The Use of the Environmental Water Account for the Protection of Anadromous Salmonids in the Sacramento/San Joaquin Delta in 2000-2001

Prepared by

State and Federal Management and Project Agency Biologists with Stakeholder Biologist Input

Jim White – DFG
Martin Kjelson – USFWS
Pat Brandes – USFWS
Jeff McLain – USFWS
Sheila Greene – DWR
Bruce Oppenheim – NMFS
Rick Sitts – MWDSC

Prepared for

Sam Luoma
Lead Scientist
CALFED Bay-Delta Program

October 2001

Acronyms In Order of Occurrence

EWA .... Environmental Water Account
SWRCB .... State Water Resources Control Board
WQCP .... Water Quality Control Plan
ESA .... Endangered Species Act
CVP .... Central Valley Project
SWP .... State Water Project
OCAP .... Operations Criteria and Plan
CVPIA .... Central Valley Project Improvement Act
af .... acre feet
b(2) water .... Federal Environmental Water Authorized in CVPIA Section 2406 (b) (2)
ERP .... CALFED Ecosystem Restoration Plan
DEFT .... CALFED Diversion Effects on Fisheries Team
NMFS .... National Marine Fisheries Service
USFWS .... United States Fish and Wildlife Service
DFG .... Department of Fish and Game
USBR .... United States Bureau of Reclamation
DWR .... Department of Water Resources
MAs .... Management Agencies (CALFED)
Pas .... Project Agencies (CALFED)
VAMP .... Vernalis Adaptive Management Plan
DCC .... Delta Cross Channel
D-1641 .... Decision 1640 (SWRCB)
RST .... rotary screw trap
YOY .... young-of-the-year
KLCI .... Knights Landing Catch Index
SCI .... Sacramento Catch Index
DAT .... Data Assessment Team (CALFED Ops)
CWT .... coded wire tagged
CNFH .... Coleman National Fish Hatchery (USFWS)
GCID .... Glenn-Colusa Irrigation Diversion
WY .... water year
CALFED Ops .... CALFED Operations group
USEPA .... United States Environmental Protection Agency
WAPA .... Western Area Power Administration
CCWD .... Contra Costa Water District
BI .... Bay Institute
OFF .... Operations and Fish Forum (CALFED Ops)

Contents

I. Introduction

A. Purpose of the Report

The purpose of this report is to provide information on the use of the Environmental Water Account (EWA) for anadromous salmonids (chinook salmon and steelhead). We describe EWA implementation procedures, explain how decisions on the use of EWA water were made, and describe the assessment of the potential biological benefits of EWA actions. The report was prepared for the CALFED Science Review Panel and other parties interested in the EWA. We review the outcome in 2000-2001, the first year with the EWA, and provide an assessment of the accomplishments and limitations we encountered. Finally we describe the information needed from a science program standpoint to improve the implementation and evaluation of the EWA in the future and recommend changes in EWA implementation for 2001-2002.

This report is one element of the description of the EWA prepared for the CALFED science review process. There are two other reports, "Summary Report of the June 21, 2001 Salmonid Workshop for the CALFED Environmental Water Account" and "Environmental and Institutional Background for the CALFED Environmental Water Account" prepared in September 2001 by the CALFED EWA Science Advisors (Brown and Kimmerer 2001 a, b). We refer the reader to those reports for background information on the EWA, the environmental setting and the species targeted for protection using the EWA. They also provide an account of EWA uses and discussion of factors related to the biological benefits of EWA actions.

The use of the EWA for delta smelt in 2000-2001 is described in a separate report. Although a separate report was prepared for delta smelt, we always integrated information on salmon, steelhead and delta smelt in making decisions regarding use of the EWA water.

EWA science advisors Drs. Randy Brown and Wim Kimmerer, as well as several other agency biologists, reviewed an earlier draft of this report and provided helpful comments.

B. Purpose of the EWA

The EWA is part of the CALFED Bay Delta Program water management program intended to provide environmental protection for Bay-Delta Estuary fish in addition to that provided by the existing regulatory baseline including the State Water Resources Control Board (SWRCB) 1995 Bay Delta Water Quality Control Plan (1995 WQCP), Endangered Species Acts (ESAs) biological opinions relative to the effects of Central Valley Project (CVP) and State Water Project (SWP) operations on listed fish species (Operation Criteria and Plan (OCAP) opinions), and the Central Valley Project Improvement Act (CVPIA). The 1995 WQCP prescribes water quality, flow and other standards to protect the various beneficial uses of water in the Bay-Delta. The OCAP opinions specify terms and conditions for the operation of the CVP and SWP facilities upstream and in the Delta in relation to effects on four listed species of fish: Sacramento River winter-run chinook salmon, Central Valley spring-run chinook salmon, Central Valley steelhead and delta smelt. The OCAP opinions include incidental take statements that specify "take" limits for each species. The CVPIA is a broad federal law that includes, in Section 3406(b)(2), the dedication of 800,000 af of CVP water annually to be managed for fish and wildlife purposes (b(2) water). The EWA is intended to provide sufficient water, combined with implementation of the CALFED Ecosystem Restoration Program (ERP) and the existing baseline regulatory requirements, to address the CALFED fishery protection and restoration and recovery needs.

The EWA is intended to improve water supply reliability for CVP/SWP water users. On several occasions in recent years, unanticipated reductions in CVP/SWP Delta export pumping were required when the CVP/SWP exceeded an ESA take limit for a listed species. These interruptions in pumping diminished the water supply from the Delta for CVP/SWP contractors. The EWA is intended to improve water supply reliability by providing the means to reduce the impact to listed fish at the CVP/SWP at no cost to project water users, greatly reducing the likelihood that unanticipated pumping curtailments will be necessary in the future.

The EWA is part of a three-tier set of assets for fish protection. Tier 1 is the baseline water provided by existing regulation and operational flexibility. Tier 2 is the EWA water combined with the benefits of the ERP that will allow water for fish without reducing deliveries to water users. Tier 1 and Tier 2 are, in effect, a water budget for the environment and will be used to avoid the need for Tier 3, a commitment and ability of the CALFED agencies to make additional water available in the unlikely circumstance that it is needed. These specific circumstances will be determined by the fish regulatory Management Agencies with consideration of the views of an independent science panel.

C. Elements of the EWA

1. Origin of the EWA in CALFED

When the CALFED Bay-Delta Program was being developed, a team of agency and stakeholder biologists referred to as the Diversion Effects on Fisheries Team identified several deficiencies in the fish protection provided by the regulatory baseline. The team explored options for the CALFED Program to address these deficiencies. One option was to add new operational restrictions for the CVP/SWP Delta water diversion facilities. The EWA was chosen as an alternative to adding new operating rules to accomplish the CALFED restoration/recovery goals. The premise is that we can achieve more fish benefits per acre-foot of water used if we can make timely operational changes when risk to key fish species is high, than by imposing new seasonal restrictions on CVP/SWP pumping based on generalized fish occurrence patterns in the Delta.

2. EWA implementing entities

The EWA is implemented cooperatively by the following agencies:

National Marine Fisheries Service (NMFS)
U.S. Fish and Wildlife Service (USFWS)
California Department of Fish and Game (DFG)
U.S. Bureau of Reclamation (USBR)
California Department of Water Resources (DWR).

NMFS, USFWS and DFG are collectively referred to as the EWA "Management Agencies" (MAs). USBR and DWR are collectively referred to as the EWA "Project Agencies" (PAs). The MAs manage the EWA water, and other assets, and exercise their biological judgment to determine what SWP/CVP operational changes are beneficial to the Bay-Delta ecosystem and or long-term survival of fish species, including those listed under the State and Federal ESAs. The PAs cooperate with the MAs in administering the EWA; acquiring, conveying and banking EWA water; and making the operational changes proposed by the MAs.

3. Acquisition of EWA water

The EWA obtains water by annually purchasing it from willing sellers both upstream of the Delta (at least 35,000 af) and in the area supplied by water pumped from the Delta (150,000 af). Initially, another 200,000 af of water and storage space are to be purchased and managed by the EWA over time. An agreement with SWP contractors to defer delivery of a portion of their Delta water supply (up to 100,000 af) from the summer to the fall or winter also enhances flexibility for fish protection under some circumstances (source shifting). Finally, the EWA expects to obtain water (200,000 af on average) from specified operational and institutional arrangements, in variable amounts each year depending on the hydrology (variable tools).

4. Changes to CVP/SWP operations to benefit fish

The EWA assets can be used to augment river and Delta flows and to reduce exports to provide fishery benefits. In 2000-2001 all EWA uses were for Delta export reductions. In most cases, inflow was unchanged when exports were reduced; hence, Delta outflow was increased. EWA increased flows on the lower Yuba River downstream to the Delta during the summer months when water purchased by the EWA was released from reservoir storage, flowed to the Delta, and was diverted into San Luis Reservoir for the EWA. On one occasion in February 2001, the EWA guaranteed water to support maintenance of flow on the lower American River in the event there was not enough b(2) water, however, the cost of this action was ultimately charged against b(2).

Export reductions were undertaken based on fishery monitoring results and criteria in a structured decision making process for juvenile salmon and based on a separate decision guidance document for delta smelt (decision tree). We attempted to maximize the benefits of EWA use by timing the pumping reductions to coincide with periods of peak abundance of vulnerable life stages of listed species. For example, EWA actions were taken when juvenile salmon were detected migrating into the Delta from upstream, or when CVP/SWP entrainment of juvenile salmon or delta smelt was high. We also considered the current rate and cumulative seasonal total CVP/SWP entrainment of the threatened and endangered fish species relative to "take" limits in OCAP opinions. EWA was used, and will be used each year, for part of the SWP pumping reduction during the 31-day (April-May) Vernalis Adaptive Management Plan (VAMP). VAMP is a long-term evaluation of the effects of San Joaquin River flow and CVP/SWP pumping rate on juvenile salmon from the San Joaquin River tributaries, related to the 1995 WQCP and the OCAP opinion for delta smelt. In practice, the needs of salmonids and the delta smelt provided the primary justification for EWA actions, however, benefits for other Delta fish were expected to occur.

The criteria, decision process, and the actions and benefits of using EWA are described in this report.

5. Achieving water supply reliability

The EWA water is transferred to the PAs to replace project supplies interrupted by reductions in Delta export pumping called for by the MAs so that the increased fish protection is accomplished without effecting the amount or timing of water deliveries to the water projects' contractors. In this way the EWA achieves the CALFED goal of increased water supply reliability, at the least cost with respect to effects of fish restoration and recovery efforts.

The MAs deem the EWA to be "operational" in any one year when the 200,000 af of stored water (or functional equivalent) has been acquired, and if the annual 185,000 af of purchased water, a source shifting agreement for at least 100,000 af, and the variable tools for obtaining EWA water are all in place. Upon determination that the EWA is operational, the project contractors annually will receive the commitment, subject to legal requirements, that there will be no reductions in CVP or SWP Delta exports, beyond the existing regulatory levels, resulting from measures to protect fish under the Federal and State ESAs.

6. Coordination of EWA with other water management activities

Implementation of the EWA requires extensive coordination among a variety of water management activities. Coordination with the PAs' operators and administrators is needed to accomplish the acquisition, management (conveyance, storage and transfer), and accounting of EWA assets. EWA implementation is coordinated with management of the CVPIA b(2) water through the b(2) Interagency Team. Potential EWA and b(2) water use through the year is shown as monthly "placeholders" in CVP and SWP operations forecasts for the coming year. These 12-month forecasts are updated each month based on new hydrological information. The "placeholders" also are adjusted depending on how much EWA or b(2) water was used in the previous month and what reservoir releases and pumping rates are forecasted for the months ahead. Placeholders correspond to time periods when EWA use is likely based on the life history of the fish species and experience in previous years, but decisions to use EWA are made based on the actual circumstances that arise. The CALFED EWA Coordinator plays a critical role in overall EWA implementation.

D. Expectations from EWA science review

In the final section of the report we list conclusions and recommendations based on our experience with the EWA in 2000-2001. We describe the accomplishments and limitations of the EWA program, provide a list of science-related elements needed to improve our understanding of the ecosystem and to increase EWA effectiveness, and propose changes in EWA implementation for water year (WY) 2002. We welcome a critique of our conclusions and recommendations by the Science Review Panel and other participants in the review process, in light of the information presented in all EWA reports and based on interaction with us during the October 2001 review session.

II. Fish Protection Plans and Decision Processes

An advantage of the EWA is that it provides the ability to take focused actions to reduce project effects during the most appropriate times compared to prescribing new rigid operational requirements for the CVP/SWP. This assumes the highest efficiency, in terms of fish benefits per af of water used for fish protection, will be attained by making decisions about using the water based on real-time assessments of fish problems each year. Actions are taken when real-time assessments determine that the most fish are at the greatest risk rather than during a fixed time period each season, as determined from generalized fish migration patterns.

Deciding when to use EWA water to change project operations to achieve the most benefits for salmonids in the Delta requires knowledge of their movement within the Central Valley Rivers and the timing of their arrival in the Delta. It also requires that the relative benefits of potential actions are known. Monitoring juvenile salmonids is conducted by sampling at many locations either seasonally or year-round. Most the sampling programs being relied on to describe the movement and distribution of fish within the system were part of ongoing life history, habitat use, and survival studies and have been adapted as necessary to help meet the real-time information needs of fish protection plans and EWA implementation.

Closing the Delta Cross Channel (DCC) gates to reduce the number of young salmon from the Sacramento River entering the central Delta, where survival is lower, is an important baseline fish protection measure. The 1995 WQCP, water right Decision 1641 (D-1641) and OCAP opinions for chinook salmon (NMFS 1995, NMFS 2001) require the DCC gates be closed from February 1 through May 20. They also provide for closure for up to 45 days during November 1 though January 31 for fish protection, at the discretion of the fishery agencies. Decisions regarding DCC gate operations in November – January are made by the same people making decisions on EWA actions to reduce export pumping, using some of the same biological information. Therefore, both DCC operations and EWA actions are included in the protection plan and decision process. Because the DCC gates are always closed from February 1 – May 20, no decisions regarding DCC operations were necessary during this time period. The DCC gates also are closed by USBR when Sacramento River flows at Sacramento reach 25,000 cfs – 30,000 cfs to avoid causing channel scouring and flooding problems in the interior Delta. The gates also may be closed for up to 14 days from May 21 through June 15 to protect salmon and other anadromous fish such as striped bass larvae and juveniles.

A. Sources of data on relative abundance, distribution and movement of juvenile salmonids

1. Monitoring upstream of the Delta

USFWS and DFG monitored for juvenile salmon and steelhead year round at several mainstem Sacramento River locations and seasonally in several tributaries, beginning in the fall and continuing through the winter and spring as stream conditions allowed (Figure 1, Table 1).

The primary method of sampling upstream is the rotary screw trap (RST), a passive sampling gear that can be operated on a nearly continuous basis and checked periodically. Catch data from tributary streams are used to define the onset and subsequent pattern of juvenile salmon migration from tributaries to the Sacramento River. Data from main-stem sampling locations are used to track progress of downstream migration towards the Delta.

2. Monitoring in the Delta

Relative abundance and temporal distribution of juvenile salmon and steelhead on the lower Sacramento River were measured using a beach seine at eight sampling stations at sites on the Sacramento River between Verona and Garcia Bend (Table 1, Figure 2).

Kodiak trawling was done near Sacramento at the entrance to the north Delta, three days per week, to estimate the relative abundance and temporal distribution of juvenile salmonids. On the San Joaquin River at Mossdale (RM 56), ten twenty-minute tows were done with a Kodiak trawl, three days per week, to estimate juvenile salmon movement from the San Joaquin River system (Figure 2).

Midwater trawling was also done in Suisun Bay at Chipps Island to estimate the temporal distribution of salmon leaving the Delta and continuing their migration to the Pacific Ocean.

3. CVP/SWP fish facilities monitoring

The CVP and SWP water diversions in the southern Delta both have fish salvage facilities designed to screen fish from the Delta water diverted for export. In addition to salvaging fish, the fish salvage facilities are a good monitoring device, allowing the collection of important biological information. The salvage facilities operate whenever the projects are pumping water.

The PAs conduct this monitoring to help estimate the direct adverse impact of the Delta export facilities on fish for mitigation, and for ESA regulation.

B. Salmon Decision Process

A procedure for considering relevant biological information was established and specific criteria for physical and biological monitoring data were developed from historical information. This provided an understanding of how and on what basis decisions would be made regarding DCC gate closures and use of EWA and b(2) for reductions in CVP/SWP export pumping. The criteria were developed to help biologists identify significant fish migration events from monitoring results and determine when fish protection actions should be taken. The criteria were developed primarily from observations of salmon migration from 1995 through 2000. All of these years were characterized by greater than average precipitation and relatively high flows in Central Valley rivers and the Delta. However, in 2000-2001 flows were notably lower and Delta conditions were substantially different from this earlier historical period when salmon migration had been monitored.

The timing and characteristics of the EWA fish protective actions were based on a decision tree for the October through January period and a modified decision tree/process for the February – June period. The decision trees used specific criteria as triggers for EWA actions. Chinook salmon larger than 70 mm fork length were the focus of salmon monitoring in the fall and winter. From the fall through about the end of March, salmon 70 mm and larger, referred to as "older chinook", comprise a mix of late-fall run, yearling spring run, and winter run. By the end of March, the "older chinook" declined in abundance and some YOY spring-run and fall run chinook reached 70 mm and began to appear in the Delta and at the CVP/SWP. In very wet years spring run and fall run chinook fry (less than 70 mm) occur in the Delta in January and February.

1. Development of biological criteria from historical information

a. October – January

Biological and hydrological criteria (triggers) were established and used to initiate DCC gate operations and the EWA actions. The Decision Process (termed Protection Plan) for initiating fish protective actions for October 2000 – January 2001 is described in, Figures 3 and 4. The Protection Plan includes the criteria biologists used to determine if operational changes for chinook salmon protection in the Delta were warranted. The focus of the criteria development and Protection Plans is on older juvenile chinook salmon. We assumed actions taken for salmon protection would provide some benefits for any juvenile steelhead in the Delta at that time.

The Protection Plan was organized to follow the migration of juvenile chinook from tributary streams until they leave the Delta. The status of migration in the tributaries was estimated using RSTs in the mouths of tributaries (Deer and Mill Creeks) and tributary flow conditions. When juvenile salmon (greater than 70 mm) were observed at the tributaries mouth or an increase in daily tributary flows of greater than 50% was a first alert to take potential protective action was initiated. When Sacramento River flow rose by 20% then a second alert was exceeded. Under these two alerts we assumed juvenile salmonids were migrating down the Sacramento River toward the Delta where additional monitoring at Knights Landing and near Sacramento occurred as noted earlier.

Three primary criteria were used between October and January to initiate actions in the Delta: the Knights Landing Catch Index (KLCI), the Sacramento Catch Index (SCI), and chinook loss at the CVP/SWP. The prevailing inflow/export level was a factor in deciding if export reductions were appropriate when catch indices were greater than 10. Water quality conditions (salinity at key Delta locations) also were considered in deciding whether catch indices below 10 should result in the closure of the DCC gates. Closing the DCC gates reduces the flow of lower salinity Sacramento River water to the central Delta. Thus, if water quality was poor or degrading, we did not always recommend that the DCC gates be closed or remain closed when the KLCI and SCI were between 3 and 10.

The SCI criteria were developed from a review of the five graphs of catch data from 1995-2000 in Appendix 1. The two-day SCI incorporated both the beach seine and trawl information. Catch standardized to ten twenty-minute tows per day at Sacramento and 8 beach seine hauls per day between Verona and Garcia Bend on the Sacramento River was graphed along with percent daily flow change at Colusa between September 1 and February 28 for 1995-1996 through 1999-2000. The Data Assessment Team (DAT) Salmon group, made up of experienced state and federal agency staff and stakeholders, used these graphs to determine triggers based on historical catches. Catch indices between 0 and 3 fish per day appeared to be background levels in all years. Because these background levels were often observed throughout the season they were not interpreted as significant pulses of juvenile salmon. Catch indices greater than 3 and less than or equal to 5 were considered to be above background levels and were determined to warrant consideration of protection (possible DCC gate closures). Catch indices above 5 and less than 10 in these reference years appeared to be significant pulses of salmon that warranted protection (DCC gate closures). Catches above 10 per day were considered indicative of major salmon migration periods in all years and warranted maximum protection (DCC gate closure and export reductions).

The KLCI was based on examination of the historical catch data in RSTs deployed at Knights Landing since 1995. The index value was the two-day running average of chinook salmon catch per trap day. These index values were plotted for August through March of 1995-1996 to 1998-1999 (Figures 5-8) and used to establish values indicative of the three levels of downstream salmon movement described above for the SCI. The KLCI and SCI were derived from different gear types and sampling strategies and were computed in different ways. Nevertheless, the catch index values that best described background levels and the two higher levels of salmon migration past Knights Landing were, coincidentally, the same numerical index values established from the Sacramento area sampling data, i.e., catch index values 3, 5 and 10.

Chinook loss at the SWP/CVP of greater than 25 per day was identified as a significant level based on examination of the October-January salmon data from the SWP and CVP fish salvage facilities since 1995 (Figures 5-8). Our intent was to identify patterns in the salvage record to help biologists recognize the time periods when export curtailments would be most effective. The magnitude, frequency and duration of peaks in salmon entrainment were examined to determine what loss threshold should be used to guide decisions on when and for how long to reduce exports to achieve the greatest relative benefits. During October – January, in these years, the daily chinook loss ranged from 0 to over 200 per day, with peak entrainment periods typically following chinook migration pulses associated with flow increases in the Delta watershed streams. A daily loss threshold of 50 salmon per day would identify the same general periods of peak chinook salmon entrainment as a threshold of 25 salmon per day. The lower threshold tends to apply a few days earlier and later than the higher one, thus defining slightly longer periods of concern. Several episodes of high entrainment in the historical data were comprised primarily of salmon released from the Mokelumne River Hatchery. These are identified on the figures to distinguish them from high entrainment episodes presumed to be late-fall run, yearling spring run or winter run chinook salmon from the Sacramento River basin.

The export/inflow ratio of 35% was chosen to guide decisions on whether export reductions were necessary if catch indices were greater than 10. To protect fish and wildlife beneficial uses of the waters of the estuary, the 1995 WQCP limits SWP/CVP diversions to 35% of Delta inflow between February and June. There is an exception allowing up to 45% to be diverted in February following a very dry January. During October – January the SWP/CVP may export up to 65% of inflow. When the export pumping is less than 35%, exports are relatively low and/or Delta inflows are relatively high. The 35% export/inflow limit on export pumping provides some constraint on the degree to which exports affect the flow patterns and the survival of migrating juvenile salmon in the Delta. When we observed a salmon migration pattern or entrainment loss rate defined to be problematic by the catch index and loss criteria, an export reduction is assumed to be more beneficial when the percent of inflow being diverted is greater than 35% than when it is less than 35%.

Other criteria identified in the Decision Process for October 2000 – January 2001 were not explicitly used to recommend an action. Specific groups of coded wire tagged (CWT) juvenile late-fall run chinook salmon from Coleman National Fish Hatchery (CNFH) were released near the CNFH in November, December and January as "surrogates" to represent emigrating juvenile spring run chinook. Within logistical constraints, these releases were timed to coincide with observed emigration of yearling spring run chinook from Mill and Deer creeks. These fish were tracked via upriver RSTs and delta seine and trawl monitoring and at the CVP/SWP fish salvage facilities. If the cumulative number of older chinook lost to the system at the Delta export facilities (loss) of greater than 0.5% of a specific CWT release group occurs at the CVP/SWP facilities a decision was made as to what protective action if any was warranted. Data of CWT late fall from past years indicated that the trigger of greater than 0.5% cumulative loss has only occurred in three of 23 CWT release groups between WY 1994-2000 (Table 2). During 2000-2001 period these trigger levels were not exceeded and thus loss of "surrogates" was not used to justify any of the actions taken in the year.

Kodiak trawling at Mossdale was useful to identify the migration timing of fall run chinook salmon on the San Joaquin River. In addition, the lengths of fall run captured in the Mossdale trawl were compared with Sacramento and facility length distributions to help determine the source of winter run sized salmon observed. (Occasionally, San Joaquin basin fall run migrate at a larger size and overlap with the winter run size range on the Sacramento River.) No specific catch index or action criteria were established for the Mossdale monitoring site. This information was used to determine when salmon from San Joaquin River tributaries might be benefitting from an action, but not to provide the sole justification for an action.

b. February – June

The decision process initially covered October through March. Many of the justifications for decisions made in the October-January period described above, apply to the February through March period, with a few changes described below. The DAT developed a modification of the October – January decision process for February and March (Figure 9). Modifications were needed for the following reasons: the DCC gates were to be closed from February 1 through May 20 under the existing Biological Opinions, there were unusually high salmon losses occurring at the CVP/SWP diversions, and desire to incorporate criteria to minimize losses of juvenile steelhead and adult delta smelt.

The DAT developed the February-March decision process in response to a few weeks of high salmon loss densities (fish per af of water diverted), a climbing cumulative winter run chinook take, and a finite amount of EWA assets. When implementing the actual export reductions with EWA water during high loss-density periods, DAT considered whether otherwise-scheduled exports or export reductions would meet the MAs' export reduction goal for fish protection, and, how much EWA water the MAs had allocated for Delta smelt protection from April through June. Thus, DAT defined the export reduction levels in the decision tree as general goals and did not follow them strictly.

Winter and spring run salmon, steelhead and Delta smelt take limits were criteria for reinitiating consultation under the ESA. The PAs and MAs used the criteria to attempt to avoid reaching or exceeding the take limits, and to determine when to use EWA water for this purpose. The DAT monitored the daily and cumulative salvage and loss levels frequently and compared them to ESA take limits to determine when to use

EWA water to avoid adverse fish impacts and to anticipate whether a concern level would be exceeded.

The DAT developed a decision process for February through March used as guidance for the rest of the winter and spring months. The February through March decision process had basic alert and action criteria similar to the October – January decision process, but with changes including the following, by region:

(1) Upstream – Sacramento, San Joaquin

DAT replaced the juvenile salmon emigration from their natal tributaries criteria with criteria related to emigration through the lower Sacramento River. DAT assumed winter and spring run chinook had left or were about to leave their natal tributaries, and were in the mainstem Sacramento River closer to the Delta, and therefore closer to the Delta export pumps.

DAT used the RST at Glenn-Colusa Irrigation District (GCID) as an early warning emigration criterion on the mainstem Sacramento River. GCID was downstream of winter and spring run chinook spawning areas and was an appropriate location to determine early signs of emigration.

DAT revised the criteria for KLCI and SCI from triggering pumping reductions at indices of greater than10 salmon/day to "concern alerts" at greater than 9/day in February and less than 15/day in March. In January, we recognized that with a dry year emigration pattern and some juvenile salmon scattered throughout the Sacramento River and Delta, we were not always able to accurately predict when salmon numbers would increase at the CVP/SWP using catches at Knights Landing and Sacramento.

During the first two weeks in April, and prior to the VAMP, the DAT monitored the YOY fall run emigrants from the Sacramento and San Joaquin basins to determine if the YOY needed protection prior to the VAMP. DAT did not develop quantitative salmonid criteria for this time period.

(2) Delta monitoring

DAT omitted the DCC closure criteria from the decision process because the gates were to be closed until May 20 under an existing OCAP biological opinion for winter run.

DAT revised the salmon and delta smelt catches in Delta surveys from fish protection action criteria to early warning alerts. (See delta smelt report)

(3) SWP/CVP diversions

DAT revised the criteria associated with a Delta export reduction from catch indexes at Knights Landing, Sacramento, and loss at the CVP/SWP Delta export facilities to take density (fish per acre-foot diverted) at the Delta export facilities only. We learned from our experience in January that we were not able to predict when chinook would be taken at the Delta export facilities based on upstream catch indices once salmon were widely distributed in the river system and Delta. DAT revised the Delta export fish protection action and the loss level criteria from a one-tier recommendation to a two-tier recommendation to accommodate the limited EWA assets and the unusually high chinook take this year. The first tier loss criteria at the export facilities was either greater than 25 salmon per day or greater than 8 salmon per thousand af. The first tier fish protection action was to reduce exports for three days at the SWP to 6,000 cfs or at the CVP to 3,000 depending on where the greatest take was occurring. The second tier loss criteria was either 100 salmon per day or 15 salmon per thousand acre feet. The second tier protection action was to reduce exports for 3 days at the SWP to 4,000 cfs or at the CVP to 2,000 cfs at the CVP depending where the losses or densities were highest.

III. Implementation in 2000-2001

A. Process for decisions on using EWA water

1. Data collection and reporting

The USFWS and DFG collected most of the biological data. DWR and USBR collected most of the operations and water quality data. Whenever possible, the biological data was normalized for trapping effort. There were many fish monitoring sites and many different fish collecting devices. The data from one site was not equivalent to the data from another site in absolute terms because there were no efficiency calibrations. Field collection offices transmitted their data in nearly "real-time" to enable the MAs and PAs to make decisions in nearly "real-time", and to enable more operational flexibility. Each field office submitted their data to an interagency Internet database. They submitted their data either daily, or weekly depending on the decision makers needs. The agency and stakeholder biologists were able to access a tabulated summary of the data from the Internet whenever needed. Agencies further summarized, graphed and interpreted the data to help make decisions and disseminated it through email.

2. Data Assessment Team

The CALFED Operations Group (CALFED Ops) designated the DAT coordinate the information and data needed to help make recommendations on how to operate the water projects to protect fish. The DAT helped determine what kind of biological, water quality and hydrology data were needed, and at what frequency, to help manage the water projects in "real time". The DAT continually analyzed new and old data throughout the season to update and improve our understanding of the system and in order to integrate fish protection, water quality and water supply concerns.

a. Agencies and stakeholders

The DAT was composed of fish regularity agencies (NMFS, USFWS, DFG, and SWRCB), other regulatory agencies (United States Environmental Protection Agency (EPA) and Western Area Power Authority (WAPA)), and water user and environmental stakeholders (Contra Costa Water District (CCWD), CVP Water Users, State Water Contractors (SWC), Environmental Defense Fund (EDF), and Bay Institute (BI)). The water PAs operators participated as consultants for the water project information. A wide and diverse group of people participated in the DAT, which helped communication, coordination and cooperation within the water user and fisheries protection communities.

b. Evaluate data

The DAT convened through conference calls throughout most of the year. There was a regularly scheduled conference call once a week when fish were potentially impacted by the water projects (about November through June). There were numerous more conference calls when water use and fish protection issues were difficult. The summarized and analyzed data were available on the Internet or through e-mail the morning of the conference call for the DAT to discuss and evaluate.

c. Recommend actions

By the end of every conference call, DAT either concluded no actions were necessary at that time, or developed one or more action recommendations, or identified additional information needed to make a recommendation. The DAT summaries provide documentation of the reported information, the alternative discussions, and the recommendations.

3. Recommendations/approvals

The DAT action recommendations were to be implemented by the PAs. If the PAs participants on the call were able to agree on implementation of a recommended action, the DAT was able to report the outcome of the conference call to the management level.

a. CALFED Operations and Fish Forum (OFF) involvement

If the recommendation caused a significant impact to the PAs or water users, then the DAT conference call discussion and recommendations were forwarded to the CALFED Operations and Fish Forum (OFF). The CALFED Ops Group designated the OFF as a forum for the water users to discuss water operations and delivery issues related to fish protection and regulation. The OFF was analogous to the DAT, but their emphasis was water operations, whereas the DAT's emphasis was fish. When fish protection and water supply issues were complicated and difficult, both the DAT and OFF participated in joint conference calls, which greatly improved communication and cooperation, and helped make the decision processed more efficient.

b. Water Operations Management Team (WOMT) approval based on confirmation that EWA water available

If the participants in the DAT and OFF were not able to agree on a consensus conclusion, the issue and discussions were elevated to the Water Operations Management Team (WOMT). The WOMT was a management-level group of the CALFED Management and Project Agencies. The WOMT was designated by the CALFED Management Group to keep up on the fish protection and water reliability issues and make decisions rapidly. The WOMT scheduled a regular meeting once a week, usually after the DAT conference call, and also convened additional meetings when necessary.

B. General description of WY 2001

1. Seasonal hydrology

There was very little rain in the Central Valley from October through January in WY 2001 (October 1, 2000 – September 30, 2001). Only two storms noticeably affected Sacramento River inflow to the Delta. Seasonal runoff was 25% and 30 % of normal in Sacramento and San Joaquin valleys, respectively, through January.

Sacramento Valley precipitation was at or below average in February, March and April with only three brief periods with modest increases in river and Delta flows. Seasonal runoff in the Sacramento River region was 7.1 million af through April or 55 percent of normal. In the San Joaquin River region seasonal runoff through April totaled 1.9 maf, also about 55% of average for this period (DWR Bulletin 120-4-01). The WY is officially classified as dry for both the Sacramento and San Joaquin valleys according to State Water Resources Control Board criteria.

Because precipitation and runoff in the Central Valley was far below normal, Delta inflow and outflow was relatively low all year (Figure 12). The last year with hydrology similar to WY 2001 was WY 1994. Figures 10-12 show, for WYs 1993 to the present, some of the variation in hydrology that can occur. WY 1998 was one of the wettest years on record, and 1994 was one of the driest. It is fairly common to have minimal precipitation and no substantial increase in runoff until late December or January. However except in very dry years, increased river and Delta flows during January – March are expected. In very wet years high flows continue through the spring and, rarely, through the summer (WY 1998).

Very low river flows with a few short-term flow pulses of moderate magnitude in WY 2001 influenced the migration pattern for juvenile chinook.

2. Juvenile salmonid migration

a. Salmon run identification and terminology

Before describing the general fish migration patterns observed in WY 2001, we need to briefly describe how we determine which of the four runs the juvenile salmon observed in our monitoring belong to and explain some terminology we use in this report.

We know the juvenile salmon captured in the fall in Mill, Deer and Butte creeks are yearling spring run chinook based on life history studies conducted in these streams (DFG, 1998). Similarly, we know the juvenile salmon captured in the upper Sacramento (Balls Ferry) in August – October are winter run chinook. However as these salmon disperse downstream and become mixed, and later when other juvenile salmon appear in the river, we lose the ability to make inferences about the run designation of an individual fish based on when and where we observe it.

In 1989, the DFG began development of a method to classify juvenile salmon by run based on time of spawning and juvenile growth rates (Fisher 1992). Fisher assumed the four runs spawned during distinct time periods and therefore an emergence time interval for each run could be estimated based on incubation time. By applying a growth function to salmon fry from the discrete emergence periods assumed for each run, curves were developed and used to distinguish juveniles of the four chinook runs based on their size and the date (Table 3). Several refinements of the Fisher length at date ("size criteria") model have been made in the past decade. We recognize that for a number of reasons the method does not, and in fact cannot, result in completely accurate run classification of juvenile chinook, however the method is still used, even as another method using genetic characteristics is being refined and applied.

We sometimes use the terms "older chinook" or "larger chinook" to describe the salmon greater than about 70 mm fork that are captured at sampling locations throughout the system in the fall and early winter. We had used 70 mm as the minimum size in previous years in earlier versions of our current salmon protection plan specifically targeting yearling spring run which emigrate from Mill and Deer creeks at about 70 – 150 mm (CALFED, 1998). In the Sacramento basin in the fall and early winter months the observed chinook greater than 70 mm may include all four runs (fall run yearlings, spring run yearlings, late-fall run smolts and winter run juveniles) (Table 3, Figure 13).

Note that yearling spring run chinook, from Mill and Deer creeks in particular, cannot be recognized using the length at date method because the environmental conditions during incubation and rearing depart substantially from the assumptions of the Fisher method. Due to low water temperature unique to the high elevation spawning habitat used by spring run chinook in these two streams, emergence is delayed and juvenile growth rate is slowed (DFG 1998). Yearling spring run from Mill and Deer creeks are consistently much smaller (65 -150 mm) than the length at date criteria would suggest for these salmon emigrating in October – January, the progeny of spawning that occurred about one year earlier. In fact they are in the same size range as late-fall and winter run chinook and cannot be distinguished from juveniles of these other run which also are present in the Sacramento River and Delta in the fall and winter months.

We use the term YOY to refer to the spring run and fall run fry, juveniles and smolts as distinguished from the "older" yearling, late-fall run and winter run chinook mentioned above. Spring run (from the Sacramento River basin) and fall run (Sacramento and San Joaquin basins) fry may appear in the Delta in January or February in very wet years, but generally the migrating juveniles begin to appear in March and peak emigration is in April and May. We have referred to winter run chinook observed in the Sacramento River and Delta as being part of the "older chinook" group because of their affinity with the other older juvenile salmon in the regulatory/management context, even though they are YOY fish.

b. Upper Sacramento River and tributaries

Based on RST catches in the valley floor reaches of Mill and Deer Creeks, small numbers of juvenile chinook began migrating from these tributaries to the Sacramento River in early October. Brief peaks in downstream movement coincided with minor local storms and brief periods of increased flow in November and

December. Peaks in catch also occurred during episodes of increased stream flow in mid- and late-January (Figure 14). These salmon are assumed to exit the tributaries within a few days because sampling locations are only a few miles from the confluence of these respective tributaries with the Sacramento River. In Butte Creek, two distinct peaks in the downstream migration of spring run yearlings were observed in January at a sampling location near Chico (Figure 14). These salmon must still migrate many miles through the lower Butte Creek basin and the Sutter Bypass system to reach the Sacramento River immediately downstream of Knights Landing. In general we observed yearling spring run migrating from these tributaries later in WY 2001 than in WY 2000 (Figure 15).

Catches at the Glenn-Colusa Irrigation District (GCID) diversion near Hamilton City (RM 205) indicate when juvenile salmon are moving downstream in the Sacramento River. Older chinook (greater than 70 mm FL), assumed to include late-fall run and yearling spring run based on their earlier presence upstream, were observed at low levels through December, with several short term peaks in movement associated with minor storms and flow increases. Peak movement of older chinook occurred in January following two flow spikes of moderate magnitude (Figure 16). The number of winter run chinook moving past GCID was highest in September and early October as winter run fry spread from the spawning area throughout the upper and middle Sacramento River (Figure 17). Juvenile winter run catch was low during November – January and increased in early February. Again following modest flow increases in mid- to late-

January fall run fry were abundant at GCID in early February. The peak catch of fall run smolts was in late April and early May.

c. Lower Sacramento River and Delta

Further downstream at Knights Landing (RM 89.5) the pattern of juvenile chinook movement as indicated by catch in two RSTs was similar to that at GCID (Figure 16). Peaks in catch appeared to lag GCID by a few days. Small numbers of spring run yearlings (potential occurrence was based on earlier observations upstream) and late fall run salmon were caught in November and December. Catch of older chinook, including winter run was substantially higher in January and February with two distinct peaks in catch in January and another in late-February (Figure 16). Based on their size and on earlier observations of salmon in upstream areas, the salmon migrating past Knights Landing in January and February were assumed to be a mix of spring run yearlings, late-fall run and winter run chinook.

Phases of juvenile chinook salmon migration have been described by Snider and Titus (2000). The first phase involving the late-fall run, yearling spring run, and juvenile winter run chinook (the "older chinook" mentioned previously) typically occurs in November or December and is strongly linked to the initial flow increase of the season. Due to the lack of precipitation, river flows were relatively low and stable until January 2001. Without river conditions conducive to downstream movement, older chinook, including the yearling spring run that had begun leaving Mill and Deer creeks earlier in the fall, apparently did not move very far downstream to the Delta until higher flows later in January. Young winter run chinook appeared to have spread out through the upper and mid-Sacramento River in the fall months (Figure 17). These fish did not appear in the lower river in substantial numbers until relatively late in the season compared to recent, mostly wetter, years (Figure 16 and Figures 5-8).

Farther downstream near Sacramento, catches of older chinook (yearling spring run, winter run, and late-fall run salmon, greater than 70 mm fork length in October -January) in the Sacramento area beach seine were sparse until the first significant storm event in mid-January, where catches climbed above background levels (Figure 18). Two more peaks were observed in mid- and late-January. The last peak in catch of older chinook was observed on February 22, 2001. The first peak in the Kodiak trawl at Sacramento was not detected until February 16, 2001. A second, higher peak occurred on February 25, 2001. At Sacramento, the majority of the older chinook salmon were captured in mid to late-February, somewhat later than past years (Figure 18 and Appendix 1).

When Sacramento River flow exceeds about 23,000 cfs near Colusa, some Sacramento River water flows over weirs upstream of the Knights Landing site into a floodway, the Sutter Bypass. This water returns to the Sacramento River between Knights Landing and the mouth of the Feather River, providing a pathway for some downstream migrating fish around the Knights Landing sampling site. In some wet years, a large fraction of the river flow enters the Sutter Bypass, however, this only occurred to a very limited degree (small discharge and for only a few days) in March 2001, after most of the older chinook had already migrated past Knights Landing. Sacramento River water at times flows over a weir downstream of Knights Landing into another floodway, the Yolo Bypass, providing a route for emigrating salmon to the Delta around the Sacramento trawl and beach seine sites. This did not occur in WY 2001.

Catch of fall run salmon at Mossdale on the San Joaquin River (southeastern Delta) occurred mostly between early-April and early-June (Figure 19). With the exception of several yearling sized salmon captured in mid-February, only fry/juvenile sized salmon (less than 70 mm) were captured prior to mid-March (Figure 20).

Salmon between 70 and 150 mm captured leaving the Delta at Chipps Island show three distinct abundance pulses (Figure 21). An initial pulse of salmon in January, most likely late-fall run and yearling spring run; another larger pulse in February and March comprised mostly of winter run; and a much larger pulse of young of the year spring run and fall run in April and May. These results indicate the presence of three distinct migration pulses of salmon leaving the Delta. Figure 22 shows the daily catch of winter run sized salmon (excluding the older salmon in the late-fall run size range and the YOY spring and fall run shown in Figure 21 was highest in late-February and March. The lower catch of winter run sized salmon during January and early February indicates smaller numbers of salmon were migrating out of the Delta then. These could be winter run salmon, spring run salmon that are not distinguished from winter run by the length-at-date criteria or a mix of fish from both runs. Previous seasonal capture distributions at Chipps Island have recovered winter run sized salmon as early as December and as late at April with peaks in February, March, and April.

From this information and later descriptions of the Delta fish monitoring data and chronology of fish protection actions, it is apparent that WY 2001 hydrology influenced when substantial numbers of emigrating juvenile salmon reached the Delta and when DCC gate closure and EWA actions reducing export pumping were most appropriate. The salmon migration patterns observed in WY 2001 may be typical of what happens in dry years. It is important to remember that this was the first dry year we have experienced since we put this extensive fall/winter season salmon monitoring and fish protection effort in place. We also note that water project operations becomes increasingly difficult in dry years. CVP/SWP export pumping is often constrained by the lack of natural inflow into the Delta during the winter months and by the lack of water in upstream reservoirs to release and pump in the late spring and summer.

C. Chronological account of EWA actions and DCC gate operations

This section provides a narrative description of each EWA fish action (and sub-action). The reader should refer to Figures 23 to 25 that provide a graphical representation of the chronology of hydrology, fish abundance (catch indices), water quality, delta inflows, CVP/SWP exports, criteria for considering or taking an action (trigger) (T), and individual fish actions taken (A). By following these figures the reader will be able to see how the pre-action conditions changed to warrant the recommendation to take action, when the action occurred over time, the general cost of the action, and the conditions following the action period. The individual fish actions are described further in Appendix 2. In the following narrative the formal numbering system for some of the fish actions were refined to include sub-actions (1a, 1b, etc.) to more clearly describe the action. The detailed nature of this section reflects the complex nature of making EWA decisions on a daily or weekly basis as biological, hydrological, and physical conditions in the Delta change.

1. October - December, 2000

No EWA fish protective actions were implemented in WY2001 during October, November and December reflecting the lack of significant fish movement or population risks (see above fish abundance data).

No EWA assets were used through December 2000.

2. January, 2001

The DCC gates were closed for 17 days in January. The gates were closed on January 14 (A1a) for four days based on a SCI on January 13 of 12 (total greater than 10) (T1a) (Figure 23). On 1/17/02 the KLCI was 6 (T1b) thus the gates were kept closed until the 1/21/01 (A1b). The gates were opened on 1/23/01 because catch indices were less than 5 and water operators wanted to DCC gates to maintain the best water quality possible while maximizing exports during the spring tide and low chinook catch. The operators expected that keeping the gates closed during this time could have had an adverse effect on water quality (i.e. increasing ocean-derived salinity) during the spring tide and up to 2/1/01, when the gates would be closed under the Water Quality Control Plan. The gates were closed again for four days on the morning of the 1/26/01, based on a SCI of 6.7 on 1/25/01 (T2a) (A2a). Although the operators expected the gates to remain closed through the end of the month due to higher flows, a SCI greater than 10 (T2b) on the 1/27/01 also triggered (A2b) the gates remaining closed for the final four days in January.

Exports were reduced for 10 in January. Combined exports were reduced to 6000 cfs for five days starting on 1/17/01 (A1c) as a result of the SCI being 13 (T1c) on 1/15/01. On 1/18/01 exports were further reduced to 3000 cfs for 3 days (A1d) at the request of the MAs to enable the USFWS to track the movement of radio tagged juvenile salmon under a low export condition (observations had previously been made during a high export period). Based on high older juvenile chinook loss (T2c) over several days a second five-day export reduction to 6000 cfs was implemented between 1/27/01 and 1/31/01 (A2c). The need for the export reduction was reassessed on 1/29/01 with DAT biologists supporting the continued reduction for the remaining two days due to Knights Landing and Sacramento catch indices of greater than 10.

In January 2001 69,000 af of EWA assets were used.

3. February 2001

Environmental Water Account actions during this time were primarily targeting the large number of yearling sized chinook salmon entering the Delta from Knights Landing. USFWS sampling effort in the Delta changed as of 2/1/01 due to staff limitations. A new SCI was considered due to this change.

DAT biologists recommended ramping up exports to 8000 cfs for 2/1/01 and 2/2/01 (A4a) due to decreasing catch at Knights Landing and Sacramento (T4a) (Figure 23). On 2/1/01 DAT biologists recommended allowing combined exports at 8000 cfs through 2/5/01 (A4b) because catch indices appeared to be decreasing (T4b) (Figure 24). The SCI increased from 7.6 on 2/1/01. The index was 4.6 on 2/2/01. No export reductions were recommended on 2/5/01. Export reductions necessary to meet water quality standards were anticipated for the next several days. No export changes were recommended on 2/6/01 or 2/13/01 based on low catches at Knights Landing and in the Delta. There was, however, a pulse in steelhead in the Delta sampling and in salvage noted on 2/13/01. Salvage of non-clipped steelhead reached a high of 72 on 2/11/01 and a high of 141 of clipped steelhead on 2/12/01. Delta smelt salvage also increased to a peak of 357 on 2/11/01. The authorized take level for delta smelt was a 14-day running average of 400 smelt salvaged per day ("yellow light") and a monthly total salvage of 10,910 in a dry year ("red light"). Salvage of Coleman late-fall also was lower than the yellow light of 0.5% for upstream releases and 1% of Delta releases. E/I ratio was anticipated to be 45% on 2/14/01 and would start controlling operations. (Because January was very dry, the allowable percent diverted for February was 45% instead of 35%.) During this time DAT biologists began to base their recommendations on salvage and loss at the CVP/SWP facilities. A new salmon protection plan for the February – April period was later developed to reflect this change.

The recommendation was made on 2/15/01 to reduce combined exports from 9,500 to 7,000 on 2/16/01 and 2/17/01 (A5a) based on a doubling of loss of winter run-length chinook at the SWP (T5a) from

15.6 on 2/13 to 36.1 on 2/14. The loss of clipped chinook also increased to 70 on 2/13/01. Non-clipped steelhead salvage increased and clipped steelhead salvage stayed the same. Salvage for delta smelt was over 200/day for the fourth day in a row. Delta smelt salvage was 300 on 2/13/01 and 371 on 2/14/01. The export reductions were to occur at the SWP. Since SWP winter-run loss per acre-foot diverted (density) remained above 10/taf (T5b) then combined exports remained at 7000 cfs on 2/18/01 and 2/19/01 (A5b). On 2/20 DAT biologists recommending keeping exports reduced to 7000 cfs through 2/23/01 (A5c) to re-evaluate the low-density trend (T5c) the next day. On 2/22/01, the DAT biologists recommended terminating the export reduction beginning on 2/23/01 due to chinook losses and densities and adult delta smelt salvage rates decreasing and EWA assets running low and to reserve some EWA assets for March. Export capacity was to be reached for the CVP on 2/23/01 and for the SWP on 2/24/01. Combined exports were expected to be 7,600 cfs on 2/23/01 and 11,700 cfs on 2/24/01 and 2/25/01. Actual exports were 12,050 on 2/24/01 and 2/25/01.

On 2/26/01 the DAT biologists requested the SWP reduce exports from the planned 8,500 cfs to 4,000 cfs for 2/27 and 2/28. The reduction was recommended at the SWP because most of the chinook loss and a majority of the steelhead salvage and delta smelt salvage were at the SWP. This recommendation was based on the highest yearling size chinook losses and loss densities at the SWP in the last 5 years. Genetic characterization results indicated that there were many genetic winter run among the losses occurring during the second week of February.

In February, 2001 the managing agencies (USFWS, NMFS, and DFG) proposed the potential use of EWA assets to maintain flows in the lower American River at approximately 1,500 cubic feet per second (cfs) to provide increased habitat for spawning steelhead trout and fall-run chinook salmon redds and rearing salmon fry. This proposal was summarized as EWA Fish Action #3 (Appendix 2). The steelhead started spawning in late December and most of the fall-run chinook salmon spawned during November, December and early January in flows ranging from approximately 2,000 cfs to 3,000 cfs. Because the inflow into Folsom Reservoir had decreased due to dry hydrologic conditions in October through December, lower American River releases from Nimbus Dam had declined to 1,500 cfs by mid-January. Without the potential use of EWA assets, or other environmental water (such as CVPIA (b)(2) water), it was projected that lower American River releases would continue to be reduced from 1,500 cfs to 1,100 cfs or less in February, adversely affecting incubating steelhead and fall-run chinook salmon redds.

Subsequently, the managing agencies and the PAs agreed to account for the water that was used to maintain the releases to the lower American River for the purposes described in EWA Fish Action #3 as (b)(2) water and not EWA assets. However, in the future EWA assets may be used on Central Valley streams to provide adequate flows for anadromous fish spawning, rearing, and migration; for habitat restoration purposes, to eliminate to the extent possible losses of anadromous fish due to flow fluctuations, and to increase reservoir storage to protect the cold water pool and help meet downstream water temperature objectives.

In February, 69,000 af of EWA assets were used.

4. March, 2001

The DAT biologists recommended continuing the SWP export reduction to 5,000 cfs (A6a) for 3/1/01 through 3/2/01 due to the continued chinook loss. (T6a) (Figure 25).

The DAT biologists recommended allowing exports to increase to pumping capacity pumping on 3/6/01 as they wanted to reserve some EWA water for late March. They also predicted a pulse of yearling sized chinook observed in the Sacramento River would be in the Delta soon and vulnerable to export effects during the following week. It was anticipated that the authorized take level of 2% of the juvenile winter run population in the Delta ("red light") would be exceeded soon.

The winter-run "red light" was exceeded on 3/5/01 (T6b). The daily loss at the SWP on 3/5/01 was 978. Under this circumstance, the MAs recommended an export reduction at the SWP to 5,000 cfs (A6b).

On 3/6/01 the DAT biologists recommended maintaining SWP exports at 4,000 cfs through 3/11/01 (A6c) as long as winter-run loss remained high (T6c). The criterion to increase SWP pumping back to capacity was a density of yearling/winter run-sized Chinook of 15 or less for two consecutive days.

As of 3/13/01 the EWA assets reserved for chinook in the winter season was depleted. The MAs recommended DWR do everything it could to reduce winter-run losses. They also recommended evaluating the factors involved in estimating the adult escapement, the juvenile production, and the loss at the facilities to determine whether there were any significant unforeseen errors in the calculation of juvenile production or loss.

On 3/20/01 the DAT biologists conferred but recommended no operational changes. Daily loss of winter run chinook had declined substantially.

By the end of March the daily loss of winter run chinook had declined to relatively low levels and the cumulative loss has leveled off at nearly 20,000 chinook.

In March 65,000 af of EWA assets were used.

5. April, 2001

On 4/3/01 DAT discussed the significant increase in spring run YOY chinook losses, from classification based on length criterion over the previous two weeks. Loss of fall run YOY had increased significantly too and likely made up the majority of loses since fall-run spawner numbers exceeded those of spring run.

On 4/4/01 staff reported that the combined loss of YOY spring run size chinook had been about 1,000 on 4/1/01, (T7) (Figure 25). The combined losses decreased to 630 fish on Monday and increased to 863 fish on Tuesday. Non-clipped steelhead salvage (cumulative total since December 2000) exceeded the 2% take level of 2,600 in the interim OCAP Biological Opinion for the year (T7). The DAT biologists recommend reducing exports at the SWP by 2,000 cfs from 4/5/01 through 4/9/01 (A7) to provide additional protection for YOY spring-run chinook, steelhead, delta smelt larvae, and San Joaquin fall-run chinook. DAT biologists also recommended that during the export reduction the operators reduce releases and hold some water in their reservoirs to lessen the water cost if there would be no harmful effects of reducing flow downstream.

On 4/10/01 it was estimated that the EWA had 100 taf of water left based on projected uses in the dry year operation's forecast (90% forecast). There was no EWA water allocated (placeholder) for April and May because low exports were forecasted. Of the 100 taf remaining, 67 taf was surface water, and the rest was source shift and groundwater (which couldn't be extracted). The DAT biologists recommended increasing SWP pumping as soon as possible to gain some pumping credit for the EWA. The operators evaluated this proposal and concluded that because increasing exports 400 cfs either 4/11/01 or 4/12/01 would cause require exports be reduced on 4/13/01 or 4/14/01, there would be no net gain in EWA assets.

VAMP was conducted between 4/20/01 and 5/20/01. Under the conditions set forth within the San Joaquin River Agreement and the VAMP experimental design, the target export rate was 1,500 cfs. The actual average combined CVP/SWP export rate was 1420 cfs during this period. Flow at Vernalis was increased as per the VAMP from approximately 2500 cfs to 4500 cfs for the 31-day period. No export reductions related to EWA were implemented during this period.

In April 29,000 af of EWA assets were used, 21,000 af prior to VAMP and 8,000 af for VAMP.

6. May, 2001

As the end of the VAMP on May 20 was approaching, juvenile chinook were still being caught in screw traps on the San Joaquin tributaries and the catch of juvenile chinook at Mossdale on the San Joaquin River increased. Delta smelt in the south Delta also were a concern. The 14-day running average delta smelt take exceeded 400 (yellow light limit as defined in the NMFS 1995 OCAP opinion), and the expanded daily salvage of delta smelt had increased sharply (exceeding 2000). The MAs requested the VAMP export rate of 1500 cfs be maintained from May 21 through May 27 to reduce entrainment of delta smelt and to provide improved migration conditions for salmon smolts migrating through the southern Delta from the San Joaquin River tributaries. The term "shoulder" on the VAMP describes a reduction in export pumping just prior to or, in this case, just after the 31-day VAMP period. Breaching the temporary barrier at the Head of Old River was delayed until May 26.

A series of DAT calls and Delta Smelt Working Group sessions took place in the last 10 days of May and numerous recommendations were made regarding temporary barrier operations (see chronology in delta smelt report for more detail on temporary barrier operations) and exports. CVP/SWP exports were maintained at 1500 cfs through May 31. During maintenance at Banks PP on May 31 and June 1 no water was taken into Clifton Court Forebay through the radial gates.

In May, 49,000 af of EWA assets were used, 34,000 af for VAMP and 15,000 af after VAMP.

7. June, 2001

On May 31 the MAs requested moderation of the planned increase in pumping following the "shoulder" on VAMP. A schedule was developed for CVP and SWP exports to increase in stepwise fashion over several days, not to exceed a combined 3,000-4,000 cfs through June 5. The purpose of this action was to reduce entrainment of delta smelt and allow them to grow and migrate downstream to Suisun Bay. Salmon smolts still migrating from the San Joaquin basin through the southern Delta also would benefit from this action.

By mid-June salmon losses at the CVP/SWP were negligible and delta smelt salvage had declined to minimal levels by the end of June. No further export reductions were requested for fish protection. Agricultural barrier operations were resumed by June 14. Very little water was diverted at the Banks PP during repair of a leak in the California Aqueduct. Pumping at Tracy PP ranged from 4400 cfs – 4600 cfs.

In June, 2001 9,000 af of EWA assets were used.

For the season, a total of 290,000 af of EWA assets were used for export reductions in the south Delta (Figure 26).

IV. Biological Basis and Assessment of Benefits of EWA Actions

The following section describes the actions implemented under the EWA and some of the known factors that may affect the survival of juvenile salmon as the emigrate through the Delta. The relative importance of various environmental effects and associated mortality mechanisms for juvenile salmon is not fully understood. Based on our present knowledge and conceptual model of factors affecting survival in the Delta the following actions were used to improve the survival of juvenile salmon migrating through the Delta: the DCC gate closure and CVP and SWP export pumping reductions.

As explained earlier in Section II, DCC gate closure does not involve the EWA unless the DCC gate are closed for fish protection for additional days beyond those provided in the regulatory baseline and the additional closure leads to water quality and, indirectly, water supply impacts. Gate closure beyond what is provided in the baseline requirements did not occur in WY 2001.

A. Conceptual models of factors influencing juvenile salmonid survival in the Delta

As juvenile salmon from the Sacramento basin migrate through the Delta towards the Pacific Ocean they encounter numerous junctions in the river and Delta channels. Two such junctions are located near Walnut Grove at the DCC (a man-made channel with an operable gate at the entrance) and Georgiana Slough (a natural channel). Both channels carry water from the Sacramento River into the Central Delta. The relatively high quality Sacramento River water flows into the central Delta, mixes with water from the east-side tributaries (Mokelumne, Cosumnes and Calaveras rivers) and the San Joaquin River. This mixture which much of the time is predominantly Sacramento River water is pumped out of the Delta by the SWP and CVP or flows westward through the estuary.

Significant amounts of flow and, we assume, many juvenile salmon from the Sacramento River enter the DCC (when the gates are open) and Georgiana Slough. Mortality of juvenile salmon entering the central Delta is higher than for those continuing downstream in the Sacramento River. We hypothesize this difference in mortality is due to a combination of factors: the longer route through the central Delta to the western Delta, higher water temperatures, higher predation, more agricultural diversions, and a more complex channel configuration making it more difficult for salmon to find their way to the western Delta and the ocean. In addition, upon reaching the mouth the Mokelumne River the emigrating juvenile chinook are often exposed to net upstream (reverse) flows on the lower San Joaquin River, Old and Middle Rivers with water moving to the south towards the pumping plants.

Water is drawn from the central Delta through lower Old River to the export pumps when combined CVP/SWP pumping exceeds the flow of San Joaquin River water down the upper reach of Old River and Middle rivers. This situation, with net reverse flow in the southern Delta channels, increases the risk of juvenile salmon mistakenly migrating to the south Delta and perhaps being entrained at the SWP and CVP facilities. Even if migrating salmon are not entrained, reverse flow may increase their residence time in the central Delta, increasing the exposure to other mortality factors and thereby decreasing survival to the ocean. The unfavorable reverse flow condition can be improved either by reducing exports or increasing Delta inflows. Decreasing exports to eliminate net upstream flows (or, if net flows are downstream, cause an increase in positive downstream flows) is hypothesized to reduce the chances of migrating juvenile salmonids moving up lower Old River towards the CVP/SWP export facilities.

Juvenile salmon, steelhead and other species of fish in the south Delta are directly entrained into the SWP and CVP export water diversion facilities. Many juvenile salmon die from predation in Clifton Court Forebay before they reach the SWP fish screens. Salmon from the San Joaquin basin, and those migrating from the Sacramento River or east Delta tributaries through the central Delta are more directly exposed to altered channel flows due to exports and to entrainment because their main migration route to the ocean puts them in proximity to these diversions. Some juvenile salmon migrating down the mainstem Sacramento River past Georgiana Slough may travel through Three-mile Slough or around Sherman Island and end up in the southern

Delta. There is considerable lack of understanding about how or why salmon and steelhead from the north Delta end up at the diversions in the south Delta, particularly regarding the influence role of the export pumping. Nevertheless it is clear that once juvenile salmon are in the vicinity of the pumps, they are subject to being drawn into the export facilities with the water being diverted. We assume that entrainment of fish and therefore loss or "take" of these fish is reduced by reducing the pumping rate. If reservoir releases are not reduced simultaneously, then the net flow patterns in Delta channels is changed, presumably to the benefit of emigrating salmonids and other fish.

B. Evidence supporting biological benefits of EWA actions

The scientific hypotheses and data generated to support the benefit to juvenile salmon of closing the DCC gates and reducing CVP/SWP pumping is described below. Much of the data used to determine the effects on salmon of closing the cross channel gates and reducing exports are based on mark and recapture experiments conducted during the past 25 years using coded wire tagged (CWT) juvenile hatchery salmon. While this methodology has proven useful, it also has many limitations. Field experiments of this type have proven to be very challenging because of limits on the control of environmental variables being evaluated, intra- and inter-annual variability in other factors, difficulties of sampling in a large aquatic system, limited availability of CWT salmonids, and uncertainty as to how to describe quantitatively the environmental variables being evaluated. Measuring survival also is problematic since the system is large and the number of tagged salmon recaptured is relatively small.

1. Delta Cross Channel Gate operations

a. Empirical evidence from mark and recapture studies

We hypothesized that juvenile salmon survival was lower in the central Delta than on the mainstem Sacramento River. We further hypothesized that, overall, the survival of the juvenile salmon population migrating down the Sacramento River through the Delta will increase if the DCC gates are closed because more salmon will stay in the river and fewer will enter the central Delta. These hypotheses were tested using several mark and recapture experiments where marked fish were released at various locations in the Delta and recovered at Chipps Island. All surviving juvenile salmon pass through the relatively confined area of the western Delta near Chipps Island as they migrate to the ocean (Figure 27). Marked juvenile salmon were recovered near Chipps Island using a large vessel and mid-water trawl net (mouth opening 10' X 30') towed at the surface (Brandes and McLain, 2001). Indices of survival were estimated by expanding the number of marked fish recovered by the fraction of time and channel cross-section sampled and dividing by the number released. Survival also was independently estimated from CWTs recovered in sampling salmon landed by the commercial and recreational ocean salmon fisheries.

To test whether the survival of juvenile salmon migrating through the Delta was higher with the DCC gates closed, fall run hatchery smolts were released on the Sacramento River upstream (Courtland) and downstream of the DCC and Georgiana Slough (Ryde) (Figure 27). The two release locations were approximately 6.5 miles apart. The results of these experiments were that smolts released upstream of the DCC and Georgiana Slough survived to Chipps Island at a significantly lower rate than those released downstream. Significantly lower survival to Chipps Island was observed for the groups released upstream both when the DCC gates were open and when they were closed (Tables 4 -5). This data suggests poor survival of the salmon traveling down Georgiana Slough and through the DCC when the gates were open. Smolt survival estimates derived from catches in the ocean fishery showed generally the same trends but were less consistent and differences were not statistically significant (Table 6 and 7). The difference in survival between the upstream and downstream groups was greater when the gates were opened, but the effect of gate status on these differences was not statistically significant using either the Chipps Island indices or ocean recovery estimates.

We tested the hypothesis that salmon smolts migrating into the central Delta have lower survival by comparing the survival of fall run smolts released into Georgiana Slough and, simultaneously, into the main-stem

Sacramento River either at Ryde or Isleton, in the spring. The survival indices and ocean recovery rates obtained for smolts from the two release locations indicated that fall run smolts survived at a significantly higher rate when released at Ryde or Isleton than into Georgiana Slough (Tables 8 and 9). Similar relationships also were observed when using late-fall run hatchery fish released during December and January, despite the cooler water temperatures during migration and the larger size of the fish relative to the fall run used in the spring (April-May) experiments (Tables 10 and 11).

The hypothesis that survival of juvenile salmon is greater in the mainstem Sacramento River than in the interior Delta is further supported by the results of experiments that released fall run hatchery smolts at numerous locations in the interior Delta. Smolts released in the South and North Fork of the Mokelumne River, the lower Mokelumne River and in Lower Old River had lower survival to Chipps Island than smolts released at Ryde. Survival indices were similar to or lower than for salmon released at Courtland in other experiments (Figure 28).

These studies suggest that some of the smolts released upstream were diverted into the central Delta via the DCC (when the gates were open) and Georgiana Slough and that their survival is lower than for smolts migrating downstream via the mainstem Sacramento River. The studies also indicate relative mortality is higher in Georgiana Slough and other areas of the central and south Delta for fall and late-fall juvenile salmon migrating through the Delta in the fall, winter and spring months. From these results we infer there are survival benefits for Sacramento River salmon from closing the DCC gates if doing so reduces the proportion of salmon entering the central Delta.

Knowing the percent of downstream migrating juvenile salmon that migrates into the interior Delta via the DCC when the gates are open is key to understanding the benefit of closing the DCC gates. Studies conducted to date indicate the numbers diverted may be related to the flow and tidal conditions when individual smolts pass the junction (Vogel, per. comm. and Pierce, per comm.). Studies to estimate the percent of juvenile salmon diverted into the DCC and/or Georgiana Slough have not produced consistent results. Schaffter (1980) found that the densities of salmon in the Sacramento River above the diversion channels at Walnut Grove were similar to those in the DCC suggesting that fish are diverted in proportion to the flow. USFWS (1990) found that densities were significantly lower in the DCC than in the mainstem Sacramento River except during flood tides. Hanson (Hanson, pers. comm.) estimated that during ebb tides the percentage of salmon entering Georgiana Slough was correlated to the corresponding flow split, but the relationship was not directly proportional. At lower flows (Figure 29) and on flood tides (Oltmann, pers. comm.) a greater proportion of Sacramento River water and presumably juvenile salmon are diverted into the DCC and Georgiana Slough. It seems clear that closing the DCC gates would reduce the percentage of Sacramento River water and presumably fish moving into the interior Delta.

Lower smolt survival in the Central Delta relative to that on the main-stem Sacramento River has been hypothesized as being related to the amount and direction of net flow in the lower San Joaquin river, the longer route to the western Delta for smolts migrating through the central Delta, and increased vulnerability to the effects of exports. A positive net flow indicates that water flowing from the interior Delta is making it to the western Delta. Tidal flows are much greater than the net flows, but if juvenile salmon use net flows to help orient them towards the western Delta and Pacific Ocean, net upstream flows in Delta channels may hamper this process. The results of analysis of the potential relationship of positive net flow to the survival indices (to Chipps Island), of fall run smolts and late-fall run yearlings released into Georgiana Slough, show no relationship between positive net flow and survival.

A longer route through the Delta could account for the increased mortality observed in the interior Delta. A longer route would expose the fish to various mortality factors (e.g. predation) for a longer period of time. However, the difference in distance, assuming the most direct routes to Chipps Island for both groups, is only 37 percent greater for the Georgiana Slough group (White, 1998). The Ryde groups survived between 1.5 and 22 times that observed for the Georgiana Slough groups (Table 12). Differences of between 1.3 and 6 times are observed in the ocean recovery rate data but some of the most recent releases have not been recovered in the ocean fishery yet (Table 13). Increased distance alone could account for only the smallest of these differences in survival between the two groups. The role of exports on smolt survival is discussed in the next section.

b. Evidence from modeling survival of tagged smolts

Models generated using the marked fish (coded wire tag) data obtained in the Sacramento Delta also support the conclusion that closure of the DCC gates will improve survival for smolts originating from the Sacramento Basin, emigrating through the Delta. Kjelson, Greene and Brandes (1989) found that the greatest mortality for smolts between Sacramento to Chipps Island was that in the central Delta and that survival could be improved if the gates were closed.

Ken Newman, Statistician from the University of Idaho has three additional statistical analyses evaluating factors important to smolt survival through the Sacramento Delta using the coded wire tag data (CWT). The model he developed with John Rice was a generalized linear model to estimate the effects of various parameters on salmon smolt survival through the Delta. They found that mortality was higher for smolts released in the interior Delta relative to those released on the mainstem Sacramento River (Newman and Rice, 1997). The open cross channel gate also was associated with lower survival for releases on the Sacramento River (Newman and Rice, 1997). In the second analyses, using a Baysian framework, Newman found that smolts released at Sacramento survived at a much higher rate than those released in the interior delta when the DCC gate was closed. (He also found that smolts released in the interior delta do slightly better when the gates are open with both the Baysian and GLM modeling) (Newman and Remington, 2000). The third approach used paired release data to estimate and model absolute survival through the Delta (Newman, 2000). He found using this methodology that the open cross-channel gate had a negative effect on the survival of smolts migrating through the Delta in both a product multinomial and quasi-likelihood model.

All of the analyses to date appear to support the conclusion that closing the DCC gates will improve the survival of smolts, originating from the Sacramento basin, migrating through the Delta. It should be noted that even with the DCC gates closed Sacramento River water still flows into Georgiana Slough and some, but presumably fewer Sacramento salmon still travel that route into the interior Delta.

2. CVP/SWP export pumping effects on survival of juvenile salmon

This discussion on the effect of exports is focused on juveniles originating from the Sacramento basin. EWA export reductions implemented to help protect listed fish species emigrating from the Sacramento basin are expected to have benefits for any juvenile chinook and steelhead that are migrating from the San Joaquin and east side Delta tributaries (Mokelumne, Cosumnes and Calaveras Rivers).

Given the limitations of each of the analyses described below, the pieces of evidence provided support the conclusion that reducing exports will improve the survival and reduce the losses relative to export effects of juvenile salmon in the Delta. With reductions in exports, direct losses, entrainment and indirect losses relative to hydrodynamic changes would all be reduced and survival for Sacramento smolts diverted into the central Delta would be improved.

a. Evidence from mark-recapture studies

A reduction in exports is hypothesized to improve the survival of juvenile salmon of which are diverted into the interior Delta via Georgiana Slough or the open DCC. For mark and recapture experiments in December and January, we released juvenile late-fall salmon into Georgiana Slough in the central Delta and at Ryde on the mainstem Sacramento River. Regression and correlation analyses of these data (1993-1998) indicate that the survival of smolts released into Georgiana Slough is increased as exports are reduced, relative to the survival of salmon released simultaneously at Ryde (Figure 30). These findings are the basis for reducing exports to further protect juvenile salmon migrating through the Delta.

Results from the 1999 experiments with late fall chinook releases at Ryde and in Georgiana Slough do not fit within this relationship. When the data from 1999 are added, the slope and significance of the relationship are reduced (Figure 31). It is unclear why the 1999 data do not fit better with previous data, but one likely explanation is that instead of being held constant during the experiment, CVP/SWP exports (and the status of the DCC gates) varied throughout the 17-day period when salmon were at large and being recovered.

The trend of increasing survival at lower exports is still apparent when the results of similar experiments with fall run chinook are combined with the late-fall run chinook results, however, the relationship of exports and survival is not statistically significant (Figure 32).

Survival of yearlings released into Georgiana Slough relative to those at Ryde appeared to be more variable at the exports less than 6000 cfs (Figure 30). Thus export pumping was reduced to 6000 cfs and generally not lower in recognition of this uncertainty and to extend the duration of reductions given a finite EWA budget.

Newman and Rice (1997) and more recent work by Newman suggests that reducing export pumping will increase the survival for smolts migrating through the lower Sacramento River in the Delta. Newman and Rice's updated 1997 extended quasi-likelihood model (Ken Newman, per. comm.) provides some evidence that increasing the percent of Delta inflow diverted (export to inflow (E:I) ratio) reduces the survival of groups of salmon migrating down the Sacramento River, but the effect was slight and not statistically significant. In Newman's extended quasi-likelihood model using paired data, there was a significant export effect on survival (approximate P-value of 0.02 for a 1 sided test) (Newman, 2000).

3. Effects of net flow in Delta channels

The following is a brief summary of a more comprehensive discussion of Delta hydrodynamics that is included in the EWA Background Report (Brown and Kimmerer 2001b).

Flow in the Delta is a result of river-derived net flow and tidal movement. The relative magnitudes of net and tidal flow depend on location and river flow with greater tidal dominance toward the west and at lower river inflows. The presence of channel barriers at specific locations has a major influence in flow dynamics. Tidal flows oscillate, however, because of the complex geometry of the Delta they can produce net flows independent of river flow and can cause extensive mixing. During high flow periods, water flows into the Delta from Valley streams and exits the Delta as net Delta outflow. During low flow periods, flow in the San Joaquin River is lower than export flows in the southern Delta so water is released from reservoirs to provide flow for export and to meet salinity and flow standards in the Delta.

Particle tracking models, using data from direct measurement of flow velocities and volume transport at various Delta locations, have given us our most recent view of net flow in Delta channels. The general trend of model results seems to be that a patch of particles released in the Delta will move generally in the direction of net flow but the patch spreads extensively due to tidal dispersion. The export pumps and Delta island agricultural diversions impose a risk that the particle will be lost to the system. This risk increases with greater diversion flow, initial proximity of the particle to the diversion, and duration of the model run. The absolute magnitude of project exports was the best predictor of entrainment at the export pumps while the computed reverse flow in the western San Joaquin River (QWest) had, at most, a minor effect.

Tidal flow measurements allow calculation of tidally averaged net flows. Results indicate that tidal effects are important in net transport, i.e. net flow to the pumping plants is not greatly affected by the direction of net flow in the western (lower) San Joaquin River.

If the above view of net flow is correct then in respect to fish movement, relatively passive life stages as delta smelt larvae should move largely under the influence of net flow with increasing behavioral component of motion as fish develop. Larger, strong-swimming salmon smolts are more capable of moving independently but may be affected to some degree by net flow.

a. Behavior of radio-tagged juvenile salmon in response to export pumping

As part of Action A1 (i.e., A1 d) during January 18-20th, 2001, total project exports were reduced for three days to 3000 cfs. During this time period radio-tagged juvenile late-fall salmon were released in lower Old River to evaluate their behavior at low exports and with or minimal reverse flows in lower Old River (Experiment 3 and 4). In December 2000, the same experiment was conducted when total export levels were high (8,000 to 11,000 cfs) causing net flows in lower Old River to be reversed, i.e., upstream toward the CVP/SWP intakes (Experiment 1 and 2). Preliminary results indicate that more radio tagged salmon released under high export conditions moved upstream toward the pumping plants while more released at low exports remained in the channel where they were released (Table 14) (Natural Resources Scientists Inc. draft report to USFWS, September 2001). These findings indicate that as exports decrease and reverse flows in the water conveyance channels also decrease, radio tagged juvenile salmon remain in that channel and are more likely to move downstream toward the ocean. For migratory salmon this latter behavior must be considered advantageous for their survival compared to behavior observed with large net reverse (upstream) flows in these channels. With reverse flows, more of the radio- tagged juvenile salmon moved rapidly toward the CVP/SWP diversions, and "upstream" away from the ocean. This behavior is counter to their natural behavior during this stage of their life cycle and probably detrimental to their survival.

Based on the contrasting behaviors observed for juvenile salmon during the two phases of the evaluation, we hypothesize improved survival for juvenile salmon in the central and southern Delta when conditions are like those during the low export (3000 cfs) phase compared to the high export (8,000 to 11,000 cfs) phase with net upstream flow. We presume migratory salmon survival would tend to be higher whenever net flows are downstream compared to when net flows are upstream. The change in net flow needed to produce consistent and substantial differences in migratory behavior and survival is unknown. Neither do we know just what flow condition may be needed to avoid eliciting what we presume is undesirable upstream migratory behavior by juvenile salmon that are trying to successfully migrate to the ocean. Nevertheless, the studies in 2001 suggest net flow affects juvenile salmon behavior and therefore EWA actions to change flow patterns in Delta channels may be beneficial for these migrating fish.

C. Quantitative Assessment of EWA Benefits

1. Incremental reduction in entrainment of salmon and steelhead (direct loss)

A direct benefit of reducing Delta exports using EWA for fish in the immediate vicinity of the intakes was the reduced entrainment. We presume fish entrainment is reduced in proportion to the reduction in diversion rate. We assumed that some of the fish not entrained move away from the intakes, avoid entrainment altogether and be saved.

A simple way to quantify the benefit to salmonids of using EWA water to reduce SWP and CVP Delta exports is to calculate the reduction of the number of salmonids directly taken at the exports. Few assumptions are involved. We assume we can accurately and precisely measure the number of fish taken at the Delta export facilities. We also assume we know how much water would have been diverted if there were no EWA action. To estimate the benefit to salmonids of export pumping reductions using EWA water we compared the estimated number of salmon taken each day during an EWA export reduction to the number that would have been taken under the Base Operation Plan. The Base Operation Plan is the operation that would have occurred without the EWA action. We assume the number of fish per acre-foot diverted each day is the same in both cases. The equation is: Number Saved = (Actual Number Taken * (Base Exports/Actual Exports)) - (Actual Number Taken).

The number of winter-run chinook, all "older chinook", and steelhead saved on a daily basis during individual EWA actions 1 through 6 are tabulated in Appendix 3 and summarized in Table 15.

This estimate of benefit is the reduction of direct mortality at the SWP diversion facility where all the EWA pumping reductions occurred. In real-time it will always be impossible for the DAT know when to use the

EWA water for the maximum benefit of the emigrating population within one season. After the season is over, we can use this assessment to determine if the available information was adequate to help us predict the maximum benefit occurring within the season, and apply that result to improving future decision. Figure 33 is an illustration of the winter run loss, loss density and cumulative density for 2000-2001. EWA actions through March 11 saved 6,000 winter run. Record densities of winter run chinook persisted at the SWP facility after the amount of EWA water reserved for protecting salmonids in March was depleted. Winter run take reached almost three times the "red light level", or high concern level by the middle of March. The winter run take finally abated by the end of March.

Figure 34 is an illustration of the 2000-2001 steelhead salvage and cumulative salvage. Again, although EWA actions saved 675 steelhead, the quantity of EWA water reserved for salmonids was exhausted well before the main steelhead emigration period ended in mid-April.

2. Incremental survival improvement for emigrating salmon

An analysis was conducted to evaluate the benefit of Environmental Water Account Actions (reducing exports and closing the DCC to juvenile, late-fall and tributary spring run and winter run salmon survival during emigration through the Delta.

Two simplistic spreadsheet models were constructed to estimate survival for juvenile salmon migrating through the Delta. The first was for juvenile salmon migrating through the Delta between November 1 and January 31 and was developed to index the survival of late-fall and tributary spring run (juveniles between 70 and 150 mm). The second was for winter run sized juvenile salmon migrating through the Delta between February 1 and March 31. Each survival model was run using different operational conditions – the base conditions (no changes due to EWA) and EWA conditions.

Survival through the Delta for the each juvenile population was estimated by summing the daily estimates of survival multiplied by an estimate of the percentage of the population present on that day. Each daily estimate of survival was based on the percentage of juvenile salmon diverted into the interior Delta (Georgiana Slough or DCC relative to the percentage diverted into Steamboat or Sutter Sloughs or staying in the mainstem Sacramento River and an estimate of survival in each reach. The percentage of the population migrating through the Delta on any one day was estimated by dividing the daily catch per cubic meter by the sum of the daily catch per cubic meter for the entire time period (November 1 to January 31 or February 1 to March 31). Although sampling was not conducted daily it was assumed catches represented the pattern of the population migrating into the Delta.

The daily catch per cubic meter was derived using the catch of juvenile salmon divided by the cubic meters of water sampled in the midwater and kodiak trawl, at Walnut Grove or Sacramento, respectively. The Walnut Grove estimates did not incorporate a time lag whereas those from Sacramento incorporated a two-day lag.

The percentage of the daily population that was diverted into the different reaches of the Delta with the DCC gates open and closed (interior Delta or Steamboat or Sutter Sloughs) was assumed to be the same as the percent of water diverted and determined using flow equations published by DWR. The unaccounted proportion of the water was assumed to stay in the mainstem Sacramento River. Daily flow and DCC gate status were used to estimate the percentage of flow and juvenile salmon that were diverted into each reach on a daily basis.

Survival was assumed to be 0.8 for smolts entering Steamboat and Sutter Sloughs and for those staying in the mainstem Sacramento River. Previous studies suggest survival is relatively high in these areas (Brandes and McLain, 2001). Survival in the interior Delta was based on the on the relationship between the survival of late-fall hatchery smolts released into Georgiana Slough relative to those released at Ryde versus CVP +SWP exports. Georgiana Slough survival relative to Ryde survival was equal to (0.52-.(00003 * CVP + SWP exports in cfs)). The resulting estimate was then multiplied by 0.8 (estimate of Ryde survival) to get the ratio of Georgiana Slough to Ryde survival into absolute Georgiana Slough survival.

Daily estimates of survival were calculated by multiplying the percent of juvenile salmon in the mainstem and Steamboat and Sutter Sloughs by the survival there (0.8) and adding it to the product of the percent of juvenile salmon diverted into the interior Delta and an estimate of interior Delta survival. The following equation was used to estimate daily survival through the Delta:

(((0.8 * (1-% diverted into GS and DCC))+(% diverted into GS and DCC * ((0.52 – (0.00003 * CVP + SWP exports))*0.8))))

Survival estimates for the two juvenile populations were generated for the different conditions (with and without EWA actions). For the late-fall and tributary spring run model estimates were generated with base exports and no DCC gate closures, with DCC gate closures and with DCC gate closures and export reductions. For the winter run estimates, the closure of the DCC gates were not estimated since the gates were closed for the entire period due to regulatory mandates. Estimates for the benefit relative to winter run were made under base export conditions and with export reductions due to EWA. Survival estimates were then compared across conditions to estimate the benefits due to the change in operational conditions.

Estimates of survival for the late fall and tributary spring run populations under the three conditions between November 1 and January 31 were 0.55 (no DCC closures or export curtailments), 0.66 (for DCC closures) and 0.67 (for DCC closures and export curtailments). This is an increase of 20% with the DCC closures and a 22% increase with both the DCC closures and export curtailments.

Estimates of survival for the juvenile winter run salmon population were 0.69 with base export conditions and 0.70 with the EWA export curtailments - a change of approximately 1 percent. Export reductions in this model affected a smaller proportion of the population because the DCC gates were closed, reducing the number of juveniles entering the central Delta and benefitting from the export reductions

Several key assumptions drive these results. Two of the most important assumptions are the percentage of fish diverted into the interior Delta and the percentage of the population affected by the change in conditions. In the analyses I conducted I assumed that the juvenile salmon split in direct relation to flow. As the percentage of fish diverted into the interior Delta increases the estimated benefit of reducing exports would increase. If the proportion of the population that was exposed to the changes in conditions was overestimated then the benefit would be lower. The converse would also be true.

This analyses shows that survival through the Delta is always highest when the DCC gates are closed. Survival is further improved by reducing exports. The percentage increase due to export reductions is increased when the gates are open because a greater percent of the population is exposed to the improvement but the absolute survival is less than when the gates are closed. Closing the DCC gates and reducing exports for as much of the time as possible during the period of time the fish are migrating would further increase the survival of the population through the Delta. Curtailing exports without closing the DCC gates will be less effective at protecting the population than closing the gates alone or closing the gates and curtailing exports.

What the benefit of the survival increase in the Delta is to the overall adult population is uncertain, and is dependent upon the link between the relationship of the juvenile population to the adult population. If you assume survival is density independent in the ocean, a 1 to 22% increase in survival through the Delta, would correspond to a 1 to 22% increase in the adult population. Over time the benefits to the adult population may compound such that the benefits would be greater to future adult populations as the increase in Delta survival is levied to larger juvenile populations.

V. Issues arising from fish protection decisions and outcomes in 2000-2001.

A. Winter run chinook losses at the CVP/SWP

The high winter run chinook loss at the CVP/SWP diversions in the south Delta was the fisheries/EWA issue of greatest interest during WY 2001. The daily losses for much of February and March and cumulative seasonal loss of winter run chinook at the CVP/SWP were very high relative to both historical observations in the 1990s and expectations for 2000-2001 based on the incidental take limit established using the standard methods and data sources. The loss ("take" in ESA parlance) was an estimated 20,000 juvenile winter run chinook, or 5.4 % of the 370,000 expected to migrate into the Delta this year based on the traditional method of estimating juvenile winter run production. Both the daily losses and the density (fish per acre-foot of water diverted) of winter run chinook were higher than ever before observed. This outcome raised many questions both during and after the winter run chinook migration season. In an effort to explain and understand this unprecedented and unanticipated outcome, some of these questions and brief summary responses from our perspective are presented here.

1. Was the loss of juvenile winter run in 2000-2001 extraordinarily high?

Under the OCAP biological opinions for winter run chinook, spring run chinook and steelhead, the NMFS and DFG set annual numerical limits on the take of juvenile winter run, yearling spring run, and juvenile steelhead that is authorized due to operation of the SWP and CVP Delta export facilities. The purpose of the take levels is to avoid significant impact to these listed species from the Delta export facilities. The PAs operate their facilities to try to avoid the authorized take levels. If these limits are exceeded, the PAs must reopen consultation to determine what if any additional measures are needed. Use of EWA by the MAs to reduce pumping from the Delta helps to reduce the take of listed fish species.

For winter run Chinook, two levels of take are described. These levels are 1% and 2% of the Juvenile Production Estimate (JPE), an estimate of the number of juvenile winter run salmon that will reach the Delta each year. The winter run chinook JPE is calculated from information about the spawning population and assumptions about survival rates for eggs, fry and juveniles. The 2000-2001 (brood year 2000) JPE was 370,221 salmon and the 1% and 2% take levels were 3,702 and 7,404 salmon, respectively (Figure 35).

The 1% level is the early warning concern level (often referred to as the "yellow light") and the 2% is the high concern level ("red light"). The term "red light" incorrectly suggests that SWP/CVP pumping stops when the 2% take level is reached.

Since the first winter run biological opinion with a numerical take limit was issued in 1993, the PAs have avoided reaching the "red light" take level in most years, exceeding it by a slight amount in two years (Table 16). Additional measures (pumping curtailments) were necessary to achieve those results in several years. A distinctly different outcome was observed in 2000-2001 when the winter run chinook take reached 20,008. This number of winter run taken is 5.4% of the JPE and 2.7 times the 2% "red light" limit.

How does this level of take effect compare with the effects on the other juvenile salmonids occurring in the Delta at the same time as winter run Chinook? We rely on hatchery late-fall run salmon released during the yearling spring run emigration as surrogates for the spring run salmon which cannot be identified in the Delta using the length-at-date criteria. The fate of the surrogates is presumed to mirror the fate of the yearling spring run. In November – January, groups of hatchery late-fall run salmon, similar in size to the spring run, are released in the upper Sacramento River (including the large "production" release) and in the Delta (for salmon survival experiments). The take limits for yearling spring run at the CVP/SWP are losses of 0.5% and 1% of the hatchery late-fall run released upstream, and 1% and 2% of the hatchery late-fall run released in the Delta. Since the OCAP opinion for spring run chinook and steelhead was first issued in 1998, the PAs have avoided exceeding the yearling spring run surrogate 2% take level every year, including 2000-2001 (Table 17). Higher percentages of several surrogate groups were taken in earlier years.

CVP/SWP losses of hatchery winter run chinook released in the upper Sacramento River in 1999, 2000 and 2001 provide another reference for assessing winter run losses at the CVP/SWP in 2000-2001. Loss of hatchery winter run chinook at the SWP/CVP in 2000-2001 was 0.03 %, lower than in 1999 or 2000 (Table 17) and much lower than the apparent percentage of "in-river-produced" winter run taken in 2001.

The high take of winter run salmon relative to the JPE-based 2% take limit is not consistent with the apparently low level of take of hatchery winter run and late-fall run serving as surrogates for spring run. Of course the validity of using marked hatchery fish as surrogates depends on the surrogate fish and the target fish both experiencing the same conditions and responding in a similar way. Thus, surrogate results must be interpreted cautiously. Some regulatory agency fish biologists think the hatchery winter run may not be an adequate surrogate for "in-river" winter run because the hatchery winter run are released in late January or later and "in-river" winter run are in the system several months earlier (Stern, pers. comm.). The same concern exists for the late-fall run as surrogates for the spring run, although use of multiple surrogate groups released over time provides much more information. For example, loss of 0.38% and .0.34% from two January late-fall run release groups may not indicate a greater CVP/SWP impact on these fish compared to the November and December groups with loss rates of 0.11% and 0.21%. Instead, the difference may indicate that more fish from the January groups survived to reach the Delta than fish from the November and December groups, as suggested by catches of salmon from these respective groups at Sacramento and Chipps Island (Figure 36). A higher percentage loss may indicate better survival upstream or greater pumping-related impact in the Delta.

A comparison to steelhead take is not as meaningful because the take limit is not based on an annual abundance assessment. Steelhead take is based on the number salvaged, with no conversion to the number lost as is done for salmon because required information is not available. The take limit for juvenile steelhead was 3,500 at the export facilities in 1999/2000. A two-tiered approach was used in 2000/2001; 2,250 steelhead was the "yellow light" concern level and 4,500 was the "red light" high concern level. About 23% more wild steelhead were taken in 2000-2001 than the year before. Take of steelhead slightly exceeded the "red light" level in 1999-2000 and in 2000-2001. In both years, the limit was not reached until near the end of the emigration season (Figures 37 and 34). The CVP/SWP salvage of hatchery steelhead was about 50% higher in 2000-2001 than in 1999-2000 but to determine the meaning of this difference we will have to consider the number of hatchery steelhead released each year.

2. Was the take of juvenile winter run higher than expected because more winter run salmon spawned in 2000 than we supposed when calculating the JPE and, in turn, more juvenile winter run reached the Delta than expected?

The JPE is calculated using a formula and information on the spawner population provided by DFG based on counting adult salmon passing the Red Bluff Diversion Dam. Because the dam gates have been raised in recent years during most of the winter run adult migration season to facilitate fish passage, we no longer have the ability to count all the salmon migrating upstream. We must make an assumption about the percentage of salmon passing the dam before we counting them can begin in order to produce a winter run spawner escapement estimate. A fixed percentage is used even though we know the fraction of the run historically passing Red Bluff during the present counting period was quite variable. We estimated 1,350 adult winter run passed Red Bluff in 2000 and used this number to calculate the JPE (Figure 35). Two percent of this number of juveniles becomes the 2000-2001 incidental take limit for winter run at the CVP/SWP diversions in the Delta.

Since 1996 we also have estimated the winter run spawning population from a carcass survey conducted by DFG and USFWS in the reach of the Sacramento River where most winter run spawning occurs. In the 2000 carcass survey we handled 1,954 winter run salmon carcasses, more than the number of winter run spawners estimated from the RBDD counts, indicating the extrapolation from the RBDD counts underestimated the spawner population in 2000. The Petersen, Schaefer and Jolly-Seber models were used to estimate the spawner population in 2000. The Petersen formula applied to data from fresh adult salmon carcasses yielded an estimate of 6,492 adults +/- 4% (SE). The Schaefer and Jolly-Seber formulas yielded estimates of 5,555 and 4,227 adult winter run chinook, respectively (Snider et al. 2001). In addition, in the JPE calculation we assumed a 1:1 sex ratio for adult salmon and estimated that 503 adult female winter run actually spawned. The minimum number of adult female spawners from the carcass survey estimates is 3,508 (Jolly-Seber), or seven times the effective spawner population determined using the JPE formula.

From these data it seems clear that more winter run spawned than we assumed when calculating the JPE and the 2% CVP/SWP winter run take limit. This suggests the number of juvenile winter run actually reaching the Delta may have been proportionately higher than we estimated because more spawning female salmon will produce more eggs, fry, juveniles and smolts, absent any density dependent mortality for any of these life stages.

The JPE calculation uses a survival rate of 25% from egg to emergent fry and a survival rate of 59% from emergent fry to smolts arriving at the Delta (Figure 35). Constant survival for these life stages year after year seems unlikely. We would expect relatively little inter-annual variation in the survival of incubating eggs and pre-emergent fry because water flow and temperature are closely managed during this period. We might expect more year-to-year variation in the rearing and migration habitat conditions and in survival rate between the spawning grounds and the Delta due to wide variation in hydrology, weather and other factors. Inappropriate assumptions for any step in the calculation may affect the accuracy of the JPE, potentially in either direction. Poor assumptions about survival could either exacerbate or offset the underestimate in juvenile abundance caused by the low spawner population estimate.

We assessed the possibility that the high take of winter run in 2000-2001 was due to an exceptionally large number of juvenile winter run reaching the Delta by comparing the calculated JPE with two other estimates of juvenile winter run abundance upstream and downstream of the Delta. The first estimate is calculated from the catch of juvenile winter run in RSTs at Knights Landing, expanded for gear efficiency and sampling effort (Snider and Titus 2000 and Snider pers. comm. Sept. 2001). The second is from trawl catches at Chipps Island in the western Delta, expanded for percent of channel cross section and time sampled. Catch at these locations represent salmon entering and leaving the Delta, respectively (Figure 2).

Exceptionally high values in 2001for juvenile winter run estimates from either sampling location in comparison to recent years would indicate a relatively large number of winter run were subjected to potential entrainment at the CVP/SWP intakes in 2000-2001, perhaps accounting for the very high take. No statistical analysis was done.

Even using the low spawner abundance estimate from Red Bluff counts, the 2000-2001 JPE was the second highest ever computed, so take of more winter run in 2001than in most recent years would not have been unexpected (Table 18). If the higher and likely more accurate effective spawner abundance estimate from the carcass survey were used, take of more winter run than ever experienced might have been expected based on the potentially higher production of juveniles.

In six years we have sampled at Knights Landing, slightly more winter run were estimated to have passed the site in two years than passed in 2000-2001. Sampling indicates many fewer winter run passed the site in the other three years. This would indicate the potential for winter run take in 2001 at the CVP/SWP to be at the high end of the recent historical range if juveniles were being entrained generally in proportion to their abundance in the Delta. However, we would not expect losses to be almost three times the highest take level observed in this period.

More juvenile winter run apparently migrated past Chipps Island in five of the last six years than in 2000-2001; only in one year, 1993, was the apparent number of juvenile winter run leaving the Delta substantially lower than 2000-2001. This below-average estimate of juvenile winter run leaving the Delta is not consistent with the relatively high number of emigrating winter run that the JPE would lead us to expect or with a number of winter run salmon entering the Delta in the high end of the recent historical range at Knights Landing. Below average abundance at Chipps Island compared to relatively high abundance upstream suggests that mortality may have been quite high between Knights Landing and the western Delta. If we consider the higher carcass survey-based estimate of spawner abundance likely means higher fry production, the catch of juveniles at Knights Landing suggests relatively high mortality between the spawning area and the Delta. High mortality during rearing and downstream migration would be consistent with potentially poor river habitat conditions in a dry year. High mortality in the Delta would be consistent with the high take at the CVP/SWP. Further analysis clearly is warranted.

DFG, NMFS, USFWS and others are discussing issues related to estimating winter run spawner abundance and juvenile abundance and exploring ways of improving our knowledge of factors affecting winter run during their freshwater existence. Modifications of historically used methods will be considered and appropriate changes implemented.

3. Was the take of winter run high because all the juvenile/ chinook salmon identified as winter run at the CVP/SWP were not actually winter run?

The MAs use length-at-date criteria, based on run-specific spawning periods, size at emergence and subsequent growth rate, to try to distinguish juvenile winter run from the other three Central Valley chinook runs. The length-at-date criteria were developed by DFG in 1992 (Fisher 1992) (Table 3). The criteria were modified by USFWS in 1996 (Pierce 1996) to better characterize winter run size chinook in the Delta. The tabulated criteria have been adapted to produce size curves that graphically represent the boundaries between runs as defined by this method (Figure 38).

We recognize that every salmon is not correctly classified as to run by the length-at-date criteria. The method can never be perfect because, given the variability in the biological factors that define the boundaries, no matter where the lines are drawn separating two runs, individual fish from both runs will fall on each side of the boundary. Following modification of the criteria in 1996 to account for faster Delta growth, the same criteria have been applied each year. Consequently it is difficult to conclude that the exceptionally high take in WY 2001 is due to errors in run identification caused by the length-at-date criteria. When the modified growth criteria are applied to the data prior to 1996, the CVP/SWP winter run loss in 1994/1995 and 1995/1996 would have been less than instead of slightly greater than the "red light " level.

In 1997, the PAs proposed a second, independent method to identify winter run based on genetic characteristics. Genetic characterization has proven to be relatively effective for distinguishing winter run chinook from the other runs (Figure 39). The take of salmon identified as winter run based on genetic characteristics is consistently lower than the take based on length-at-date criteria. From 28% to 80% of the winter run sized chinook have had winter run genetic characteristics (Figures 40 and 41) with the largest proportion in 2000-2001.

The MAs look at the results of both classification methods when evaluating take of winter run at the CVP/SWP diversions. The size-based determination is still used as the primary reference for judging compliance with the take limit. Recognizing that perhaps only about half of the winter run sized chinook were winter run based on genetic characteristics, the "red light" take limit was increased from the original value of 1% to 2 % in 1995 (NMFS, 1995).

One explanation for variation in the percentage of genetic winter run among winter run sized salmon is the presence of varying numbers of spring run yearlings in the system with the winter run each year. These yearlings are the most likely to be in the winter run size range and occur in the Sacramento River and Delta at the same time as winter run. Recall these spring run yearlings are not represented by the length-at-date criteria because they are from the high-elevation, cold water spawning and rearing habitat in Mill and Deer creeks. Relatively larger numbers of yearling spring run chinook will reduce the percentage of winter run sized salmon with winter run genetic characteristics. The percentage of genetic winter run did not appear to change between two-week intervals during the period of highest winter run losses (Figure 40). No consistent pattern is apparent from previous years (Figure 41).

Given the highest documented percentage (80%) of genetic winter run among the winter run size salmon, the unprecedented high CVP/SWP take of winter run chinook in 2000-2001 cannot likely be explained by extensive errors in classification of salmon using the length-at-date criteria. The loss of winter run size chinook was nearly three times the previous high, however, the loss of genetic winter run was more than six times the previous high (Table 16).

4. Was the take of juvenile winter run at the CVP/SWP higher than expected because of unrealistic assumptions in the conversion of the number salvaged to the number lost?

The DWR and USBR maintain fish salvage facilities at the SWP and CVP to reduce the impact on the fish. These facilities are located just upstream of the pumping plants and operated to separate as many fish as possible from the water pumped from the Delta. The "salvaged" fish are transported and released at other locations in the Delta, away from the export pumping facilities.

There is fish mortality throughout the salvaging process and the screens are not 100% effective, so DFG calculates the number of fish "lost to the system" (loss) based on the number of fish salvaged and the mortality factors. There are two mortality factors in the loss calculation that the Management and PAs assume introduce significant error and/or variability.

The largest mortality factor is the "pre-screen" mortality at the SWP where water is first taken into a large forebay by opening intake gates on high tides. Water is pumped out of the forebay through fish screens on a pattern determined by determined by system demand for water and daily variation in the value of the electricity to run the pumps. The USBR pumps water directly from the Delta channels on a continuous basis. The large "pre-screen" mortality at the SWP is primarily from striped bass and bird predation in the forebay. The DFG conducted predation rate experiments in the SWP forebay between 1976 and 1993 (Gingras 1997). They conducted eight mark-recapture experiments and estimated predation rate ranged from 63% to 99%. For a mitigation agreement, DFG and DWR agreed to use 75% mortality in the forebay in the loss calculation. DFG assumes the pre-screen predation rate is 15% at the CVP. At the SWP, in any single year, the calculated loss could be significantly overestimated or underestimated if there were substantial variation in the SWP forebay predation rate.

The second largest mortality factor is the primary screen efficiencies at both the SWP and CVP. The primary screens are actually louvers and are a behavioral barrier. The fish avoid the turbulence created by water passing through the louvers, and are guided into the salvage facilities. The optimal louver efficiency occurs when the water velocity is 3.5 feet per second. At the SWP, there are seven gates that DWR operates to optimize the water velocity through the louvers. There are no operable gates at the CVP, therefore USBR cannot control the water velocity and the louver efficiency as well as DWR can at the SWP.

In 2000/2001, 94% of the winter run size juvenile chinook loss was at the SWP facility. Some parties speculated the large difference between the SWP and CVP was not real and the high loss at the SWP was due to an overestimate of the pre-screen mortality at the SWP. DFG and DWR have not measured the predator population in the SWP forebay or the predation rate in the last three years. Although there is no evidence that either changed in the last three years, the NMFS and DFG are considering the value of conducting more assessments.

Lower apparent salmon loss at the CVP could be due to other factors, including inaccuracy of our assumptions about screen efficiency for salmon. If a smaller percentage of salmon are being screened from the exported water than we assume, then a salvaged fish represents the loss of more fish that were not screened than the loss calculations indicate. CALFED fish facilities studies are investigating this and other related issues.

Aside from the uncertainty associated with calculating loss at the SWP and CVP, there is another issue associated with location and timing of entrainment. In some situations, if exports are reduced at one facility, but concurrently increased at the other facility, the fish saved at one facility may simply move the one-mile distance to the other facility and become entrained. If exports are reduced for a period of time followed by a makeup period of higher exports, the fish may still be in the vicinity of the diversion and still be entrained.

In summary, we have no evidence that large inaccuracies in the loss calculation contributed to the high take of winter run in 2000-2001, however, we will have to consider all these factors in evaluating the effect of reduced exports on salmon, steelhead and other fish loss.

5. What is the significance to BY 2000 winter run population of losing 20,000 juveniles at the CVP/SWP in 2000-2001?

We have not completed full evaluation of the effect of the loss of 20,000 juveniles at the CVP/SWP on the brood year 2000 winter run population. Nor have we completed our evaluation of the benefits of reducing winter run losses by 6000 juveniles or otherwise improving the survival of emigrating salmon using EWA water.

An assessment of the significance of the salmon loss in the Delta due to CVP/SWP pumping or the number saved by fish protection actions depends on the abundance of the spawner population, the upstream survival of young salmon, the relationship between the number of juveniles successfully migrating through the Delta and the abundance of adult salmon in the ocean and returning to spawn. The annual take limit is tied to the abundance of winter run spawners, so in years when more juveniles are produced the higher take that might logically be anticipated is authorized. The point of the winter run take limit established by NMFS (1993) is to keep the CVP/SWP losses from increasing above the level commensurate with CVP/SWP salvage estimates from the 1980's and early 1990's. Combined with the reasonable and prudent alternative for the upstream operations of the CVP, this level of loss would avoid jeopardy to winter run from combined operations of the CVP and SWP facilities. A determination about the population consequences of exceeding the limit in one year would have to take into account that only one of the three winter run cohorts that exists at any one time was affected. In the regulatory framework, exceeding the take limit on a regular basis would certainly be considered detrimental to the species.

Reducing entrainment losses of winter run by 6000 using EWA water prevented losses from reaching 26,000. Clearly if the loss of 20,000 winter run were judged to be significant, preventing higher losses was important.

We have not completed our assessment of the outcome for winter run chinook in 2000-2001. NMFS and DFG will continue to examine all available information to determine if the present approach to managing winter run chinook take is satisfactory.

Brown and Kimmerer (2001b) discuss the population consequences for salmon in their section on Conceptual Models for EWA Actions.

6. Could we have anticipated this level of loss? Can we do so in the future?

The MAs analyzed historical data and developed an objective decision process for fish protection actions. Unfortunately the data set for winter run chinook and all older chinook is small. The earliest monitoring that targets winter run and yearling spring run started in 1994. Many of the monitoring programs started later. In the years for which we have good data we have not observed such high catches of winter run.

Based on the available data, we could not have realistically predicted this high level of loss. In past years we had the Red Bluff RST to help estimate the timing and abundance of juvenile winter run chinook. The Red Bluff RST is in the area of winter run spawning and rearing and provides additional information. The Fish and Wildlife Service did not operate the Red Bluff RST in 2000/2001 but plans to in 2001/2002.

7. Could we have done a more effective job of reducing the losses of juvenile Chinook salmon, including winter run?

We used 69,000 af of EWA water to reduce exports in January based on salmon catch indices at Sacramento and Knights Landing that were above background levels for the season. Salmon numbers are typically low in this season because the late-fall and spring runs are expected to migrate through then are not abundant. The actions seemed to be effective since salmon entrainment was low when pumping was reduced and high when pumping increased. Loss of salmon at the CVP/SWP facilities, even though well above action levels established for January, was minimal compared to what would come later. Steelhead entrainment began to increase in late January too, but much higher numbers of steelhead also would be seen in February and March.

No EWA water was used from February 5-15. Then entrainment of salmon, steelhead and adult delta smelt all increased. More EWA water was used to reduce pumping from February 16-23. With high and fluctuating density of winter run, and variable but increasing daily losses, the rate of increase in cumulative winter run take also increased in mid-February (Figure 33). The cumulative number of steelhead entrained (represented by number salvaged) climbed steadily in February also (Figure 34). Delta smelt salvage, comprised mainly of pre-spawning adults, was variable and at times quite high. More EWA water was used in the last 4 days in February, bringing the total used in February to 69,000 af, coincidentally the same amount used in January. Based on the number of fish of all of these species in the Delta, we assume substantially greater benefits were achieved with the water used in February, despite the high numbers of fish entrained, than in January.

In spite of continued use of EWA to reduce SWP pumping in early March, winter run densities and daily losses got even higher and the cumulative loss rate increased again from the already high rate of the previous 3 weeks. Biologists expected more salmon would soon arrive in the Delta based on monitoring upstream of the Delta. CVP pumping declined when unable to store more water in San Luis Reservoir but SWP pumping increased concurrently. Use of EWA continued through March 11 in an attempt to deal with the highest number of winter run per acre-foot of water diverted and the highest daily winter run losses ever experienced. The winter run "red light" was exceeded on March 5 (Figure 33). Peak numbers of steelhead for the season were being entrained at the same time. Delta smelt entrainment was below yellow light levels (14-day average salvage of 400) but both adults and YOY were being entrained. Despite continuing high salmon and steelhead entrainment, no more EWA was used in March because we chose to reserve some EWA water for VAMP and the high likelihood, based on recent experience, that delta smelt take would become a serious problem in May or June. With high SWP pumping, winter run losses continued to accumulate until gradually the winter run density and daily losses declined in late March. Comparatively few winter run were taken in April. We used 65,000 af of EWA water in March.

The 203,000 af of EWA water used in January-March was spread evenly among the 3 months. Looking back, if less EWA had been used in January larger pumping reductions could have been made in February and March or pumping reductions could have continued after March 11 because more EWA water would have been left. We can probably all agree that either scenario would have produced more fish benefit than the expenditure in January, but that is a hindsight determination. Similarly, greater benefits may have been achievable if EWA actions taken in early February had been delayed, leaving more EWA to use when winter run abundance in the Delta eventually reached its peak. However, there was nothing in our experience, albeit limited, that could have led us to such a decision. Refinements in our data collection and assessment methods may improve our capability in this regard.

We also could have elected to continue using EWA water in March and taken the risk that delta smelt would not become a problem later in the year, although some water would need to be reserved for the VAMP export reduction costs. EWA was used in early April (21,000 af) when the "red light" for steelhead was exceeded, with concurrent benefits for San Joaquin fall run chinook, Sacramento spring and fall run, and young delta smelt. The VAMP was conducted from April 20 – May 20 and cost the EWA a total of 46,000 af. As it turned out, high salvage of delta smelt did not occur in 2001, perhaps in part due to the beneficial effects of EWA used in April and May. Only small amounts of EWA were used after VAMP (15,000 af in May and 9,000 af in June) for delta smelt and San Joaquin fall run chinook. We ended the year with some EWA water on hand. We could have gambled and used more water for winter run and made it through the year satisfactorily, however, we were unwilling to take that risk in March when a decision had to be made. We must seriously consider how we will approach a decision in a similar circumstance in the future.

We estimated that about 200,000 af of pumping curtailment would have been necessary to contain the winter run take within the authorized take level, assuming the same pattern and duration of high densities. The EWA expects to obtain about that amount of water annually, on average, from its variable tools. In WY 2001, we fell far short of that amount. If more water had become available from those tools or if water had previously been stored by the EWA, more aggressive action could have been taken in February and March and winter run losses probably could have been kept lower.

Tier 3 water was not available in WY 2001. If it had been, we may have decided to use more water in February and March, knowing that if delta smelt take got alarmingly high in May or June, additional water could have been provided then.

B. Adequacy of salmonid monitoring and application of information to decision making

Was the salmonid monitoring in place in 2000-2001 sufficient to provide enough information about salmon abundance and migration timing to support good decisions about using EWA for salmon and steelhead protection? Were available data fully utilized or could more information be derived from data collected during the season to support decisions?

Generally the information was adequate. Tributary monitoring for spring run provided good information on when yearling spring run chinook moved through the valley floor reaches of the tributaries. Sampling at GCID and Knights Landing provided a general picture of salmon migrating through the middle reach of the Sacramento River and approaching the Delta. Moderate flow conditions created few sampling problems. Trawling and beach seining in the Sacramento River near Sacramento and beach seining in the Delta further identified periods of increased downstream movement of salmon into the Delta. Clear water may have reduced gear efficiency for traps and trawls and perhaps clouded comparisons with historical catches. Varying sampling frequency, although generally adequate, made computing the Knights Landing and Sacramento Catch Indices impossible at times. We probably did not make maximum use of the available data as we went through the season. Measuring gear efficiency at existing and additional monitoring sites would enable better tracking of fish movement and in-season assessment of the number of salmon reaching points progressively farther downstream through time. This additional information would increase our understanding of juvenile salmon behavior and improve our decisions with respect to the timing, magnitude and duration of EWA actions in the Delta, and helps us evaluate the benefits.

1. Upriver monitoring

RST sampling in the valley floor reaches of Mill, Deer and Butte creeks revealed the pattern of yearling spring run migration, but from these data we could not know what proportion of the entire emigrating population had come through by any date. In wetter years the migration typically begins with early storms and most salmon emigrate by December. In 2000-2001, with a relatively flat hydrograph, this migration occurred in three or four distinct peaks beginning in early November and extending through January and into February. Tributary monitoring provided enough information to identify the period of concern when some of the spring run yearlings began migrating towards the Delta and over time revealed the duration of migration from the tributaries.

In smaller, uncontrolled streams like Mill, Deer and Butte creeks, use of RSTs during periods of high discharge from storm runoff becomes infeasible due to risk of damage or loss of the traps, increased debris load and personnel safety issues. In wet years, high creek flows preclude sampling for an extended period of time. This fact, combined with the lack of enough salmon to do gear efficiency evaluations has prevented us from making estimates of the number of juvenile chinook emigrating each year.

At GCID, RST sampling provided an adequate general picture of the sporadic and protracted salmon migration that we hypothesize is typical of dry year hydrological conditions. Efficiency measurements and additional sampling in the main river channel would enable estimates of the number of salmon passing this point in the Sacramento River.

At Knights Landing, RST sampling provided a clear picture of the delayed and protracted movement of salmon from upstream areas to the Delta apparently due to absence of river conditions normally associated with earlier downstream movement of salmonids. Periods of increased numbers of salmon moving towards the Delta were readily apparent. Varying the trap checking interval between daily and every second or third day made computing the pre-defined KLCI, a 2 day running average catch per unit effort, impossible at times. This could be resolved by redefining the index to accommodate the data. Daily trap checking is not warranted except during periods of highest catch, when it is essential.

Estimates of salmon passing Knights Landing are calculated from nearly continuous sampling data and periodic gear efficiency determinations. Obtaining this type of information from more locations would increase our ability to interpret catch data in the lower Sacramento River and the Delta as well as data on salmon loss at the CVP/SWP.

If protracted sampling difficulties and peaks in fish movement occur together, RSTs may tend to underestimate the number of salmon moving downstream past a monitoring location during high flows. At Knights Landing, disruptions in sampling typically are short-term, 1-2 days or less and may not involve all traps. When necessary to estimate the number of juvenile salmon passing this location, catches are expanded to account for interruptions in sampling.

2. Delta monitoring

Trigger levels for the October through January decision process were subjectively determined based on our examination of the historical record of catches at Sacramento in the Kodiak trawl and beach seine. All years used in the analysis were above normal or wet WYs; there were no dry years during this period.

Trawl efficiency likely increases during turbid conditions because fish are less able to see and avoid the net. This increase in efficiency has never been quantified in the Sacramento River trawl or beach seine. Low catches during a period of high water clarity may be explained by a combination of poor efficiency and low abundance. Reduced effectiveness of the trawl gear due to unusually clear water during dry years will likely reduce the chance of reaching trigger levels based on wet year catch data.

The significance of peaks in daily catches cannot be fully assessed during the season without knowing the total abundance of the migrating population of interest. Trawl and seine catches prior to mid-February during 2000-2001 were unusually low compared to previous years and might resemble what would be expected during a dry year (Figures 1, 2, 3 and 4). Catches in previous years showed peaks during late-November in both the trawl and seine. Even considering the likely effect of clear water of sampling effectiveness, both trawl and seine catches in 2000-2001 suggested a late migration of juvenile salmon.

Figure 5 charts daily catch of winter run sized salmon at Chipps Island, CVP and SWP export pumping, and winter run loss between January 1 and March 31, 2001. Because chinook loss and densities at the CVP/SWP were low and delta smelt salvage was low during early February, DAT biologists recommended terminating the export reductions on February 22nd triggered by earlier high catches at Knights Landing, reserving EWA water for later use. One day later (2/23), Sacramento Kodiak trawl catches increased considerably to the highest values for the season. Daily winter run loss at the facilities increased sharply to 650 on 2/26 at SWP and 978 on 3/5. Salmon loss continued to be high in March. Peaks were observed in trawl catch at Sacramento on Friday (2/23). Because no trawling was done over the weekend, the magnitude of this peak in migration could be underestimated. Because no trawling was done over the weekend, the magnitude of this peak in migration could be underestimated. The above data indicated that peaks were observed at Sacramento prior to their observation over the following weeks at the fish facilities and Chipps Island (Figures 3-5).

A significant correlation exists between density of winter run at the facilities and catch of winter run at Chipps Island (Figure 6) suggesting that when salmon are present and moving out of the Delta, they are vulnerable at the facilities.

More analysis is needed to assess the relationship of Chipps Island catch, Sacramento River catch, loss at the facilities, and various environmental factors such as tide, flow, temp, etc.

VI. Conclusions and Recommendations

A. Accomplishments during EWA implementation in WY 2001

1. The DAT salmonid team developed a structured process for evaluating data (decision tree) and used it to assess conditions and formulate recommendations for EWA actions to benefit fish in WY 2001.

2. Staff of the MAs and PAs and stakeholders communicated, cooperated, and coordinated effectively during WY 2001 to implement the EWA. This professional interdisciplinary team approach was evidence of a solid commitment to the EWA effort.

3. Through close coordination via the DAT conference calls the DCC Gates were operated to provide survival benefits to juvenile anadromous salmonids while avoiding water quality problems in the western and southern Delta.

4. An extensive and reliable fish monitoring effort enabled us to identify periods of peak salmon movement at various locations, from the tributaries and upper Sacramento River spawning areas downstream to the Delta. While not perfect, this information helped us anticipate periods of heightened concern for salmon in the Delta and judge the best timing for export reductions.

5. A vast amount of biological, hydrological, and operational data was collected and transferred to databases or otherwise made available to the DAT to support the decision process for use of EWA. Without this critical foundation and the cooperation of colleagues and strong professional commitment of field crews and data management staff working throughout the Valley, we could not implement this program.

6. A comprehensive set of DAT conference notes was compiled through the diligent effort of agency staff who prepared the notes and DAT participants who reviewed them prior to posting. The notes provide an excellent record of events and decisions, and that record, supplemented by the "fish action description" documents, served us well in recapping the entire EWA process in WY 2001.

7. Implementation of the EWA program and the outcome in WY 2001, particularly with regard to salmon, has helped us focus on gaps in our knowledge of salmon and steelhead in the Valley and Estuary. Data collected in 2000-2001, both upstream and in the Delta, already have stimulated new lines of inquiry and analyses and provided direction and justification for augmenting sampling programs to get the data needed to answer our questions. For salmon, the important questions are: where in the system, at what life stage and due to what factors does mortality to juvenile salmon occur, and what is the relative significance of these components of mortality to the prospects for recovery of listed and other depleted salmonid stocks.

8. The use of genetic information was valuable in the run classification of chinook salmon and in making recommendations for and evaluating the outcome of EWA actions relative to ESA incidental take limits for winter run chinook.

9. EWA water was used to save listed juvenile salmonids from direct loss to SWP export pumping and reduce take. These savings included about 6,000 winter run salmon and an estimated 675 steelhead.

10. The uncertainty characterizing fish sampling methods was better defined following application of diverse fish data to the EWA process.

B. Limitations encountered during EWA implementation in WY 2001:

1. Tier 3 water was not available in this first year of EWA implementation. This fact constrained options in March when the loss rate of winter run chinook at the pumps was very high.

2. The absence of adaptation in the overall winter run chinook take management mechanism for the CVP/SWP

by NMFS and DFG was highlighted by the unprecedented winter run chinook losses in WY 2001.

3. Our present limited ability to quantify juvenile salmon and steelhead production and describe survival by river reach presently constrains our ability to place Delta losses of these fish and the benefits of EWA actions into perspective at the population level.

4. Limits on the number of juvenile salmonids (natural and/or hatchery stocks) available to tag and release for experimentation constrains our ability to gain knowledge important to ascertaining EWA. effectiveness.

5. Our inability to track the migration of small discrete populations of endangered juvenile salmon and steelhead in time and space greatly limits our ability to implement the EWA actions in an optimal fashion and maximize the efficient use of scarce water resources.

C. Science needs for improved EWA implementation and evaluation

1. Address information gaps in the Sacramento River salmon population model.

2. Use the particle-tracking model to simulate smolt migration though Delta with varied salmon behavioral assumptions.

3. Define, relative to EWA use, the value and limits of existing statistical models of smolt survival in the Delta.
4. Evaluate salmon abundance and survival estimates to determine what level of confidence is achievable for EWA decisions.

5. Document the present knowledge of the effect of flow on salmon smolt survival through the upper Sacramento River and the Delta using CWT smolt data and from consistent sampling of wild and hatchery salmon during emigration.

6. Evaluate historical CWT salmon data to better quantify relative direct and indirect losses in the Delta.

7. Evaluate the effect of predators on juvenile salmon in central and south Delta using past electrofishing survey information, other predator data and food chain/energy flow assumptions.

8. Evaluate the benefit of establishing a regular salmon monitoring site at the mouth of the Mokelumne River and lower Middle and Old rivers to assess salmon migration toward the pumps.

9. Continue population benefit analysis of to include cohort analysis and predict effects of alternative operational scenarios.

10. Evaluate the benefit of implementing a "VAMP type" experiment for the Delta using CWT Coleman late fall to assess the effects of Sacramento River Delta inflow and export levels on smolt survival.

11. Evaluate the importance of rearing in the Delta to Central Valley salmon populations.

D. Proposed changes in the methods of implementing EWA in WY2002:

1. Refine steelhead juvenile production estimate based on steelhead abundance at Chipps Island from past three years mark/recovery data.

2. Develop a comprehensive set of performance criteria to measure the effectiveness of using EWA water.

3. Modify salmon decision trees for October-January and February-June as appropriate based on WY 2001 experiences. Modify the Knights Landing and Sacramento catch indices; both had computational idiosyncrasies

which confused interpretation.

4. Meet with Pacific northwest salmon biologists with specific experience in quantifying the benefits of fish protection actions.

5. Evaluate results of the CALFED DCC experiments of 2000 and 2001 and determine their relevance to EWA implementation in WY 2002.

6. Evaluate the DAT conference and note preparation process and modify as appropriate to improve the efficiency of staff time commitment and of management level review of DAT recommendations.

7. Evaluate current fish sampling efforts and (using experience of IEP real-time sampling) and, if justified, establish additional fish sampling stations and efforts to increase the accuracy and precision of fish abundance and survival data (i.e., mouth of Mokelumne River or lower Old and Middle Rivers).

8. Improve the utility of upriver salmon sampling by incorporating gear efficiency measurements that enable expansion of catch to abundance estimates. Use these estimates to make in-season assessments of juvenile salmon migration and populations status.

9. Develop strategies to guide decisions that will consider the needs of all target species when EWA asset limitations come into play.

10. Develop criteria for identifying circumstances when Tier 3 may be needed and establish a procedure for activating Tier 3 when any of the criteria are met.

11. Hold scientific workshops on specific topics relevant to EWA implementation in WY 2002. Workshops on conceptual and mechanistic models of salmon populations and on statistics of sampling data are needed.

12. Prioritize and implement key scientific studies important to EWA in WY 2002 (potential use of CALFED directed studies) based on above list of EWA science needs.

13. Commit greater staff resources to the EWA program with particular focus on improving agency hiring processes and use of graduate students and post docs.

14. Use evaluation from the EWA science panel review process for WY2001 to increase its efficiency and provide the panel, stakeholders and general public and media with the most accurate view of the EWA program.

15. Develop a strategy to accomplish the EWA scientific and management needs identified in WY2001.

VII. Literature Cited

Brandes P. and J. McLain. 2001. Juvenile chinook salmon abundance, distribution and survival in the Sacramento-San Joaquin Estuary. In: Brown RL, editor. Fish bulletin 179: Contributions to the biology of Central Valley salmonids. Sacramento, CA: California Department of Fish and Game.

Brown, R. and W. Kimmerer. 2001a. Summary Report of the June 21, 2001 Salmonid Workshop for the CALFED Environmental Water Account. September 2001.

Brown R. and W. Kimmerer. 2001b. Environmental and Institutional Background for CALFED's Environmental Water Account. September 2001.

CALFED Operations Group Sacramento River Spring Run Chinook Salmon Protection Plan, 1998 Amendment, November 6,1998.

California Department of Fish and Game (CDFG). 1998. Report to the Fish and Game Commission: A Status Review of the spring-run Chinook Salmon (*Oncorhynchus tshawytshca*) in the Sacramento River Drainage. Candidate Species Status Report 98-01, June 1998.

California Department of Water Resources. 2001. Water Conditions in California. Bulletin 120-4-01. May 2001.

Fisher, F. W. 1992. Chinook salmon, Oncorhynchus tshawytscha, growth and occurrence in the Sacramento-San Joaquin river system. Department of Fish and Game, Inland Fisheries Division Office Report, June 1992.

Gingras, M. 1997. Mark/Recapture Experiments at Clifton Court Forebay to Estimate Pre-Screening Loss to Juvenile Fishes: 1976-1993. Interagency Ecological Program for the San Francisco Bay/Delta Estuary, Technical Report 55.

Hanson, personal communication. Draft report entitled "Evaluation of the Response of Juvenile Chinook Salmon to the Flow Split at the Confluence Between Georgiana Slough and the Sacramento River. Charles H. Hanson. Hanson Environmental, Inc. 10/27/95.

Kjelson, M., Greene, S. and P. Brandes, 1989. A model for estimating mortality and survival of fall-run chinook salmon smolts in the Sacramento River Delta between Sacramento and Chipps Island. U.S. Fish and Wildlife Service, Stockton, CA 95205.

National Marine Fisheries Services, 1993. Winter run chinook salmon Biological Opinion for the Operations of the Central Valley Project and California State Water Project. Issued in 1992 as amended in 1993.

NMFS, 1995. Winter run chinook salmon biological opinion for CVP/SWP Operations issued in 1992 and amended in 1993, 1994 and 1995.

NMFS, 2001. Steelhead and spring run chinook OCAP biological opinion for CVP/SWP Operations, January 1, 2001 through March 31, 2002 issued May 8, 2001.

National Resource Scientists Inc. 2001. Draft report to the U.S. Fish and Wildlife Service: Juvenile Chinook Salmon Radio-Telemetry Study in the Southern Sacramento –San Joaquin Delta December 2000 – January 2001, September, 2001.

Newman, K., and Rice, J. 1997. Statistical model for survival of chinook smolts outmigrating through the lower Sacramento- San Joaquin system. Interagency Ecological Program Technical Report No. 59.

Newman, K. and Remington, R. 2000. Final Report: A Bayesian analysis of recoveries of tagged Sacramento river chinook salmon smolts. March 21, 2000. Submitted to California Department of Water Resources as a deliverable for Contract Agreement NO. B-81353.

Newman, K. 2000. Estimating and modeling absolute survival rates for juvenile chinook salmon outmigrating through the lower Sacramento River using paired release data. August 4, 2000. Submitted to California Department of Water Resources as a deliverable for Contract Agreement No. B-81353.

Newman, Ken, personal communication. Electronic mail correspondence entitled Updated Sacramento model coef's. May 30, 2001 to Pat Brandes (USFWS) from Ken Newman. Associate Professor , Division of Statistics, University of Idaho.

Pierce, Mark, personal communication. U.S. Fish and Wildlife Service. Stockton, CA, February 2001.

San Joaquin River Group. 2000. Vernalis Adaptive Management Program Technical Report.

Schaffter, R.G. 1980. Fish occurrence, size, and distribution in the Sacramento River near Hood, California, during 1973 and 1974. (Administrative Report No. 80-3) California Department of Fish and Game. Sacramento, CA.

Snider, B and R Titus. 2000. Timing, Composition and Abundance of Juvenile Anadromous Salmonid Emigration in the Sacramento River Near Knights Landing October 1998 – September 1999. CDFG Stream Evaluation Program Technical Report 00-6, December 2000.

Snider, B., B. Reavis, and S. Hill. 2001. Upper Sacramento River Winter-run Chinook salmon Escapement Survey May-August 2000. CDFG, Stream Evaluation Program, Technical Report 01-1, April 2001.

State Water Resources Control Board. 1995. Water Quality Control Plan for the Sacramento-San Joaquin Estuary. State of California.

State Water Resources Control Board. Revised Water Rights Decision D-1641. March 15, 2000.

Stern, Gary, personal communication, National Marine Fisheries Service. September 2001.

USFWS, 1990. 1990 Annual Progress Report. Abundance and Survival of Juvenile Chinook Salmon in the Sacramento-San Joaquin Estuary. Sacramento-San Joaquin Estuary Fishery Resource Office USFWS Stockton, CA. December 1990.

Vogel, D., K. Marine, 1992. Guide to upper Sacramento River chinook salmon life history. U.S. Bureau of Reclamation, Central Valley Project, Biological Assessment for the Operation of the Central Valley Project and State Water Project, July 1991.

Vogel, personal communication. Dave A. Vogel, Natural Resources Scientists, Inc. Red Bluff, CA.

White, J. 1998. State of California Department of Fish and Game Testimony of Jim White, Bay-Delta Water Rights Hearings Before the State Water Resources Control Board. Phase 6. The Petition of the Untied States Bureau of Reclamation and the California Department of Water Resources for Joint Point of Diversion in the southern Delta., Submitted November 23, 1998.

VIII. FIGURES, TABLES, AND APPENDICES

as referenced in the report entitled:

"THE USE OF THE ENVIRONMENTAL WATER ACCOUNT FOR THE PROTECTION OF ANADROMOUS SALMONIDS IN THE SACRAMENTO-SAN JOAQUIN RIVER DELTA IN 2000-2001"