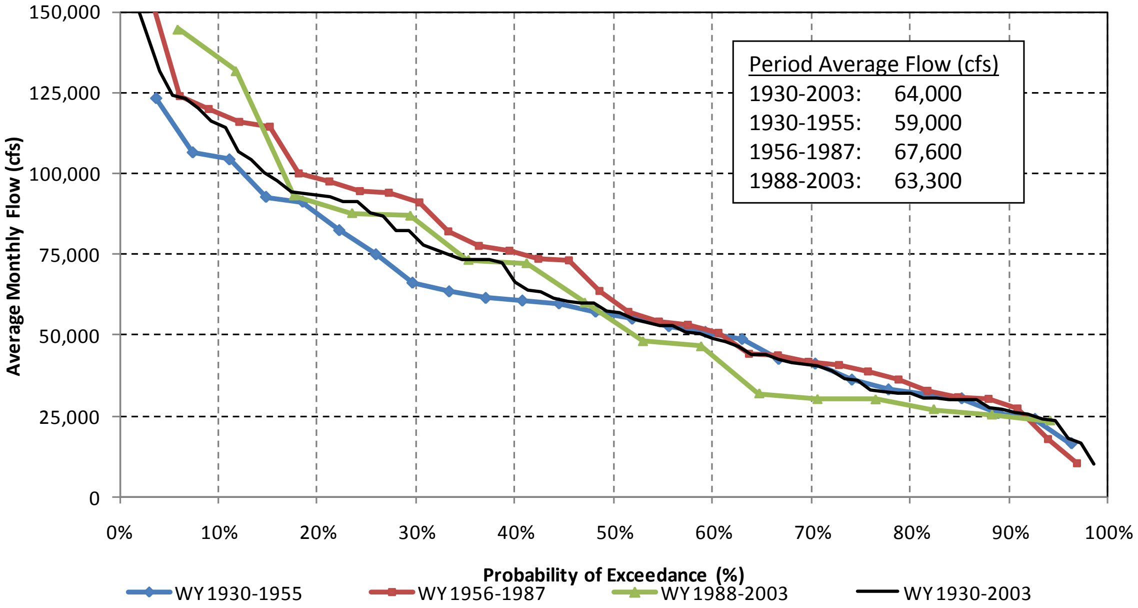


Figure 3 – Average January – June Unimpaired Net Delta Outflow from 1930 - 2003

COMPARING HYDROLOGIC PERIODS DURING <u>FALL</u> PERIODS

In discussing the proposed fall X2 action, the SWRCB Delta Flow report states that "the average position of X2 during fall has moved upstream, resulting in a corresponding reduction in the amount and location of suitable abiotic habitat." (p. 108). The report then refers to a period since 1987 and particularly since 2000 during which the fall X2 has moved upstream. (p. 109). The report continues by using data from 1960-2010 (report Figure 15) and data from 1956-2008 (report Figures 16-18). (pp. 110-112).

Again, these data seem largely to reflect the contrast between a relatively wet period from 1956-1987 and the relatively drier period since 1988. Figures 4, 5, and 6, below, compare average unimpaired Delta outflow for September, October and November, respectively. In each of those months, the period from 1956-1987 was substantially wetter than the long-term average (1930-2003) and very much wetter than the period from 1988 to 2003. Again, unimpaired flow is used for this comparison to demonstrate the differences due to hydrology alone, without human influence.

The purpose of these charts is to illustrate the importance of using representative periods when comparing fish abundance. Only if two periods being compared have the same hydrology can one attribute the increase or decline in abundance to factors other than hydrology (e.g., changes in exports, introduced species, etc.).

From a policy perspective, these data cast significant doubt on the efficacy of a proposed fall X2 action. Implementation of the fall X2 action is based on the concept that there have been man-made changes in project operations (perhaps to increase exports) since 1987 and that part of the suite of actions needed to restore Delta fisheries is the reversal of those changes. However, if the upstream movement of X2 during the fall since 1987 is largely a reflection of drier hydrology during the post-1987 period and if the goal of Delta restoration efforts is to replicate "natural" conditions to the extent feasible, then "fixing" natural hydrology may be a well-intentioned, but counter-productive, action that diverts attention from the actual causes of declining Delta smelt populations, such as invasive species or other ecosystem stressors of the type identified in the Vogel report referred to earlier. Attempting to impose historical wet-year hydrology on the Delta and its tributaries in all years also could severely reduce the amount of cold water available to support the needs of salmon and steelhead in Delta tributaries at important times of the year.

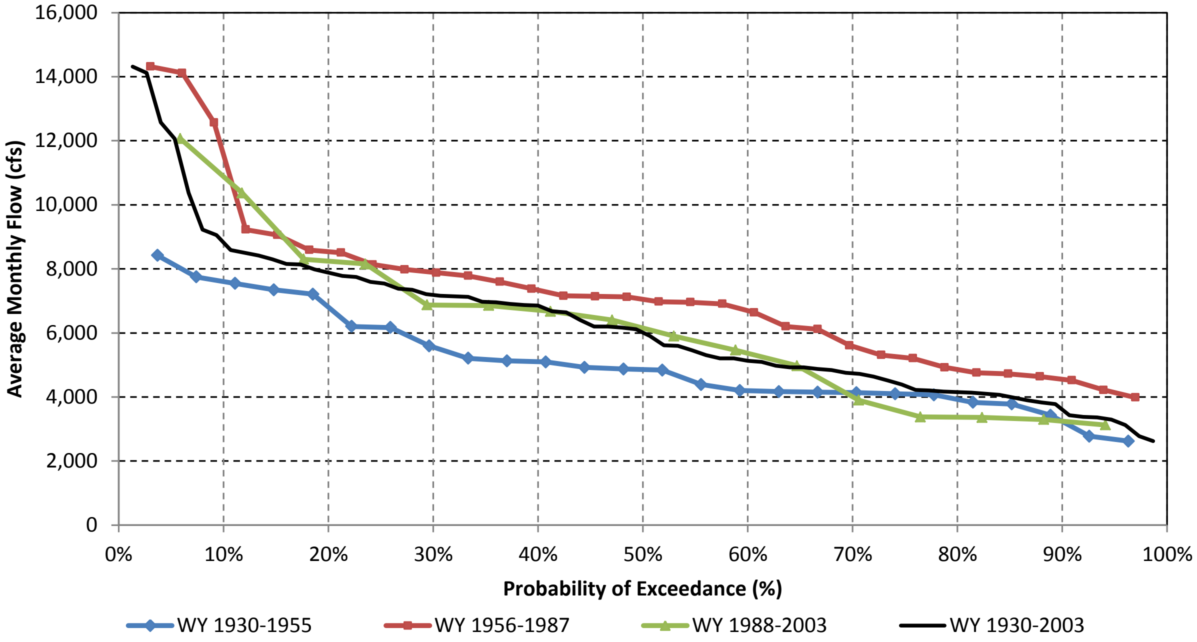


Figure 4 - Average <u>September</u> Unimpaired Net Delta Outflow from 1930 – 2003

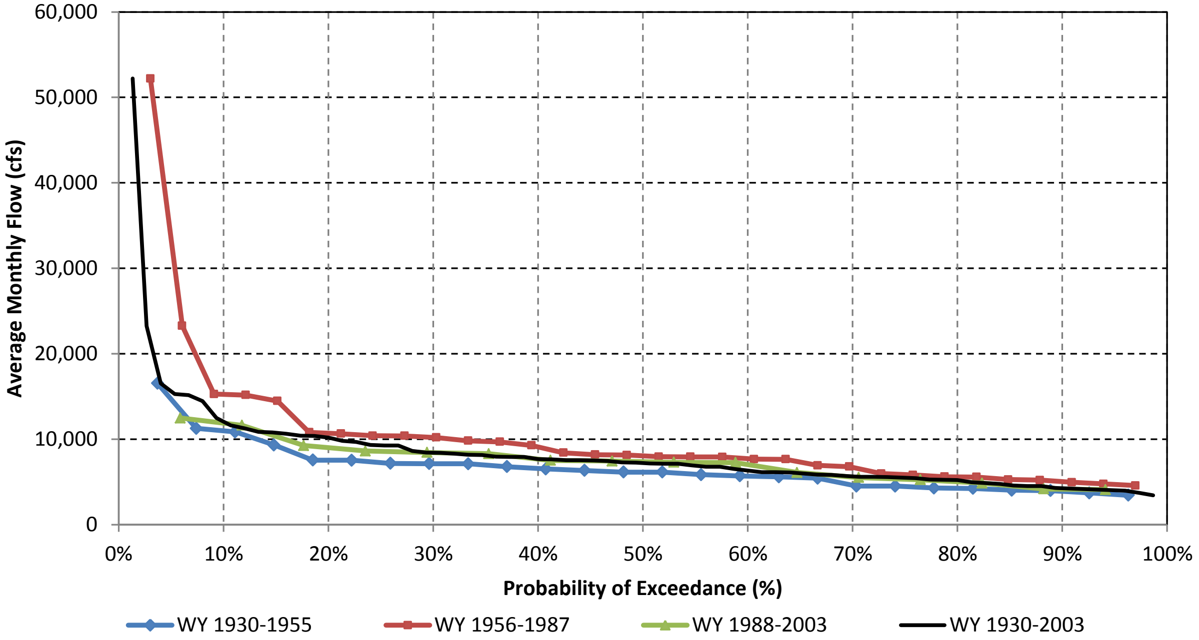


Figure 5 - Average October Unimpaired Net Delta Outflow from 1930 - 2003

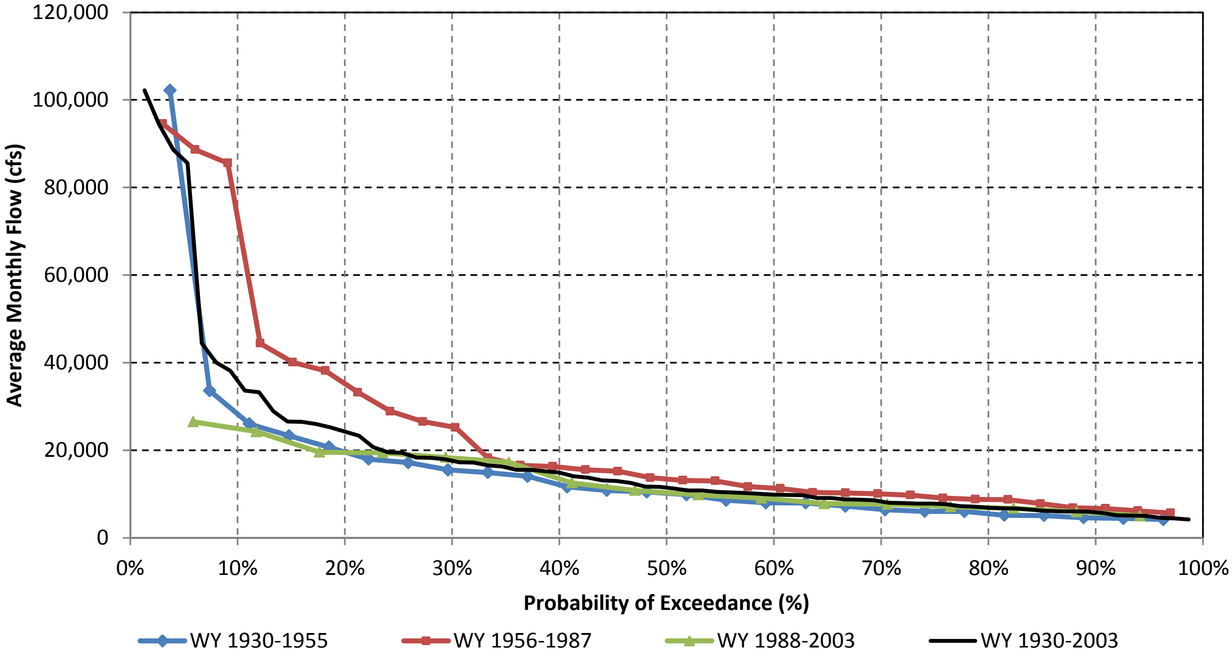


Figure 6 - Average November Unimpaired Net Delta Outflow from 1930 - 2003

The USEPA's Advanced Notice of Proposed Rulemaking ("ANPR") concludes that the "low salinity zone in the fall has moved upstream, especially after 2000." (p. 53). This statement is almost identical to the statement in the SWRCB's 2010 Delta Flow Report and is subject to the same criticism: it compares a wetter period (1956-1987) with a drier period (1988-2008) and attempts to draw conclusions regarding the status of delta smelt without acknowledging that the species is likely to do more poorly in a drier period. Similarly, the ANPR states there has been a "dramatic decline in the variability of the location (and therefore the extent) of low salinity habitat." (p. 53). The ANPR also states "In the late 1990's, the median areal extent of this low salinity estuarine habitat was about 9000 hectares in the fall; since 2000, that habitat declined by about 78 percent."(p.52). This statement compares a few very wet years in the late 1990's to a drier period that contains a mix of year types, including several very dry years, to conclude there has been a 78 percent decrease in habitat. The decline is in part due to hydrology, but may also be due to changes in regulatory standards. The increased Delta outflow requirements in the spring contained in SWRCB D-1641 have mandated increased reservoir releases during the spring months and lower upstream reservoir storage during the summer and fall period. This reduction in upstream reservoir storage has resulted in decreased reservoir releases during fall months, which in turn has resulted in X2 moving upstream in the fall. **In other words, the ANPR is correct to note that the location of X2 during the fall has moved upstream since the year 2000; the ANPR, however, fails to understand and acknowledge that the cause of that upstream movement is the requirement for increased spring Delta outflow contained in D 1641 as well as dry conditions throughout California. The lesson here is that it is important to recognize that measures to benefit one life stage or one species can have unintended effects on other life stages or other species.**

Figure 7, below, contains the average X2 location during the months of September, October, and November for the period of 1930 – 2008. The average X2 location presented in the ANPR's Figure E on page 54 displays X2 locations for the period from 1967 – 2008. Figure E implicitly uses the late 1960's and early 1970's as the baseline against which to evaluate subsequent changes in X2 locations, and concludes that X2 has moved substantially upstream over time. However, as can been seen in Figure 7, analyzing X2 position for the entire period of record (1930-2008) leads to a different a conclusion. The periods before and after the 1967-1975 period are drier, therefore this period should not be used as a baseline from which to draw conclusions. The entire period of record should be used to better understand how the system has changed. In the earlier period from 1930 to the early 1940's, before the Projects began operation, X2 position during the fall was farther upstream. When the Projects began operation, releases were made to satisfy instream flow requirements and Delta requirements causing Fall X2 to move downstream. The "natural" position for X2 during fall months is farther upstream than has occurred since the Projects began operations and releasing water to comply with environmental flow requirements. Because the delta smelt index is not available prior to 1967 it is not possible to determine if there is a relationship between fall X2 and the delta smelt index.

The consequence of these errors is that many of the effects that both the SWRCB's 2010 Delta Flow report and the USEPA's Advanced Notice of Proposed Rulemaking have attributed to reduced Delta outflows are, to a substantial extent, actually reflections of the variations in the natural hydrology of the Delta watershed since the late 1980's. It is not clear what is actually causing that change in hydrology or whether it will continue. What is clear is that the pre-1987/post-1987 comparison that has been used to justify both proposals for increased Delta outflows during the springtime and the proposed fall X2 action is a comparison between a relatively wet period and a relatively dry period.

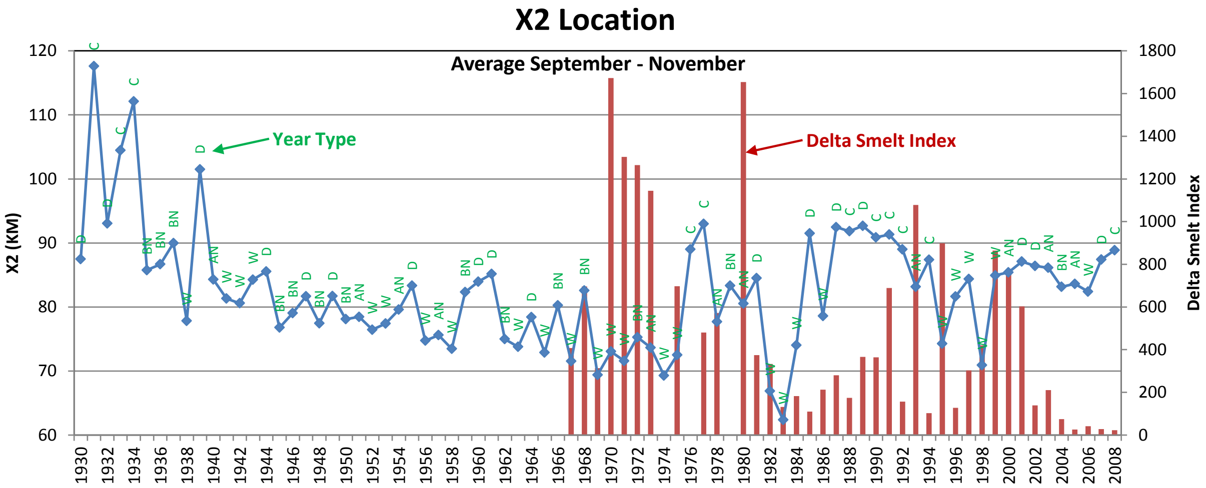


Figure 7 – Average September Through November X2 Location and Delta Smelt Index

CHANGES IN SACRAMENTO BASIN FLOWS AND DIVERSIONS DURING THIS PERIOD

Figure 8 shows Sacramento Valley irrigated acreage and combined annual diversions of water by the eight largest Sacramento River Settlement Contractors (SRSCs) for the period 1964 to 2008. Together, these eight diversions comprise about 90 percent of total settlement contract diversions in the Sacramento River Basin. These data indicate, that despite hydrologic variability, irrigated acreage has not increased and diversions by the SRSCs, while fairly consistent from year to year, have declined slightly over the past twenty to thirty years. This decline is probably due to changes in cropping mix, increased irrigation efficiency, and cultural practices.

Figure 9 contains a chart of historical diversions and consumptive use produced by the state’s 2007-2008 Delta Vision Task Force. The data on the bottom of the bar chart is labeled “Estimated Sacramento Valley agricultural consumptive use of applied water + urban demand.” This chart shows that upstream water use has been fairly constant over the past 40+ years.

Figure 10 shows the historical Delta smelt index from 1967 to present, Sacramento Valley irrigated area, and annual diversions by the Sacramento River Settlement Contractors. During the period between 1967 and 1980, the Delta smelt index varied significantly. During the 1980’s, the Delta smelt index was largely stable, but relatively low. During the 1990’s, the Delta smelt index was quite variable, but with little relation to hydrology. Since 2002, the Delta smelt index has been very low. This variability presents a clear contrast with Sacramento Valley irrigated area and diversions by the Sacramento River Settlement Contractors, which – as noted above – have been fairly consistent over the 40+ year period.

In summary, the available data indicate that the populations of the fish species that have been the focus of Delta restoration and recovery efforts for the past fifty years have been quite variable. There may be some relationship for some species to hydrology (e.g., the very low levels of Delta smelt during the 1976-77 drought) but those relationships are, at best, unclear. What is clear is that there does not appear to be a relationship between populations of Delta smelt and Sacramento Valley irrigated area or diversions by the Sacramento River Settlement Contractors, which were quite consistent over that period.

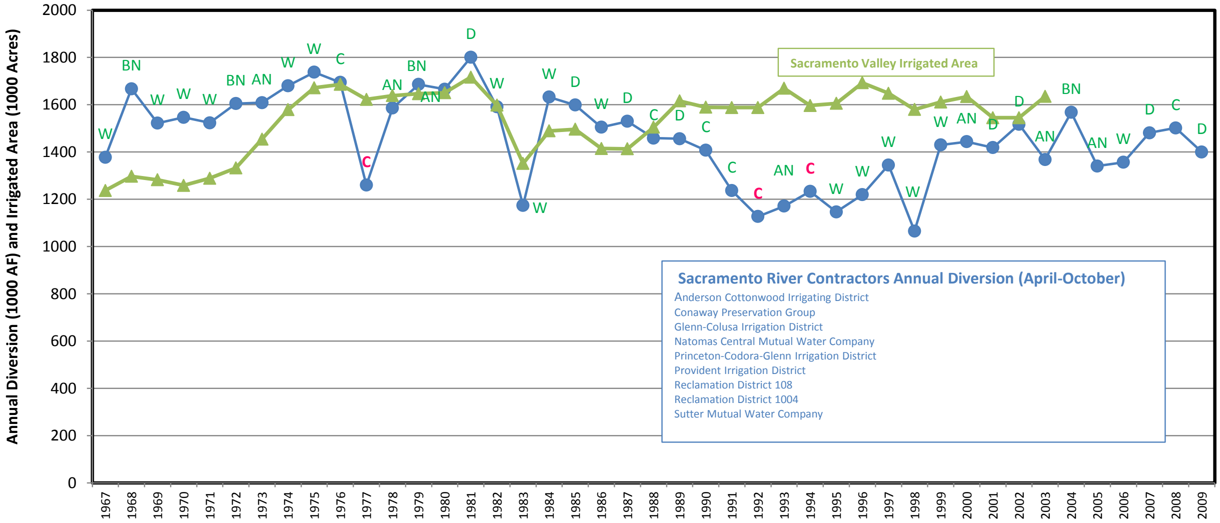


Figure 8 – Sacramento Valley Irrigated Area and Annual CVP Settlement Contract Diversions

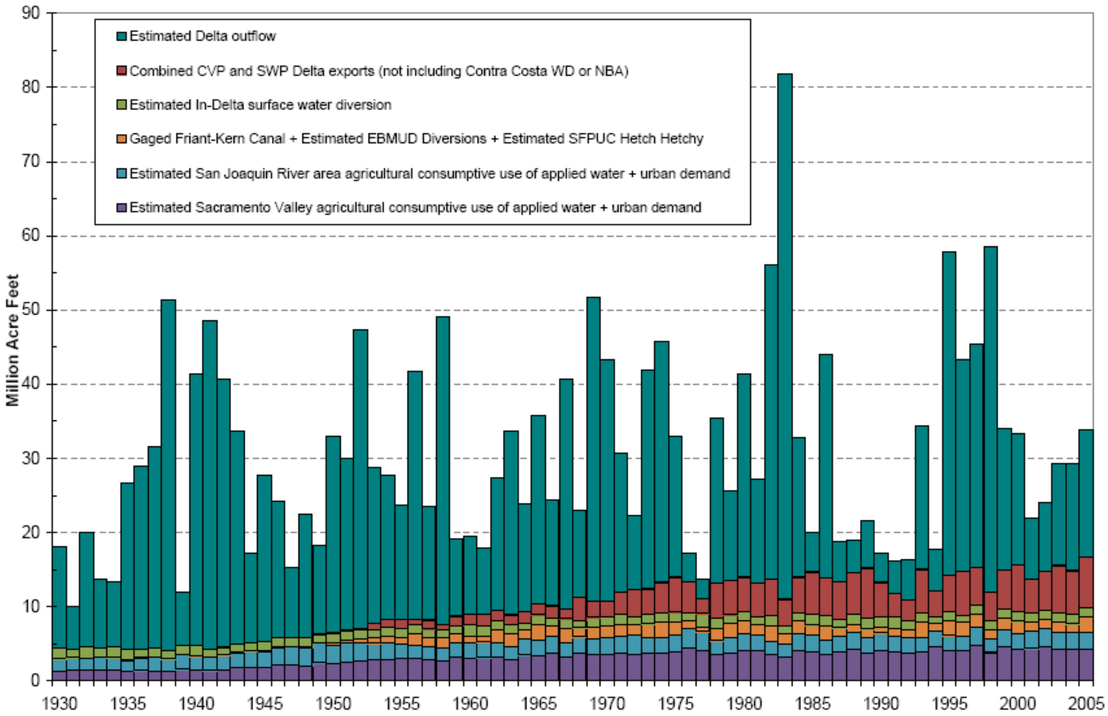


Figure 9 –Delta Vision "Revised Figure 7b – Historic Diversion from the Delta"

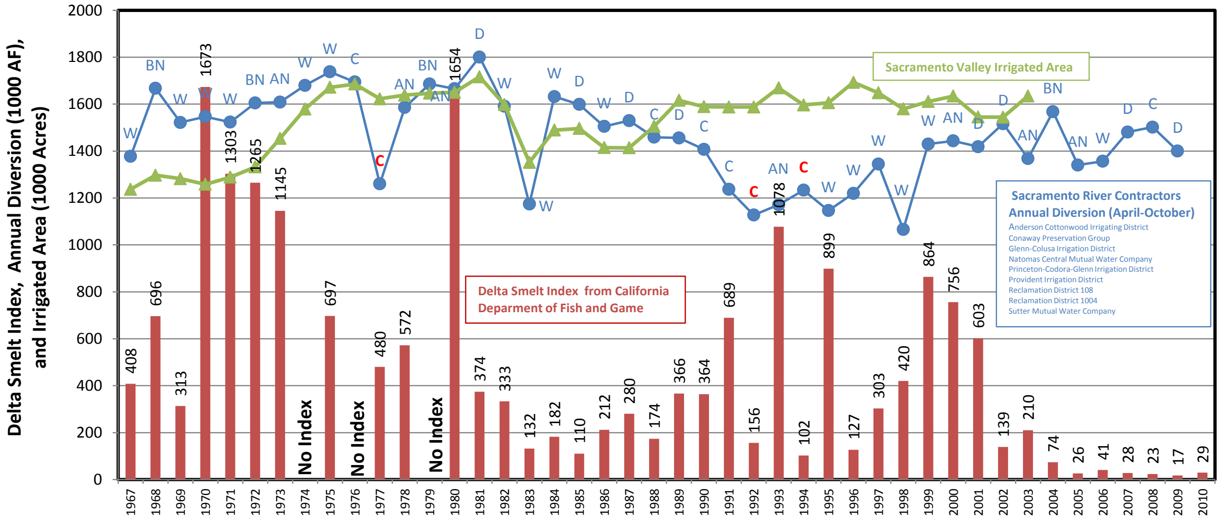


Figure 10 – Sacramento Valley Irrigated Area, Annual CVP Settlement Contract Diversions, and Delta Smelt Index

Evaluation
Of
Potential
State Water Resources Control Board
Unimpaired
Flow
Objectives

April 25, 2012

Prepared for: Sacramento Valley Water Users Group
Prepared by: MBK Engineers

EXECUTIVE SUMMARY

This report was prepared to support the Sacramento Valley Water Users in submitting comments to the State Water Resources Control Board (SWRCB) regarding proposed Delta outflow and Sacramento River flow requirements that would be based on percentages of unimpaired flows, and potentially included as water quality objectives in the SWRCB's update and implementation of the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay-Delta Plan). This report summarizes the results of a reconnaissance level analysis of the estimated effects that implementation of such requirements would have on water users in the Sacramento River Basin and on CVP/SWP reservoirs and operations.

Initially, an analysis was performed to determine the average percentages of unimpaired Delta outflows that would have occurred in different water-year types if Existing Conditions had been in effect during the entire period of historical record. Consistent with standard hydrological modeling practice, Existing Conditions are defined by today's regulatory requirements, land use, water demands, and facilities and are used to establish how the CVP/SWP currently operates. Existing Conditions percentage of unimpaired Delta outflow is calculated by averaging total modeled Delta outflows for the period of January through June and dividing by the average total unimpaired Delta outflow over that same period. The outflows were not calculated on a month-to-month basis for the initial analysis to determine Existing Conditions percentage of unimpaired Delta outflow. This analysis determined that, under Existing Conditions, average January-June Delta outflow over the period of record is about 50% of unimpaired flows and the critical year average Delta outflow is about 40% of unimpaired flows.

These average percentages of 50% and 40% of unimpaired flows then were modeled, in separate analyses, as minimum monthly Delta flow requirements for each month in the January through June period to estimate the hydrological and related impacts that would result from implementation of such minimum requirements. In other words, this report presents the estimated impacts that would occur if the existing average and average critical year percentages of unimpaired Delta outflows during the January through June period – 50% and 40%, respectively – were imposed as regulatory minimum Delta outflow requirements for each separate month from January through June. The approach of applying a constant percentage of unimpaired flow as a requirement for each month from January through June is consistent with the SWRCB August 2010 Delta flow criteria report and recent analysis performed by SWRCB on certain tributaries to the San Joaquin River as part of its update to the Bay-Delta Plan

The overall conclusions are summarized in the following list, and the detailed analytical results are summarized in this report. The overall conclusions regarding the estimated effects of implementing January-June minimum monthly Delta outflow requirements of 50% and 40% of unimpaired flows are as follows:

- Effects to the CVP and SWP reservoirs and operations would be severe and would result in the inability to maintain viable operations
- Increases in average annual Delta outflows would be:
  - 1,100,000 acre-feet for a 50% of unimpaired flows requirement; and
  - 480,000 acre-feet a 40% of unimpaired flows requirement
- The following reductions and decreases in Sacramento Basin CVP and SWP reservoir carryover storage would occur:

    - Significant reductions in cold water pools would occur under both the 50% and the 40% of unimpaired flows scenarios
    - An average reduction of 2,200,000 acre-feet in reservoir carryover storage would occur under the 50% of unimpaired flows scenario
    - An average reduction of 1,000,000 acre-feet in reservoir carryover storage would occur under the 40% of unimpaired flows scenario
- The following increases in Sacramento Basin groundwater pumping to meet reductions in surface-water deliveries would be necessary:
    - For the 50% of unimpaired flows scenario, groundwater pumping in the Sacramento Basin would have to increase by 250,000 acre-feet per year on average annual basis , and by an average of 1,000,000 acre-feet per year in Critical years
    - For the 40% of unimpaired flows scenarios, groundwater pumping in the Sacramento Basin would have to increase by 100,000 acre-feet per year on average annual, and by an average of 400,000 acre-feet per year in Critical years
- Such increases in groundwater pumping would not be realistic and therefore would not actually occur. Instead, there would have to be reductions in irrigated acreage
- Under both scenarios, there would be increased groundwater overdrafts in the export service area
- The following seasonal changes in river flows and Delta outflows and impacts would occur:
    - Increases in March through June
    - Decreases in July through December
    - Impacts to key instream temperature and habitat
- There would be regular and multiple violations of existing SWRCB standards and ESA Biological Opinion requirements
- There would be severe water supply impacts, including the following:
    - Water-supply impacts to CVP settlement and exchange contractors, and SWP settlement agreement holders, which have water rights senior to the CVP and the SWP
    - Significant reductions in north-of-Delta CVP and SWP water-service contract deliveries.
    - Inability to meet public health and safety water deliveries
    - Reductions in water deliveries to wildlife refuges

UNIMPAIRED FLOW

For hydrological analyses, unimpaired flows are the calculated flows that the Department of Water Resources (DWR) has developed to estimate the flow conditions that would have occurred in the absence of any human alterations of flows. These estimated unimpaired flows have been calculated by taking the stream flow conditions that actually occurred and by subtracting the effects of reservoir storage, water diversions, resulting return flows, and other factors that were caused by human influences on flows.

Unimpaired flow data used for this evaluation were provided by DWR and published in the 2006 report titled: *California Central Valley Unimpaired Flow Data, Fourth Edition*. DWR defines unimpaired flow on page 1 of this report as:

> *"Unimpaired flow is runoff that would have occurred had water flow remained unaltered in rivers and streams instead of stored in reservoirs, imported, exported, or diverted. The data is a measure of the total water supply available for all uses after removing the impacts of most upstream alterations as they occurred over the years. Alterations such as channel improvements, levees, and flood bypasses are assumed to exist."*

The State Water Resources Control Board (SWRCB) has suggested that it may establish new Delta outflow and Sacramento River flow requirements that are based on specified percentages of unimpaired flows. The SWRCB's August 2010 Delta Flow Criteria report suggested that in order to protect aquatic public trust resources in the Delta, 75% of unimpaired Delta outflow would be necessary from January through June, and that 75% of unimpaired Sacramento River flow would be needed for these months, as well as for November and December. The SWRCB has also analyzed the potential imposition of 20%, 40% and 60% unimpaired flow requirements on certain tributaries to the San Joaquin River as part of its update to the Bay-Delta Plan.

The percentages of unimpaired flow that flow into and out of the Delta are highly variable and are influenced by hydrologic conditions, historical development, and regulatory requirements. Fluctuating hydrologic conditions are the dominant factor contributing to variations in the percentages of unimpaired flow that occur over time at various locations in the Delta watershed. Historical development has influenced the percentages of unimpaired flows that have occurred as project reservoirs have been developed. However, it is not possible to ascertain the precise effects of these developments by analyzing historical data, because these data are heavily influenced by changes in hydrologic conditions. Regulatory conditions have also influenced the percentages of unimpaired flow that have occurred, particularly during summer and fall months where regulatory minimum river flow and Delta outflow requirements are greater than the corresponding unimpaired flows.

Because current operating requirements have only been in place for a short period of time, there is not enough available historical data to estimate the Existing Conditions percentage of unimpaired Delta outflow. Therefore standard hydrological modeling practice is to analyze the hydrologic impacts that would occur when current cultural and regulatory conditions – Existing Conditions – are applied to the variable hydrology that has occurred over a period of record. This approach enables projections about what effects existing requirements, or possible new requirements, will have going forward. In this report, to determine the average percentage of unimpaired Delta outflows that would occur, Existing Conditions are applied to a long-term hydrologic period, CalSim II is used to depict streamflows and those modeled streamflows then are compared to DWR's unimpaired flow data to estimate the Existing Conditions percentage of unimpaired Delta outflow. Actual historical flow data are included in this report to provide a historical perspective on the modeled percentages of unimpaired flow over the period of record under Existing Conditions. That comparison demonstrates that the modeled data is sufficiently reliable for analytical purposes.

Figure 1 is a plot of historical average monthly Delta outflows as percentages of average monthly unimpaired Delta outflows for the following periods:

- 1930-1943: Pre-Shasta Reservoir
- 1944-1955: Pre-Folsom Reservoir
- 1956-1968: Pre-Oroville Reservoir
- 1969-2003: Post Sacramento Basin Project Reservoirs
- All years: 1930-2003

During 1969 through 2003, hydrologic conditions varied significantly and regulatory standards became more stringent. Figure 2 is a plot showing average January through June historical Delta outflows during the 1969-2003 period as percentages of unimpaired Delta outflows for the same period of each year. Each data point is labeled with the Sacramento River Basin 40-30-30 index water year type. The average percentages of unimpaired flow for each water year type during the 1969-2003 period are listed in Table 1. Values in Table 1 are calculated by taking the average of total January through June historical flows divided by average total January through June unimpaired flows and is expressed in the following equation:

$$Average\left(\sum January\ through\ June\ historical\ flow\right) \div Average\left(\sum January\ through\ June\ unimpaired\ flow\right)$$

This equation can be used to calculate:(1)average percentage of unimpaired flow for all years; (2) percentages for each year type, as displayed in Table 1; and (3) average percentages based on a comparison of modeled flows over the period of record and DWR's calculated unimpaired flows. As indicated by this table, Delta outflows in wetter years tend to be higher percentages of unimpaired outflows, while Delta outflows in drier years tend to be lower percentages of unimpaired outflows. These differences generally occur because reservoir storage capacity does not change with changes in water year types, and reservoirs therefore are capable of storing a greater percentage of unimpaired flows in drier years than in wetter years.

Figure 1 – Average Historical Delta Outflow as a Percentage of Unimpaired Delta Outflow

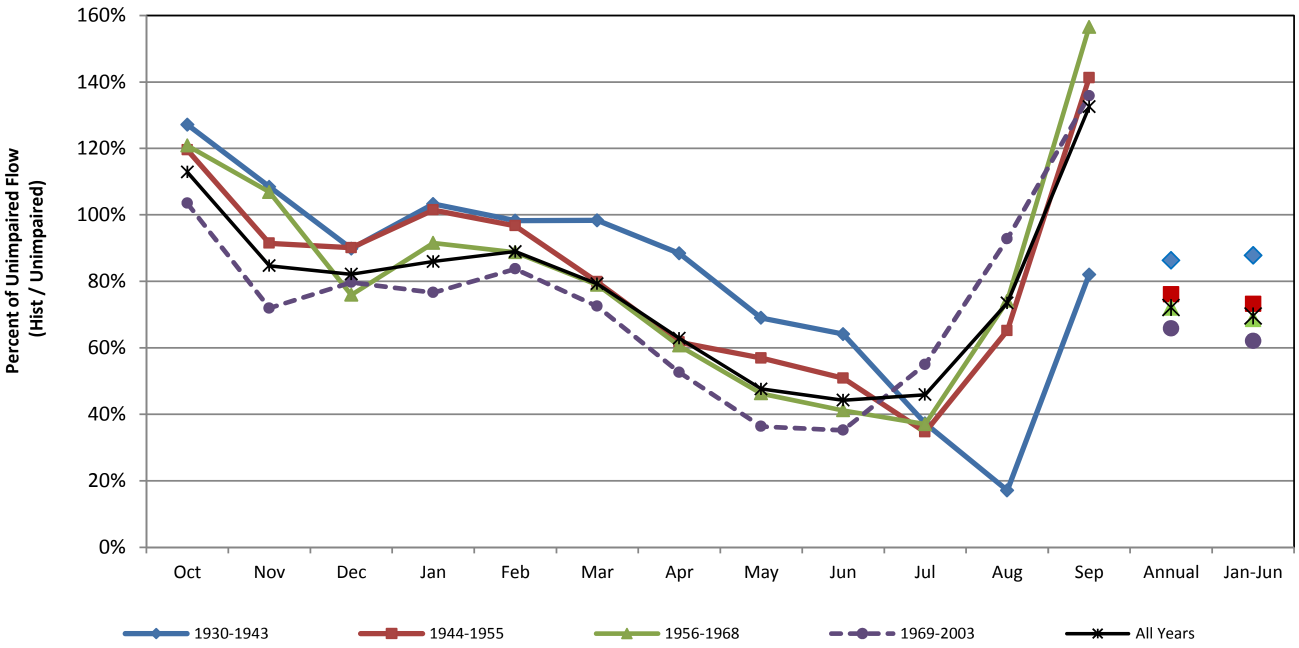


Figure 2 - Historical 1969-2003 Average January through June Historical Delta Outflow as a Percentage of Unimpaired Delta Outflow

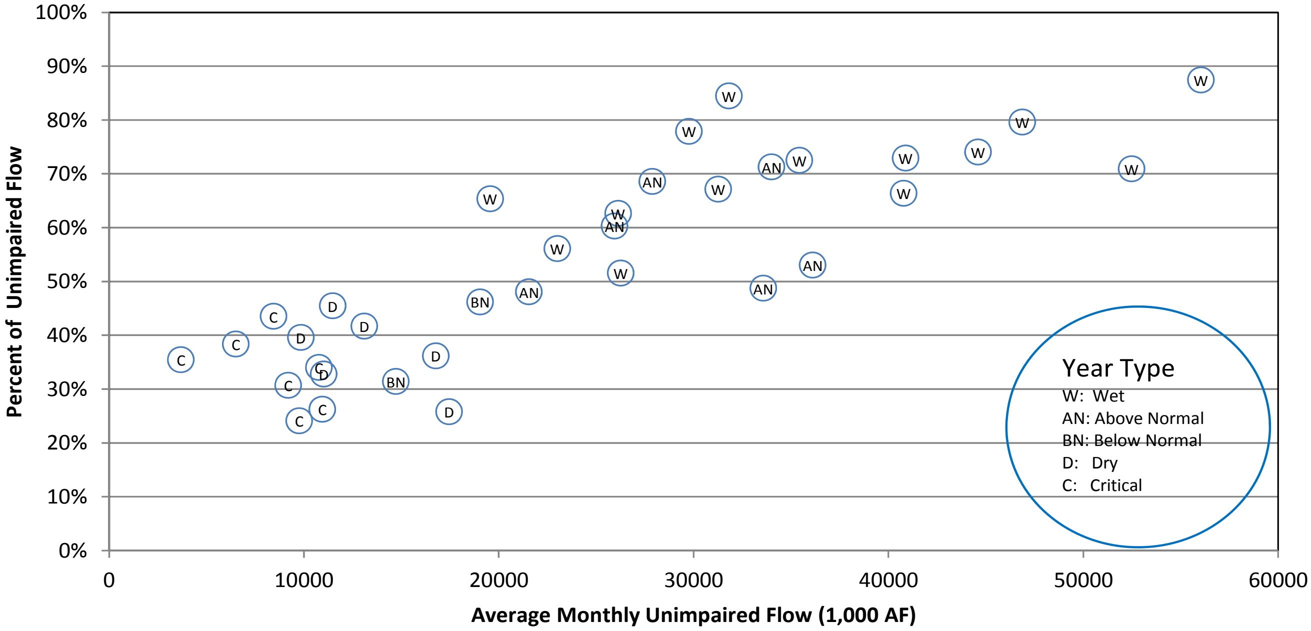


Table 1 - Historical 1969-2003 Average January through June Historical Delta Outflow as a Percentage of Unimpaired Delta Outflow by SRI Water Year Type

Wet	Above Normal	Below Normal	Dry	Critical	All Years
72%	59%	40%	36%	32%	62%

Due to the difficulties in using historical records to determine the average percentage of unimpaired flows that flow into and out of the Delta under Existing Conditions, an evaluation of CalSim II results was performed to estimate what Delta outflows would occur as percentages of unimpaired flows under Existing Conditions, under the variable hydrology that occurred during the 1922-2003 period of record. CalSim II is designed to represent existing CVP/SWP operating and system conditions by using existing operating criteria, facilities, and land use to model the CVP/SWP system and Delta for the 1922-2003 hydrologic period. Using CalSim II to determine the percentage of unimpaired Delta outflows that occur under this Existing Conditions scenario, and then using the average unimpaired outflow percentage developed from this scenario to create new model runs with these average percentage as minimum monthly Delta outflow requirements is the best available method of estimating what might happen if one of these existing percentages were implemented as a minimum Delta outflow requirement.

Figure 3 is a plot showing, by water year type, the monthly average modeled Delta outflows for the 1922-2003 period of record as percentages of monthly average unimpaired Delta outflows over the same period. Because Existing Conditions operating criteria are the same in every year of this CalSim II simulation, variations due to fluctuating hydrologic conditions can be more easily identified under this approach. For example, the percentages that modeled Delta outflows are of unimpaired flows for March vary from 40% in dry years to 78% in wet years. Figure 4 is a plot showing the average January through June modeled Delta outflow percentages of unimpaired Delta outflows for each year. Each data point is labeled with its water year type in this figure. The average percentages that modeled Delta outflows are of unimpaired flows for each water year type are listed in Table 2. In wetter years, modeled Delta outflows tend to be higher percentage of unimpaired outflows, averaging 65%, while in drier years modeled Delta outflows tend to be lower percentage of unimpaired outflow, averaging 40%.

The CalSim II modeling results indicate that over the 1922-2003 period of record, the average modeled Delta outflows under Existing Conditions is 53% of unimpaired outflows for the January through June period; the average percentage for critical years is 40%. To estimate the effects of imposing the existing average January through June percentage of unimpaired flow as a Delta outflow requirement, the value of 50% (rounded down from 53% to ensure that the effects are not overestimated) then is used as a minimum monthly regulatory requirement in further analysis. For the purpose of this further analysis, it is assumed that the 50% of unimpaired flow requirement is applied on a monthly basis from January through June, i.e., for each month from January through June, Delta outflow must be equal to or greater than 50% of unimpaired Delta outflow for that month. A second stage in the further analysis then was performed to estimate the effects of imposing the average January through June critical year Delta outflow percentage of unimpaired flows, 40%, as a minimum monthly regulatory requirement.

Figure 3 - Modeled with CalSim II: Average Delta Outflow as a Percentage of Unimpaired Delta Outflow

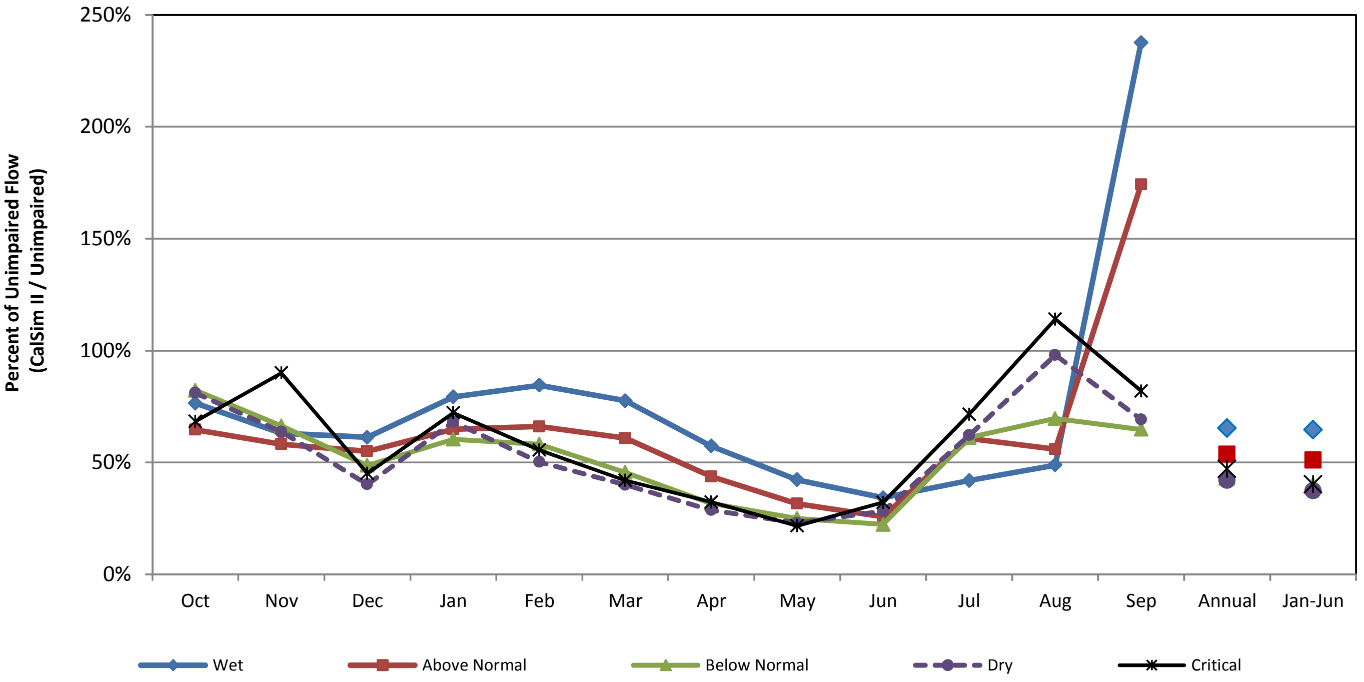


Figure 4 - Modeled with CalSim II: Average January through June Delta Outflow as a Percentage of Unimpaired Delta Outflow

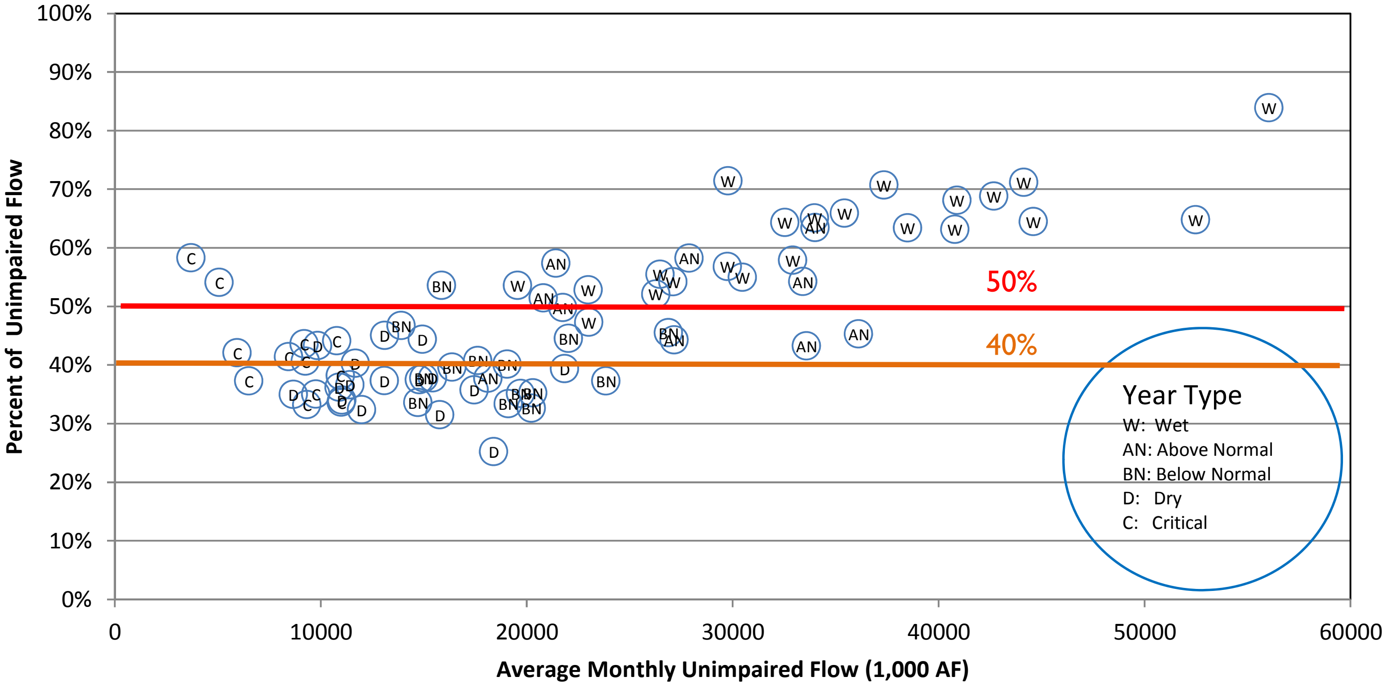


Table 2 - Modeled with CalSim II: Average January through June Delta Outflow as a Percentage of Unimpaired Delta Outflow

Wet	Above Normal	Below Normal	Dry	Critical	All Years
65%	51%	40%	37%	40%	53%

Sacramento River Basin Delta Inflow

Figure 5 is a plot of historical Sacramento River Basin Delta inflows as percentages of unimpaired flows, averaged for the following periods:

- 1930-1943: Pre-Shasta Reservoir
- 1944-1955: Pre-Folsom Reservoir
- 1956-1968: Pre-Oroville Reservoir
- 1969-2003: Post Sacramento Basin Project Reservoirs
- All years: 1930-2003

Although there were hydrologic fluctuations and varying regulatory requirements during the post-1944 period, the January through June averages of Delta inflows as percentages of unimpaired flows into the Delta from the Sacramento River have changed minimally during this almost 70-year period.

During the period from 1969 through 2003, hydrologic conditions varied significantly and regulatory standards became more stringent. The percentage of historical Sacramento River Delta inflows to unimpaired flows for the July through October period have increased through time due to increases in flow and salinity requirements and Delta exports. Figure 6 is a plot showing, for the 1969-2003 period, average January through June historical Sacramento River Basin flows to the Delta as percentage of unimpaired flows for each year. Each data point is labeled with the year type. The average percentages of Sacramento River Delta inflows to unimpaired flows for each water year type are listed in Table 3. In wetter years, Sacramento River inflows tend to be higher percentage of unimpaired outflows, while in drier years these percentage tend to be lower.

Figure 7 contains a chart showing monthly average Sacramento River Basin Delta inflows as percentages of unimpaired flows by water year type for the 1922-2003 period. Based on the CalSim II baseline, the average percentage of Sacramento River Basin Delta inflows to unimpaired flows for the January through June period is 78%; the average of these percentages for critical years is 67%. Although Sacramento River Basin inflows to the Delta are a higher percentage of unimpaired flows (69%) than are Delta outflows (50%), the percentage of Delta outflow to unimpaired flows is applied as a minimum flow requirement for Sacramento River inflows to the Delta for this analysis. This assumption will estimate less adverse effects to the Sacramento River Basin than would occur with a 78% minimum flow requirement.

Figure 5 - Average Historical Sacramento Basin Delta inflow as a Percentage of Unimpaired Sacramento Basin Delta Inflow

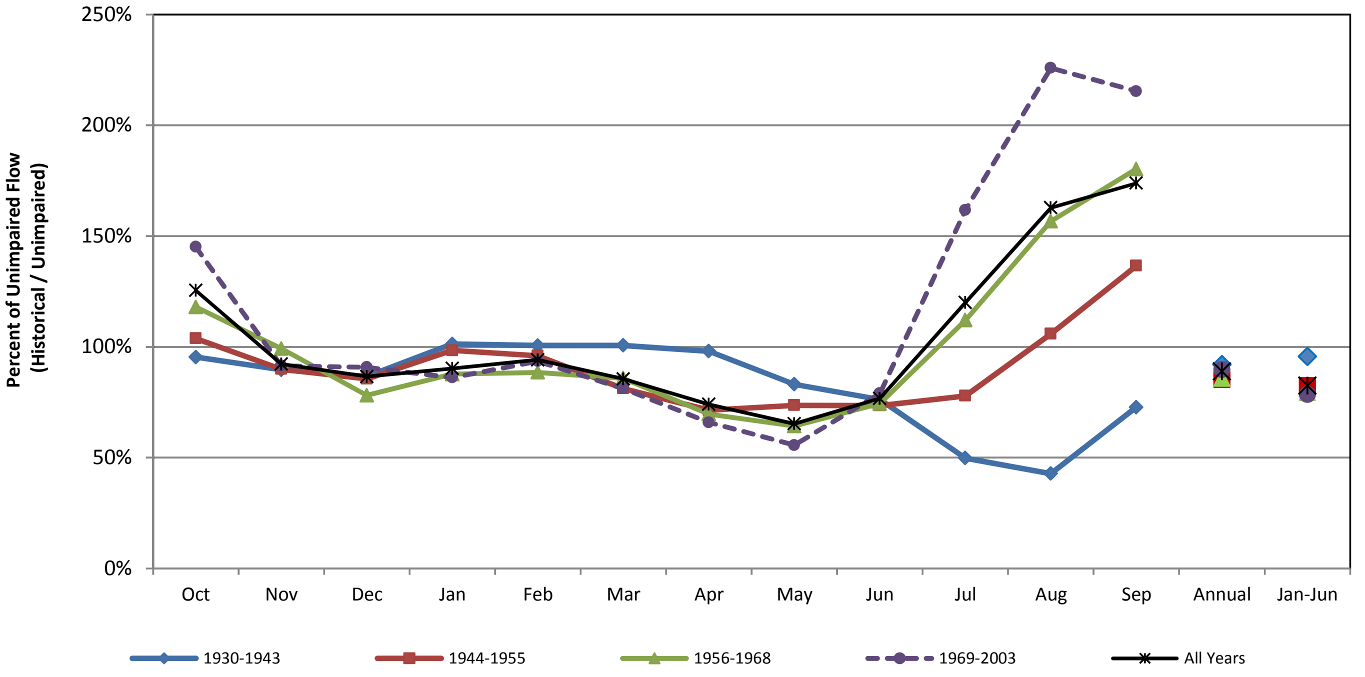


Figure 6 - Historical 1969-2003 Average January through June Sacramento Basin Delta inflow as a Percentage of Unimpaired Sacramento Basin Delta Inflow

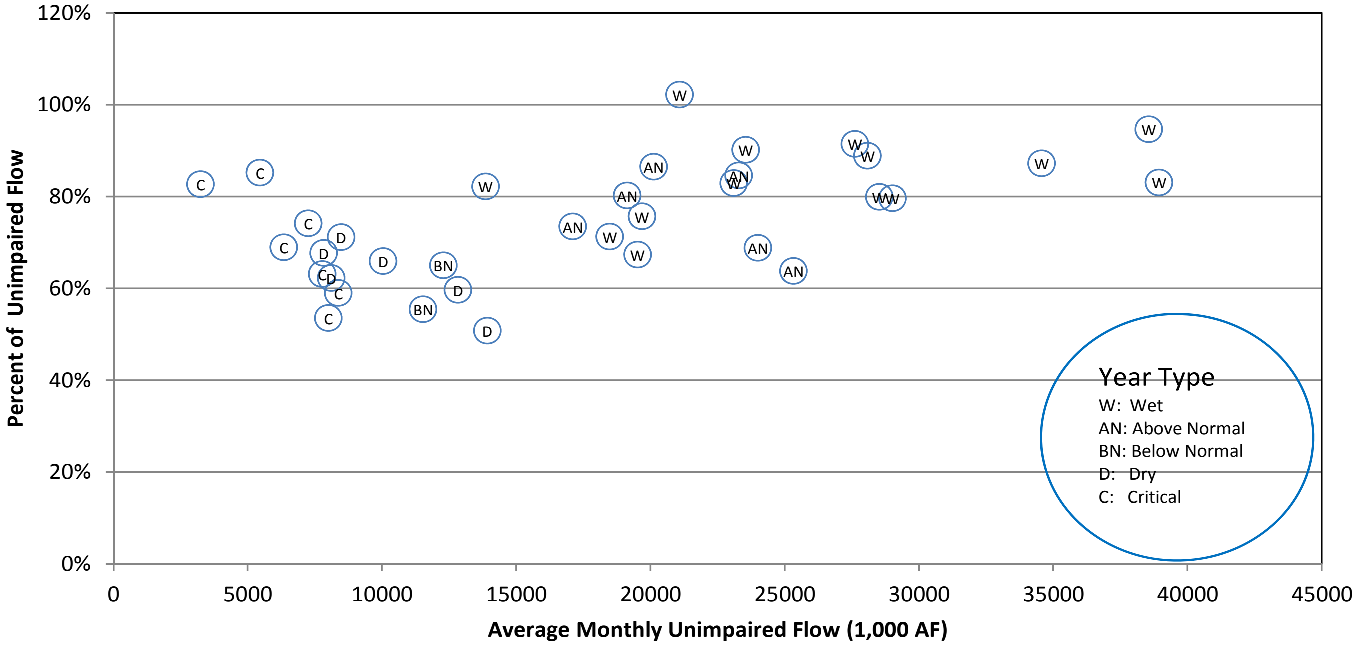


Table 3 - Historical 1969-2003 Average January through June Historical Sacramento Basin Delta Inflow as a Percentage of Unimpaired Sacramento Basin Delta Inflow by SRI Water Year Type

Wet	Above Normal	Below Normal	Dry	Critical	All Years
85%	76%	60%	62%	67%	78%

Figure 7 - Modeled with CalSim II: Average Sacramento Basin Delta Inflow as a Percentage of Unimpaired Sacramento Basin Delta Inflow

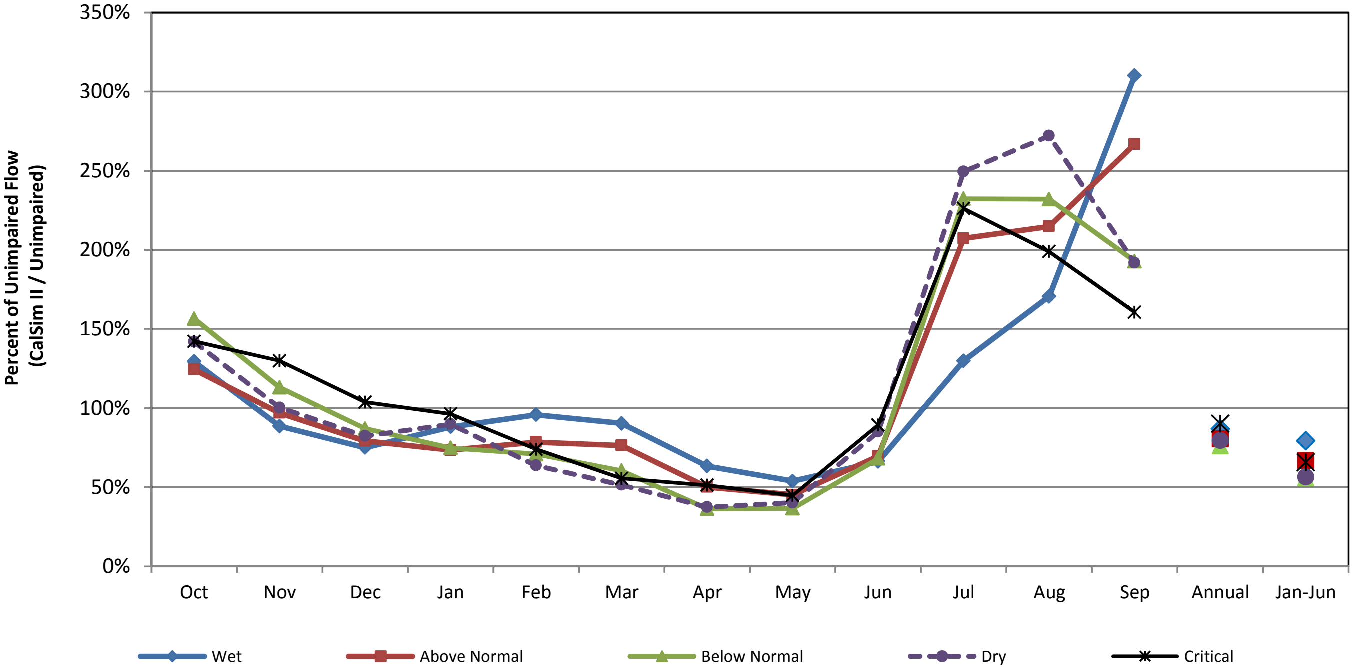


Table 4 - Modeled with CalSim II: Average January through June Sacramento Basin Delta Inflow as a Percentage of Unimpaired Sacramento Basin Delta Inflow

Wet	Above Normal	Below Normal	Dry	Critical	All Years
79%	67%	56%	56%	65%	69%

MODELING ASSUMPTIONS AND LIMITATIONS

The primary analytical tool used for this effort is the latest publically available version of the CalSim II model. The CalSim II model simulation used to support the State Water Project Delivery Reliability Report (SWP DRR) is the best available modeling tool and latest public release of the model. The DRAFT Technical Addendum to SWP DRR 2011, titled January 2012 of the SWP DRR, describes the CalSim II modeling assumptions. For this analysis, CalSim II was used to assess changes in CVP / SWP storage, river flows, water deliveries, and Delta conditions. The SWP DRR may be found at the following web location: http://baydeltaoffice.water.ca.gov/swpreliability/2011DraftDRR012612.pdf.

The Delta outflow requirements based on 50% and 40% of unimpaired flows described above were inputted into the CalSim II Existing Conditions model simulation to develop two new model simulations, which estimate how the system would operate with such Delta outflow requirements. Two CalSim II model simulations were developed to perform this analysis: one with a 50% of unimpaired Delta outflow requirement and a 50% of unimpaired Sacramento River flow requirement from January through June, and the other with a 40% of unimpaired Delta outflow requirement and a 40% of unimpaired Sacramento River flow requirement from January through June. These two model simulations were then compared to Existing Conditions to estimate the changes to the water system that would occur with the new Delta outflow requirements. The applicable Delta outflow requirement for each simulation then was applied as an average monthly net Delta outflow requirement, and the Sacramento River Basin requirement was applied as a minimum requirement for the sum of Sacramento River flow at Freeport plus the Yolo Bypass inflow to the Delta.

The SWRCB's 2010 Delta flow criteria report suggests that its proposed criteria that are stated in percentages of unimpaired flows could be implemented as 14-day running averages. The CalSim II model, however, simulates on a monthly time step and does not provide daily or hourly results and, therefore, simplifies the hydrologic diversity that exists in reality. Accordingly, when using the CalSim II model – which is the best available model -- it is difficult to predict how requirements that are based on a percentage of the unimpaired flows would be implemented or operated on 14-day average basis. Modeling using the CalSim II model probably understates the real impacts of implementing the proposed Delta outflow and Sacramento River flow requirements as percentage of unimpaired flows on a time-step less than one month, as suggested by the proposed Delta flow criteria in the SWRCB's 2010 report.

In addition, the CalSim II model primarily simulates operations of the CVP and SWP Systems. The SWRCB's 2010 Delta flow criteria report suggests that the SWRCB would seek to spread the impacts of implementing the proposed Delta outflow and streamflow requirements over all upstream users, but no integrated model with this capability currently exists. Therefore, the CalSim II model for the SWP/CVP was used for this analysis as a surrogate for the kinds of impacts that may be observed if Delta outflow and Sacramento River flow requirements based on percentage of unimpaired flows were implemented as minimum outflow and flow requirements.

The water supply impacts that would result from 50% and 40% of unimpaired flow requirements for Delta outflow and Sacramento River flow would be extreme and would go far beyond what CalSim II is designed to evaluate. If these requirements were implemented, then SWP and CVP reservoirs would be at the “dead pool” levels by the end of summer in many years, CVP and SWP settlement contracts would be violated due to the lack of adequate water supplies, and existing temperature and water quality standards could not be met much of the time due to exhaustion of water supplies in the reservoirs. None of these events are consistent with how the CVP and SWP actually would be operated. For this reason, to more accurately model the effects of such requirements, a new in-basin depletion analysis would need to be constructed, and this analysis necessarily would have to simulate the additional reductions in water supplies that would result from implementation of such requirements. The CalSim II modeling described in this evaluation was used to evaluate the order of magnitude of water system impacts. However, because of these limitations in the CalSim II model, the results discussed in this evaluation are underestimates of the impacts that actually would occur from implementing these Delta outflow and Sacramento River flow requirements.

OBSERVATIONS

When a 50% of unimpaired Delta outflow requirement and a 50% of unimpaired Sacramento River Basin inflow to the Delta requirement from January through June are imposed on the Existing Conditions scenario, the average annual Delta outflow increases by 1,057,000 AF. The model results show that the 50% of unimpaired flow requirement for Sacramento River inflows to the Delta normally would not govern CVP/SWP operations because the more onerous Delta outflow requirement would control in all but 3 monthly time steps in the 82-year simulation. The model results indicate that, to meet a Delta outflow requirement based on 50% of unimpaired flows, Sacramento River Basin inflows to the Delta would increase by an average of 331,000 AF annually, Delta exports would decrease annually by 703,000 AF, and other Delta diversions (including the North Bay Aqueduct) would decrease by 23,000 AF annually. The CalSim II modeling estimated that the increased Sacramento River Basin inflows to the Delta of 331,000 AF would require increased imports from the Trinity River Basin of 91,000 AF, increased Sacramento River Basin groundwater pumping of an annual average of 248,000 AF, and other average annual changes of 8,000 AF. Figure 8 shows these estimated average annual flow changes by water year type.

When a 40% of unimpaired Delta outflow requirement and a 40% of unimpaired Sacramento River Basin to Delta flow requirement from January through June are imposed on the Existing Conditions scenario, the average annual Delta outflow increases by 484,000 AF. The model results show that the 40% of unimpaired flow requirement for Sacramento River inflows to the Delta normally would not govern CVP/SWP operations because the more onerous Delta outflow requirement would control in all months of the simulation. The model results indicate that, o meet a Delta outflow requirement based on 40% of unimpaired flows, Sacramento River Basin inflows to the Delta would increase an average of 136,000 AF annually, Delta exports would decrease annually by 333,000 AF, and other Delta diversions (including the North Bay Aqueduct) would decrease by 15,000 AF annually. The CalSim II modeling estimated that the increased Sacramento River Basin inflows to the Delta of 136,000 AF would require increased imports from the Trinity River Basin by 32,000 AF, increased Sacramento River Basin groundwater pumping of an annual average of 99,000 AF, and other changes of 7,000 AF. Figure 9 shows these estimated average annual flow changes by water year type.

Imports from the Trinity River Basin

The requirements of 50% and 40% of unimpaired flows are outside the operational parameters that CalSim II was designed to model. The CalSim II logic that balances Trinity and Shasta Reservoir storage amounts properly for Existing Conditions therefore may not be suitable for modeling the operations that would be necessary to satisfy these outflow and flow requirements. In particular, desired increases in releases from Trinity Reservoir to the Trinity River may be inconsistent with the CalSim II modeled operations that would be triggered by these requirements based on 50% and 40% of unimpaired flows. Additional modeling logic that isolates Trinity operations from the Sacramento River Basin operations therefore may need to be developed. Because imports from the Trinity River Basin actually might not increase as much as is indicated by the CalSim II modeling done for this evaluation, the model results described in this report probably underestimate the impacts within the Sacramento River Basin that actually would occur with implementation of these requirements.

Figure 8 - Annual Average Changes in Flow by Water Year Type
50% Unimpaired Flow Requirement

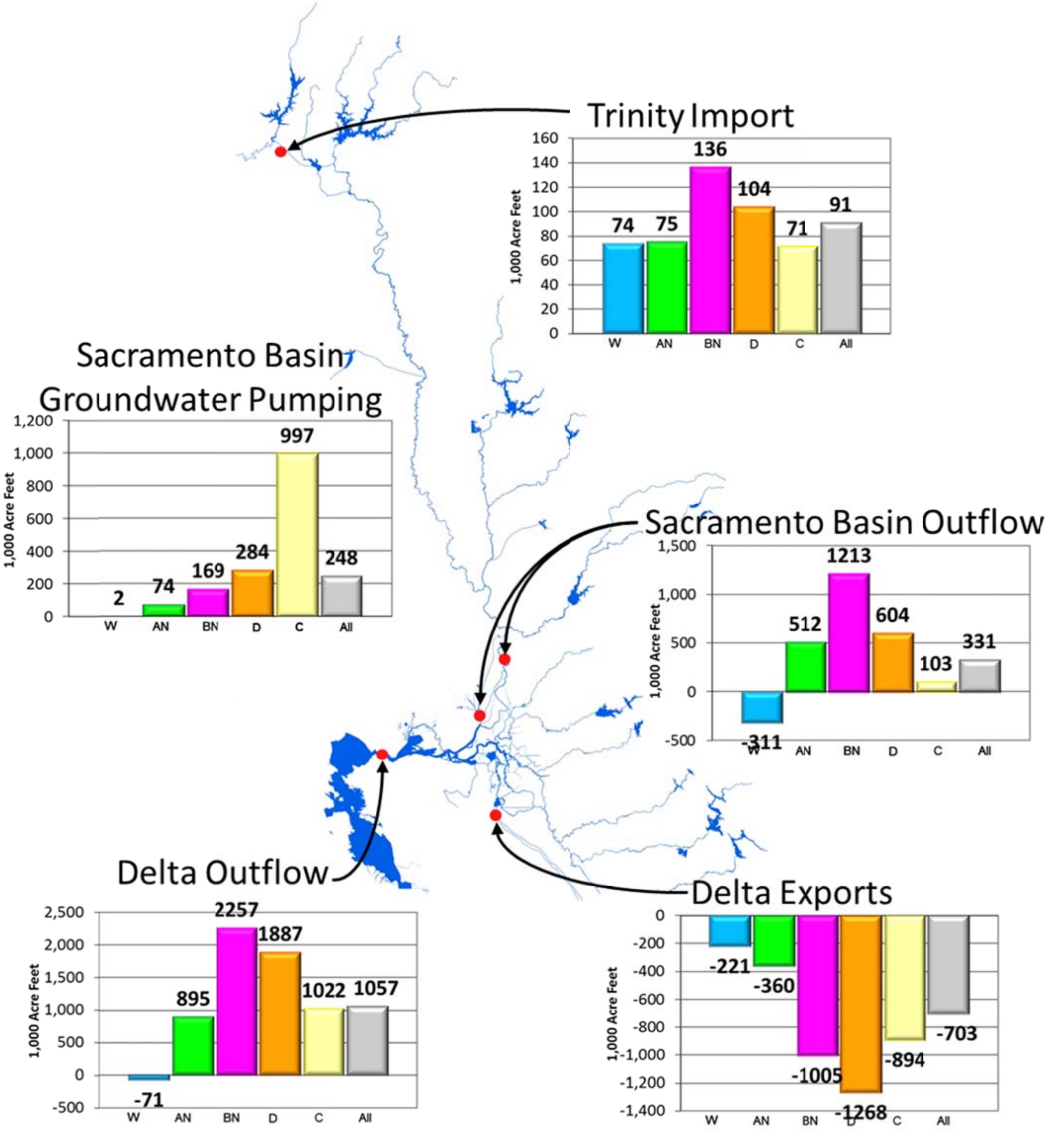
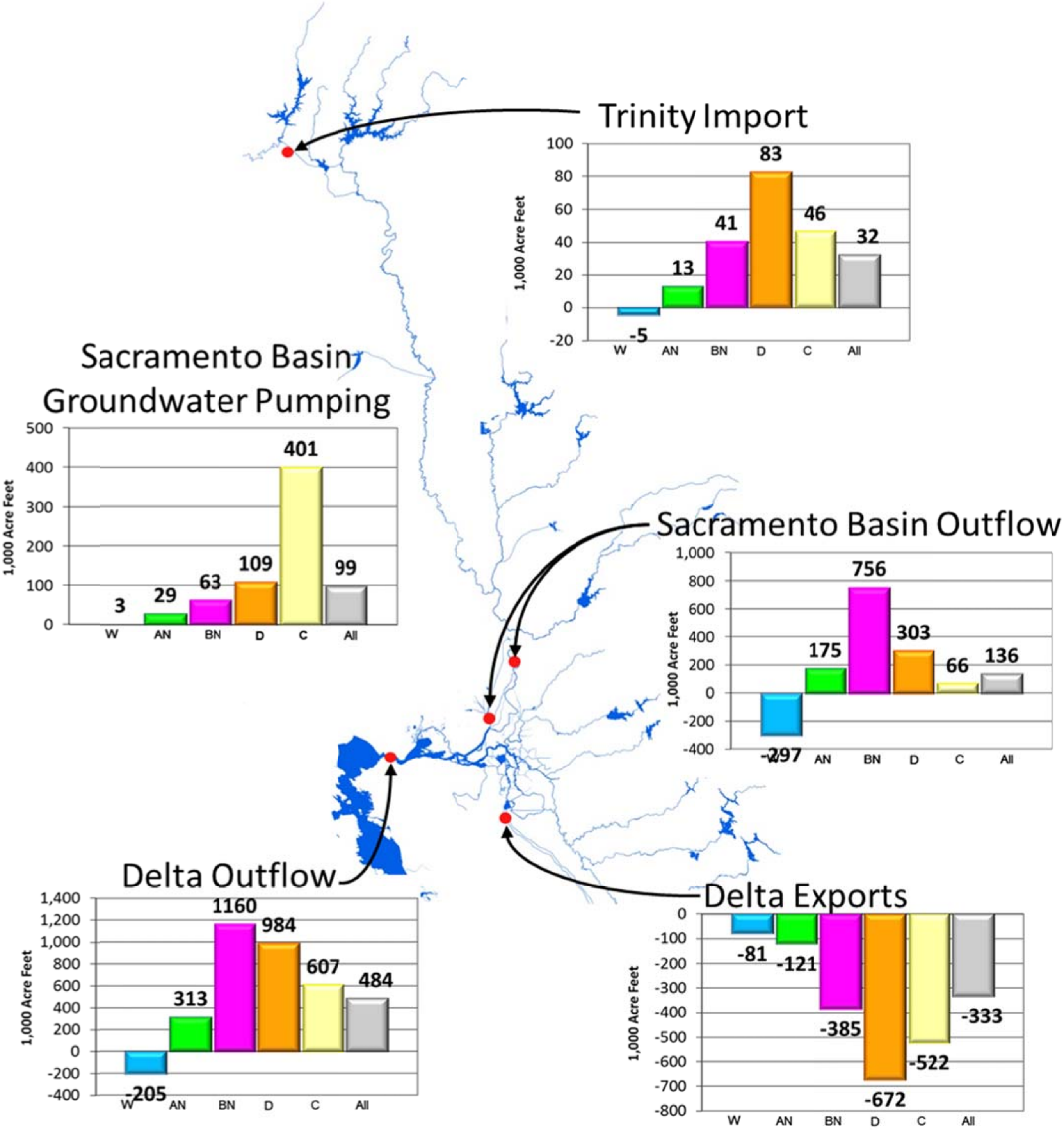


Figure 9 - Annual Average Changes in Flow by Water Year Type
40% Unimpaired Flow Requirement



Groundwater and land fallowing

As noted above, water supply impacts of the requirements that are 50% and 40% of unimpaired flows would exceed what the existing CalSim II model can readily assess. For example, when a CalSim II modeling scenario does not have enough water to meet in-basin demands, the model simply assumes that groundwater in the Sacramento Valley will be pumped to make up the shortage. However, the groundwater pumping that would be necessary to make up for the water supply losses to water users in the Sacramento River Basin with implementation of requirements that are 50% and 40% of unimpaired flows would not be physically possible or sustainable. Figures 10 and 11 show the added groundwater pumping that would be needed to meet in-basin demands that would be necessary to make up for the losses in surface water supplies that would occur with implementation of these requirements.

Although the CalSim II modeling for these requirements assumes that groundwater pumping would increase as necessary to make up for all losses in surface-water supplies in the Sacramento River Basin, in reality this would not be possible, so, in reality, there probably would be reductions in total crop acreage and wildlife refuge water supplies. Also, any increases in actual groundwater pumping probably would result in lower groundwater levels and increases in groundwater recharge (similar in magnitude to the increases in pumping). These increases in recharge would result in decreases in stream flows, which would cause additional needs for groundwater pumping, reservoir releases, and crop fallowing. Decreases in groundwater levels also probably would cause adverse impacts to major surface water systems and ephemeral stream habitat (by inducing greater recharge through streambeds) and to urban wells. There are a large number of factors affecting the interrelationships between groundwater levels and pumping, stream-groundwater interactions, deep percolation of applied water, percolation of precipitation, and natural recharge, all of which make it difficult to speculate how much additional pumping, recharge, and fallowing would occur if these requirements were implemented.

Figure 10 – Required Groundwater Pumping Due to 50% Unimpaired Flow Requirement

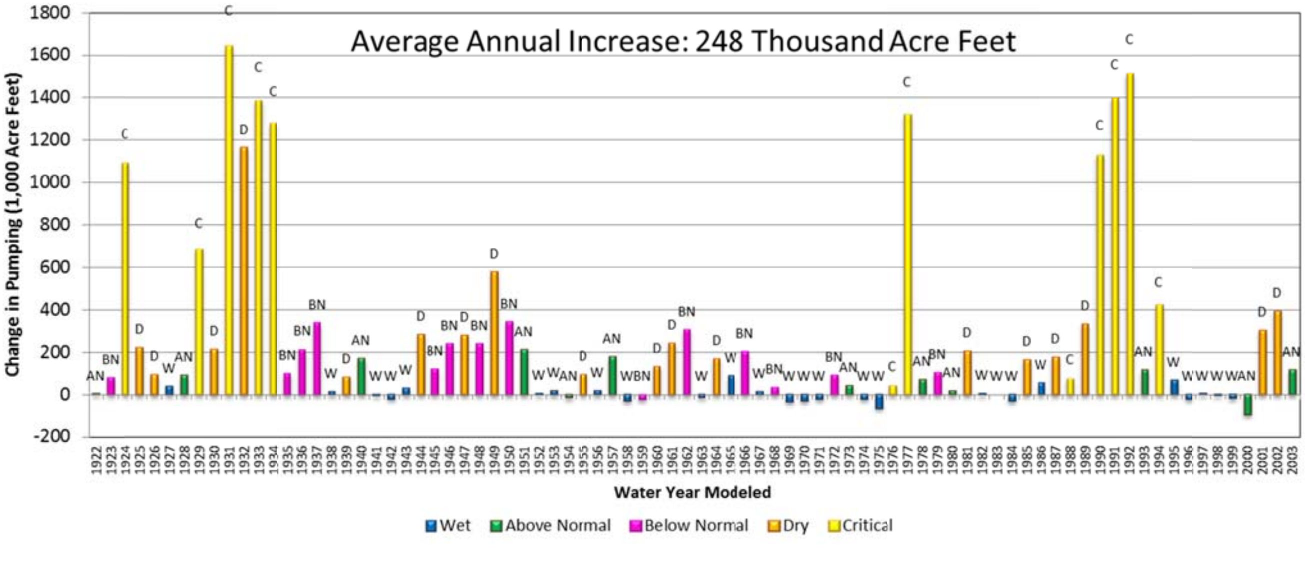
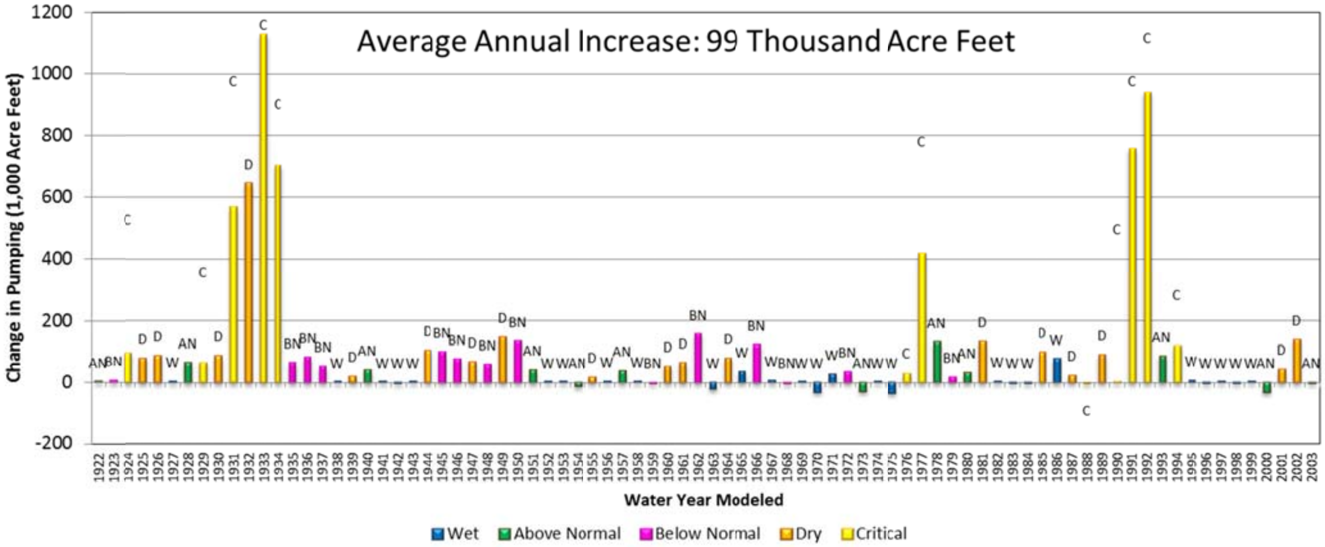


Figure 11 – Required Groundwater Pumping Due to 40% Unimpaired Flow Requirement



Project Reservoir Storage

Figure 12 and Figure 13 show the expected CVP and SWP reservoir levels that would occur at the end of September with implementation of requirements of 50% and 40% of unimpaired flows. The 50% of unimpaired flow requirements would cause Trinity, Shasta and Folsom Reservoirs to be at the dead pools (effectively empty) by the end of September in 20% of all years, and Oroville Reservoir to be at its minimum pool in 40% of all years. In contrast, under current operating rules, such dead pool levels would occur only rarely. With implementation of the 50% of unimpaired flow requirements, average carryover storage reductions for the major project reservoirs would be :

- Trinity Reservoir: - 460,000 AF
- Shasta Reservoir: - 960,000 AF
- Oroville Reservoir: - 620,000 AF
- Folsom Reservoir: - 150,000 AF

The total reduction in upstream carryover project storage that would be caused by implementing a 50% of unimpaired flow requirement would be about 2.2 million AF, and the carryover reduction would be even greater in drier years. These reductions in carryover storage, coupled with substantially increased groundwater pumping, would result in water supply deficits in the Sacramento Valley that would be greater than 2 million AF in below normal, dry, and critical years. Under these conditions, the CVP and SWP reservoir storage levels required by in the National Marine Fisheries Services' 2009 salmon Biological Opinion (BO) could not be maintained. In addition, the cold-water pools in these reservoirs that are necessary to meet temperature conditions downstream for salmon survival and reproduction would be completely depleted in 20% of years, and would be greatly reduced in other years. These depletions and reductions would make it virtually impossible for CVP and SWP operations to achieve acceptable temperature requirements in the rivers downstream of these reservoirs. With implementation of these requirements, maintaining acceptable storage levels in these reservoirs throughout summer months may not be possible, even with severe reductions in agricultural diversions. Reducing reservoir releases by 2 million AF from July through September would result in violations of applicable instream flow requirements and would make it difficult or impossible to meet applicable instream temperature requirements.

Implementation of the 40% of unimpaired flow requirements would result in Trinity, Shasta, Folsom Reservoirs being at their dead pools (effectively empty) by the end of September in roughly 10% of all years, and in Oroville Reservoir being at its minimum pool in 30% of all years. With implementation of the 40% of unimpaired flow requirements, average carryover storage reductions for the major project reservoirs would be:

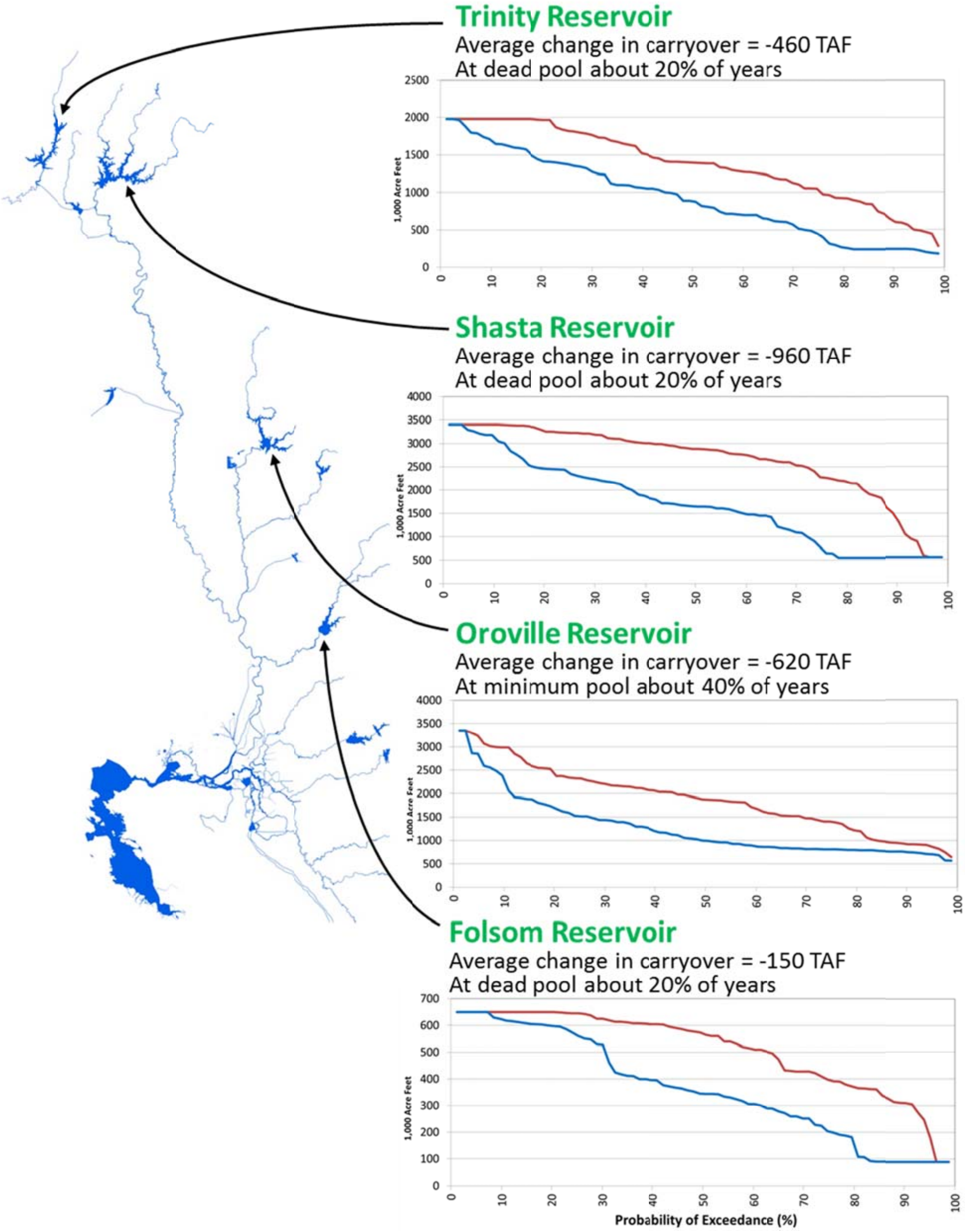
- Trinity Reservoir: - 200,000 AF
- Shasta Reservoir: - 423,000 AF
- Oroville Reservoir: - 390,000 AF
- Folsom Reservoir: - 79,000 AF

The total reduction in upstream carryover project storage that would occur with implementation of the 40% of unimpaired flow requirement would be about 1.1 million AF. Although such reservoir deficits would be about half of the reservoir deficits that would occur with implement of the 50% of unimpaired flow requirement, there still would be similar types of impacts. Reducing upstream reservoir releases by 1 million AF from July through September would result in violations to the applicable instream flow requirements and would make it difficult or impossible to meet the applicable instream temperature requirements.

This extensive loss of carryover reservoir storage would have significant impacts to hydropower, recreation, lake fisheries, and downstream fisheries. During multiyear droughts, project reservoirs would be at minimum or dead pool levels throughout the drought period, which would lead to adverse conditions for fisheries in many consecutive years. Figures 14 through 17 show monthly storage in Trinity, Shasta, Oroville, and Folsom Reservoirs respectively for the 1922-2003 CalSim II simulation period for Existing Conditions and the 50% and 40% of unimpaired flow requirements. By comparing Existing Conditions storage to the 50% and 40% of unimpaired flow storage prolonged reductions in storage due to unimpaired flow requirements are noticeable, particularly in dryer conditions. These prolonged reductions in storage would result in adverse conditions that could persist for several years.

Figure 12 - Project Reservoir Carryover Storage

50% Unimpaired Flow Requirement



Trinity Reservoir

Average change in carryover = -460 TAF

At dead pool about 20% of years

Shasta Reservoir

Average change in carryover = -960 TAF

At dead pool about 20% of years

Oroville Reservoir

Average change in carryover = -620 TAF

At minimum pool about 40% of years

Folsom Reservoir

Average change in carryover = -150 TAF

At dead pool about 20% of years

Figure 13 - Project Reservoir Carryover Storage
40% Unimpaired Flow Requirement

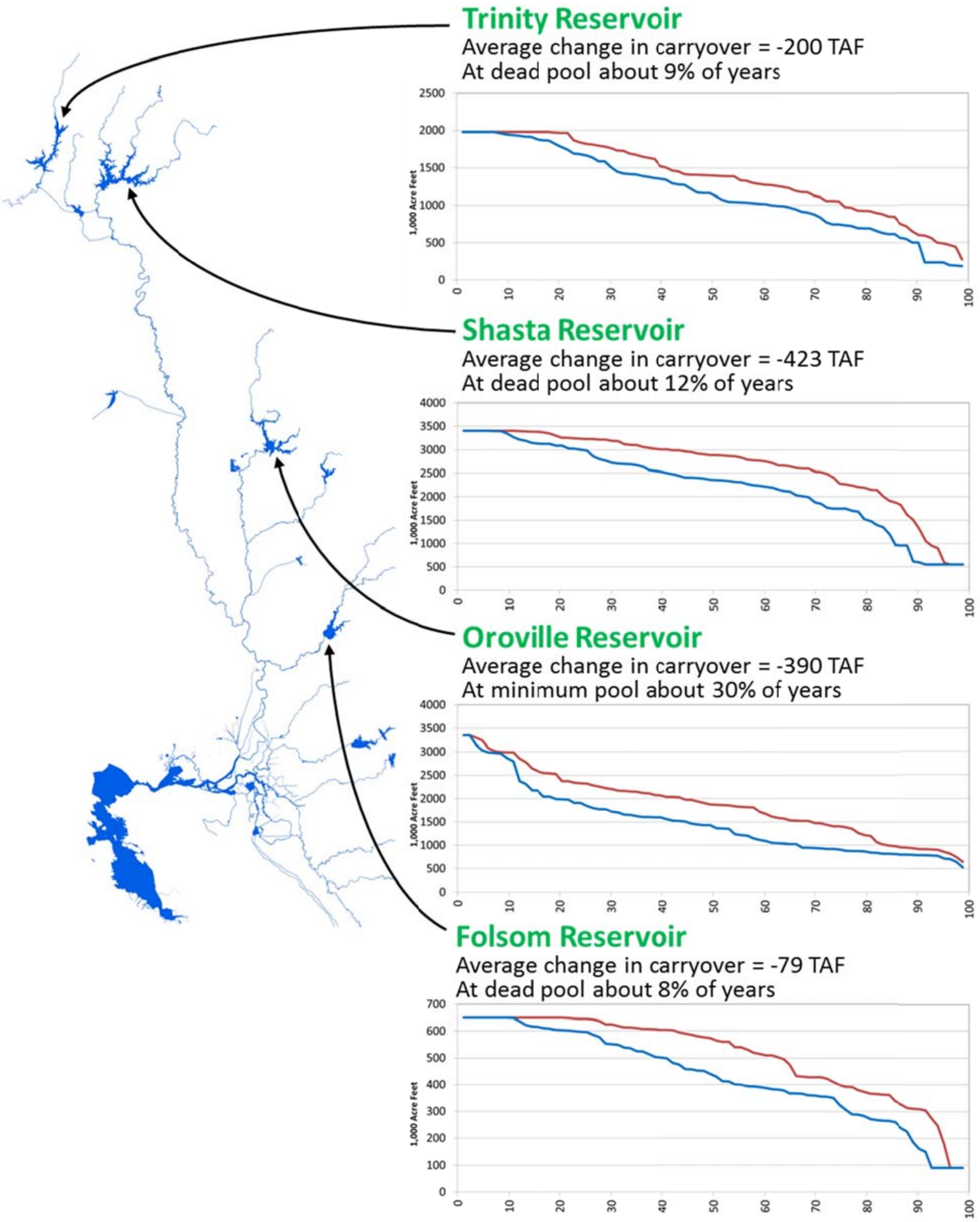


Figure 14 - Monthly Trinity Reservoir Storage
50% and 40% Unimpaired Flow Requirement

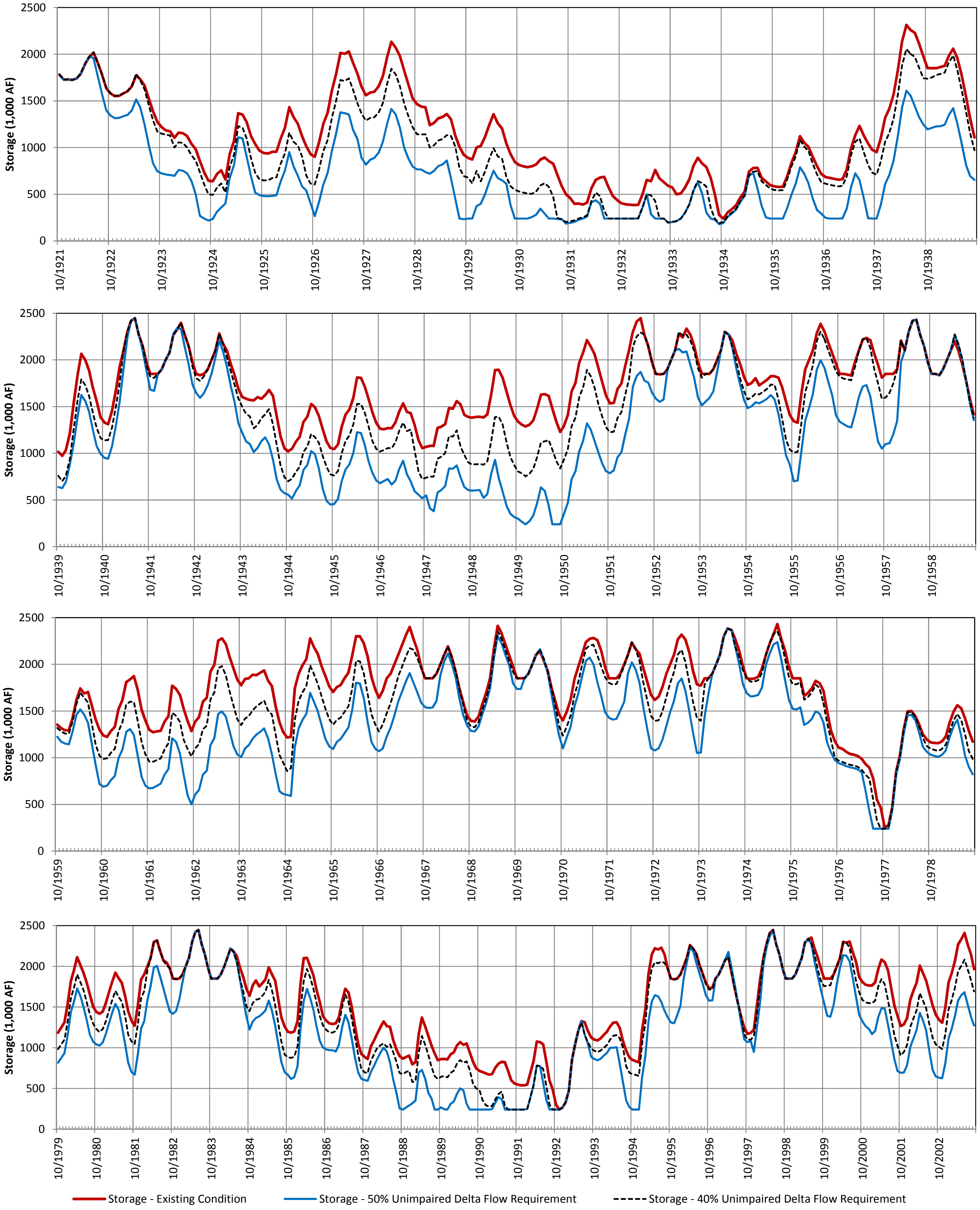


Figure 15 - Monthly Shasta Reservoir Storage
50% and 40% Unimpaired Flow Requirement

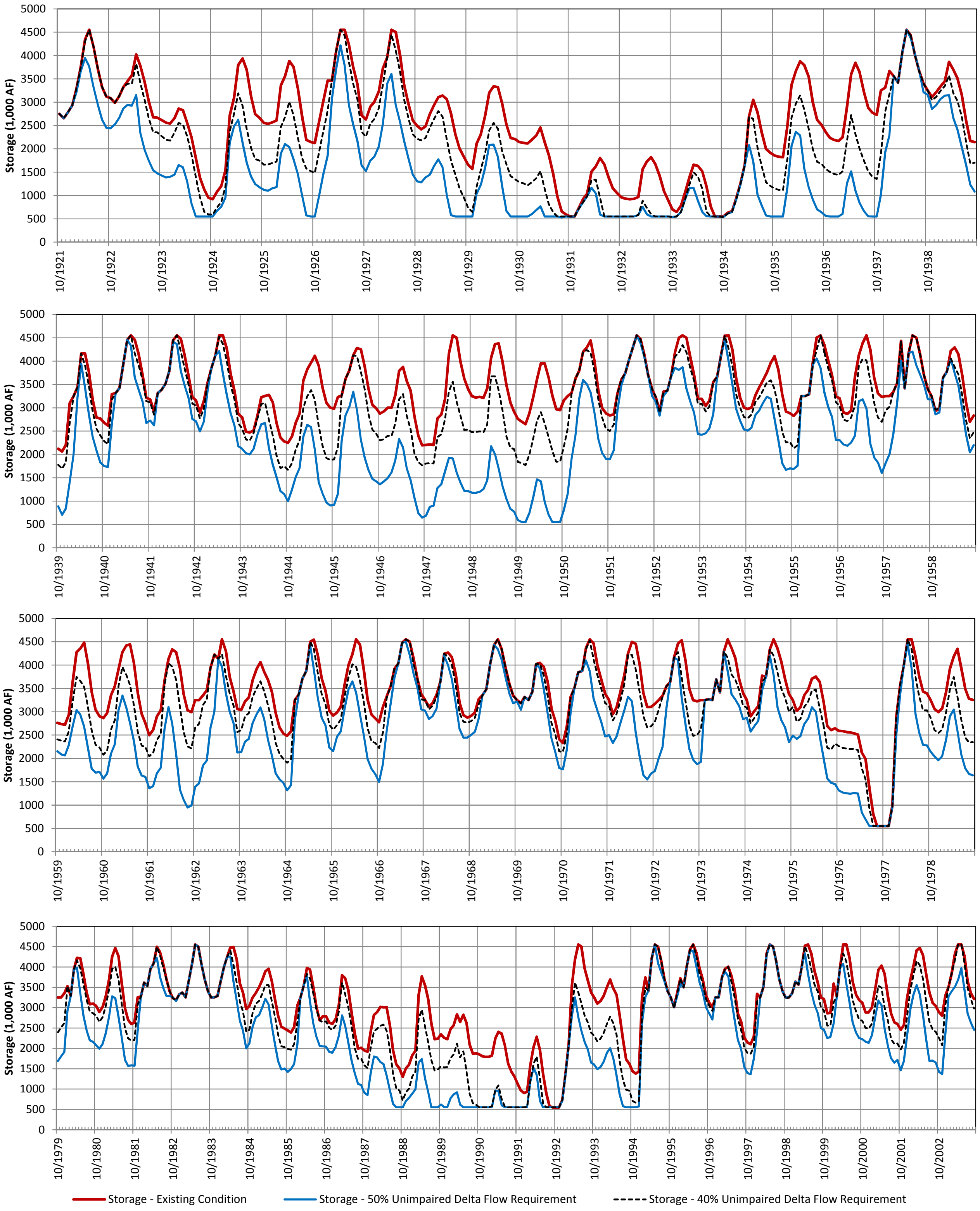


Figure 16 - Monthly Oroville Reservoir Storage
50% and 40% Unimpaired Flow Requirement

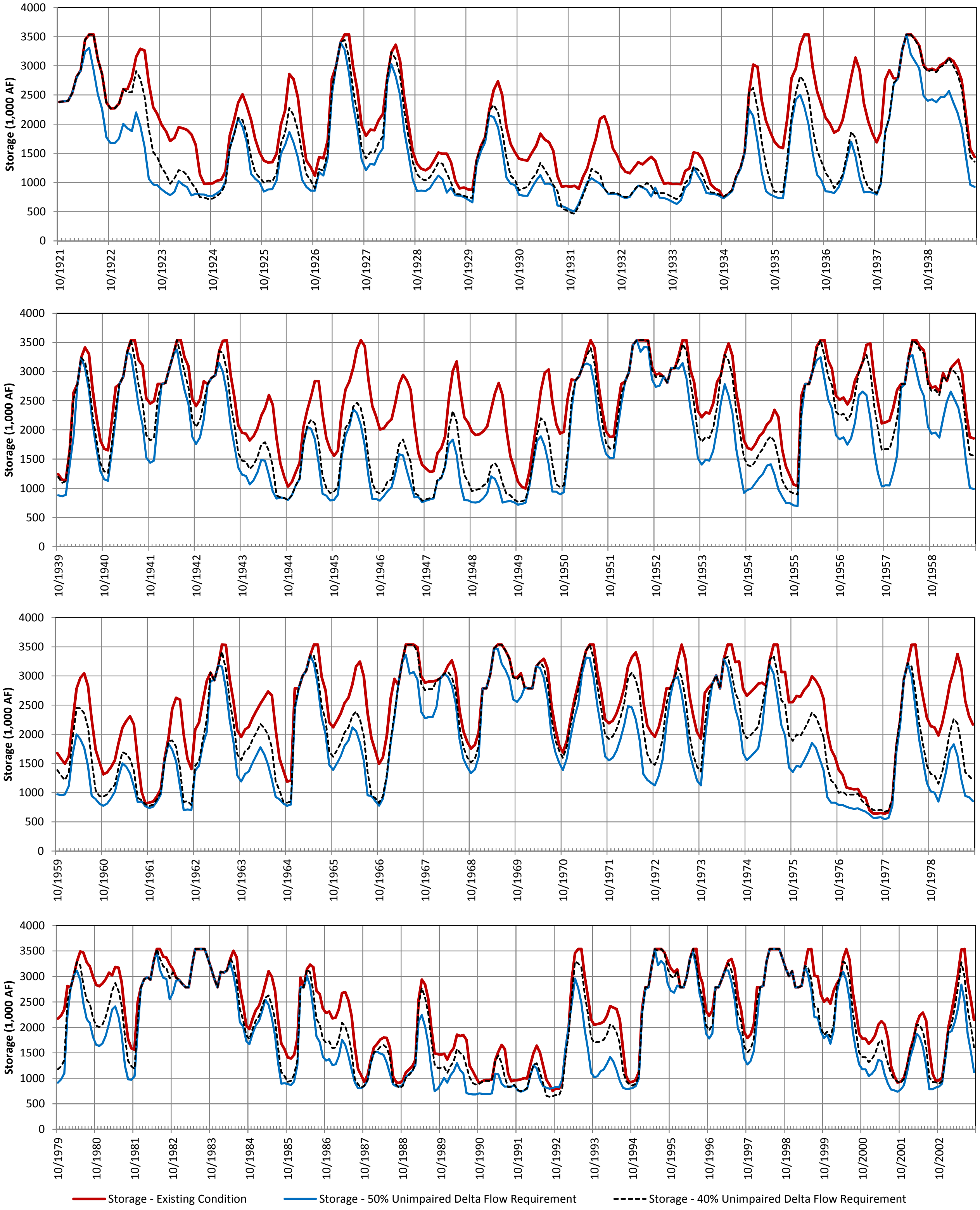
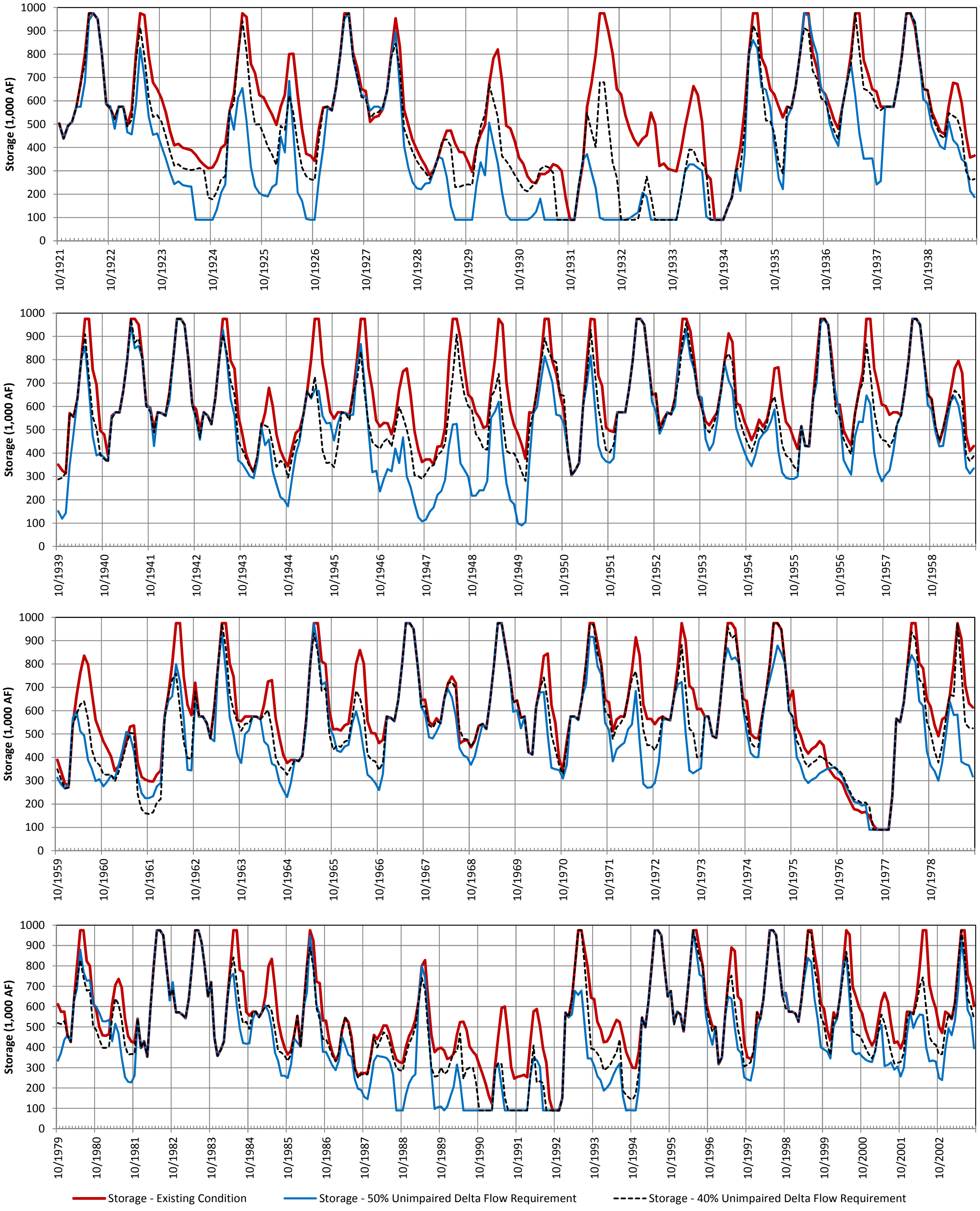


Figure 17 - Monthly Folsom Reservoir Storage
50% and 40% Unimpaired Flow Requirement



Changes in Flow Patterns

Figure 18 and Figure 19 provide summaries of the kinds of changes in the monthly flow patterns that would occur in rivers below the major CVP and SWP reservoirs with implementation of the 50% and 40% of unimpaired flow requirements. These river flows would typically be higher in the months of March, April, and May, and in some Junes, but would be lower in the other months, especially the summer months. Also, as mentioned in the above discussion of impacts to project reservoirs, the changes in river flow patterns that are estimated by CalSim II are underestimates of the impacts that actually would occur. Moreover, reductions in summer river flows would be much greater if reservoir releases were decreased further, to meet reservoir carryover requirements in order to maintain cold-water pools.

These decreased flows, and the resulting increased residence times, would cause the warmer water released into rivers to increase in temperature during the summer, when air temperatures are high. Effects below Oroville and Folsom Reservoirs would be equally dramatic.

These changes in flow patterns would impact hydropower generation as well. There would be increases in generation during spring months when hydropower is already abundant, and there would be decreases in generation during summer months when the State’s power demand is greatest.

Figure 18 - Changes in Key River Flow
50% Unimpaired Flow Requirement

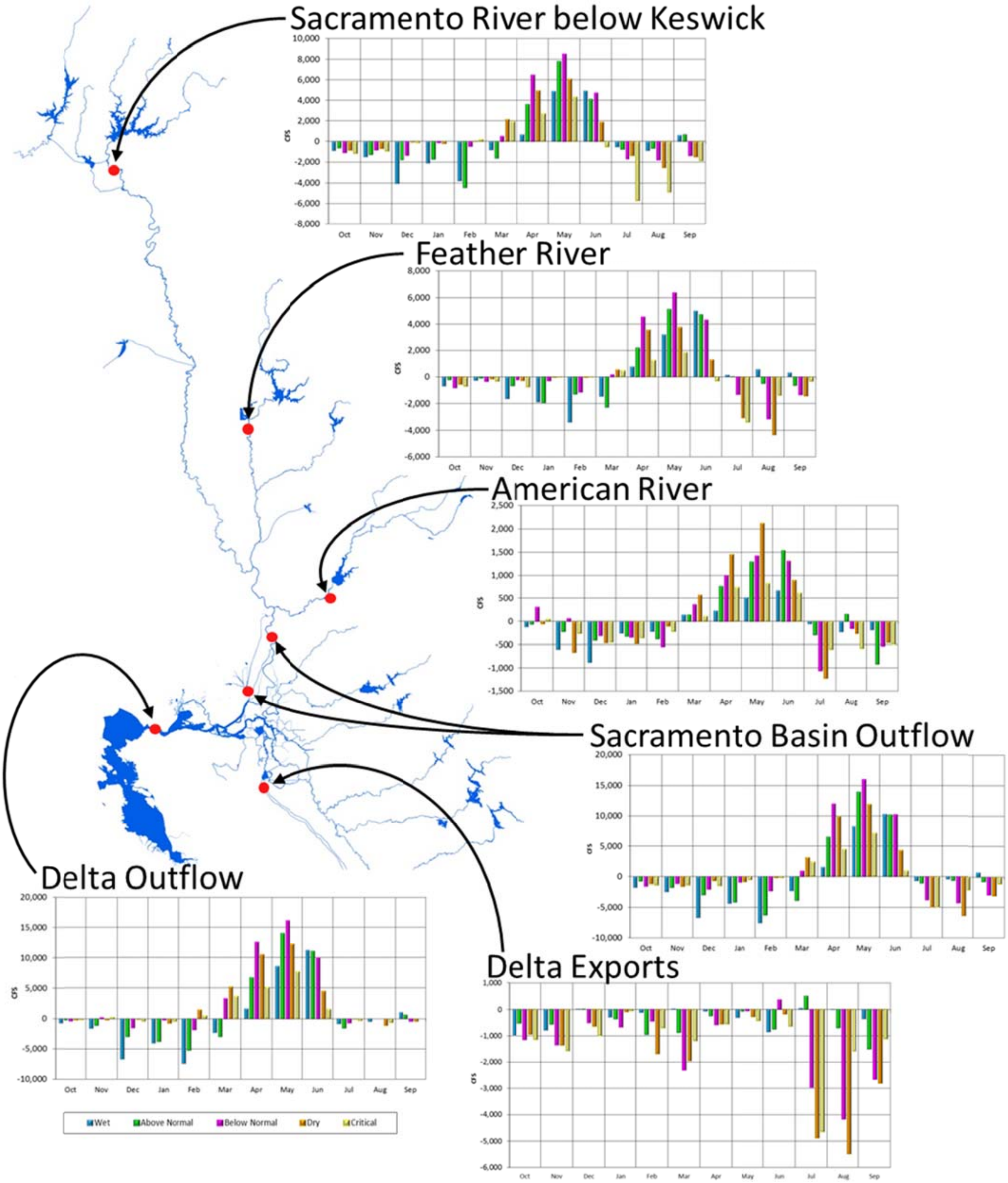
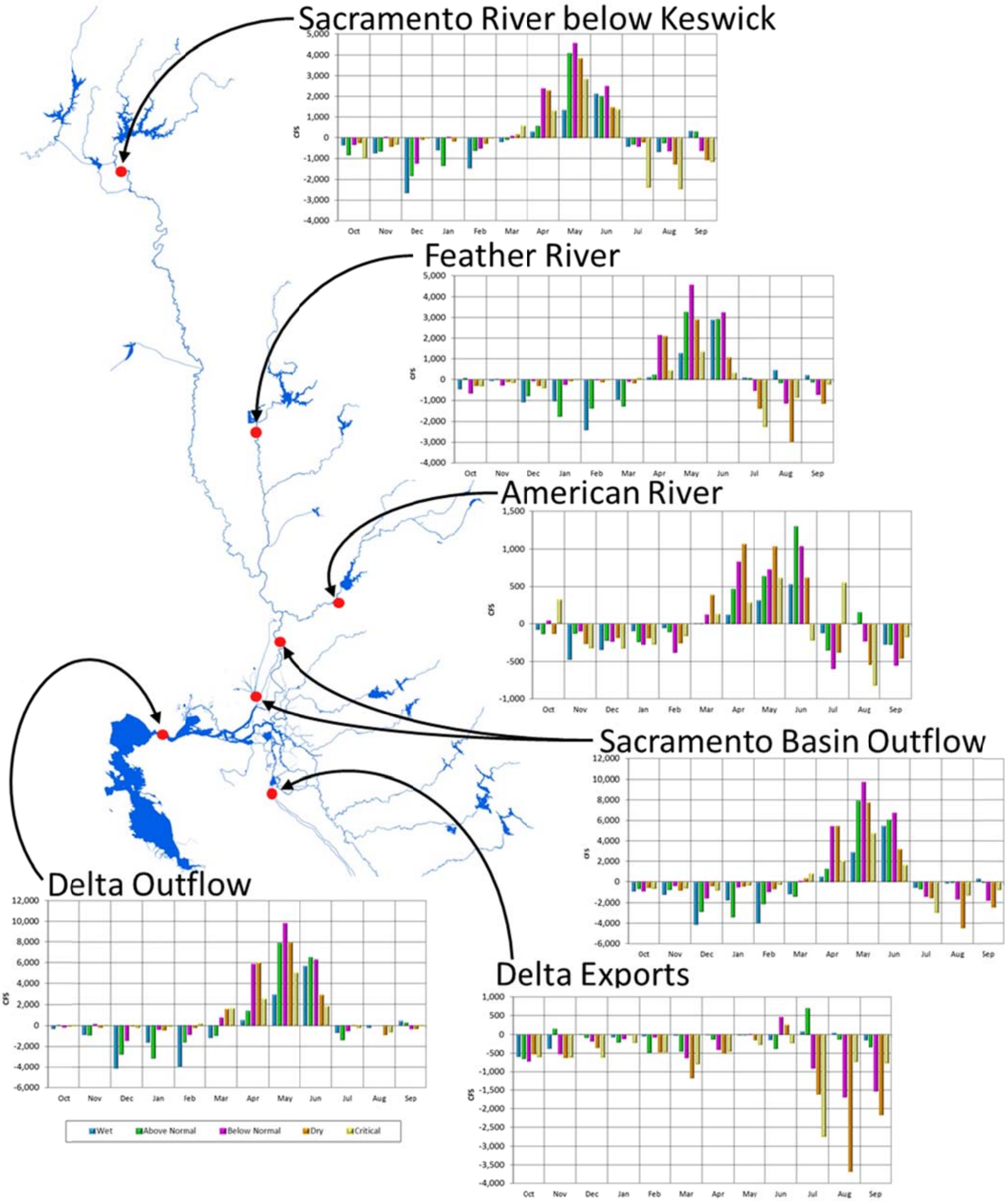


Figure 19 - Changes in Key River Flow
40% Unimpaired Flow Requirement



Violations of Existing Instream flow, Bay-Delta Plan, and ESA Biological Opinion Requirements

The increases in Delta outflows and Sacramento River flows that would occur during the January through June period with implementation of the 50% or 40% of unimpaired flow requirements would result in reduced river flows and Delta outflows in the July through December period. When the CalSim II model is run with these January through June percentage of unimpaired flow requirements, the model assumes that water would be released to satisfy the requirement during a specific month, even if the model then indicates that the reservoir would run out of water in the following month. For the 50% and 40% unimpaired requirement model runs, the model indicates that the CVP and SWP reservoirs would run out of water in about 20% of years. This situation would results in the inability of the CVP and SWP to comply with existing SWRCB requirements. In addition to the inability to comply with SWRCB requirements, there would be an inability to satisfy the requirements specified in the National Marine Fisheries Services' 2009 salmon biological opinion.

Figures 20 and 21 contain charts showing the monthly violations of SWRCB D-1641 requirements for the Sacramento River at Rio Vista that would occur under the 50% and 40% of unimpaired flow CalSim II model runs. In both unimpaired flow scenarios these violations would be larger than 1,000 cfs and typically would occur in drier years. There also would be a potential that D-1641 Delta water quality standards would be violated; however, this issue has not yet been analyzed.

Figure 20 - Violations in D-1641 Flow Requirement at Rio Vista – 50% Unimpaired Flow Requirement

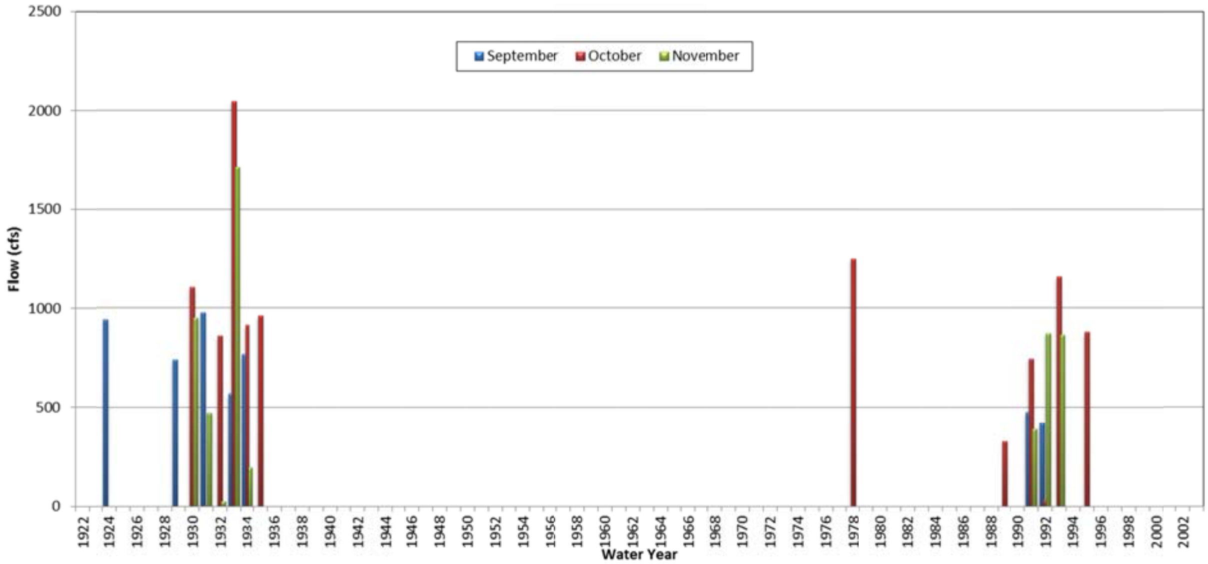
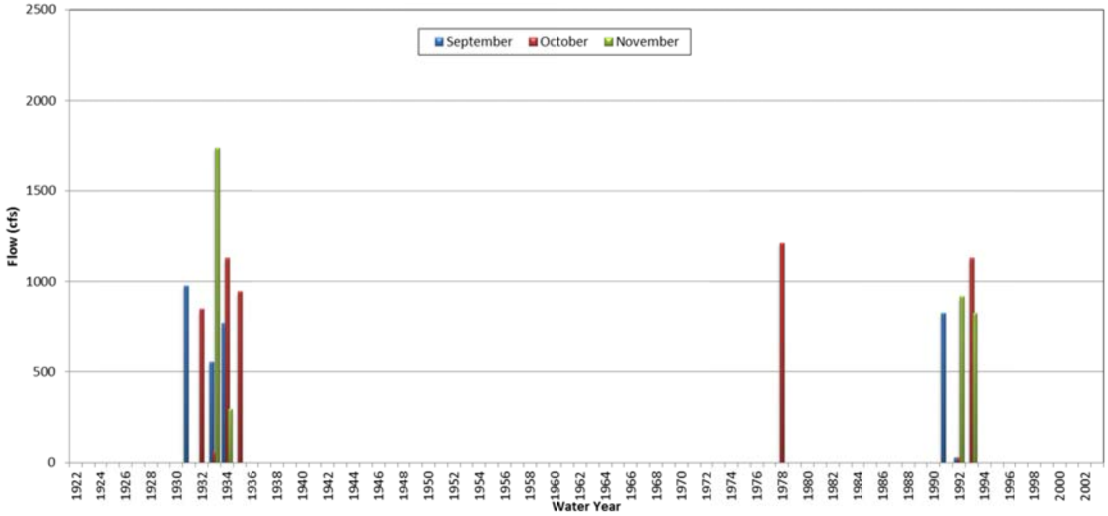


Figure 21 - Violations in D-1641 Flow Requirement at Rio Vista – 40% Unimpaired Flow Requirement



Figures 22 and 23 contain charts showing the monthly violations in Delta outflow requirements that would occur under the 50% and 40% of unimpaired flow CalSim II model runs. Delta outflow requirements include those contained in D-1641, the Delta smelt Biological Opinion, and the unimpaired flow requirement. In many years of the CalSim II model simulations there is not enough water to satisfy both the unimpaired flow requirement and existing Delta outflow requirements.

Figure 22 - Shortage in Minimum Required Delta Outflow– 50% Unimpaired Flow Requirement

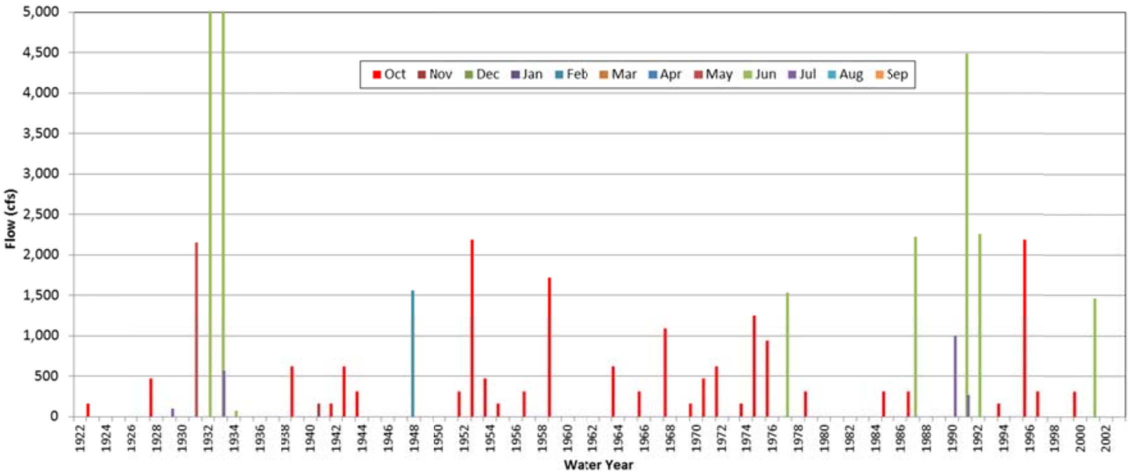
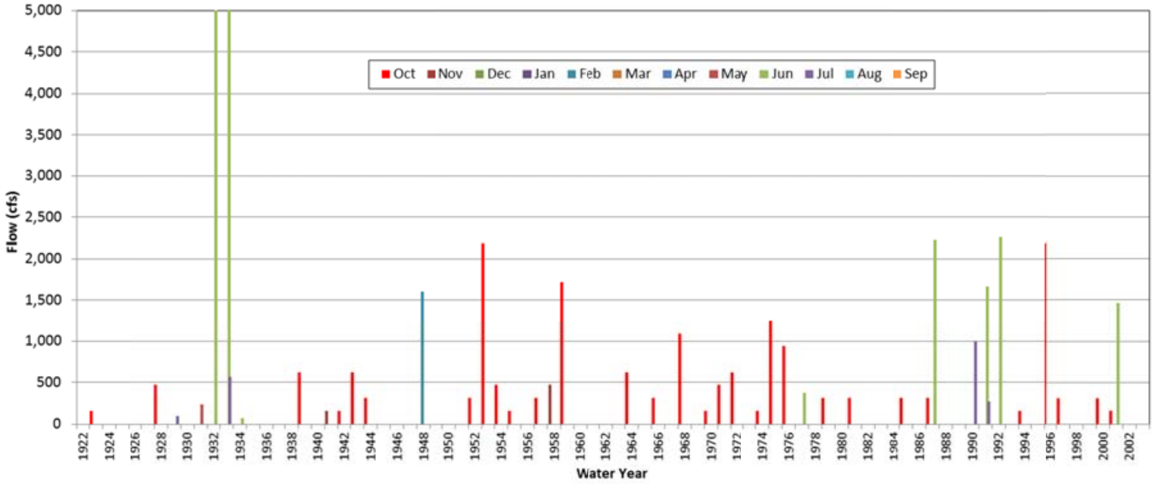


Figure 23 - Shortage in Minimum Required Delta Outflow– 40% Unimpaired Flow Requirement



The CalSim II model assumes that flows in the Sacramento River below Keswick Dam would be reduced when Shasta Reservoir reaches dead pool. The simulation modeling the 50% and 40% of unimpaired flow requirements, indicate that, with implementation of these requirements, Sacramento River flow below Keswick Dam would drop below the minimum flow requirement of 3,250 cfs. Figures 24 and 25 contain monthly exceedance plots of the Sacramento River flows below Keswick Dam that would occur under the 50% and 40% unimpaired flow scenarios. These figures indicate that violations would occur from July through November in the 50% of unimpaired flow scenario and from August through November in the 40% of unimpaired flow scenario. If the 50% or 40% of unimpaired flow requirement model runs were adjusted to maintain required carryover reservoir storage levels, then there would need to be additional dry year reduction of about 2 million AF in the 50% scenario and 1 million AF in the 40% scenario in reservoir releases from July through September; these reductions would require Keswick releases to be reduced from July through September to levels below the applicable flow standards.

Figure 24 – Monthly Exceedance plots of Sacramento River Flow below Keswick
50% Unimpaired Flow Requirement

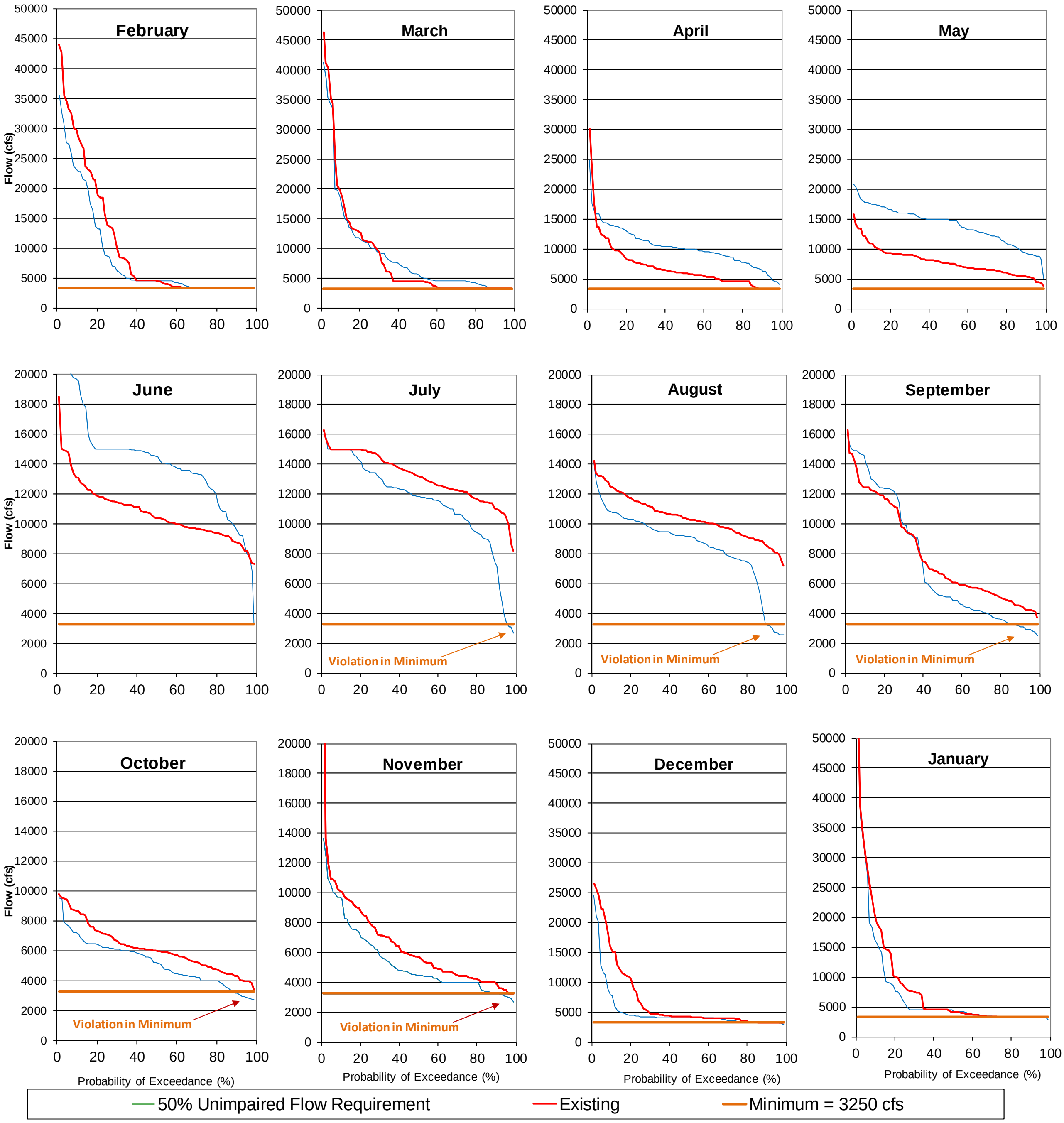
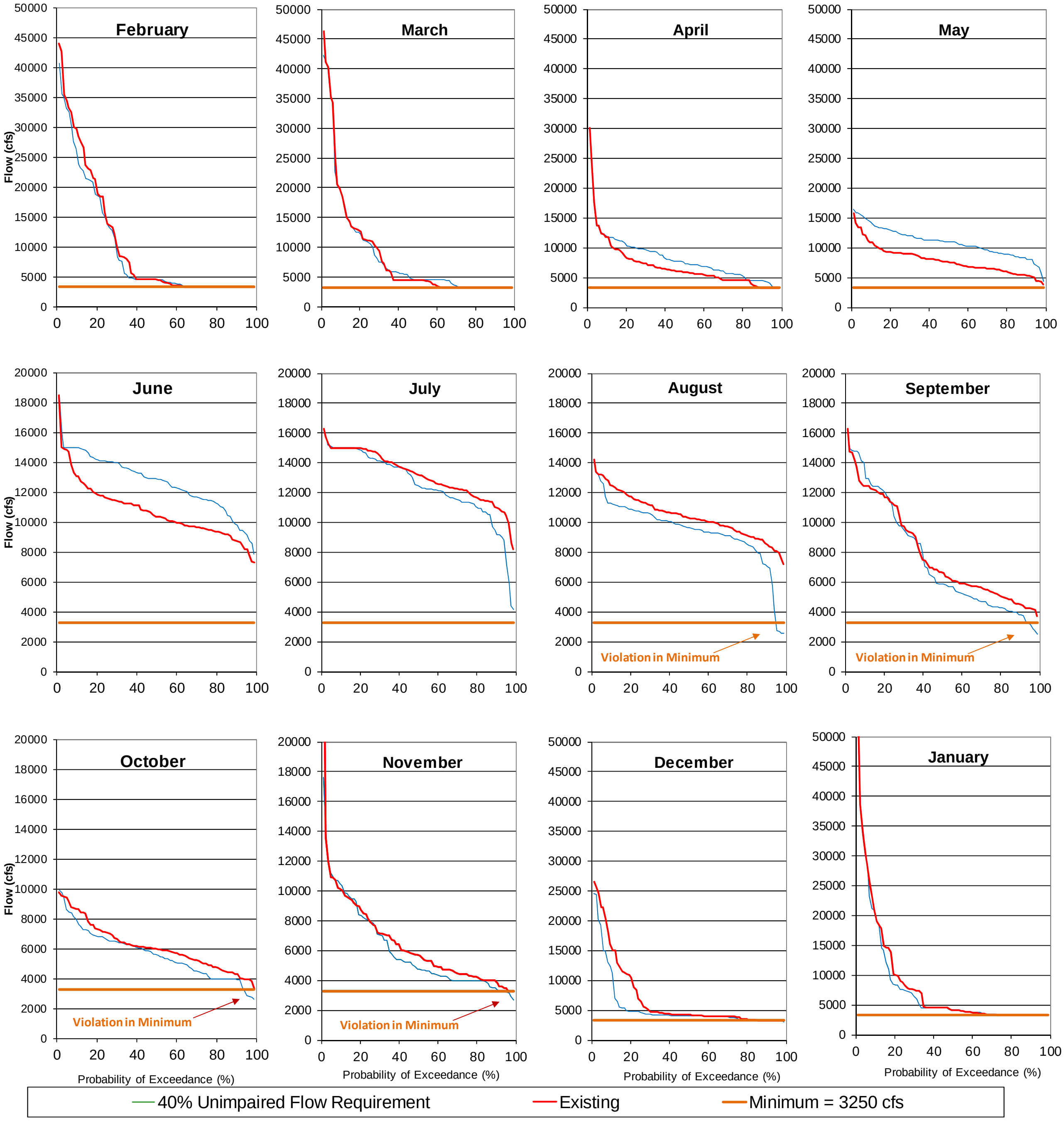


Figure 25 – Monthly Exceedance plots of Sacramento River Flow below Keswick
40% Unimpaired Flow Requirement



Water Supply Impacts

This analysis assumes that the CVP and SWP reservoirs will be operated to meet the 50% and 40% of unimpaired flow requirements; therefore, the analysis assumes that all water supply impacts would be on the CVP and SWP. As discussed above, all of the estimated water supply impacts are underestimates of the actual water supply impacts that would occur from implementation of these requirements. This is because although rules governing CalSim II's simulations of the CVP / SWP system have been developed to produce meaningful operations under a wide range of alterative scenarios, simulation of the 50% and 40% of unimpaired flow requirements requires simulation of operating conditions that would be outside of the range of CalSim II's existing rules. Nevertheless, modeling under CalSim II is the best available method of estimating the impacts of implementing such flow requirements. Additional features would need to be incorporated into the CalSim II model to estimate the full range of impacts to the water system that implementation of the 50% and 40% of unimpaired flow requirements would cause.

Table 5 contains summaries of estimated average annual water deliveries to CVP contractors under Existing Conditions and under the 50% unimpaired flow requirement, and a summary of the differences. Average annual North of Delta (NOD) deliveries would be reduced by 172,000 AF and South of Delta (SOD) would decrease by 346,000 AF. Average critical year reductions NOD would be 542,000 AF and reductions SOD would be approximately 368,000 AF. Table 6 contains summaries of estimated average annual water deliveries to CVP contractors under Existing Conditions and under the 40% unimpaired flow requirement, and a summary of the differences. Average annual North of Delta (NOD) deliveries would be reduced by 74,000 AF and South of Delta (SOD) would decrease by 140,000 AF. Average critical year reductions NOD would be 216,000 AF and reductions SOD would be approximately 172,000 AF. It is important to note that the model assumes that diversions by settlement and exchange contractors would be curtailed, both NOD and SOD, and that the model does not contain any adjustment to maintain these contractors' water diversion priorities. The model results also indicate that municipal and industrial (M&I) deliveries north and south of Delta would be reduced to levels such that public health and safety water supply needs would be difficult or impossible to satisfy.

The model results indicate that water deliveries to wildlife refuges would be reduced to extents that could have effects on the Pacific Flyway. The water supply reductions to agriculture in both the Sacramento and San Joaquin Valleys would also result in water supply reductions to wildlife refuges in these areas. Additionally, the loss of rice production acreage in the Sacramento Valley would affect the Pacific Flyway due to the loss of fall flood-up habitat.

Tables 7 and 8 contain a summary of estimated annual water deliveries to SOD SWP contractors under the Existing Conditions and 50% and 40% of unimpaired flow requirements scenarios, and a summary of the differences. The estimated average annual reductions in SOD SWP contractor deliveries is 352,000 AF in the 50% of unimpaired scenario and 191,000 AF in the 40% of unimpaired scenario. Estimated dry and critical year delivery reductions are 863,000 AF and 460,000 AF, respectively in the 50% of unimpaired flow scenario and 516,000 AF and 299,000 AF, respectively in the 40% of unimpaired flow scenario.

Figure 26 contains exceedance probability plots of CVP water supply allocations for CVP NOD agricultural service contractors, CVP SOD agricultural service contractors, CVP NOD M&I contractors, and CVP SOD M&I contractors for the Existing Conditions and 50% of unimpaired flow scenarios. Figure 27 contains this information for the 40% of unimpaired flow scenario. Under the 50% of unimpaired flow scenario, both NOD and SOD agricultural service contractors would receive no water supplies in 20% of all years, and would experience significant reductions in allocations in most years. Under 50% of unimpaired flow scenario, both NOD and SOD M&I contractors would receive 50% allocations in 20% of all years, which would result in difficulties in meeting public health and safety water needs. There would be difficulty in satisfying public health and safety water needs in the 40% of unimpaired flow study, but not to the degree of the 50% of unimpaired flow scenario. In addition to reduced water supply allocations, when project reservoirs would reach dead pool, most M&I water supply deliveries would be further reduced, and in many months would be zero.

Figures 28 and 29 contain exceedance probability plots of SWP SOD water supply allocations under both of these scenarios. The plots indicate that, in 60% of all years, SWP SOD water supply deliveries would be significantly reduced with implementation of the 50% of unimpaired flow requirements and in 50% of all years with implementation of the 40% of unimpaired flow requirements.

Table 5 - CVP Delivery Summary (1,000 AF)

50% Unimpaired Flow Requirement

	AG NOD	AG SOD	Exchange	M&I NOD	M&I SOD	Refuge NOD	Refuge SOD	Sac. Setlmnt	CVP NOD Total	CVP SOD Total
Existing										
All Years	226	879	852	85	117	68	296	1840	2219	2326
W	318	1380	875	93	136	70	305	1837	2318	2879
AN	286	962	802	85	113	65	279	1696	2131	2325
BN	220	717	875	86	112	70	305	1881	2257	2192
D	159	605	864	81	108	69	300	1876	2184	2061
C	53	233	741	68	87	56	252	1740	1917	1492
50% Unimpaired Flow Requirement										
All Years	150	592	836	75	99	65	287	1758	2048	1980
W	303	1278	875	92	131	71	304	1836	2301	2772
AN	206	686	802	78	105	65	279	1695	2045	2040
BN	78	233	865	70	88	70	301	1859	2077	1660
D	29	125	847	64	79	68	293	1833	1994	1506
C	17	84	664	51	56	35	206	1272	1375	1124
Difference										
All Years	-75	-286	-17	-10	-18	-3	-9	-83	-172	-346
W	-15	-103	0	-1	-4	0	0	0	-16	-107
AN	-80	-277	0	-6	-8	0	0	0	-86	-284
BN	-142	-484	-10	-15	-24	0	-3	-22	-180	-532
D	-130	-479	-17	-17	-30	-1	-8	-43	-190	-554
C	-36	-149	-77	-16	-31	-22	-45	-468	-542	-368

Table 6 - CVP Delivery Summary (1,000 AF)

40% Unimpaired Flow Requirement

	AG NOD	AG SOD	Exchange	M&I NOD	M&I SOD	Refuge NOD	Refuge SOD	Sac. Setlmnt	CVP NOD Total	CVP SOD Total
Existing										
All Years	226	879	852	85	117	68	296	1840	2219	2326
W	318	1380	875	93	136	70	305	1837	2318	2879
AN	286	962	802	85	113	65	279	1696	2131	2325
BN	220	717	875	86	112	70	305	1881	2257	2192
D	159	605	864	81	108	69	300	1876	2184	2061
C	53	233	741	68	87	56	252	1740	1917	1492
40% Unimpaired Flow Requirement										
All Years	190	756	850	80	110	66	292	1809	2145	2186
W	313	1346	875	92	135	70	304	1837	2312	2843
AN	256	896	802	82	113	65	279	1695	2099	2258
BN	158	500	875	80	104	70	305	1881	2188	1968
D	88	375	860	72	99	68	300	1850	2079	1816
C	31	144	730	59	68	47	230	1565	1701	1320
Difference										
All Years	-36	-123	-2	-5	-6	-1	-4	-32	-74	-140
W	-5	-34	0	-1	-1	0	-1	0	-6	-36
AN	-29	-67	0	-2	0	0	0	0	-32	-67
BN	-63	-217	0	-6	-7	0	0	0	-69	-225
D	-71	-229	-4	-9	-9	0	0	-26	-106	-244
C	-22	-88	-11	-9	-19	-9	-21	-176	-216	-172

Table 7 - SWP South of Delta Delivery Summary (1,000 AF)

50% Unimpaired Flow Requirement

	MWD	"Other" M&I	AG SOD	Art. 56	Art 21	M&I	Table A	Total
Existing								
All Years	1037	610	596	303	71	1647	2242	2616
W	1186	713	738	393	140	1899	2637	3169
AN	1065	606	601	222	60	1671	2271	2554
BN	1121	641	618	376	31	1762	2380	2788
D	1001	582	535	225	39	1583	2118	2382
C	551	348	298	196	21	899	1196	1414
50% Unimpaired Flow Requirement								
All Years	906	540	521	232	66	1446	1967	2264
W	1202	711	738	328	120	1913	2651	3099
AN	1067	605	600	148	113	1672	2272	2533
BN	968	578	521	297	41	1546	2067	2404
D	619	387	334	168	11	1006	1339	1519
C	388	243	210	107	6	631	841	954
Difference								
All Years	-131	-70	-75	-71	-5	-201	-275	-352
W	15	-1	0	-65	-19	14	14	-70
AN	2	-1	-1	-74	53	1	0	-21
BN	-154	-62	-98	-80	10	-216	-314	-384
D	-383	-195	-201	-56	-28	-578	-779	-863
C	-163	-105	-88	-89	-16	-268	-356	-460

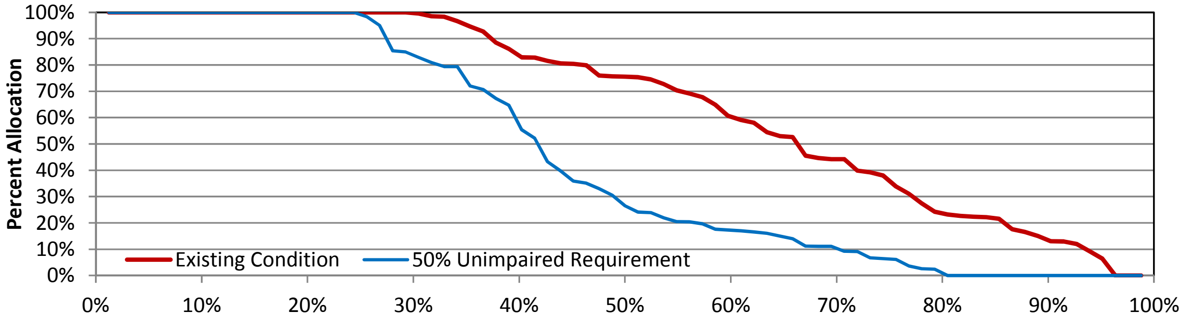
Table 8 - SWP South of Delta Delivery Summary (1,000 AF)

40% Unimpaired Flow Requirement

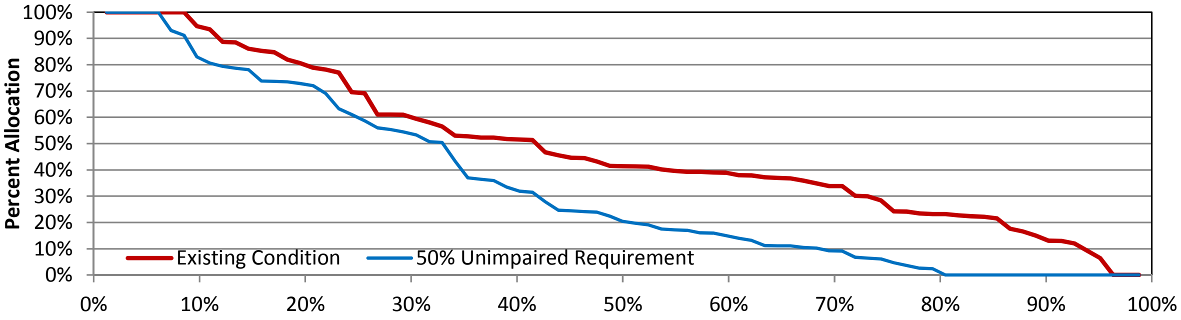
	MWD	"Other" M&I	AG SOD	Art. 56	Art 21	M&I	Table A	Total
Existing								
All Years	1037	610	596	303	71	1647	2242	2616
W	1186	713	738	393	140	1899	2637	3169
AN	1065	606	601	222	60	1671	2271	2554
BN	1121	641	618	376	31	1762	2380	2788
D	1001	582	535	225	39	1583	2118	2382
C	551	348	298	196	21	899	1196	1414
40% Unimpaired Flow Requirement								
All Years	968	571	555	265	65	1539	2094	2425
W	1194	712	738	356	142	1906	2644	3142
AN	1064	601	598	211	69	1666	2263	2543
BN	1096	619	586	317	41	1715	2301	2659
D	777	475	419	189	7	1251	1671	1866
C	438	278	237	155	6	717	954	1115
Difference								
All Years	-69	-39	-41	-37	-6	-107	-148	-191
W	7	-1	0	-36	2	7	7	-28
AN	0	-5	-3	-11	9	-5	-8	-10
BN	-25	-22	-33	-59	10	-47	-79	-129
D	-225	-107	-116	-35	-33	-332	-448	-516
C	-113	-69	-61	-41	-15	-182	-243	-299

Figure 26 – CVP Water Supply Allocation
50% Unimpaired Flow Requirement

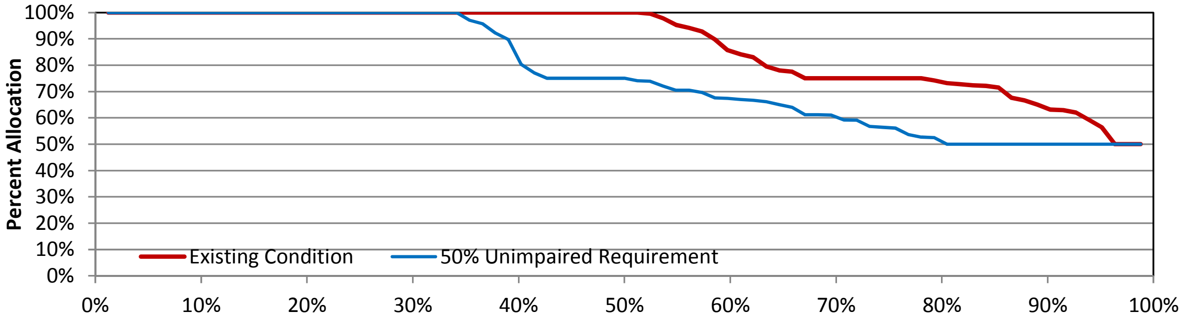
CVP North of Delta Agricultural Service Contract Allocation



CVP South of Delta Agricultural Service Contract Allocation



CVP North of Delta M&I Contract Allocation



CVP South of Delta M&I Contract Allocation

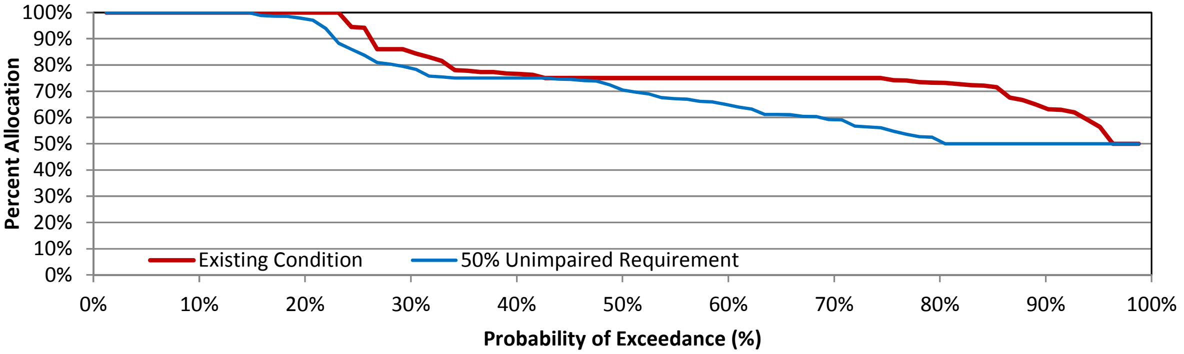
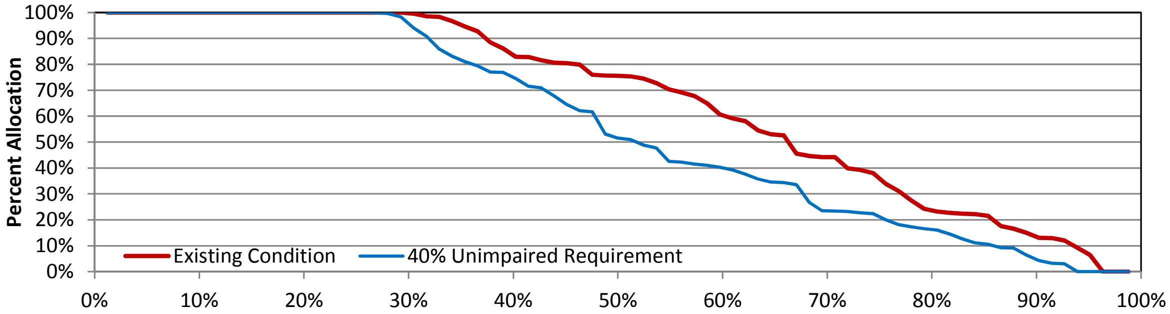
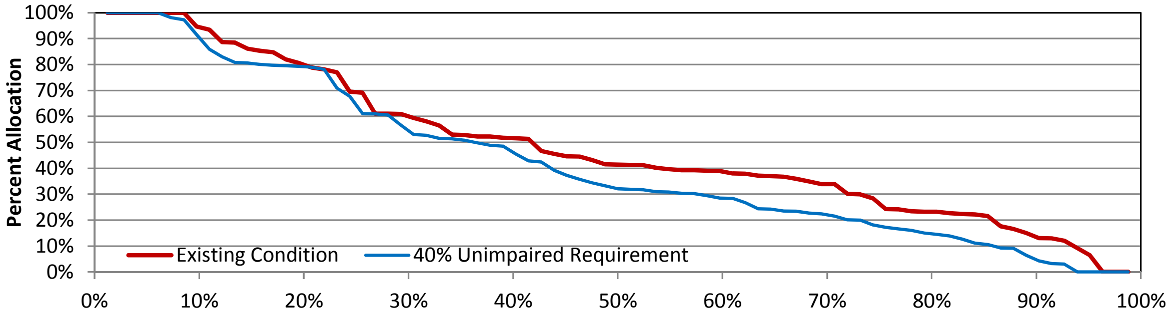


Figure 27 – CVP Water Supply Allocation
40% Unimpaired Flow Requirement

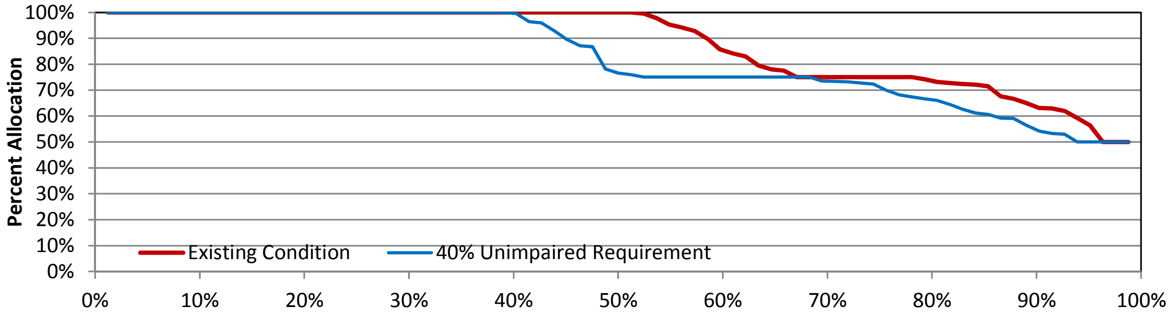
CVP North of Delta Agricultural Service Contract Allocation



CVP South of Delta Agricultural Service Contract Allocation



CVP North of Delta M&I Contract Allocation



CVP South of Delta M&I Contract Allocation

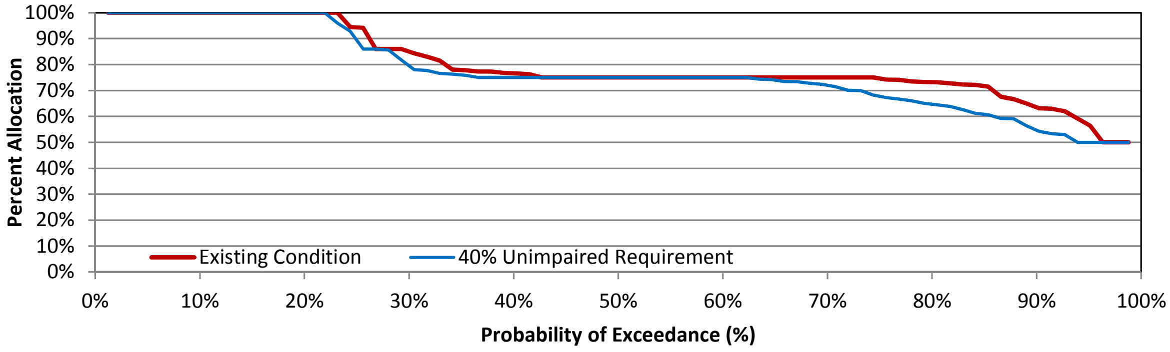


Figure 28 – SWP Water Supply Allocation
50% Unimpaired Flow Requirement

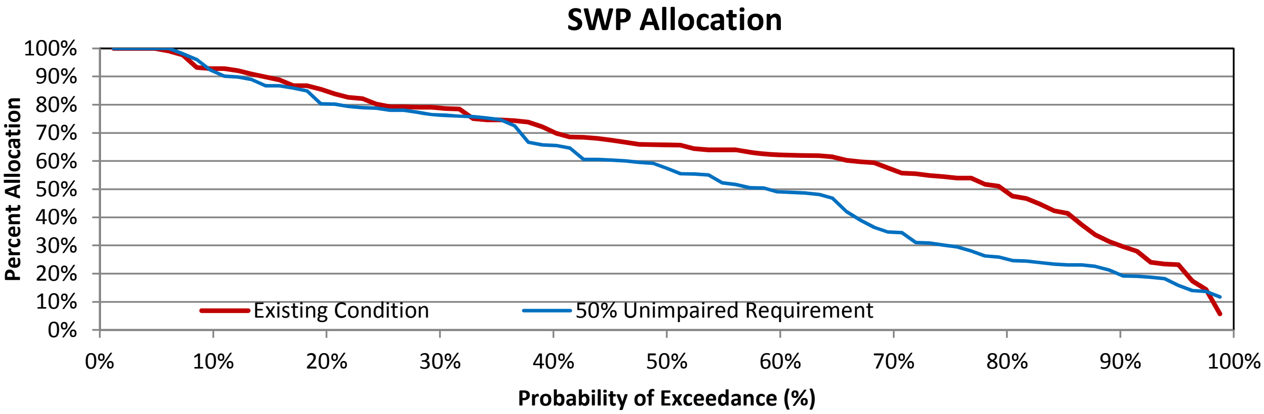


Figure 29 – SWP Water Supply Allocation
40% Unimpaired Flow Requirement

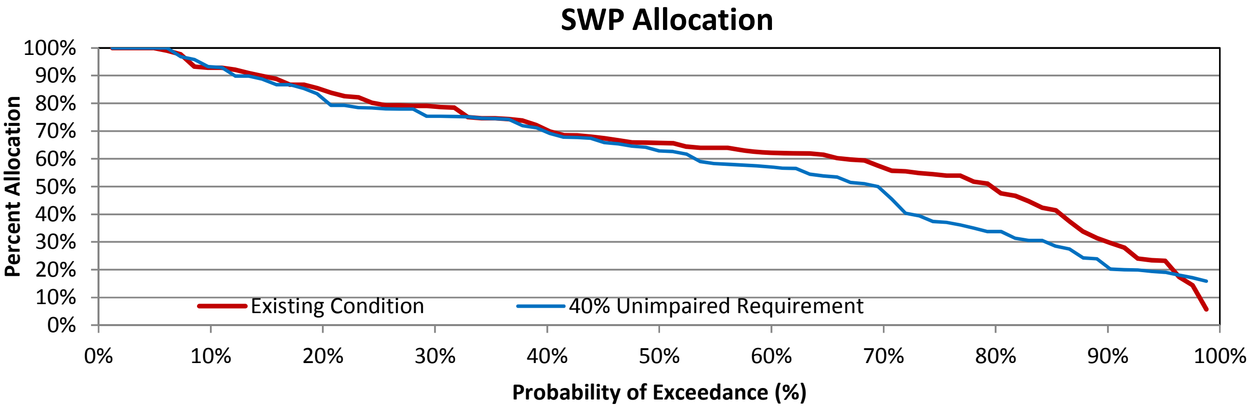
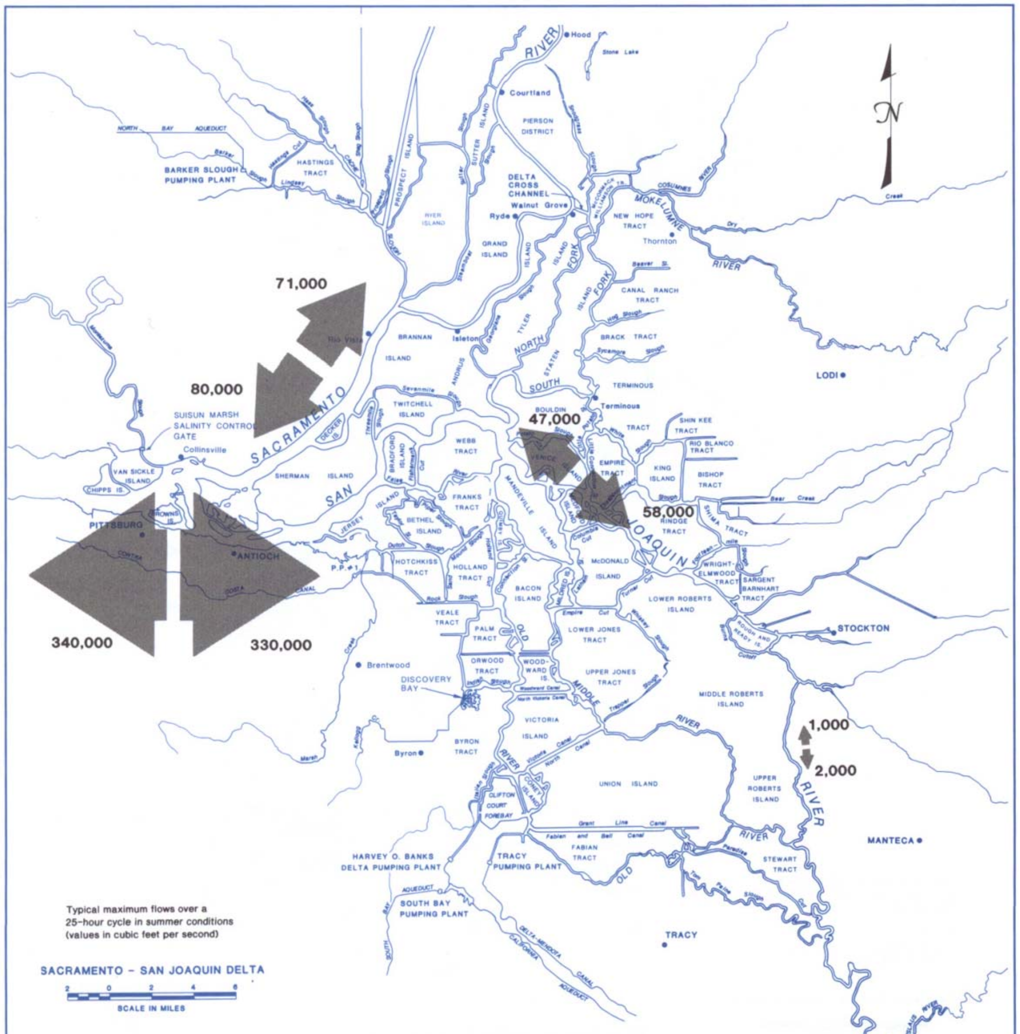


Exhibit 4
Tidal Influence in The Delta

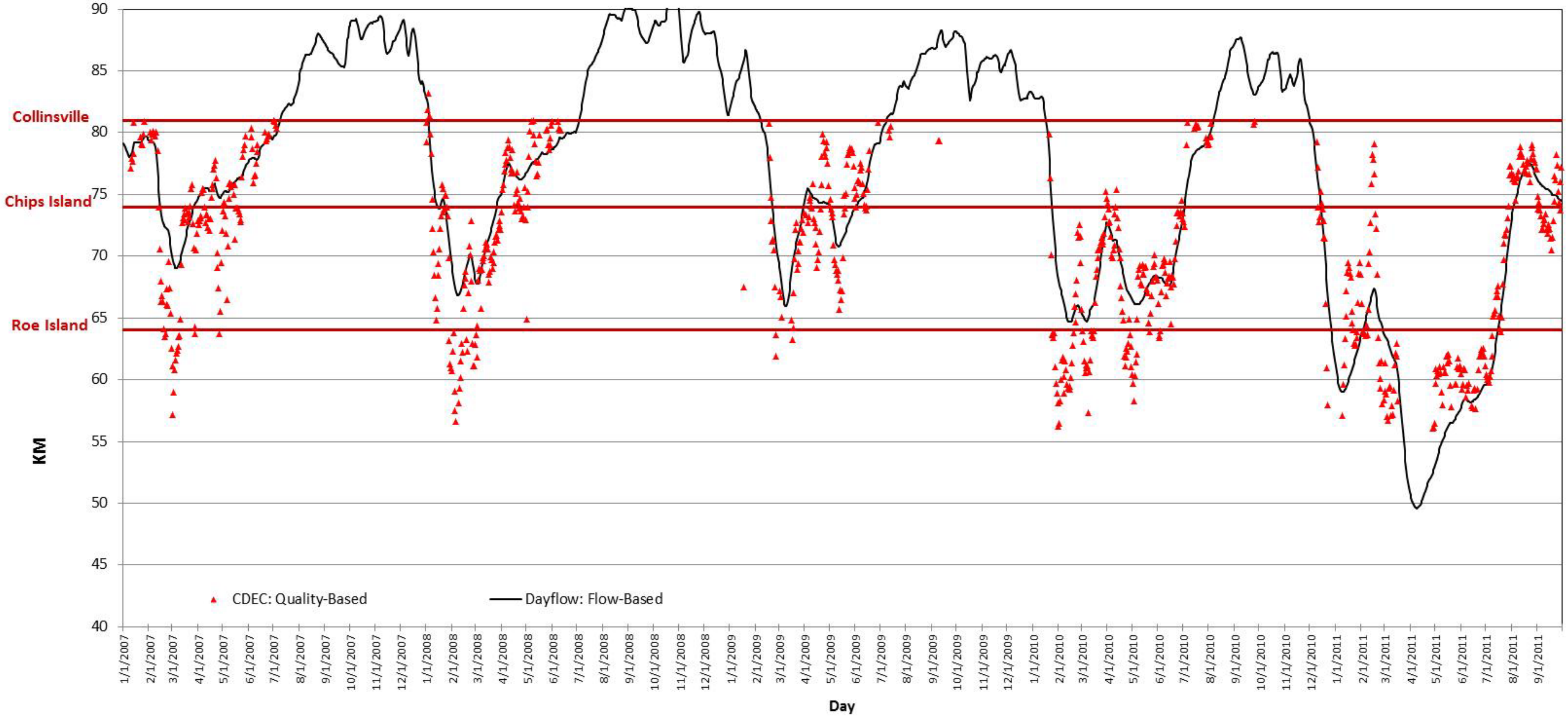
Sacramento San Joaquin Delta Atlas (DWR 1995):

"During the tidal cycle, flows can . . . vary in direction and amount. For example and as shown on the map below, the flow near Pittsburg during a typical summer tidal cycle can vary from 330,000 cfs upstream to 340,000 cfs downstream. The 'net' summer Delta outflow is a very small amount of the total water movement, generally 5,000 to 10,000 cfs."



Delta Tidal Flows

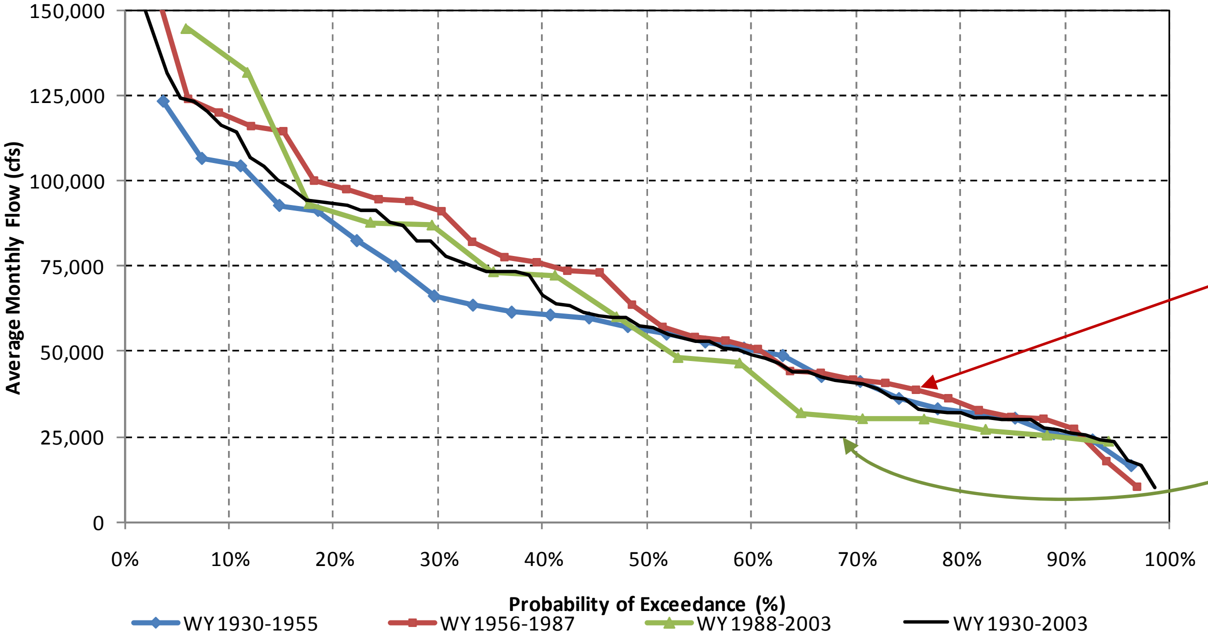
Exhibit 5
X2 Location



- X2 position is not measured, but only estimated, and varies significantly based on the estimation method

- There are significant discrepancies between flow-based X2 values (DAYFLOW) and water quality-based X2 values (CDEC)

Exhibit 6
Unimpaired January - June Delta Outflow

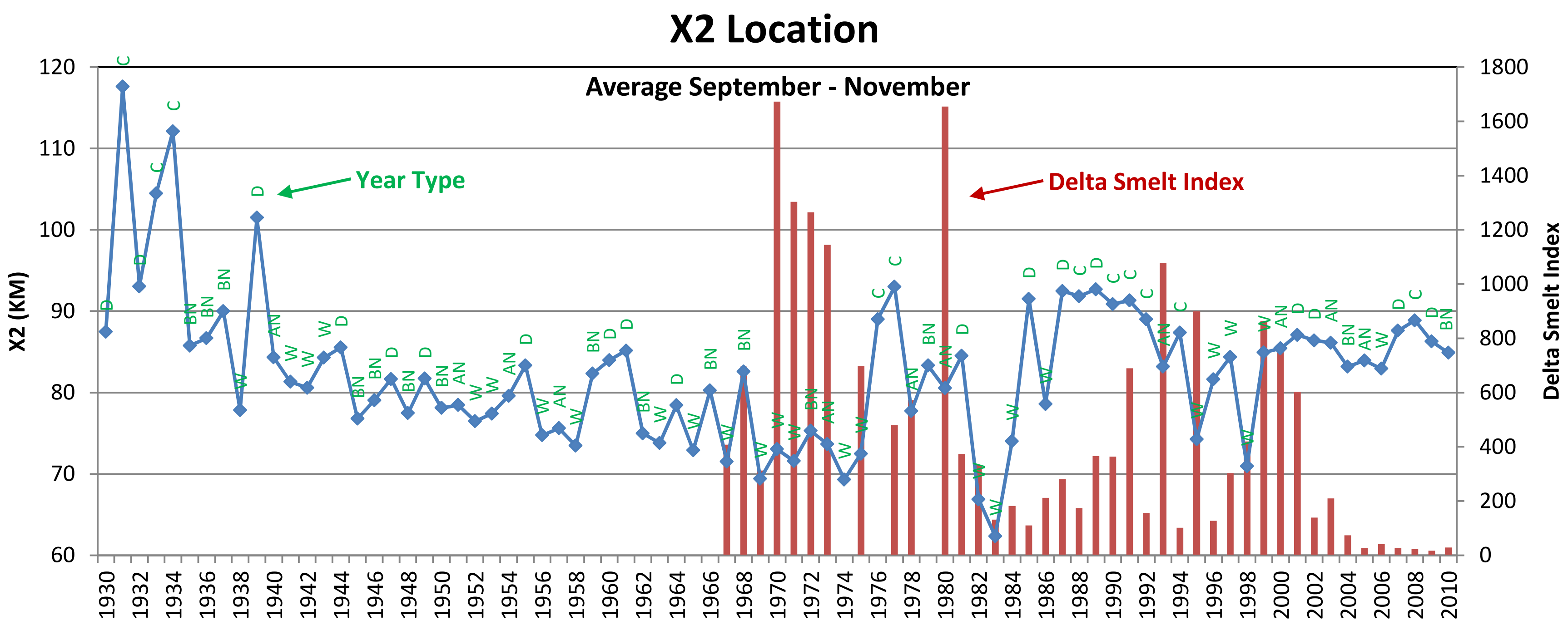


1956-1987 average flow is 4,300 cfs greater than 1988-2003 average flow

Period	Average Flow (cfs)
1930-2003:	64,000
1930-1955:	59,000
1956-1987:	67,600
1988-2003:	63,300

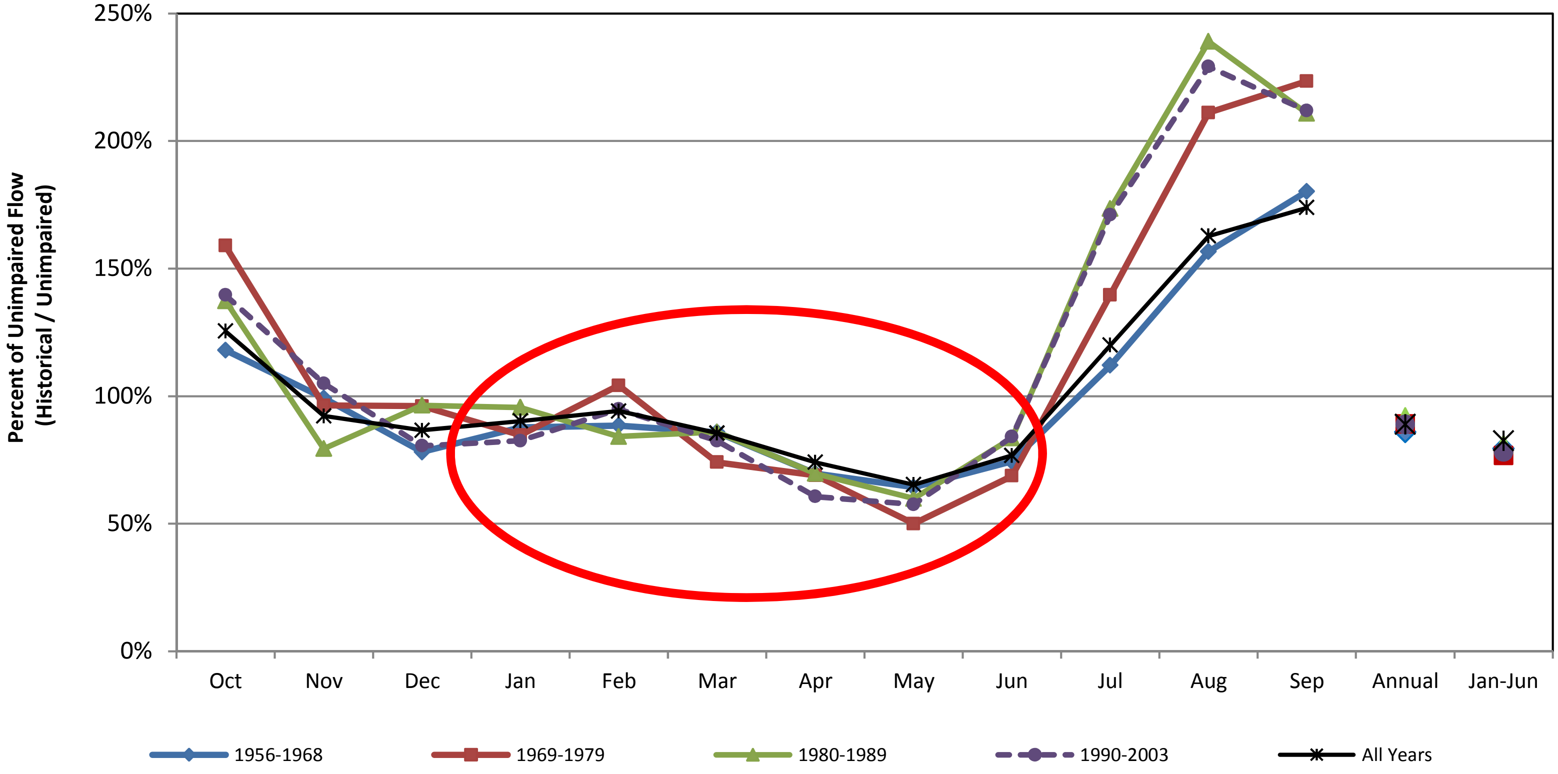
- Differences in hydrology must be considered in comparing environmental conditions in different time periods
- Attempting to recreate past hydrology through regulatory requirements will not produce past environmental conditions

Exhibit 7
September-November X2 Location & Delta Smelt Index



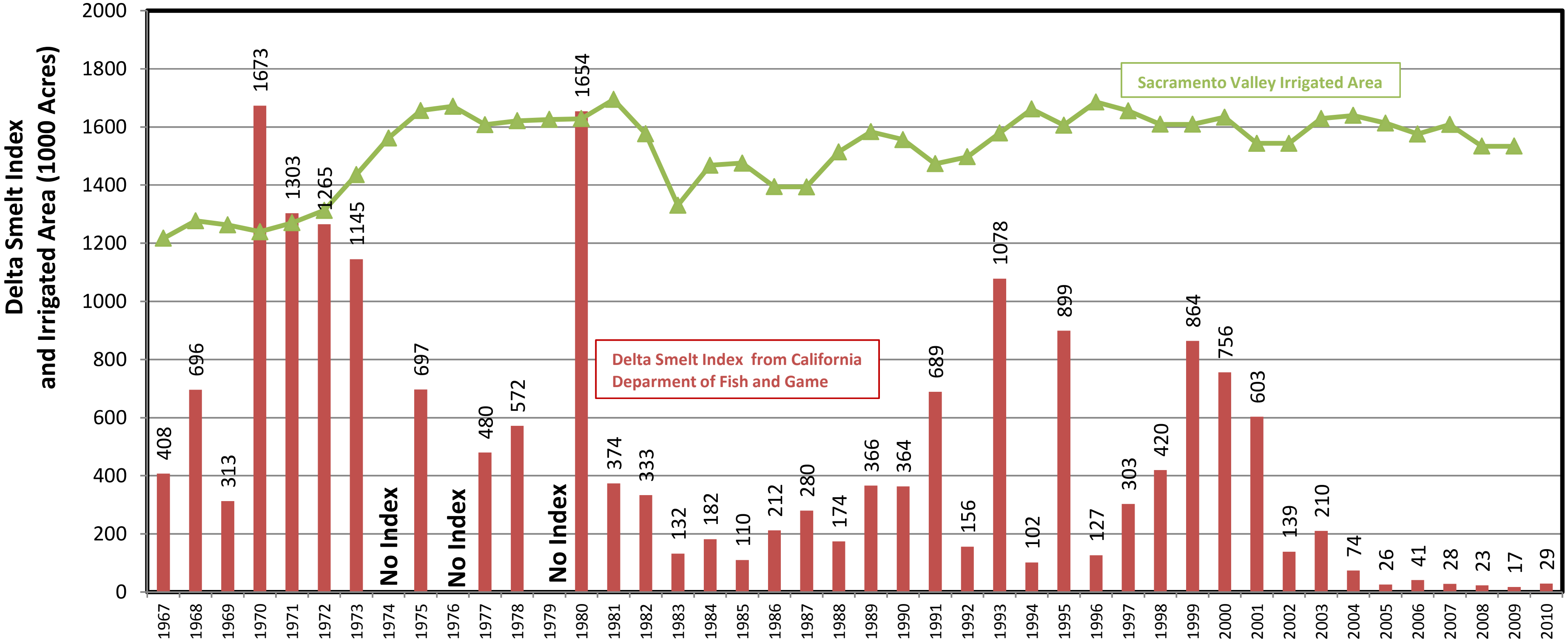
- Seasonal estimated X2 position varies significantly by hydrology
- There are significant variations in the relationship between Delta fish populations and estimated fall X2 position – e.g., low populations with low X2 in 1982-1984, high populations with high X2 in 1993, 1999-2000

Exhibit 8
Historical Average Percent of Unimpaired Sacramento River Basin Outflow (1956–2003)



- The 2010 Delta Flow Criteria Report addresses January-June Delta flows
- Hydrology has varied, but the percentage of January-June unimpaired flow that flows from the Sacramento River basin to the Delta has not changed significantly since the late 1950s

Exhibit 9
Sacramento Valley Irrigated Area and Delta Smelt Index



- Sacramento Basin irrigated acreage has been essentially constant since the mid-1970's, while fish populations have varied dramatically

Exhibit 10

Average Annual Impacts Of Requiring 50% of Unimpaired January-June Flows

- Delta outflow increase:
  1,057,000 AF (acre-feet),
  1,887,000 AF in dry years,
  1,022,00 AF in critical years

- Sac. Basin groundwater pumping increases 997,000 AF in critical years

- Imports from Trinity basin increase

- Exports to San Joaquin Valley and So. California decrease 703,000 AF

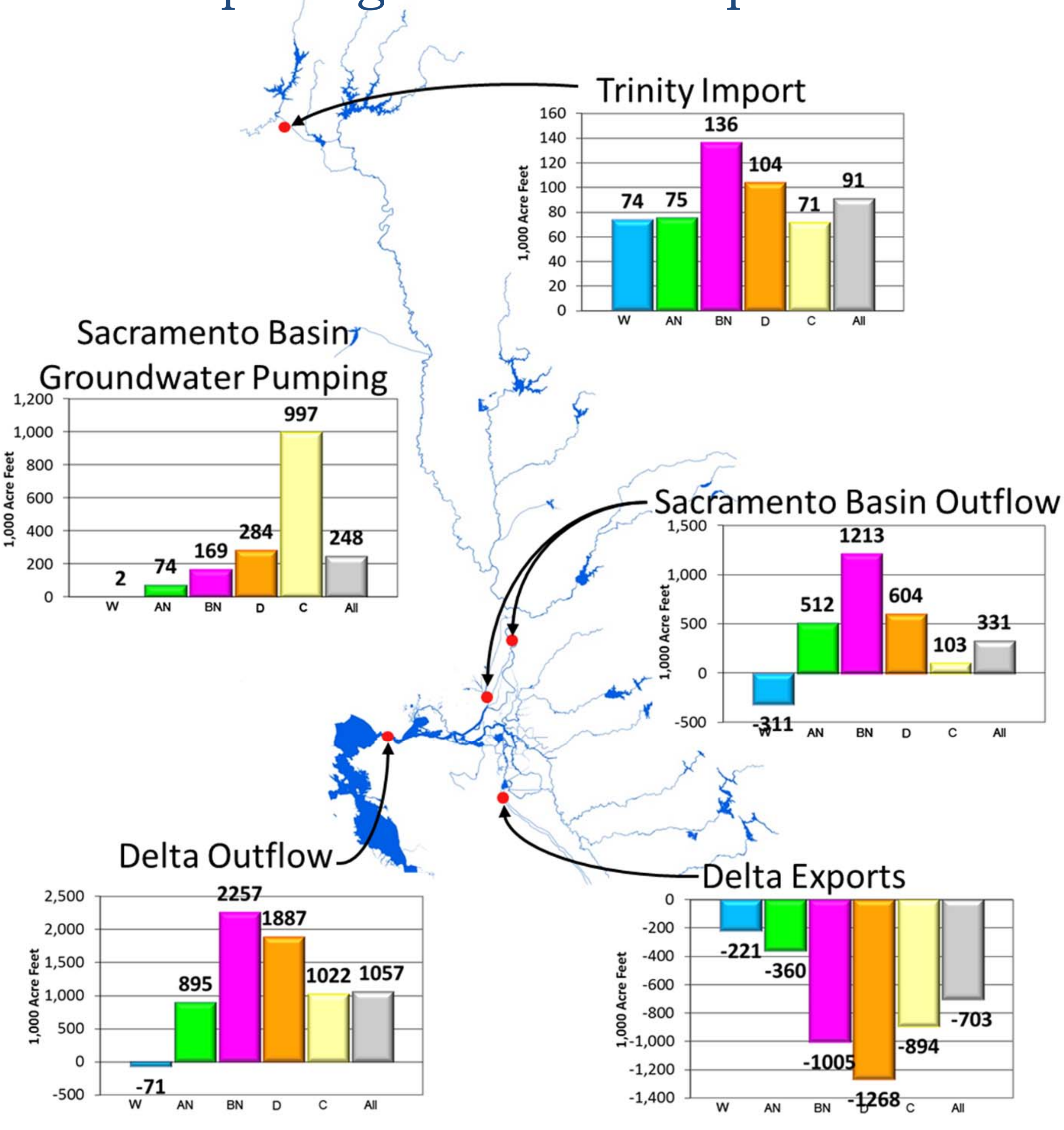
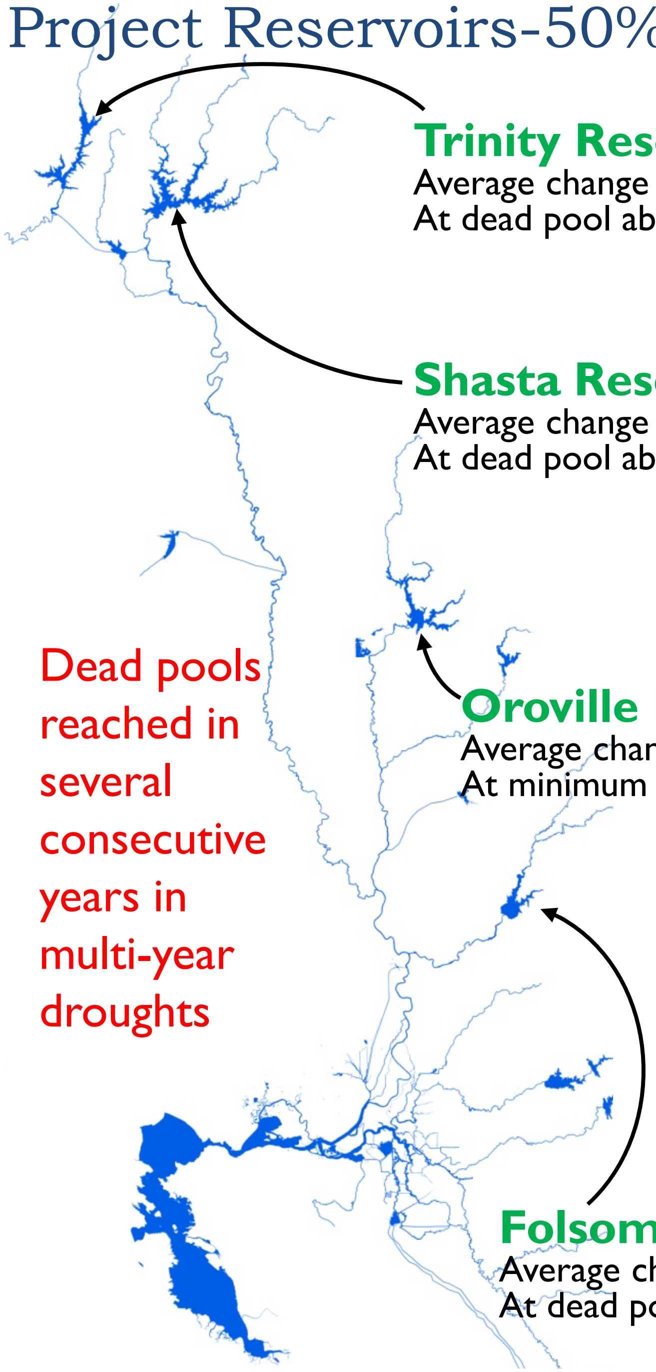
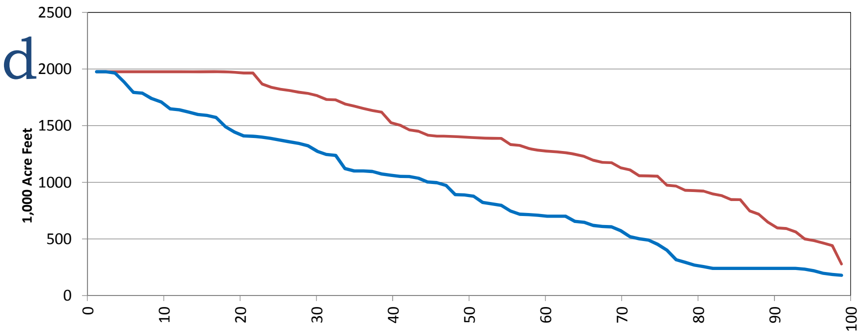


Exhibit 11
Project Reservoirs-50% of Unimpaired



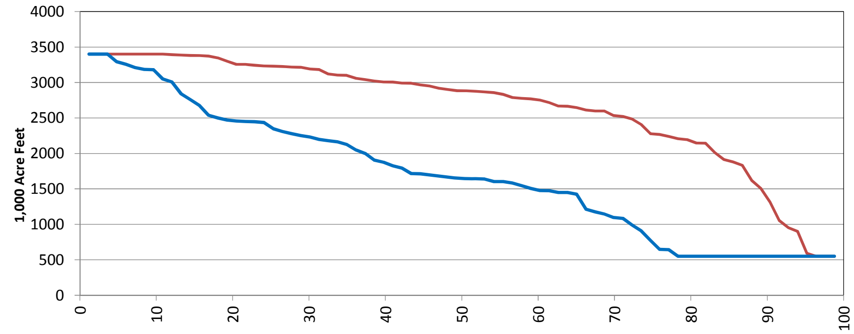
Trinity Reservoir

Average change in carryover = -460 TAF
At dead pool about 20% of years



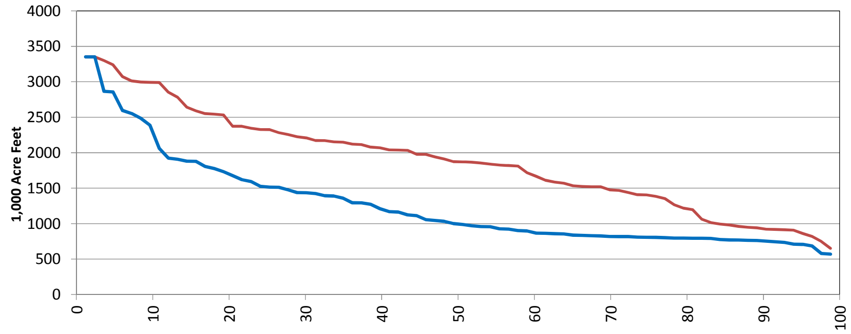
Shasta Reservoir

Average change in carryover = -960 TAF
At dead pool about 20% of years



Oroville Reservoir

Average change in carryover = -620 TAF
At minimum pool about 40% of years



Dead pools reached in several consecutive years in multi-year droughts

Folsom Reservoir

Average change in carryover = -150 TAF
At dead pool about 20% of years

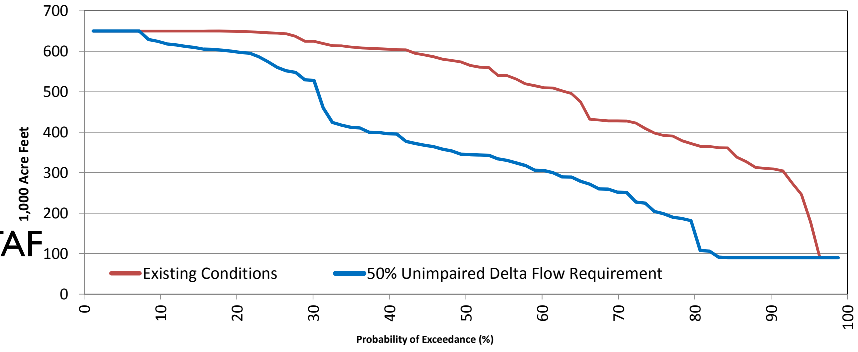


Exhibit 12
Average Monthly Flow Changes at 50% Unimpaired Flow

- Significant shifts of flow from summer and fall to spring

- Impacts on flows for salmon and steelhead rearing and spawning habitat

- Impacts on hydropower generation during peak-demand periods