# 2001 ANNUAL TECHNICAL REPORT

SAN JOAQUIN RIVER GROUP AUTHORITY

*Head of Old River Barrier*

# 2001 ANNUAL TECHNICAL REPORT

## On Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan

*Prepared by*

**San Joaquin River Group Authority**

*Prepared for the*

**California**

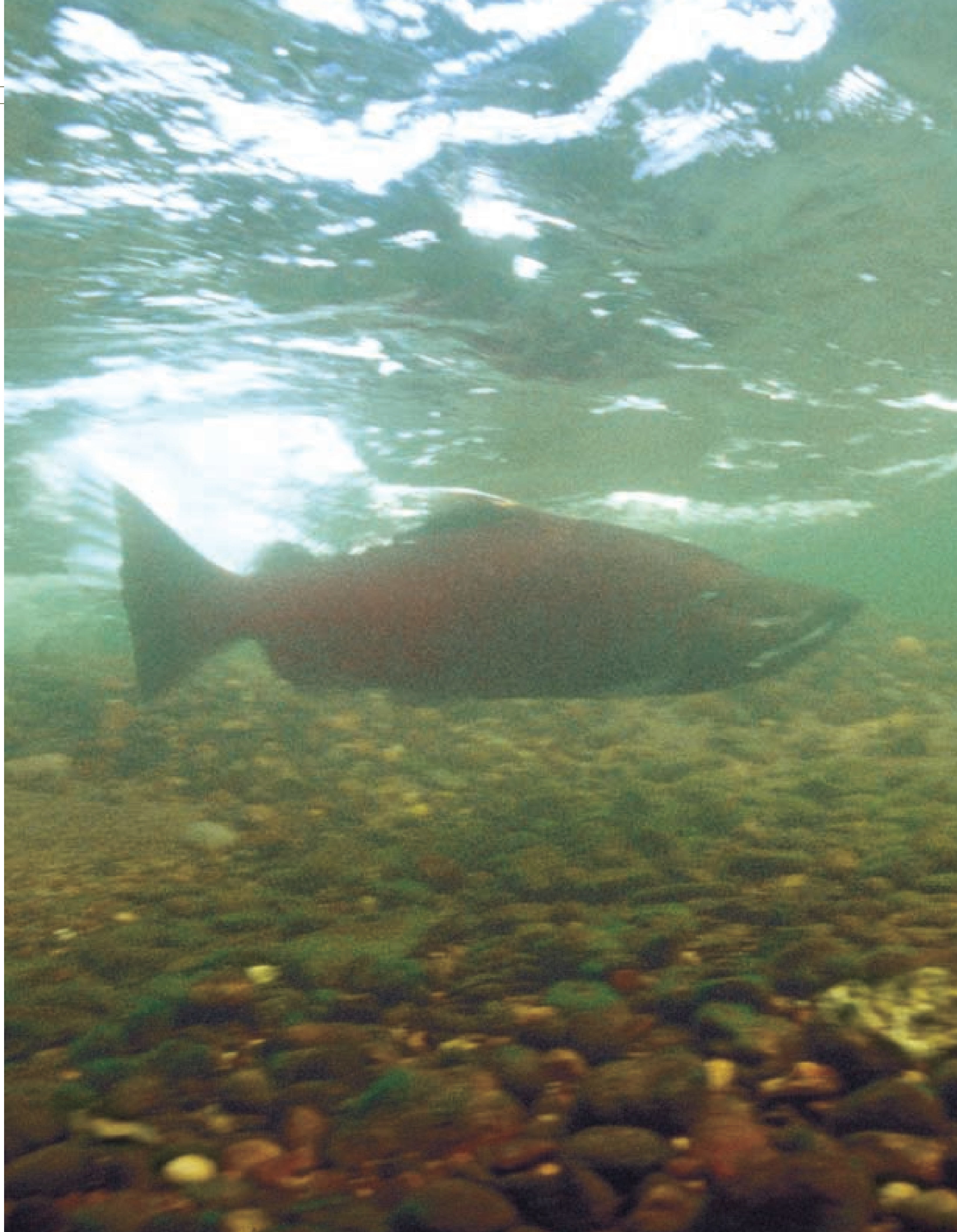
**State Water Resources Control Board**

*In Compliance with D-1641*

**January 2002**

# TABLE OF CONTENTS





# EXECUTIVE SUMMARY

The San Joaquin River Agreement (SJRA) is the cornerstone of a history-making commitment to implement the State Water Resources Control Board (SWRCB) 1995 Water Quality Control Plan (WQCP) for the lower San Joaquin River and the San Francisco Bay-Delta Estuary (Bay-Delta). Using a consensus-based approach, the SJRA united a large and diverse group of agricultural, urban, environmental and governmental interests.

The 2001 Annual Technical Report comprises the consolidated annual SJRA Operations Report and Vernalis Adaptive Management Plan (VAMP) Monitoring Report. The VAMP 2001 program represents the second year of formal compliance with SWRCB Decision 1641 (D-1641). D-1641 requires the preparation of an annual report documenting the implementation and results of the VAMP program. Specifically, this report includes the following information on the implementation of the SJRA: the hydrologic chronicle; management of the additional SJRA water; installation, operation, and monitoring of the Head of Old River Barrier (HORB); results of the juvenile Chinook salmon smolt survival investigations; discussion of complementary investigations; and, conclusions and recommendations. Condition 4.b of D-1641 directs the Department of Water Resources (DWR) and the U.S. Bureau of Reclamation (USBR) to send the Executive Director of the State Board the results of the fishery monitoring studies on an annual basis and Condition 7 of D-1641 directs Merced, Modesto, Turlock, South San Joaquin and Oakdale irrigation districts to submit a report detailing district operations as a result of the SJRA. By letter dated September 8, 2000, the SWRCB approved combining these two reports into a single comprehensive report due to the SWRCB on January 31 of each year.

A key part of this landmark agreement is the VAMP. VAMP is designed to protect juvenile Chinook salmon migrating from the San Joaquin River through the Sacramento-San Joaquin Delta.

*VAMP is designed to protect juvenile Chinook salmon migrating from the San Joaquin River through the Sacramento-San Joaquin Delta.*

VAMP is also a scientifically recognized experiment to determine how salmon survival rates change in response to alterations in San Joaquin River flows and State Water Project (SWP)/Central Valley Project (CVP) exports and the operation of the HORB.

VAMP employs an adaptive management strategy to use current knowledge of hydrology and environmental conditions to protect Chinook salmon smolt passage, while gathering information to allow more efficient protection in the future. In addition to providing improved protection for juvenile Chinook salmon emigrating from the San Joaquin River system, specific experimental objectives of VAMP 2001 included:

- Quantification of Chinook salmon smolt survival between Durham Ferry and Jersey Point using recapture locations at Antioch and Chipps Island, under target conditions of a San Joaquin River flow at Vernalis of 4,450 cfs, with an installed HORB, and SWP/CVP export rates of 1,500 cfs; and
- Comparison of juvenile Chinook salmon survival between Durham Ferry and Mossdale for use in comparing results of VAMP 2001 with results from earlier survival studies where coded-wire tagged salmon releases occurred at Mossdale.

Based on data gathered during the experimental mark-recapture studies that occurred over a 31-day period in April and May 2001, a set of conclusions and recommendations has been developed. These conclusions and recommendations provide guidance and a foundation for design and implementation of future VAMP operations. Key conclusions and recommendations derived from VAMP 2001 include:

- VAMP 2001 is the second year of full implementation of the program. Average Vernalis flow during the VAMP period was 4,420 cfs. SWP and CVP export rates averaged 1,420 cfs. The VAMP period was between April 20 and May 20, 2001.
- Survival estimates between Durham Ferry and Jersey Point using recaptures at Antioch indicated that was no difference between the two replicates conducted in 2001. Survival estimates using the Chipps Island information indicated the first replicate survived at a higher rate than the second.
- The proportion of CWT salmon released and recaptured from the combined Durham Ferry and Mossdale groups relative to the proportion of CWT salmon released and recaptured from the Jersey Point (control) releases showed that the relative proportions during 2001 (target flow 4,450 cfs and 1,500 cfs exports) were not significantly different than the proportions from the VAMP 2000 study (target flow 5,700 cfs and 2,250 cfs exports).
- No conclusions on the relative roles of San Joaquin River flow and SWP/CVP exports on juvenile Chinook salmon smolt survival can be made with these two years of data. The report recommends that the VAMP experimental test program be continued.
- The quality of the real-time flow data at Vernalis were improved by weekly measurements; however, estimation of ungauged flow (accretions and depletions) requires further investigation for use in establishing annual VAMP target flows. Alternative methods of measuring flow at Vernalis and/or alternative measurement locations should also be investigated.
- Delays in permitting and construction of the HORB delayed implementation of the VAMP 2001 studies, contributed to the second salmon release group being exposed to elevated water temperatures, and may have adversely affected their survival. Due to the high risk of losing major salmon protection benefits and biasing experimental conditions, it is strongly recommended that permitting and construction of the HORB be completed to avoid delays in implementing survival investigations. It is also recommended that modifications be made to the barrier design to avoid debris accumulation on trash racks, facilitate routine maintenance, facilitate fisheries sampling, and provide measurements of flow diverted through each culvert.
- Exposure of juvenile Chinook salmon during the second release to elevated water temperatures within the lower San Joaquin River and Delta and evidence of increased disease were identified as factors potentially affecting salmon smolt survival and the validity of the second VAMP test release in 2001. The proportion of marked salmon recaptured from all release locations was found to be significantly lower during the second VAMP release when compared to the first survival study conducted in 2001. The second set of VAMP 2001 releases may not be comparable to other VAMP data and survival results should be interpreted with caution.
- The variability inherent in conducting salmon smolt survival studies in the lower San Joaquin River and Delta makes it difficult to detect statistically significant differences in salmon survival between VAMP flow and export target conditions, which are relatively similar. It is strongly recommended that, when possible, target flow and export conditions be selected to conduct survival tests at VAMP flow and export extremes to improve the ability to detect potential differences in salmon smolt survival among test conditions.
- Approximately 65 percent of the unmarked salmon migrating past Mossdale in 2001 migrated during the VAMP period (April 20 through May 20) and were, therefore protected by increased San Joaquin River flow, installation of the HORB and decreased export pumping.
- Hydrologic conditions during VAMP 2001 were found to be close to the threshold separating two alternative San Joaquin River flow targets. If hydrologic conditions are close to a decision threshold in the future, it is recommended that target flows be selected representing new VAMP test conditions rather than repeating a previously tested flow/export case.
- The selection and management of VAMP flow conditions should, if possible, minimize or avoid requiring upstream tributary flows that adversely affect potential habitat quality or survival of natural salmon produced within the tributaries. It is therefore recommended that upstream tributary and VAMP studies be coordinated as much as possible.

# INTRODUCTION

*The Vernalis Adaptive Management Plan (VAMP) was implemented during the spring 2001 to protect juvenile Chinook salmon and evaluate the relationship between San Joaquin River flow and state (SWP) and federal (CVP) water project exports on survival of juvenile Chinook salmon migrating through the Sacramento–San Joaquin Delta. This represents the second official year of the VAMP experiment.*

## EXPERIMENTAL DESIGN ELEMENTS

The VAMP experimental design measures salmon smolt survival rates under six different combinations of flow and export rates. The experimental design includes two mark-recapture studies performed each year during the mid-April to mid-May outmigration period that provide estimates of salmon survival under each set of conditions. Chinook salmon survival indices under each of the experimental conditions are then calculated based on the numbers of marked salmon released and the number recaptured.

The VAMP 2001 experimental design included both multiple release locations (Durham Ferry, Mossdale, and Jersey Point), and multiple recapture locations (Antioch, Chipps Island, SWP and CVP salvage operations, and in the ocean fishery; (Figure 1-1). Two sets of releases were made at Durham Ferry, Mossdale, and Jersey Point. The use of data from multiple release and recapture locations allows for a more thorough evaluation of juvenile Chinook salmon survival as compared to recapture data from only one sampling location and/or one series of releases. The VAMP releases (Durham Ferry and Jersey Point) and recapture locations (Antioch and Chipps Island) will be consistent from one year to the next, providing a greater opportunity to assess salmon smolt survival over a range of Vernalis flows, SWP/CVP exports, and with and without the presence of the Head of Old River Barrier (HORB). Releases at Jersey Point serve as controls for recaptures at Antioch and Chipps Island, thereby allowing the calculation of survival estimates based on the ratio of survival indices from marked salmon recaptured from upstream (e.g., Durham Ferry) and downstream (control release at Jersey Point) release locations. The use of ratio estimates as part of the VAMP study design substantially reduces the bias associated with differential gear collection efficiency within and among years, improves the precision associated with the individual survival estimates, and improves confidence in detecting differences in salmon smolt survival as a function of Vernalis flows and SWP/CVP exports.

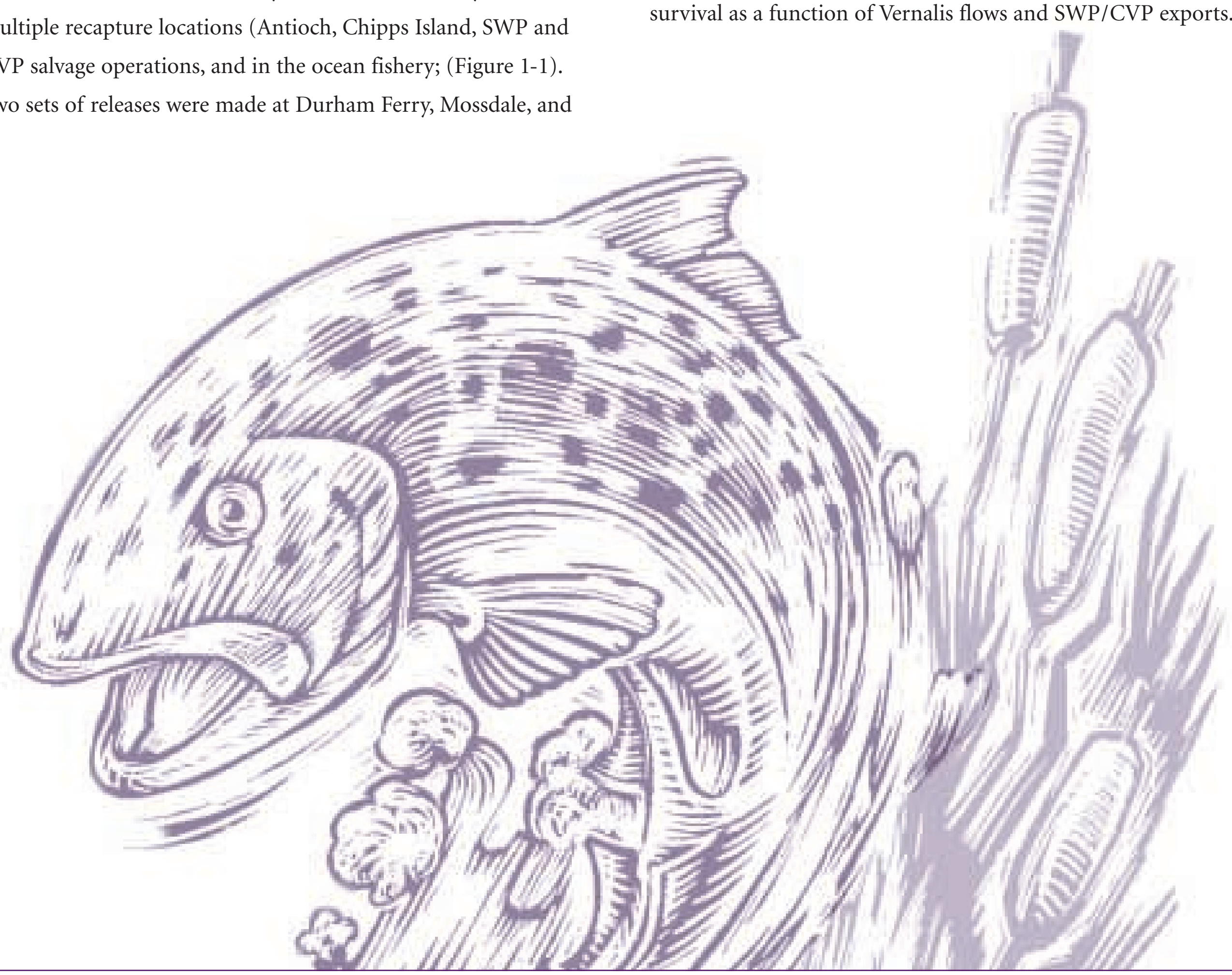
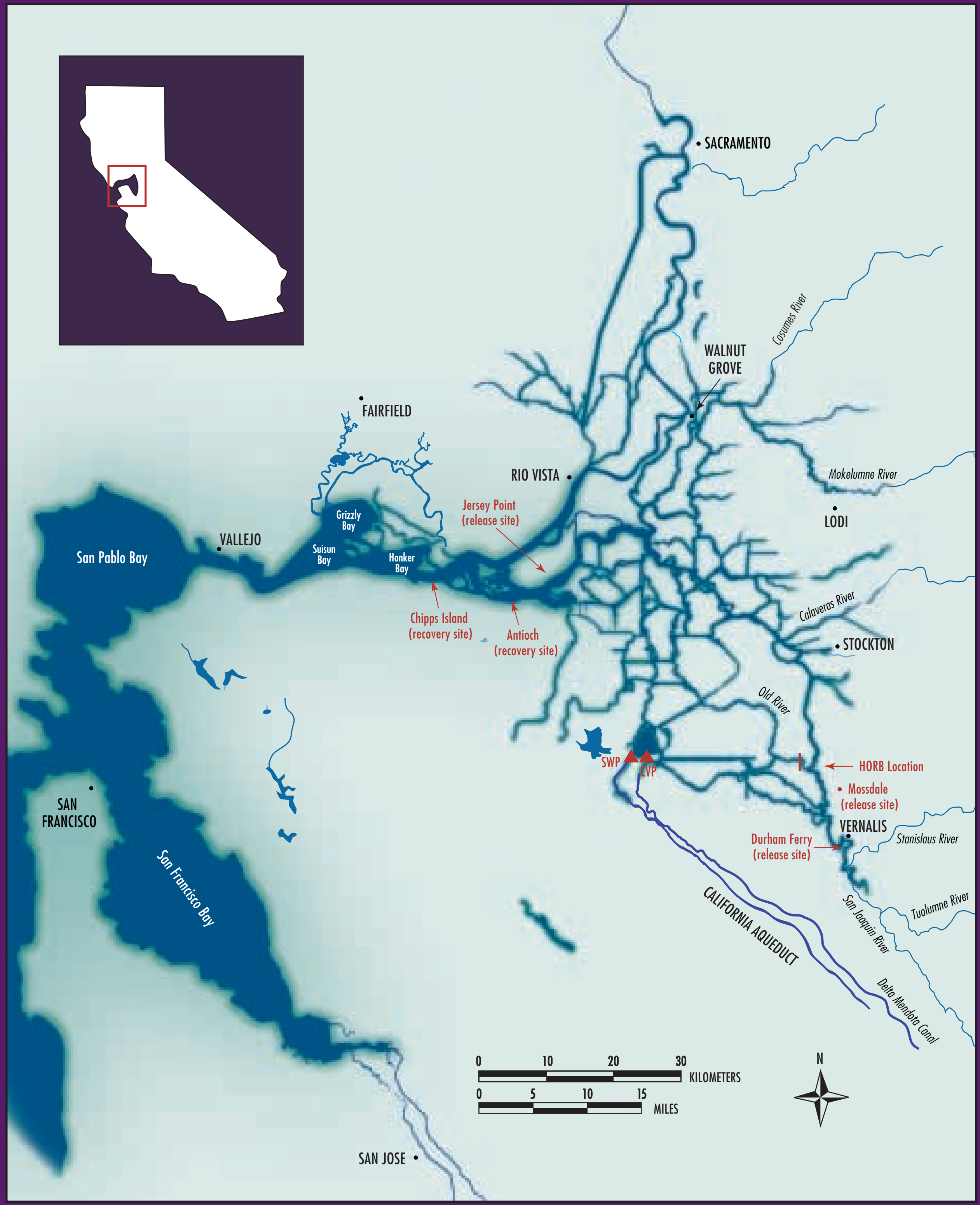




**FIGURE 1-1**
**Sacramento–San Joaquin Estuary**




*Location of VAMP 2001 release sites (Durham Ferry, Mossdale and Jersey Point), recovery locations (Antioch and Chipps Island), and Head of Old River Barrier location within the Sacramento-San Joaquin River Delta/Estuary.*

# VAMP HYDROLOGIC PLANNING AND IMPLEMENTATION

*This section documents the planning and implementation undertaken by the Hydrology Group of the San Joaquin River Technical Committee (SJRTC) for the 2001 VAMP investigations. Implementation of VAMP is guided by the framework provided in the SJRA and anticipated hydrologic conditions within the watershed.*

*The Hydrology Group was established for the purpose of forecasting hydrologic conditions and for planning, coordinating, scheduling and implementing the flows required to meet the test flow target in the San Joaquin River near Vernalis. The Hydrology Group is also charged with exchanging information relevant to the forecasted flows, and coordinating with others in the SJRTC, in particular the Biology Group, responsible for planning and implementing the salmon smolt survival study.*

*Participation in the Hydrology Group is open to all interested parties, with the core membership consisting of the designees of the agencies responsible for the water project operations that would be contributing flow to meet the target flow. In 2001, the agencies belonging to the Hydrology Group included: Merced Irrigation District (Merced), Turlock Irrigation District (TID), Modesto Irrigation District (MID), Oakdale Irrigation District (OID), South San Joaquin Irrigation District (SSJID), San Joaquin River Exchange Contractors (Exchange Contractors), and the U.S. Bureau of Reclamation (USBR). Though not a water provider, the California Department of Water Resources (DWR) was closely involved with the coordination of operations relating to the installation of the HORB and the planning of Delta exports consistent with the VAMP.*

## VAMP FLOW AND SWP/CVP EXPORTS

The VAMP investigations are designed to collect data and information on the impacts of San Joaquin River flow and Delta exports (SWP and CVP pumping at the Banks and Tracy pumping plants respectively) on the survival rates of juvenile Chinook salmon emigrating from the San Joaquin River system. The VAMP provides for a 31-day pulse flow at the Vernalis gauge during the months of April and May, along with a corresponding reduction in SWP/CVP exports, as shown in Table 2-1. The magnitude of the pulse flow is based on San Joaquin River flow that would occur during the pulse period absent the VAMP, referred to as the existing flow.

**TABLE 2-1**
**VAMP Vernalis Flow and Delta Export Targets**

| EXISTING FLOW (CFS) | VAMP TARGET FLOW (CFS) | DELTA EXPORT TARGET RATES (CFS) |
|---|---|---|
| 0 to 1,999 | 2,000 | |
| 2,000 to 3,199 | 3,200 | 1,500 |
| 3,200 to 4,449 | 4,450 | 1,500 |
| 4,500 to 5,699 | 5,700 | 2,250 |
| 5,700 to 7,000 | 7,000 | 1,500 or 3,000 |
| Greater than 7,000 | Provide stable flow to the extent possible | |

Based upon hydrologic conditions, the target flow in a given year could either be increased to the next highest value ("double-step") or the supplemental water requirement could be eliminated entirely. A numerical procedure has been established in the SJRA to determine the target flow. The State Board San Joaquin Valley Water Year Hydrologic Classification ("60-20-20" classification) is given a numerical indicator as shown in Table 2-2.

"Double-step" flow years occur when the sum of last year's numerical indicator and the 90 percent exceedence forecast of the current year's numerical indicator is seven (7) or greater.

If the sum of the two previous years' numerical indicators and the 90 percent exceedence forecast of the current year's numerical indicator is four (4) or less, indicative of an extended dry period, the San Joaquin River Group Authority (SJRG) members are not required to provide water above the existing flow. The USBR, however, has a continuing obligation to meet San Joaquin River flows pursuant to the March 6, 1995 Delta Smelt Biological Opinion.

**TABLE 2-2**
**San Joaquin Valley Water Year Hydrologic Year Classifications Used in VAMP**

| 60-20-20 WATER YEAR CLASSIFICATION | VAMP NUMERICAL INDICATOR |
|---|---|
| Wet | 5 |
| Above Normal | 4 |
| Below Normal | 3 |
| Dry | 2 |
| Critical | 1 |

Under the SJRA, the maximum amount of supplemental water to be provided to meet VAMP target flows in any given year is 110,000 acre-feet. Based on the targets outlined in Table 2-1, in a double-step year up to 157,000 acre-feet of supplemental water may be required. If the VAMP target flow requires more than 110,000 acre-feet of supplemental water, then additional water may be acquired on a willing seller basis.

## VAMP 2001 HYDROLOGIC PLANNING

### *Hydrology Group Meetings*

Beginning in February 2001, and continuing until early April, the Hydrology Group held five planning and coordination meetings (February 13; March 14 and 29; and April 4 and 11). At these meetings, forecasts of hydrologic and operational conditions on the San Joaquin River and its tributaries were discussed and refined.

### *Monthly Operation Forecasts*

As part of the early planning efforts, monthly operation forecasts were developed by the Hydrology Group to estimate the existing flow at Vernalis. Inflows to the tributary reservoirs used in these forecasts were based on DWR Bulletin 120 runoff forecasts. The monthly operation forecasts used the 90 percent and 50 percent probability of exceedence runoff forecasts. The initial monthly operation forecast was prepared in early February and presented at the February 13 Hydrology Group meeting. The 90 percent exceedence forecast called for a VAMP target flow of 3,200 cfs with a need for 73,000 acre-feet of supplemental water; the 50 percent exceedence forecast called for a VAMP target flow of 4,450 cfs with a need for 59,000 acre-feet of supplemental water. Hydrologic projections and planning were subsequently refined as additional information became available in March and April.

### *Daily Operation Plan*

Starting in mid-March, the Hydrology Group began development of a daily operation plan, updating it as hydrologic conditions and operational requirements changed. The daily operation plan calculated an estimated mean daily flow at Vernalis based on estimates of the daily flow at the major tributary control points, estimates of ungauged flow between those control points and Vernalis, and estimates of flow in the San Joaquin River above the major tributaries. The following key assumptions were used in the development of the daily operation plan:

**(1)** The travel times for flows from the tributary measurement points and upper San Joaquin River to the Vernalis gauge are assumed as follows:

| | |
|---|---|
| a. Merced River at Cressey to Vernalis | 3 days |
| b. San Joaquin River above Merced River to Vernalis | 2 days |
| c. Tuolumne River at LaGrange to Vernalis | 2 days |
| d. Stanislaus River below Goodwin Dam to Vernalis | 2 days |

**(2)** Based upon a review of the historical flow record, the ungauged flow at Vernalis was assumed to be constant throughout the VAMP period and equal to the trending value entering the period. By definition, the ungauged flow is that unmeasured flow entering the system between Vernalis and the upstream measuring points and is calculated as follows:

**Vernalis Ungauged** =

**VNS - GDWlag - LGNlag - CRSlag - USJRlag**

*where:*

| | |
|---|---|
| VNS | = San Joaquin River near Vernalis |
| GDWlag | = Stanislaus River below Goodwin Dam lagged 2 days |
| LGNlag | = Tuolumne River below LaGrange Dam lagged 2 days |
| CRSlag | = Merced River at Cressey lagged 3 days |
| USJRlag | = San Joaquin River above Merced River lagged 2 days (USJR is not a gauged flow but is the calculated difference between the gauged flows at the San Joaquin River at Newman (NEW) and the Merced River near Stevinson (MST)). |

By definition, the VAMP 31-day pulse flow period can occur anytime between April 1 and May 31. Until the VAMP flow period is specifically defined, it is assumed for the purposes of planning to be April 15 through May 15. Flexibility of the VAMP flow period exists so that it can coincide with the period of peak salmon out-migration. Other factors, including installation of HORB, availability of juvenile salmon at the hatchery, and manpower and equipment availability for salmon releases and recapture need to be considered in determining the timing of the VAMP period.

The 60-20-20 classification for water year 2000 was "above normal", giving it a VAMP numerical indicator of 4. If the 90 percent exceedence forecast on April 1 defined water year 2001 as a "below normal" or wetter year, with a VAMP numerical indicator equal to or greater than 3, then the 2001 VAMP would follow the "double-step" criteria. Early forecasts were pointing towards 2001 being a "dry" year (VAMP numerical indicator of 2), therefore all planning efforts were made using the "single step" criteria. In fact, the 90 percent exceedence forecast on April 1 for the San Joaquin Valley was for a "critical" year, resulting in the 2001 VAMP following the "single step" criteria.

Table 2-3 summarizes the various iterations of and demonstrates the evolutionary nature of the daily operation plan. Copies of the daily operation plans are provided in Appendix A.

As noted previously, initial planning efforts assume a VAMP period from April 15 through May 15. At the April 4 Hydrology Group meeting it was apparent that installation of the HORB would not be completed by April 15, therefore the VAMP period would need to begin at a later date. The planning effort preceded using start dates of April 17 and April 19. At the combined meeting of the Hydrology and Biology Groups on April 11, the decision was made to set the VAMP 2001 period at April 20 through May 20.

The greatest uncertainty in the development of the daily operation plan is the assumed ungauged flows between the upstream control points and Vernalis. Analysis of historical data indicates that a reasonable estimate of the ungauged flow for the VAMP period is the ungauged flow at the start of the VAMP period. As a result of rain on April 7 and 8, the ungauged flow, which had been running around 400 cfs, increased to 735 cfs on April 9. Therefore the planning at this point in time was done using assumed ungauged flows of 500 and 800 cfs. By April 12, refinements had been made to the ungauged flow calculations indicating that the ungauged flow prior to the rain of April 7 and 8 had been running around 600 cfs and peaked around 1,000 cfs on April 8, dropping to 832 cfs on April 11. With this information, the Hydrology Group prepared a daily operation plan on April 12 assuming ungauged flow of 650 cfs. As shown in Table 2-3, this operation plan resulted in an existing flow of 3,216 cfs, essentially on the breakpoint between target flows of 3,200 cfs and 4,450 cfs. The computed ungauged flow for April 12 was 771 cfs and still receding from the effects of the early April rain. Uncertain as to whether the ungauged flow would stabilize around the estimate of 650 cfs or continue receding, the Hydrology Group, on April 13, decided to initiate scheduling assuming a 3,200 cfs target flow with the understanding that if the ungauged flow did not recede significantly then the operation would be adjusted to a VAMP target flow of 4,450 cfs. On April 16, the ungauged flow for April 15 was computed to be 730 cfs with a slowing rate of recession, therefore the decision was made to use a target flow of 4,450 cfs, as shown in the daily operation plan of April 16.

Normally, the USGS measures the flow at Vernalis to check the current rating shift on a monthly basis. The real-time flows reported by the USGS and CDEC are dependent on the most current rating shift, therefore a new measurement and shift can result in a sudden and significant change in the reported real-time flow. In order to minimize the potential for these sudden and significant changes, arrangements were made with the USGS to measure the flow at Vernalis on a weekly basis between March 21 and May 4. The results of these measurements are summarized in Table 2-4. As can be seen in Table 2-4, even with these precautions, the measurement on May 3 resulted in a sudden decrease in the real-time reported flow of just over 300 cfs, the impacts of which will be discussed in a following section.

## VAMP 2001 Implementation

*Operation Conference Calls*

During implementation of the VAMP pulse flow, conference calls were conducted on a regular basis to discuss the status of the pulse flow and to make changes to the operation plan if needed. The calls were held at 6:30 a.m. so that potential operational changes could be implemented on that day. The first call was held on April 19. Starting on April 20 and ending on May 14, the calls were held every Monday, Wednesday and Friday.

*Operation Monitoring*

During the VAMP flow period, flows at Vernalis and in the San Joaquin River tributaries were continuously monitored using the available real-time data. Similarly, the computed ungauged flow at Vernalis and the flow in the San Joaquin River upstream of the Merced River were continuously updated. The available real-time data sources are summarized in Table 2-5. The monitoring was necessary to verify that supplemental water deliveries were adhering



## TABLE 2-3
### Summary of 2001 VAMP Daily Operation Plans Prepared During Planning Phase

| VAMP FORECAST DATE | PULSE PERIOD | ASSUMED UNGAUGED FLOW AT VERNALIS (CSF) | EXISTING FLOW (CSF) | VAMP TARGET FLOW (CFS) | SUPPLEMENTAL WATER NEEDED TO MEET TARGET FLOW (1,000 AF) |
|---|---|---|---|---|---|
| March 14 | 4/15–5/15 | 700 | 3,943 | 4,450 | 31.17 |
| | | 1,000 | 4,246 | 4,450 | 12.52 |
| March 20 | 4/15–5/15 | 700 | 2,833 | 4,450 | 22.57 |
| | | 1,000 | 3,133 | 4,450 | 4.13 |
| March 23 | 4/15–5/15 | 500 | 2,633 | 3,200 | 34.87 |
| April 3 | 4/15–5/15 | 500 | 2,636 | 3,200 | 34.66 |
| | | 1,000 | 3,136 | 3,200 | 3.91 |
| | 4/17–5/17 | 500 | 2,628 | 3,200 | 35.15 |
| | | 1,000 | 3,128 | 3,200 | 4.40 |
| April 10 | 4/19–5/19 | 500 | 2,920 | 3,200 | 17.19 |
| | | 800 | 3,221 | 4,450 | 75.55 |
| | | 500 | 2,594 | 3,600 [1] | 15.13 |
| April 12 | 4/20–5/20 | 650 | 3,216 | 4,450 | 57.72 |
| April 16 | 4/20–5/20 | 650 | 3,216 | 4,450 | 73.09 |

[1] Assumes "other supplemental water" is in addition to VAMP supplemental water.

## TABLE 2-4
### Summary of USGS Flow Measurements at the San Joaquin River

| DATE | MEASURED FLOW (CFS) | REPORTED REAL-TIME FLOW (CFS) | PERCENT DIFFERENCE | SHIFT |
|---|---|---|---|---|
| March 6 at 10:05 | 5,330 | 4,570 | 16.6% | Yes |
| March 20 at 8:20 | 2,550 | 2,970 | -14.1% | Yes |
| March 27 at 10:25 | 2,210 | 2,170 | 1.8% | No |
| April 3 at 9:40 | 2,240 | 2,180 | 2.8% | No |
| April 10 at 9:34 | 2,580 | 2,430 | 6.2% | Yes |
| April 18 at 9:45 | 2,090 | 2,140 | -2.3% | No |
| April 25 at 8:42 | 4,400 | 4,620 | -4.8% | No |
| May 3 at 10:45 | 4,220 | 4,540 | -7.0% | Yes |
| May 8 at 09:45 | 4,170 | 4,170 | 0.0% | No |

## TABLE 2-5
### Real-time Flow Data and Sources

| MEASUREMENT LOCATION | REAL-TIME DATA SOURCE |
|---|---|
| San Joaquin River near Vernalis | USGS |
| Stanislaus River below Goodwin Dam | USBR Goodwin Dam daily operation report |
| Tuolumne River below LaGrange Dam (LGN) | CDEC |
| Merced River at Cressey (CRS) | CDEC |
| Merced River near Stevinson (MST) | CDEC |
| San Joaquin River at Newman (NEW) | CDEC |

to tributary allocations contained in the SJRA to the extent possible, as well as to determine if changes in hydrologic conditions would require changes to the operation plan.

The daily operation plan was updated throughout the VAMP flow period. A summary of the updated daily operation plans is provided in Table 2-6. Copies of the updated daily operation plans are provided in Appendix A

*Operational Highlights*

As noted previously, the 2001 VAMP operation started with the uncertainty of whether the target flow would be 3,200 cfs or 4,450 cfs. The final determination was made on April 16 that the target flow would be 4,450 cfs. On April 19 and 20 a significant rain storm passed through the San Joaquin basin, resulting in an apparent peak flow at Vernalis of 4,890 cfs early in the morning of April 22. By the time of the April 23 operation conference call the apparent flow at Vernalis had receded to 4,740 cfs. Since the flow was within the desired operation bounds of plus or minus 7%, no action was taken. An updated daily operation plan was prepared on April 23 to reflect the measured flows to date. The effects of the rain had dissipated by April 26, and the flow at Vernalis appeared to stabilize within a range of plus or minus 100 cfs from the target flow (within 2% of the target). No operation changes were made through May 2 and an updated daily operation plan was prepared to reflect measured flows to date.

Things changed on May 4. The results of the May 3 USGS measurement of the flow at Vernalis indicated that the actual flow was about 300 cfs less than that in the real-time data report (Table 2-4). That is, rather than the reported flow of 4,520 cfs, the flow at Vernalis was actually 4,220 cfs, as illustrated in Figure 2-1. As a result of this news, there was a need to increase the amount of supplemental water being provided. In accordance with the Division Agreement, the additional supplemental water was the responsibility of Merced ID. The disadvantage of this was that with regulatory requirements and travel time, the soonest the increases from the Merced River would be seen at Vernalis would be in about six days. The only other alternative for getting water to Vernalis sooner would have been from the Tuolumne River, but that would have run the risk of disrupting fishery experiments on the Tuolumne as well as causing considerable deviation from the Division Agreement allotments. Since the flow at Vernalis was barely outside of the desired plus or minus 7% range, it was felt that the proper action was to increase the supplemental water contribution on the Merced River. Due to operational constraints and travel time requirements, the mean daily flow at Vernalis went as low as 4,010 cfs (almost 10% below the target) on May 10, before recovering to 4,320 cfs on May 13 and 4,520 cfs on May 14. No other operation changes were made for the duration of the 2001 VAMP period.

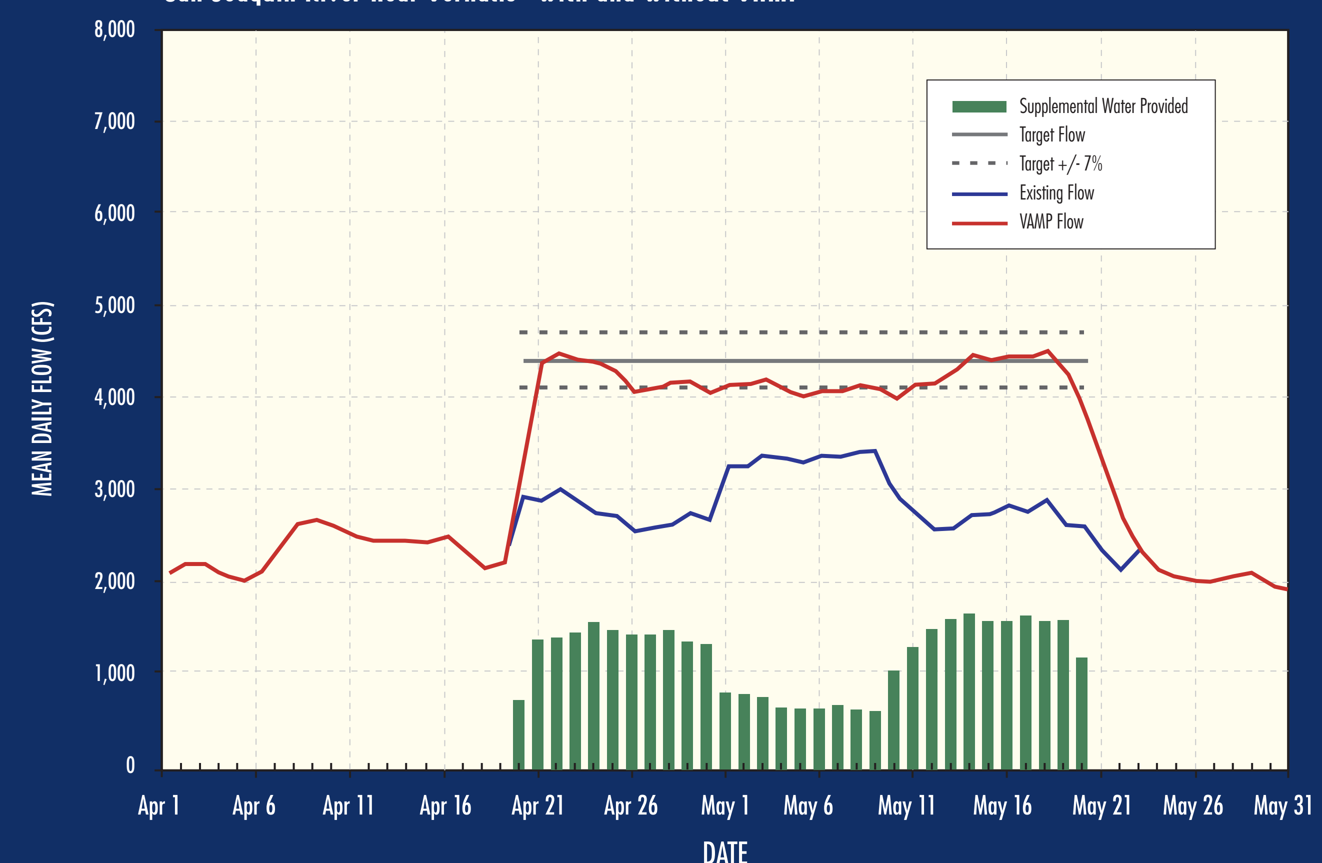
## TABLE 2-6
### Summary of 2001 VAMP Daily Operation Plans Prepared During Implementation Phase

| VAMP FORECAST DATE | VAMP PERIOD | ASSUMED UNGAUGED FLOW AT VERNALIS (CFS) | EXISTING FLOW (CFS) | VAMP TARGET FLOW (CFS) | SUPPLEMENTAL WATER NEEDED TO MEET TARGET FLOW (1,000 AF) |
|---|---|---|---|---|---|
| April 23 | 4/20–5/20 | 650 | 3,232 | 4,450 | 72.15 |
| May 2 | 4/20–5/20 | 650 | 3,211 | 4,450 | 73.39 |
| May 4 [1] | 4/20–5/20 | 500 | 3,026 | 4,450 | 86.14 |
| May 7 | 4/20–5/20 | 500 | 3,004 | 4,450 | 86.11 |
| May 14 | 4/20–5/20 | 500 | 2,950 | 4,450 | 89.48 |

[1] Rating shift at Vernalis gauge on May 3 resulted in reduced estimate of ungauged flow.

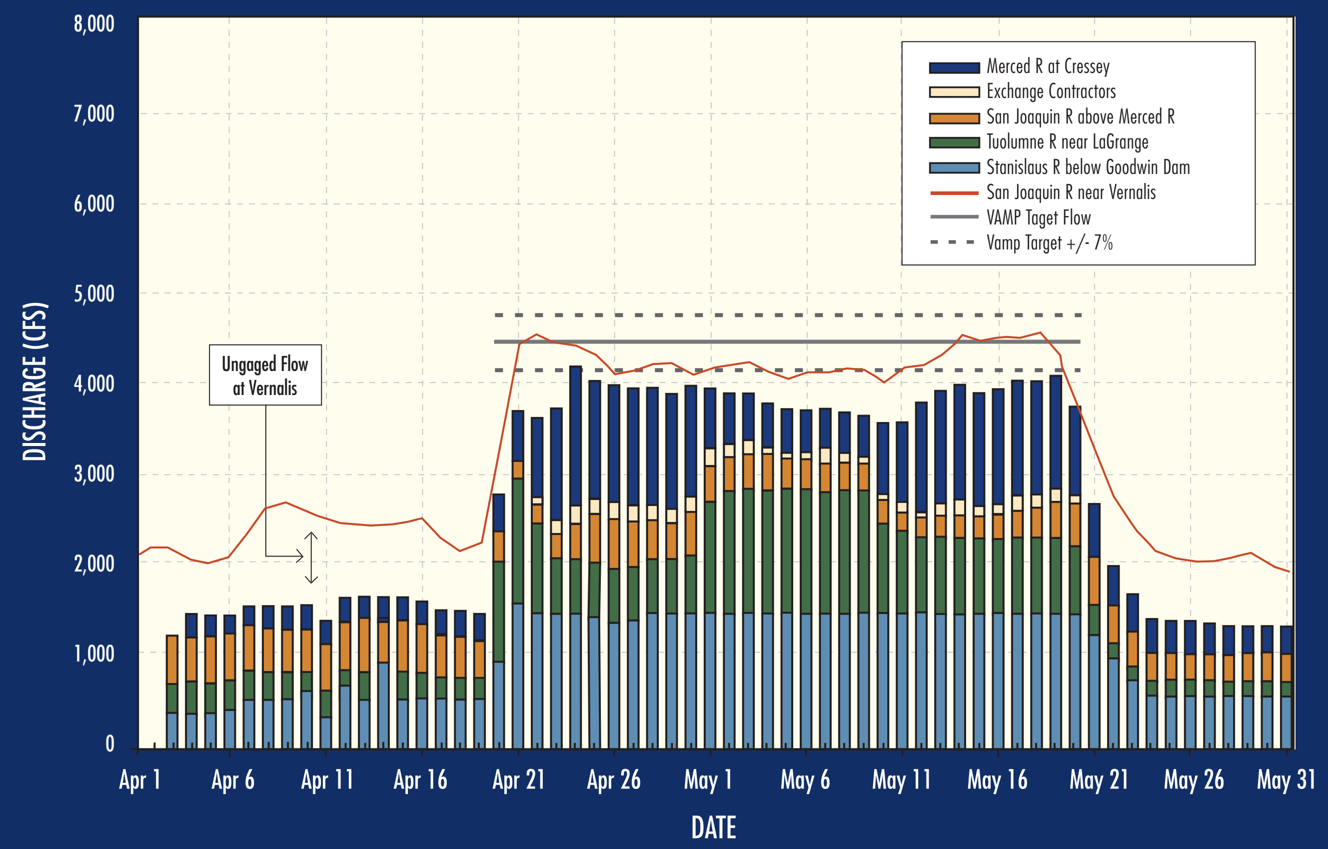
## FIGURE 2-1
### San Joaquin River Near Vernalis Effects of May 3rd Flow Measurement and Rating Shift


## FIGURE 2-2
### San Joaquin River Near Vernalis—With and Without VAMP



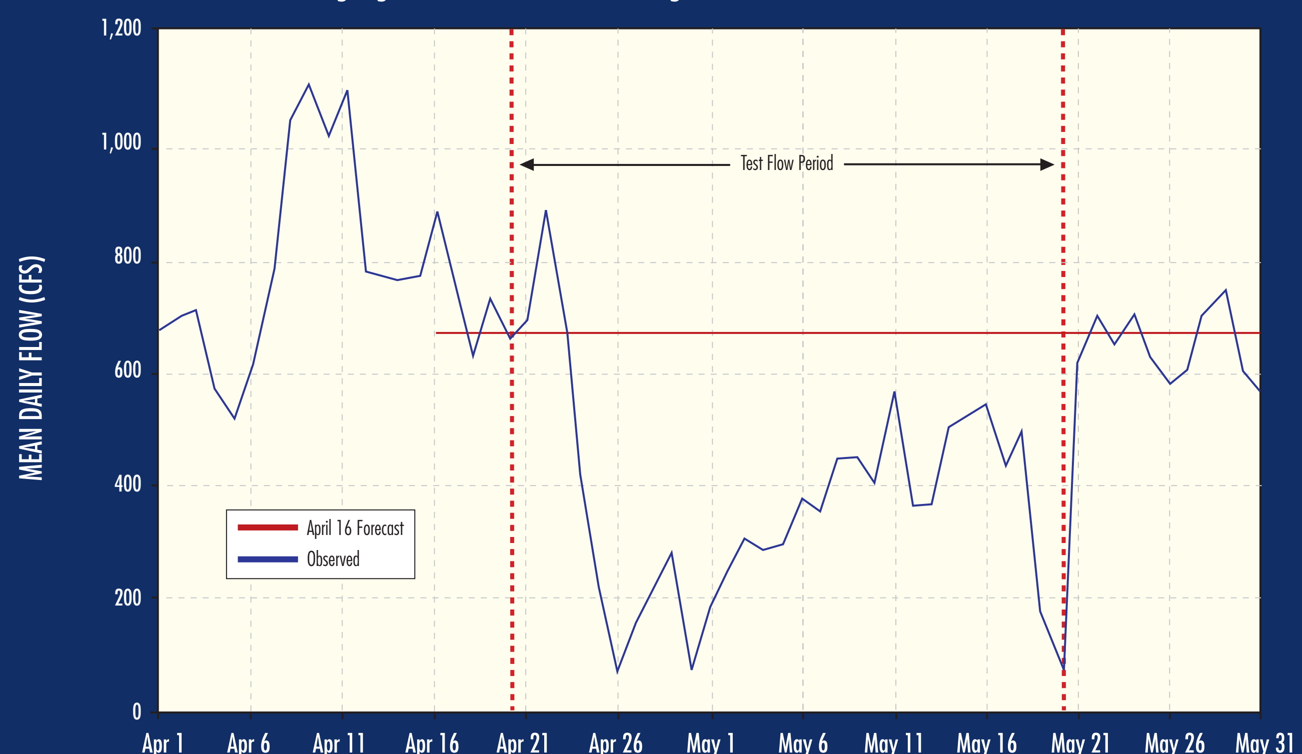
## FIGURE 2-3

### 2001 VAMP–San Joaquin River Near Vernalis With Lagged Contributions From Primary Sources




## FIGURE 2-4

### 2001 VAMP–Ungauged Flow at Vernalis During VAMP Flow Period




## RESULTS OF VAMP 2001 OPERATIONS

Planning and implementation of the VAMP spring pulse flow operation was accomplished using the best available real-time data, which has not been reviewed for accuracy or adjusted for rating shifts. The final accounting for the VAMP operation is accomplished using provisional mean daily flow data available from USGS and DWR. The provisional data, which is considered to be the best available information, has been reviewed and adjusted for rating shifts but is still considered preliminary and subject to change. To illustrate the differences between the real-time and the provisional data, plots of the real-time and provisional flows at the primary measuring points are provided in Appendix A.

The mean daily flow at the Vernalis gauge averaged 4,220 cfs during the VAMP test flow period, with a maximum of 4,560 cfs and a minimum of 3,450 cfs. The average flow for the test flow period absent the VAMP supplemental water was estimated to be 2,920 cfs. The VAMP operation resulted in a 45 percent increase in flow at Vernalis during the target flow period. Figure 2-2 shows the flow at Vernalis with and without the VAMP pulse flow. Figure 2-3 shows the sources of the flow at Vernalis. A total of 78,650 acre-feet of supplemental water was provided to meet the VAMP target flow. A daily summary of VAMP operations, along with supporting data, is provided in Appendix A.

*The combined CVP and SWP export rate averaged 1,420 cfs during the 31-day period, about 5 percent below the target of 1,500 cfs.*

As noted earlier, in planning for the VAMP operation the ungauged flow at Vernalis is the most difficult factor to forecast for the test flow period. Currently, estimates are made based on a review of historical data. The sensitivity of the VAMP planning and operation to the estimated ungauged flow was demonstrated this year. On April 16 the predicted ungauged flow was 650 cfs, resulting in an estimated existing flow at Vernalis of 3,216 cfs and a corresponding VAMP target flow of 4,450 cfs. The ungauged flow actually averaged 370 cfs during the test flow period, resulting in an estimated existing flow at Vernalis of 2,920 cfs, which would require a VAMP target flow of 3,200 cfs. In reviewing the data for this year's operation it appears that there may be a factor affecting the ungauged flow that is not accounted for through the use of the historical record, and that is the effects of the pulse flow itself on the ungauged flow. Figure 2-4 shows the ungauged flow during the test flow period and shows a correlation of reduced ungauged flow with the pulse flow. If this effect on the ungauged flow is due to the pulse flow operation, then some of the questions that need to be answered are whether this effect can be quantified, and whether the effect is dependent on the magnitude of the base flow in the San Joaquin River.

The combined CVP and SWP export rate averaged 1,420 cfs during the 31-day period, about 5 percent below the target of 1,500 cfs. The daily SWP and CVP exports during the VAMP test period are shown in Figure 2-5.

SJRG member agencies have entered into the Division Agreement, which allocates responsibility of the members for providing VAMP supplemental water. The distribution of supplemental water for the 2001 VAMP operation, compared to the distribution called for under the Division Agreement, is summarized in Table 2-7.

*Storage Impacts*

The VAMP supplemental water contributions, with the exception of that provided by the Exchange Contractors, are supplied from reservoir storage: Lake McClure on the Merced River, New Don Pedro Reservoir on the Tuolumne River and New Melones Reservoir on the Stanislaus River. Therefore, the impacts of VAMP operations can be seen directly as changes in reservoir storage. Due to the extended nature of the VAMP, a 12-year plan, the storage impacts can potentially carry over from year to year. Reservoir storage impacts are reduced or eliminated when the reservoirs make flood control releases.

The storage impacts of the 2000 VAMP operation on Lake McClure were eliminated in May 2000 due to required flood control releases. As per the SJRA, Merced I.D. provided 12,500 acre-feet of

## TABLE 2-7

### 2001 VAMP–Distribution of Supplemental Water

| AGENCY | DIVISION AGREEMENT DISTRIBUTION (ACRE–FEET) | SUPPLEMENTAL WATER PROVIDED (ACRE–FEET) | DEVIATION FROM DIVISION AGREEMENT (ACRE–FEET) |
|---|---|---|---|
| Merced I.D. | 42,150 | 42,120 | -30 |
| Oakdale I.D./ South San Joaquin I.D. | 14,600 | 14,730 | +130 |
| Exchange Contractors | 7,300 | 7,740 | +440 |
| Modesto I.D./Turlock I.D. | 14,600 | 14,060 | -540 |

supplemental water in the Fall of 2000. Therefore, prior to the 2001 VAMP operation, the storage impact on Lake McClure due to the SJRA was 12,500 acre-feet. With the 42,120 acre-feet of supplemental water provided for the 2001 VAMP operation along with 1,030 acre-feet of operational ramp-down water, the current impact of the SJRA on Lake McClure storage is 55,650 acre-feet. Figure 2-6 shows Lake McClure storage with and without the SJRA for the period of October 2000 through December 2001.

On the Tuolumne River, the storage impact from previous SJRA operations carried over into water year 2001 was 7,700 acre-feet. However, in late February 2001 precautionary flood control releases were made in excess of 7,700 acre-feet, thereby eliminating the SJRA storage impact. As a result of the 2001 VAMP operation, the current impact of the SJRA on New Don Pedro storage is 14,060 acre-feet. Figure 2-7 shows New Don Pedro Reservoir storage with and without the SJRA for the period of October 2000 through December 2001.

As part of the SJRA, 18,785 acre-feet of "additional" water was purchased from OID by Reclamation and released from New Melones Reservoir between October 17, 2000 and December 10, 2000, thereby resulting in an impact to New Melones storage of 18,785 acre-feet. This impact was carried over into 2001. The impact of the 2001 VAMP operation on New Melones storage was 16,890 acre-feet, of which 14,730 acre-feet was 2001 VAMP supplemental water and 2,160 acre-feet was 2001 VAMP operational ramp-down water. Therefore, the impact of the SJRA to New Melones storage following the 2001 VAMP operation was 35,675 acre-feet. As described in Chapter 3 of this report, Reclamation purchased and released 18,635 acre-feet of "additional" water, bringing the total current SJRA storage impact on New Melones Reservoir to 54,210 acre-feet. Figure 2-8 shows New Melones storage with and without the SJRA for the period of October 2000 through December 2001.

**FIGURE 2-5**

**2001 VAMP – Federal and State Exports**

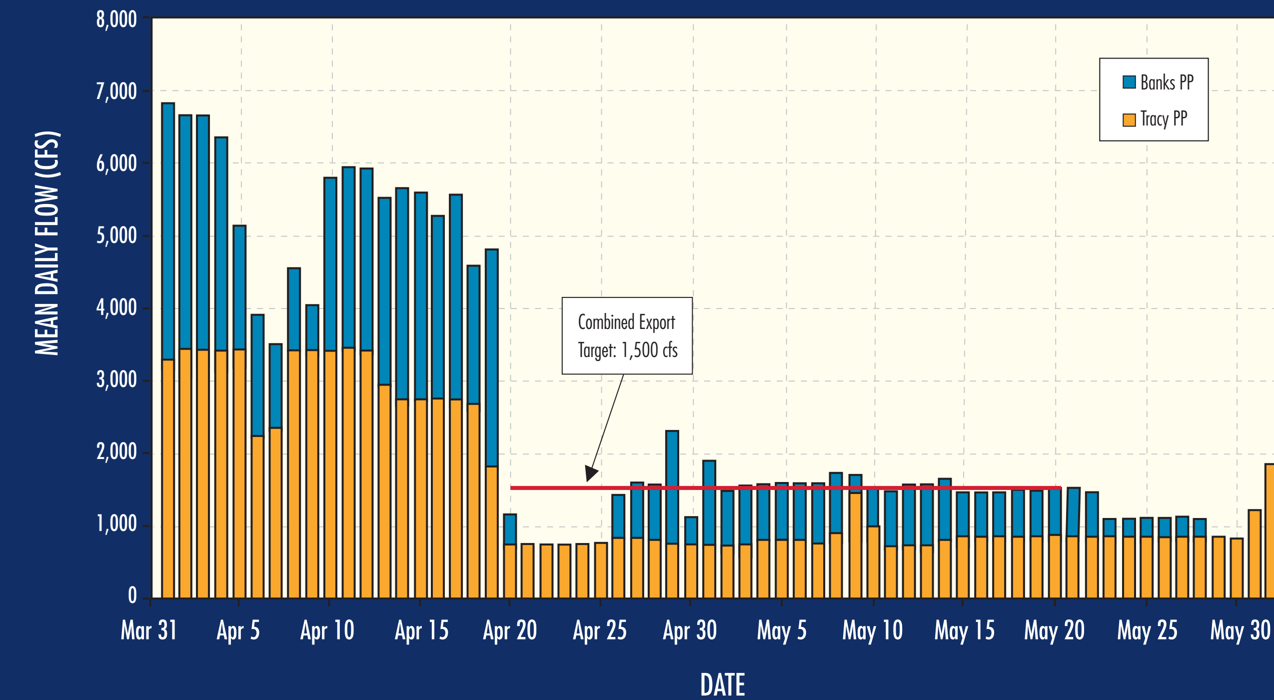
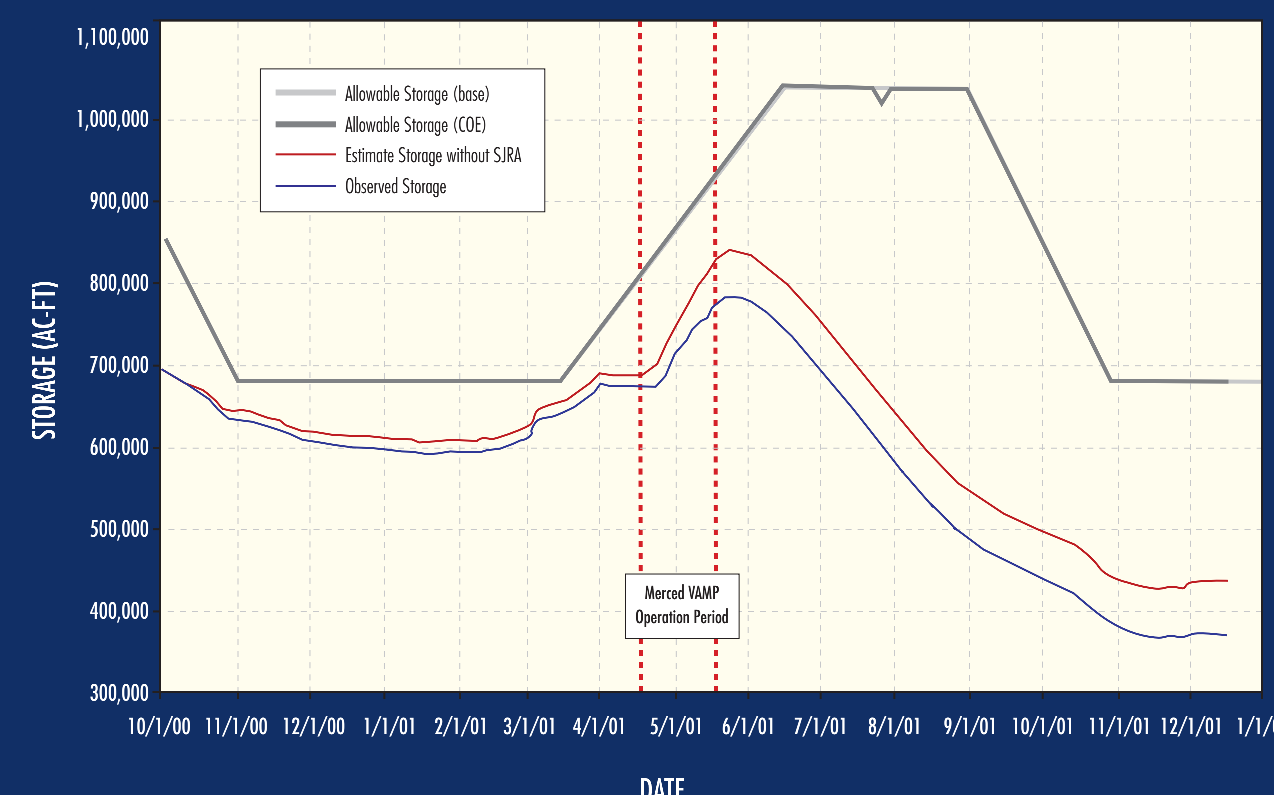


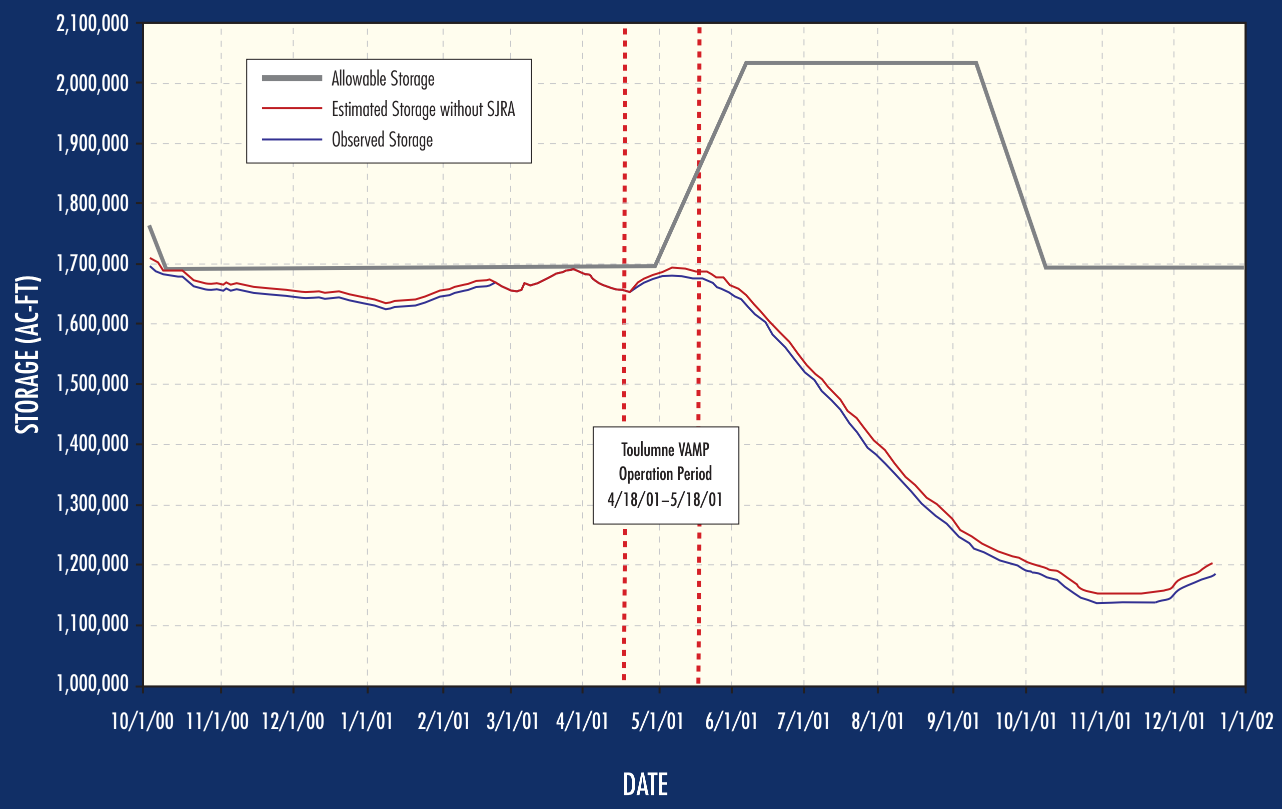

**FIGURE 2-6**

**SJRA Storage Impacts – Lake McClure (Merced River) October 2000 Through December 2001**



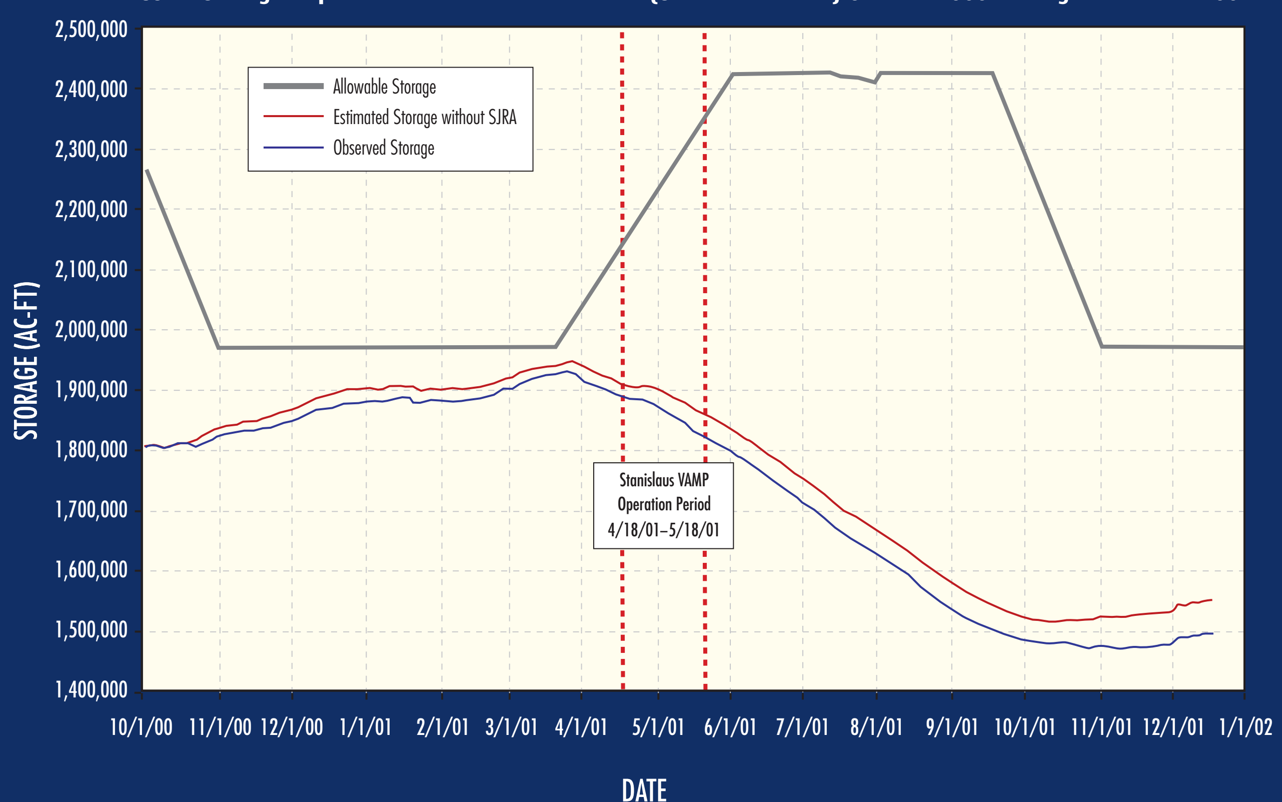
## FIGURE 2-7

**SJRA Storage Impacts–New Don Pedro Reservoir (Tuolumne River) October 2000 Through December 2001**




## FIGURE 2-8

**SJRA Storage Impacts–New Melones Reservoir (Stanislaus River) October 2000 Through December 2001**








# ADDITIONAL WATER SUPPLY ARRANGEMENTS & DELIVERIES

### MERCED IRRIGATION DISTRICT

The SJRA includes a provision (Paragraph 8.4) stating that "Merced Irrigation District (Merced) shall provide, and the USBR shall purchase 12,500 acre-feet of water… during October of all years." The SJRA also states in Paragraph 8.4.4 that "Water purchased pursuant to Paragraph 8.4 may be scheduled for months other than October provided Merced, DFG and USFWS all agree." This water is referred to as the Fall SJRA Transfer Water. The daily schedule for the Fall SJRA Transfer Water is to be developed by Department of Fish and Game (DFG), United States Fish and Wildlife Services (USFWS) and Merced ID.

In addition to providing water in the fall of 2001 pursuant to the SJRA, Merced entered into a contract with DWR to transfer up to 25,000 acre-feet of water to the CALFED Environmental Water Account (EWA). This additional water transfer is referred to as the EWA Transfer. The EWA Transfer water was to be delivered south of the Delta via the SWP, using available excess pumping capacity at the Banks Pumping Plant. Since the likelihood of having excess pumping capacity decreases near the end of the year, the desire in the initial planning for the Fall water transfers was to transfer the EWA Transfer water first and use the Fall SJRA Transfer Water to supplement flows in November and December. A tabulation and plot of the initial daily flow schedule for the Fall water transfers is provided in Appendix B.

In October DWR installs a temporary barrier at the head of Old River. As part of the land use agreement allowing for the construction of the barrier, DWR has agreed to remove it if the flow in the San Joaquin River, as measured at the Vernalis gauge, exceeds 4,500 cfs. The expected flows on the Stanislaus River and Tuolumne River were taken into consideration during the Merced River Fall water transfer schedule development to minimize the risk of the San Joaquin River flow at Vernalis exceeding 4,500 cfs while the barrier was in place.

A table summarizing the preliminary data for the observed Merced ID Fall 2001 transferred water is provided in Appendix B. Also provided in Appendix B are the final data for the year 2000 Fall transferred water.

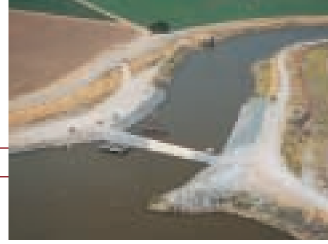
### OAKDALE IRRIGATION DISTRICT

Pursuant to Paragraph 8.5 of the SJRA, "Oakdale Irrigation District (OID) shall sell 15,000 acre-feet of water to the USBR in every year of (the) Agreement… In addition to the 15,000 acre-feet, Oakdale will sell the difference between the water made available to VAMP under the SJRGA agreement and 11,000 acre-feet." This water is referred to as the Difference water.

OID provided 7,365 acre-feet of supplemental water for the year 2001 VAMP, resulting in 3,635 acre-feet of Difference water. Therefore, pursuant to Paragraph 8.5 of the Agreement, OID sold a total of 18,635 acre-feet of water to the USBR in 2001.

Release of the OID additional water by the USBR began on October 20, 2001, and was completed on November 21, 2001. A daily tabulation of the OID additional water release is provided in Appendix B.

# HEAD OF OLD RIVER BARRIER



## BARRIER DESIGN, INSTALLATION AND OPERATION

In 2001, DWR successfully installed and operated the temporary Head of Old River Barrier (HORB) following six months of intense negotiations with regulatory agencies to obtain the necessary permits for this barrier and the three agricultural barriers in the south Delta. The spring HORB is a component of the south Delta Temporary Barriers Project (TBP). The TBP mitigates for low water levels in the south Delta and improves water circulation and quality for agricultural purposes. The HORB, as currently configured, is now fully permitted though 2005.

The spring HORB was first constructed in 1992 and again in 1994, 1996, 1997 (w/two culverts), 2000 (w/six culverts) and 2001 (w/six culverts). The HORB was not installed in 1993, 1995 and 1998 due to high San Joaquin River flows. The HORB was not installed in 1999 due to landowner access problems. The HORB, a key component of VAMP, is intended to increase San Joaquin River Chinook salmon smolt survival by preventing them from entering Old River.

The HORB was originally designed to withstand a San Joaquin River flow of about 3,000 cfs. Through the years, the design and installation of the HORB has been revised on several occasions to accommodate different needs. For 2001 and future years, the barrier design includes two versions. A "low-flow" barrier when San Joaquin River target flows are below 7,000 cfs would be built to a height of ten feet mean sea level (MSL). A "high-flow" barrier for target flows of 7,000 cfs and above would be built to a height of 11 feet MSL and additional material would be placed to raise the abutments to 13 feet MSL. Both barrier versions are equipped with six 48-inch diameter operable culverts and an overflow weir back-filled with clay. In 2001, the low-flow version was installed.

The dimensions of the 2001 HORB (Figure 4-1) were similar to the 2000 HORB, but considerably larger than those constructed in past years. The base width of the HORB in 2000 and 2001 was 100 feet and the crest elevation was ten feet MSL. The top of HORB was constructed with a 75-foot wide notch, protected with concrete grid mats and back-filled with clay. This larger HORB was designed to safely operate with flows corresponding to stages up to 8.5 feet MSL.

To help mitigate anticipated low water levels in the south Delta (downstream of the HORB) caused by the operation of the HORB, two open culverts were installed in the barrier in 1997, and six operable culverts were installed beginning in 2000. Operation of the culverts was controlled by a slide gate control structure located on the upstream side of HORB. DWR relied on daily modeling and field data collection to monitor water levels at three locations within the south Delta to determine when and how long to operate the culverts. Generally, the model forecasts would tend to forecast low-low water levels lower than what was occurring in the field. Consequently, DWR would make decisions regarding the culvert operations that would take this into consideration. It is expected that refinements to the model over time will provide modeling results that correspond more closely with field measurements.

*The downstream outlet of each culvert was designed so fyke nets could be attached to evaluate fish passage.*

The downstream outlet of each culvert was designed so fyke nets could be attached to evaluate fish passage. DFG staff conducted a fishery-monitoring program as part of the 2001 HORB operations.

### *Barrier Operations and Monitoring Plan*

DWR obtained new permits from the Corps of Engineers and the DFG to install and operate the HORB with six 48-inch diameter culverts. The culverts permitted flow through the HORB on an as-needed basis.

A barrier operations and monitoring plan was developed based on forecasting and monitoring of tidal conditions. DWR determined the number of culverts to be opened at the HORB so that water levels at Old River near Tracy Road Bridge, Middle River near Howard Road and Grant Line Canal near Tracy Road Bridge would remain above 0.0 feet MSL. Based on modeling results and/or field monitoring of water levels in the south Delta, all six culvert slide gates remained open from April 26 to May 26 when the HORB was removed.

The average daily flow through the culverts varied in response to tidal and San Joaquin River flow conditions. The characteristics of the flow through the culverts are complicated in that the flow rate is influenced by many variables, including the culvert inlet geometry, slope, size, culvert roughness, and approach and tail water conditions. An approximation of the combined net flow through the culverts, including any seepage through the barrier, was accomplished by measuring the flow in Old River just downstream of the HORB using Acoustic Doppler technology. A fixed Acoustic Doppler Current Meter was installed approximately 840 feet downstream of the HORB which recorded velocity measurements every 15 minutes during the period the HORB was operated (April 26 through May 26, 2001). The flow in Old River was then calculated using the known cross-sectional area of the channel as a function of the stage elevation at that location.

In addition, a boat mounted Acoustic Doppler Current Profiler (ADCP) was used to initially calibrate the fixed Doppler system and then recalibrate it periodically during the barrier operational period. The ACDP measured real time flow by performing several transects across the channel. The channel velocity was then calculated and used to adjust the index velocities that were measured by the fixed Doppler system.

The mean daily flow measured in Old River during the operation of the HORB ranged from 75 to 692 cfs as shown in Table 4-1. On May 26, the barrier was breached, which accounts for the maximum flow of 1,450 cfs shown in Table 4-1. The negative flows listed indicate the channel below the HORB was filling on a flood tide, however, this does not mean that flows through the culverts were negative. As long at the river stages on the upstream side of the barrier remain higher than the downstream side, flows through the culverts will always be positive.

### *Barrier Emergency Response Plan*

In addition to the operation and monitoring plan, DWR implemented an updated 2001 "Emergency Operations Plan for the Spring HORB." The plan provided that if the daily measured or forecasted flow at Vernalis exceeded a flow that would correspond to stage at the HORB of 10.0 feet MSL, and the stage was likely to exceed 11.0 feet MSL (the height of the barrier under the "high-flow" target), the barrier would be removed. Operation of the HORB was uneventful this year. Vernalis flows and stages at the barrier were not high enough in 2001 to warrant action under the emergency operations plan. The barrier remained in place until May 26.

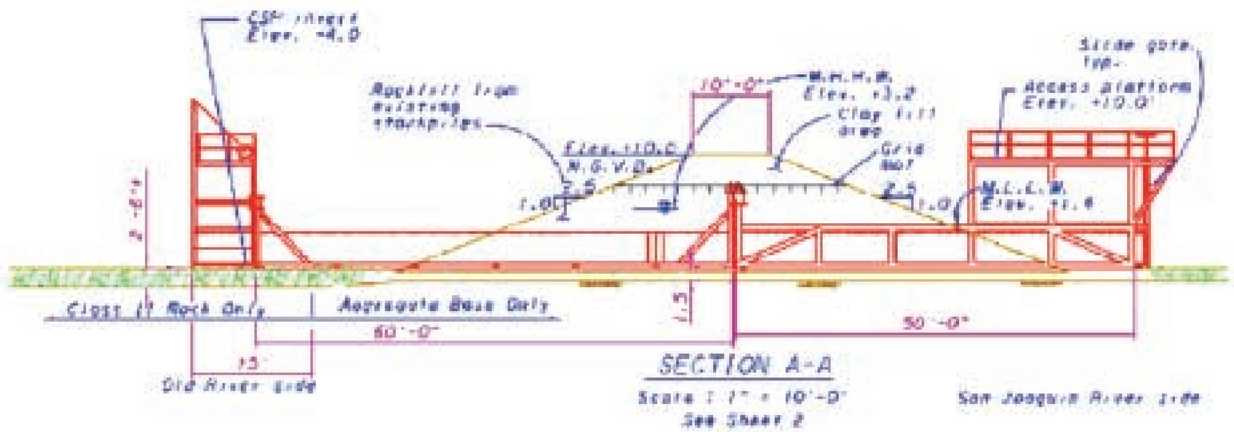
### *Seepage Monitoring*

A seepage-monitoring program was initiated in April 2000 and continued this year, to evaluate the effects of HORB operations on seepage and groundwater on Upper Roberts Island.

Three seepage monitoring well sites were chosen in 2000 on Upper Roberts Island. Each site had two shallow wells, positioned 10 feet and 100 feet from the toe of the levee to monitor seepage gradient to and from the San Joaquin River. In addition, a deeper well was drilled at Site 1 (near the Head of Old River) to determine vertical gradients.

In addition to the groundwater monitoring wells, a temporary gauge was installed in April 2000 to record water surface elevations in the San Joaquin River, about 1,500 feet downstream of the HORB. Installation of a permanent tide gauge is expected in the fall 2001.

**FIGURE 4-1**
**Head of Old River Barrier (HORB)**



## TABLE 4-1
### Flow on Old River Downstream of the Head of Old River Barrier-2001

| DATE | MEAN DAILY FLOW (CFS) | DAILY MAX FLOW (CFS) | DAILY MIN FLOW (CFS) | DATE | MEAN DAILY FLOW (CFS) | DAILY MAX FLOW (CFS) | DAILY MIN FLOW (CFS) |
|---|---|---|---|---|---|---|---|
| 4/26/01 | 692 | 1,033 | 174 | 5/14/01 | 112 | 434 | -130 |
| 4/27/01 | 661 | 1,053 | -186 | 5/15/01 | 173 | 392 | -94 |
| 4/28/01 | 675 | 1,002 | 346 | 5/16/01 | 186 | 455 | -91 |
| 4/29/01 | 530 | 940 | 0 | 5/17/01 | 112 | 349 | -99 |
| 4/30/01 | 285 | 821 | -463 | 5/18/01 | 227 | 839 | -117 |
| 5/1/01 | 331 | 896 | -147 | 5/19/01 | 523 | 817 | 149 |
| 5/2/01 | 126 | 673 | -565 | 5/20/01 | 511 | 758 | 267 |
| 5/7/01 | 292 | 644 | -210 | 5/21/01 | 360 | 672 | 10 |
| 5/8/01 | 321 | 688 | -71 | 5/22/01 | 217 | 527 | -79 |
| 5/9/01 | 223 | 604 | -303 | 5/23/01 | 216 | 460 | 0 |
| 5/10/01 | 221 | 582 | -186 | 5/24/01 | 220 | 542 | 59 |
| 5/11/01 | 91 | 474 | -246 | 5/25/01 | 263 | 492 | 31 |
| 5/12/01 | 75 | 485 | -207 | 5/26/01 | 533 | 1,450 | 62 |
| 5/13/01 | 153 | 441 | -133 | | | | |

The water surface elevations in the San Joaquin River are compared to groundwater levels on Upper Roberts Island to determine how groundwater levels change relative to changing water level conditions in the river.

In July 2001, DWR completed a "Reclamation District 544 Seepage Monitoring Study". This report documents the seepage monitoring results from Upper Robert Island. (Copies of the report are available from DWR). The report concluded that San Joaquin River stage influences groundwater levels on Upper Roberts Island. When stage increases in the river, groundwater levels will rise toward the land surface, but not as rapidly as the river stage rises. However, over the monitoring period, river stage did not reach levels sufficient to raise groundwater levels to the point where seepage into crop root zones might occur.

Given the results of the seepage monitoring since April 2000, DWR expects that if a VAMP target flow of 7,000 cfs was implemented, stages near the HORB would rise to about 7.5 to 8 feet MSL. This would translate to groundwater levels in the monitoring well closest to the levee of about 6.5 to 7 feet MSL. Because the ground surface elevation is 13 feet MSL near site 1, DWR concludes that seepage should not impact the root zone of crops that could be planted in this area.

It is recommended that the monitoring program be continued in order to gather more data, particularly during high flow periods in the spring.

### FISHERY MONITORING AT THE HEAD OF OLD RIVER BARRIER

As mentioned in the previous section, the temporary barrier installed at the HORB in 2001 was equipped with six operable culverts. During the VAMP 2001 test period all six of the culverts were open and diverted water from the San Joaquin River to maintain water quality and water levels within Old River. Juvenile Chinook salmon and other fish species were vulnerable to being entrained into the spring HORB culverts. A fisheries monitoring program was designed and implemented by DFG to evaluate and quantify fish entrainment at the HORB. The specific objectives of the investigation included:

• Determine the total number of juvenile Chinook salmon and other fish species entrained through the culverts at the HORB (entrainment monitoring);

• Determine percentage of coded-wire tagged (CWT) salmon released at Mossdale and Durham Ferry entrained into Old River (entrainment monitoring);



• Determine the effect of tidal stage and day/night conditions on juvenile Chinook salmon entrainment (entrainment special study); and

• Determine migration routes of CWT salmon released at the HORB and recovered at temporary barrier locations in Old River, Middle River, and Grant Line Canal (migration study).

Results of these investigations were intended, in part, to provide information useful in the design and operation of a permanent operable barrier at the Head of Old River in the future.

*Materials and Methods*

Ten fyke nets were ordered to monitor fish entrainment into the HORB culverts. Due to the delay in the production and delivery of these nets we had to repair three fyke nets from last year's study and borrow three fyke nets to begin this year's study. We replaced these nets as the new fyke nets arrived. The various fyke nets used in the monitoring were (1) 60 feet in length, with ¼-inch braided mesh tapering from a 48-inch cylindrical mouth opening to a 1-foot square cod end; (2) 30 feet in length, made of ¼-inch braided mesh tapering from a 48-inch square mouth opening to a 1-foot square cod end; and (3) 35 feet in length, made of ⅛-inch braided inch, tapering from a 48-inch square mouth opening to a 1-foot square foot cod end. Each of the fyke nets was equipped with a live-box (15.5 x 19.5 x 36 inches), constructed of perforated aluminum sheet metal. Each of the live-boxes included an aluminum baffle designed to reduce water velocities within the live car and improve survival of captured fish.

Operation of all six culverts at the HORB began April 30. The culverts were numbered one through six with one located next to the shoreline and six located mid-channel (Figure 4-2). Only five out of the six culverts had fyke nets attached because one culvert (no. 4) was jammed by debris and could not be closed to allow attachment of a fyke net. Fyke nets were attached to the culverts by connecting the net to the live-box, closing the culvert slide gate, strapping the fyke nets over a 48-inch diameter opening on the tracks, lowering the net over the culvert out-fall, and opening the culvert slide gate. Rubber flaps were used to seal the spaces between the culvert and the net opening to prevent fish loss. The culverts were twisted during construction of the HORB. As a result, the alignment between the net mouth opening and culvert was not exact causing the leakage of some water (and potentially fish) past the net mouth opening. By May 2 the slide gate on a second culvert (no. 2) was jammed by debris and could not be closed. Consequently, the fyke net was removed and sampling was continued on only four of the six culverts. On May 5, all fyke nets were removed to allow work to be done on the San Joaquin River side of the HORB because the trash

## FIGURE 4-2
### Culvert Numbers for HORB 2001


screens, part of the modifications for 2001, were becoming clogged by debris. However, only culverts two and four, which could no longer be closed due to the blockage of the slide gates, were cleared of debris. Beginning May 7, all six culverts were "operational" and all six fyke nets were re-attached. Sampling continued through May 18. After the 18-day sampling period was completed, the fyke nets were removed, inspected and found to have only minor holes in them.

During monitoring, entrained fish were removed from the live-boxes by closing the culvert slide gate for a period of 30 to 45 minutes with no more than two culverts being closed at one time. During this time the live-boxes were removed from the water, placed onto a boat, and the net and live-boxes checked thoroughly. Once all the nets had been checked and reset the fish that were collected and held in containers were processed. Data recorded for each sample consisted of date, time, water temperature, tidal stage, culvert number, fish species, and species count. Each Chinook salmon collected was measured, categorized as marked (CWT present based on an adipose fin clip), unmarked (natural), or color-dyed, and categorized as dead or alive. All CWT Chinook salmon were retained so tags could be processed; all other fish were released in Old River, downstream of the fyke nets.

Fyke nets were checked routinely on every high and low tide with high tide defined as the time period encompassing the flood and low tide defined as the time period encompassing the ebb. However, starting May 12, all night checks were cancelled due to the low number of Chinook salmon smolts collected. Starting May 15, fyke nets were checked once daily.

*Entrainment Monitoring*

Loss indices for the CWT salmon released as part of the VAMP survival studies at Durham Ferry and Mossdale were calculated based on data collected from April 30 to May 18. The loss index represents the percentage of CWT salmon entrained into the HORB culverts and is determined by the equation:

$$I = (TC/TR)(TT/ST)$$

*Where:*

*TC = Total number of CWT salmon collected in culvert fyke nets*
*TR = Total number of CWT released*
*TT = Total time (hours) during the test period*
*ST = Total time (hours) sampled at HORB during the test period*

Catch-Per-Unit-Effort (CPUE) for unmarked Chinook salmon was calculated as the number collected per hour. The CPUE for salmon collected from each culvert was analyzed using a single factor ANOVA with logarithmic transformation of the data (X` = log (X+1)). CPUE was further analyzed to determine differences between all possible pairs of means using the Tukey multiple comparison test.

*Entrainment Special Study:*
Eight individually marked (color coded) groups of juvenile Chinook salmon from the Merced River Hatchery were released in the San Joaquin River with respect to the following variables: release site, tidal cycle, and day/night. The first release site was directly in front of the HORB, consisting of approximately 500 juvenile salmon per release group. The second release site located nearly one mile upstream of the HORB consisted of about 3000 juvenile salmon per release group.

Juvenile Chinook salmon used in these tests were color-marked at the hatchery with photonic fluorescent microspheres. The salmon were then transported from the hatchery to the San Joaquin River and placed in 4x10x4 foot live cages lined with 3/16-inch mesh netting. The test fish were held in the live-cages for ten or more hours to reduce handling stress and observe any pre-release mortality. Night releases during high and low tidal cycles were made during the evening of April 30 and early morning of May 1. Though six culverts were in operation during this release, only five fyke nets could be attached for sampling. Day releases for both tidal cycles were made during the morning and afternoon of May 10. All six culverts were in operation for this release and all six fyke nets were attached for sampling.

The percentage of color-marked salmon recovered in the fyke nets compared to the total number released was used as an index of entrainment vulnerability at the HORB.

*Migration Study*
A pilot study was conducted to determine the migration routes through the south Delta of juvenile Chinook salmon entrained by the HORB. A total of 25,000 CWT Merced River Hatchery juvenile Chinook salmon were released May 12 (0930 hours) into Old River downstream of the HORB. Kodiak trawling was conducted daily over the next seven days upstream and downstream of the Grant Line Canal Barrier (GLCB) and the Old River Barrier near Tracy (OLDRB)(Figure 4-3). Kodiak trawl sampling could not be performed at the Middle River Barrier (MIDRB) because of shallow water depth.

In addition to Kodiak trawl sampling, marked salmon were also recovered in sampling at Chipps Island, Antioch, and at the SWP and CVP fish salvage facilities.

## RESULTS AND DISCUSSION

*Entrainment Monitoring*
Throughout the April 30 to May 18 study period, the number of culverts operated at the HORB and the number of fyke nets sampled varied (Table 4-2). During the sampling period, the six culverts were in operation approximately 2,596 hours. Total sampling time for all fyke nets combined was 2,092 hours. During the entrainment monitoring period, sampling was performed approximately 81% of the time that the culverts were in operation.

Thirty-two fish species were collected in the fyke nets during entrainment monitoring (Table 4-3). Chinook salmon (2,888) and white catfish (2,677) were the two most abundant species collected. No Delta smelt, one splittail, and two steelhead were collected. Of the 2,888 Juvenile Chinook salmon collected in the fyke nets at the culverts:

**TABLE 4-2**
**Culvert and Fyke Net Operations**

| DATES OF CULVERT OPERATION | NUMBER OF CULVERTS OPERATED | NUMBER OF FYKE NETS SAMPLED |
|---|---|---|
| 4/30/01–5/2/01 | 6 | 5 |
| 5/2/01–5/5/01 | 6 | 4 |
| 5/5/01–5/7/01 | 6 | 0 |
| 5/7/01–5/8/01 | 6 | 4 |
| 5/8/01–5/18/01 | 6 | 6 |

**FIGURE 4-3**
**Location of Temporary Barriers Throughout the Southern Delta**

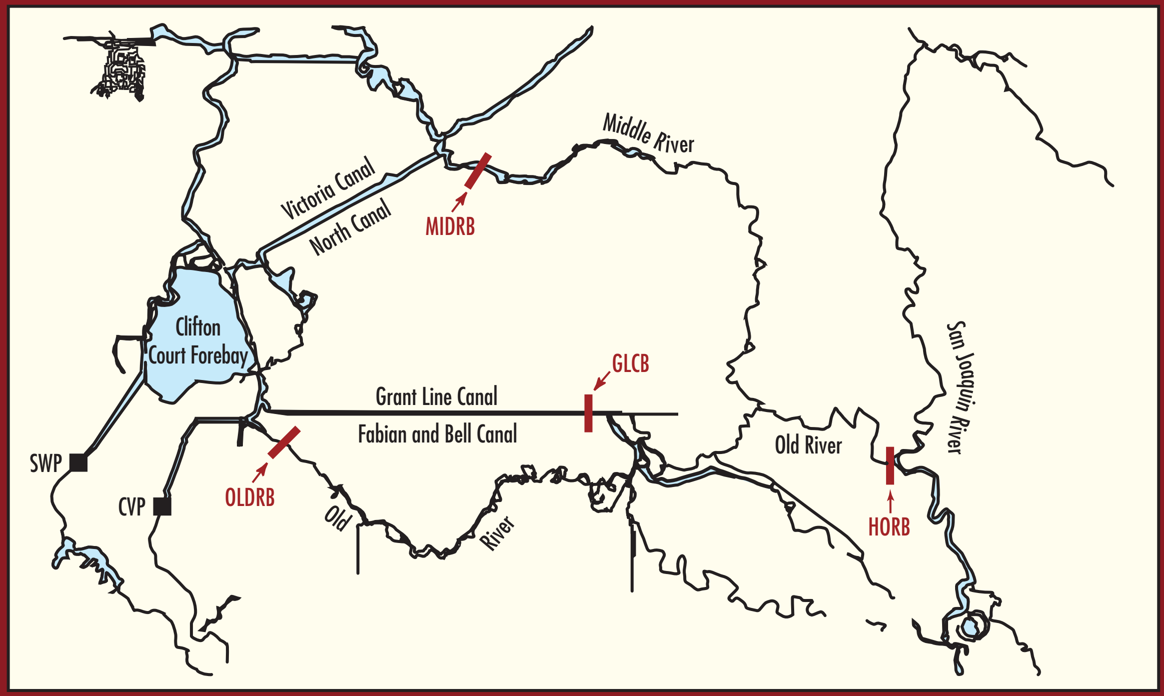
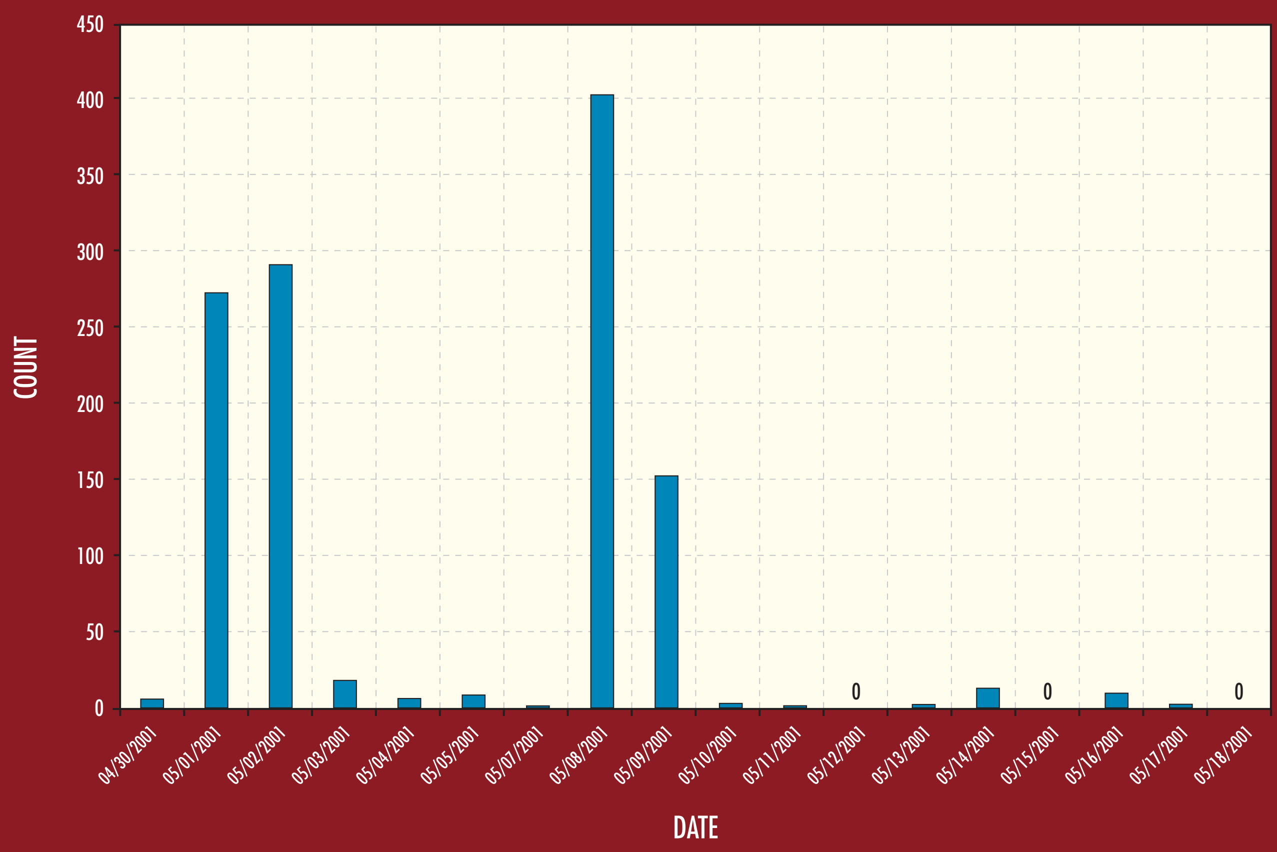



**FIGURE 4-4**
**Number of CWT Chinook Salmon Entrained Per Day From April 30 to May 18, 2001 at HORB**



- 1,268 were CWT Chinook salmon (including 92 salmon released on the Merced River, and 21 salmon released on the Tuolumne River);
- 1,014 were unmarked Chinook salmon;
- 475 were color-marked Chinook salmon (Entrainment special study); and
- 131 were mutilated Chinook salmon.

The mutilated salmon smolts observed this year could have come from various sources. The smolts could have died on the San Joaquin side of the HORB and then been diverted through the culverts. In addition, the smolts could have been regurgitated from the many catfish entrained in the fyke nets. The HORB design in 2001 included trash screens placed in front of the culvert openings. Over time, the debris accumulated on the trash screens could have acted like a filter and increased mutilation of entrained salmon.

The entrainment loss index for CWT Chinook salmon released as part of the VAMP 2001 averaged 0.54 percent. The entrainment loss index for releases at Mossdale averaged 0.49 percent (May 1 release entrainment index was 0.61 percent; May 8 release entrainment index was 0.37 percent). The entrainment loss index for releases at Durham Ferry averaged 0.58 percent (April 30 release entrainment index was 0.54 percent; May 7 release entrainment index was 0.62 percent). This year's average entrainment loss index was slightly lower than the previous years (0.75 percent in 2000 and 0.6 percent in 1997). The debris that accumulated on the trash screens, in front of the culvert openings, could have contributed to this lower entrainment loss index. The temporal pattern of CWT salmon collected in entrainment monitoring (Figure 4-4) reflects releases of salmon as part of the VAMP studies at both Durham Ferry and Mossdale. No consistent pattern in entrainment of CWT salmon was apparent under low and high tidal stages (Figure 4-5) and an obvious pattern of entrainment was apparent under day/night (Figure 4-6) with more salmon entrained at night than during the day. However, the tidal cycle did have an effect on CPUE and is represented when only one category (day or night) in Figure 4-6 is singled out and related to the same information (data bars) in Figure 4-5, showing that more salmon were entrained during low tides than high tides. The reason that tidal cycle seems to show no pattern is because day/night is a much stronger influence than tides and therefore hides the tidal cycles' smaller influence. Also, since both factors influence CPUE, they are considered additive influences, meaning a low tide occurring at night will increase the chance of Chinook salmon smolt entrainment as compared to a high tide occurring during the day.

The CPUE for unmarked Chinook salmon ranged from 0.0 to 6.7 fish per net per hour, averaging 0.5 fish per hour. This year's CPUE is approximately three times smaller than last year's estimate (1.7 fish per hour in 2000) and may again be a result of the debris blocking the culvert openings. However, this could also be indicative of a smaller population passing the barrier in 2001 relative to 2000.

Statistical analysis of CPUE for unmarked Chinook salmon showed that entrainment rates among the six culverts were significantly different ($P < 0.002$). Results of the Tukey multiple comparison test showed that CPUE among all six culverts were significantly different from one another ($P < 0.005$) except culverts four and five. Position of the culverts relative to the shoreline, culvert maintenance, eddies and turbulence, and variation in hydraulics and velocities may all be factors contributing to the observed differences in entrainment between culverts.

CPUE for both CWT and unmarked Chinook salmon showed an increasing trend from culvert one to culvert six (Figure 4-7) using data obtained between May 8 and May 18 when all six culverts were sampled. CPUE for CWT and unmarked Chinook salmon are similar for each culvert. Although CPUE was similar between CWT and unmarked salmon, examination of sampling data showed that CWT salmon were collected within two days of release at Durham Ferry and Mossdale. Unmarked salmon were collected throughout the entrainment monitoring period.

Results of entrainment monitoring indicated that day/night and tides might influence Chinook salmon entrainment at the HORB. However, day/night may be a stronger influence than tides. When both influences are occurring simultaneously, the data suggests there is an additive effect. The results also suggest that flow rates through the culverts are not equal and may increase the farther the culvert is from the shoreline.

### *Entrainment Special Study*

Release and recapture information for the entrainment special study is summarized in Table 4-4. The percentage of color-marked salmon collected in each test was extrapolated to account for the number of nets sampled and culverts operated. The percentage of color-marked Chinook salmon recovered was highest for the salmon released adjacent to the HORB and those released during the low tide.

It is evident that the salmon smolts released immediately in front of the HORB were more vulnerable to entrainment than those released further upstream. Therefore, entrainment vulnerability at the HORB for natural or CWT salmon migrating downstream in the San Joaquin River is probably better represented by salmon released upstream of the HORB resulting in greater dispersal and lower percent recoveries.

Furthermore, the finding that the percentage of marked salmon recovered was highest for all release groups during the low tide shows that tidal cycle effects salmon smolt entrainment at the



## TABLE 4-3
**Species Composition and Number of Fish Species Collected in Fyke Nets From 30 April Through 18 May, 2001.**

| | |
|---|---|
| Mosquitofish | 1 |
| Golden Shiner | 1 |
| Red Shiner | 1 |
| Redear Sunfish | 1 |
| **Splittail** | **1** |
| White Crappie | 1 |
| Yellow Bullhead | 1 |
| Yellowfin Goby | 1 |
| Black Bullhead | 2 |
| Centrarchidae | 2 |
| lamprey | 2 |
| **Steelhead** | **2** |
| Black Crappie | 3 |
| Green Sunfish | 3 |
| Striped Bass | 3 |
| Tule Perch | 3 |
| Warmouth Bass | 3 |
| Brown Bullhead | 5 |
| Goldfish | 7 |
| Inland Silverside | 7 |
| Sacramento Blackfish | 7 |
| Squawfish | 17 |
| Log Perch | 22 |
| Largemouth Bass | 38 |
| American Shad | 41 |
| Bluegill | 54 |
| Sacramento Sucker | 54 |
| Carp | 82 |
| Threadfin Shad | 105 |
| Channel Catfish | 267 |
| White Catfish | 2,677 |
| **Total Chinook Salmon** | **2,888** |
| CWT Chinook Salmon | 1,268 |
| Unmarked Chinook Salmon | 1,014 |
| Color-Marked Chinook Salmon | 475 |
| Mutilated Chinook Salmon | 131 |
| Total | 6,302 |

## TABLE 4-4
**Number of Color-Marked Chinook Salmon Released During the Entrainment Special Study and Percent Recovered During the Evening (30 April, 1 May) and Day (10 May, 2001).**

| RELEASE LOCATION | NUMBER OF FISH RELEASED | TIDE | NUMBER COLLECTED | PERCENT RECOVERED | EXTRAPOLATED PERCENT RECOVERED |
|---|---|---|---|---|---|
| Night Release (30 April, 1 May) | | | | | |
| Upstream | 3,010 | High | 21 | 0.70% | 0.84% |
| | 3,000 | Low | 50 | 1.67% | 2.00% |
| Adjacent | 500 | High | 48 | 9.60% | 11.52% |
| | 502 | Low | 297 | 59.16% | 71.00% |
| Day Release (10 May) | | | | | |
| Upstream | 3,008 | High | 2 | 0.07% | 0.07% |
| | 3,024 | Low | 21 | 0.69% | 0.69% |
| Adjacent | 515 | High | 4 | 0.78% | 0.78% |
| | 521 | Low | 15 | 2.88% | 2.88% |

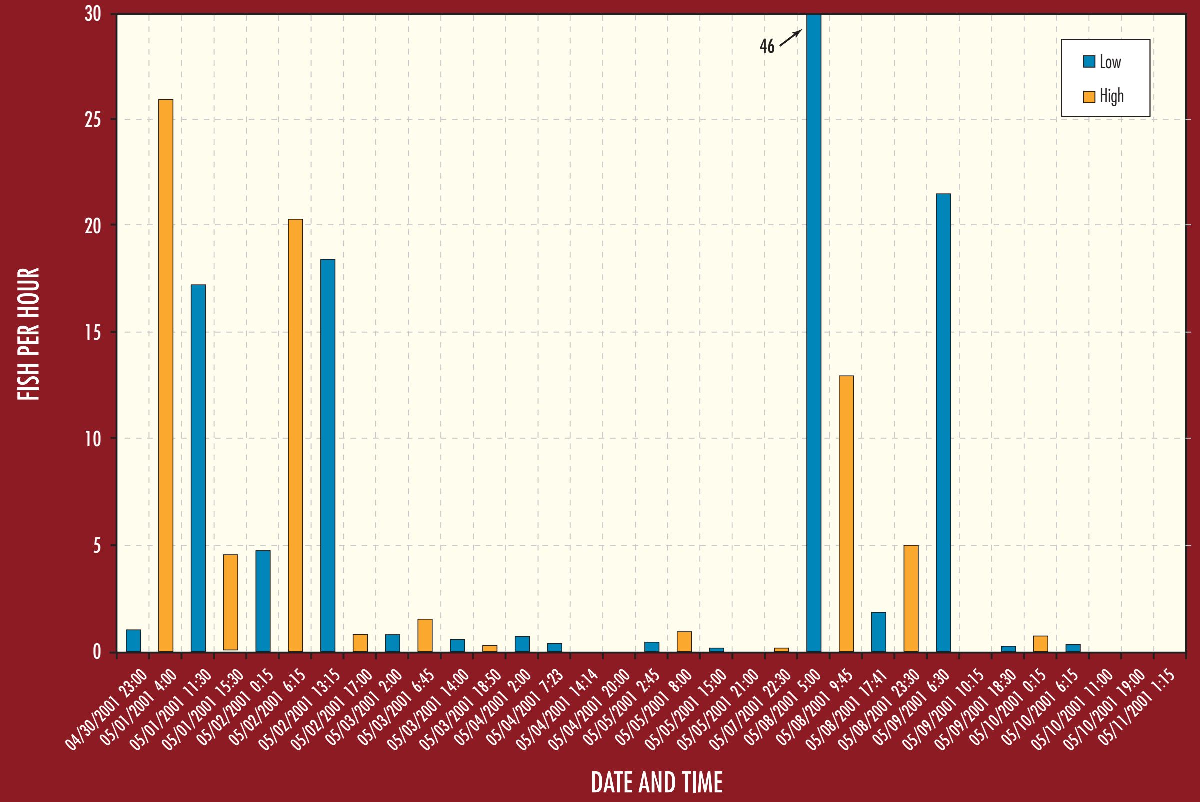
## TABLE 4-5
**Number of CWT Chinook Salmon Released and Recaptured During the 2001 Migration Study.**

| RELEASE LOCATION | DATE | NUMBER | TIDE |
|---|---|---|---|
| Release Location | | | |
| Old River, downstream of HORB | 5/12/01 | 24,398 | flood |
| Recapture Location | | | |
| Grant Line Canal Barrier, upstream | 5/13 | 16 | ebb |
| Grant Line Canal Barrier, downstream | 5/13 | 5 | ebb |
| Old River Barrier, upstream | 5/14 | 2 | flood |
| Grant Line Canal Barrier, upstream | 5/16 | 1 | ebb |
| Grant Line Canal Barrier, downstream | 5/16 | 1 | ebb |
| Old River Barrier, upstream | 5/17 | 4 | ebb |
| Chipps Island | 5/14<br>5/16<br>5/17 | 2<br>1<br>1 | |
| Antioch | 5/16 | 1 | |
| CVP | 5/14–5/18 | 390* | |
| SWP | | 0 | |

*390 is expanded value, 33 is raw value

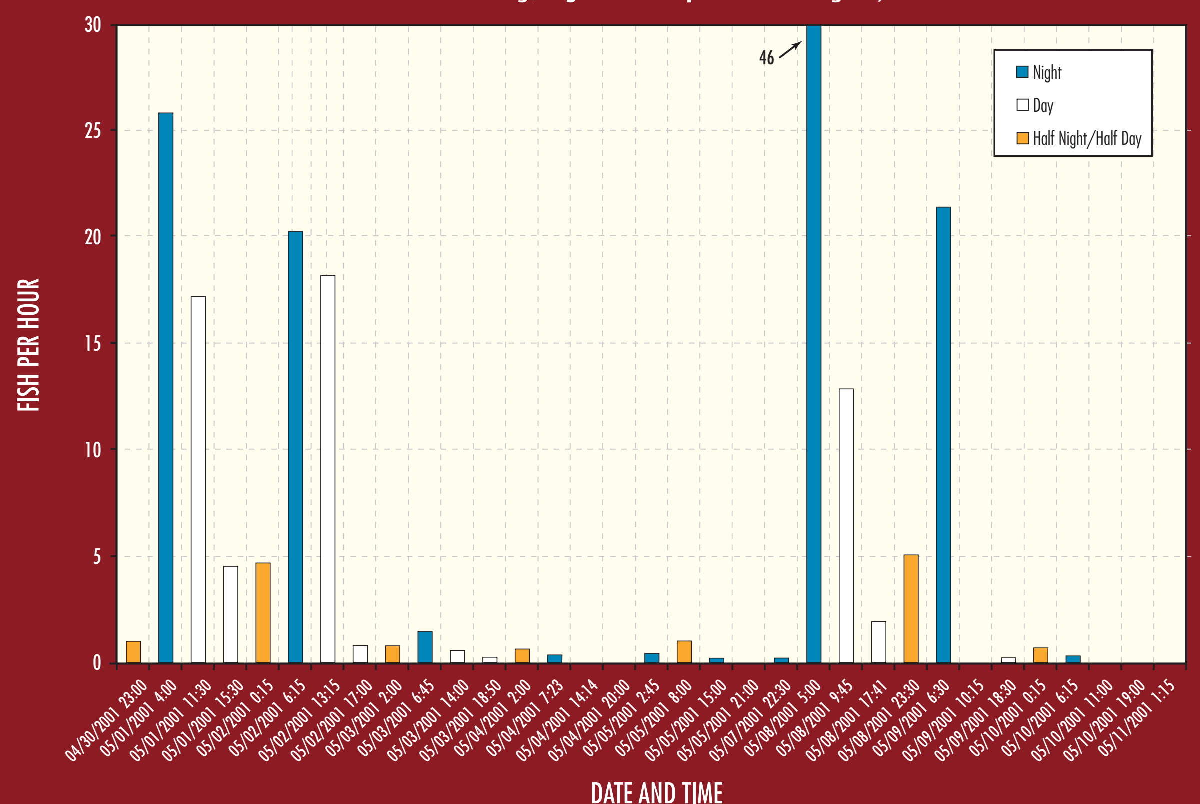
## FIGURE 4-5

**CPUE of CWT Chinook Salmon Per Tidal Cycle From April 30 to May 11, 2001 at HORB**



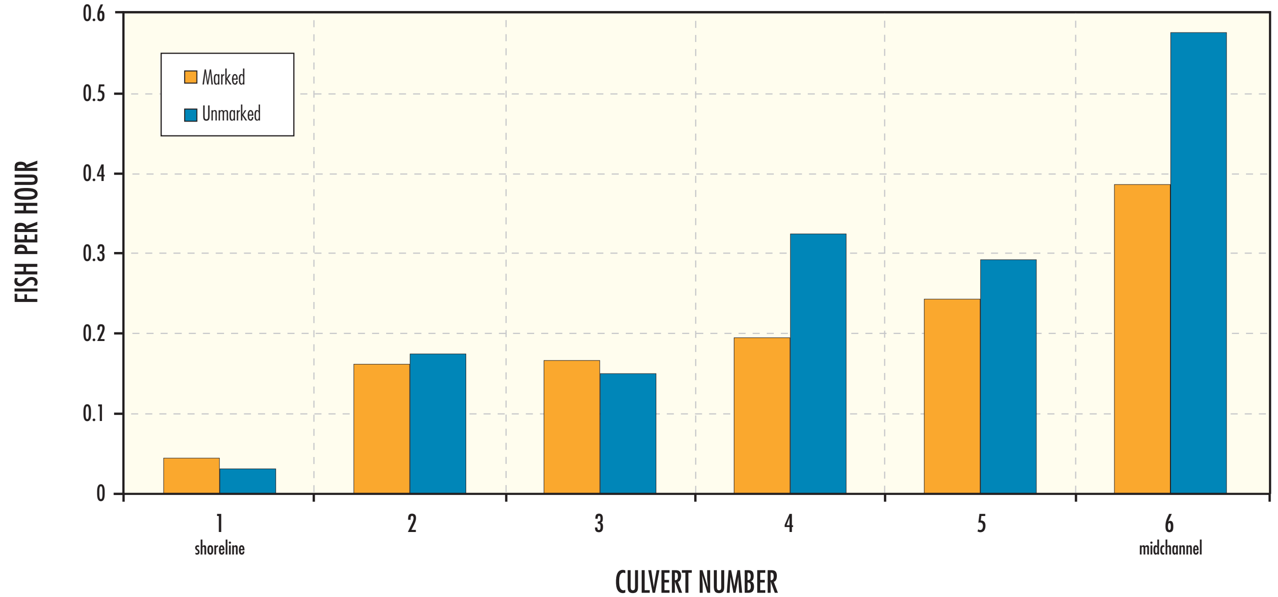

## FIGURE 4-6

**CPUE of CWT Chinook Salmon Per Day/Night From April 30 to May 11, 2001 at HORB**




## FIGURE 4-7

**CPUE of Marked and Unmarked Chinook Salmon From May 8 to May 18, 2001 at HORB**




HORB. Low tide creates higher entrainment vulnerability than high tide. Changes in hydraulic characteristics and approach velocities between high and low tidal stages are thought to be factors contributing to the observed entrainment patterns.

Results of the entrainment special study indicated that tides and release location might influence Chinook salmon entrainment at the HORB. Furthermore, the day/night variable could not be examined with confidence due to the nine-day interval between release groups. During this time debris built up on the culvert trash screens possibly effecting entrainment vulnerability.

*Migration Study*

Release and recapture information for the migration study is summarized in Table 4-5. The majority of the recovered salmon smolts were collected at the CVP fish salvage facilities. No CWT salmon released as part of this test were recaptured at the SWP fish salvage facility. CWT salmon were recaptured at Chipps Island and Antioch, suggesting that a portion of juvenile Chinook salmon entrained into the HORB culverts may successfully emigrate through the south Delta. The survival rate of these fish was not, however, quantified because of the low number of fish released and recaptured. CWT salmon were also recovered upstream and downstream of the GLCB and only upstream of the OLDRB (Figure 4-3). No statistical analysis was performed on the migration data because of the low numbers of fish recaptured at various sampling sites.

Results of the migration study show that a portion of salmon smolts entrained into the south Delta through the HORB can successfully reach Chipps Island. Whether these CWT salmon arrived at Chipps Island on their own or were salvaged at the CVP export facilities, trucked, and released is unknown. The fact is that salmon smolts traveling down Grant Line Canal were able to pass the GLCB. The salmon smolts traveling down Old River were only detected above the OLDRB so it is still unknown whether they are able to pass the OLDRB. Salmon also may have traversed down Middle River, which was not sampled. The factors contributing to the differences in recoveries between the CVP and SWP were not evaluated.

*Recommendations*

A similar study is planned for 2002 to further evaluate entrainment at the HORB. Modifications to the study design include measurement of flow through each culvert during each sampling event. This will help determine the relationship between flow rates through the culverts and entrainment rates for juvenile salmon and other species. Data that can be statistically analyzed would be beneficial in evaluating factors influencing entrainment rates, including both day/night and tidal effects. If trash screens on the culverts are utilized next year, these screens should be cleaned at regular intervals or constructed so that debris does not block the culverts. Finally, if the migration study is included in next year's plan, the study design and sampling program should be modified to provide statistically reliable data for use in evaluating migration and survival of juvenile salmon released into Old River.

# SALMON SMOLT SURVIVAL INVESTIGATION

*One of the primary objectives of the VAMP program is to identify the respective roles of San Joaquin River flow, and SWP and CVP export rates with the HORB in place on the survival of juvenile Chinook salmon emigrating from San Joaquin River tributaries. This section describes the methods used in conducting the VAMP 2001 Chinook salmon smolt survival investigations, and presents results of the calculated survival indices and absolute survival estimates for juvenile Chinook salmon during the VAMP 2001 test period. Additional data and information related to the salmon survival investigations are presented in Appendix C.*

## CODED-WIRE TAGGING

Merced River Hatchery Chinook salmon smolts, released as part of VAMP 2001, were coded-wire tagged (CWT) between March and early April. After the salmon were tagged, they were held in the hatchery for up to 21 days before being released. A sub-sample of the salmon were measured for length and checked for retention of the CWTs a day or two prior to release. The sub-sample was typically comprised of 100 to 300 salmon collected from the top, middle, and bottom of the release group's raceway. Each tag code within a release group was held separately at the hatchery with the exception of the two Durham Ferry releases. Each of these releases were made up of three tag codes that were held together in one section of the raceway.

Although tag retention is usually quite high, as a double check on the tag detector, all salmon from the sub-sample that had no tag detected were sacrificed. These sacrificed salmon were dissected to determine whether they contained an unmagnetized tag. A separate sub-sample of 25 salmon was sacrificed from each release group; the tags were removed and read to detect any incorrect tag codes in the raceways. Table 5-1 summarizes results of the CWT retention rate and the estimate of the effective numbers of salmon released to calculate survival indices. Tag retention rates were determined to be similar to last year, with an overall loss rate of 9.5% among all VAMP groups. The tag retention loss rates varied from 0.5% to 15%. It is recommended that this loss rate be reduced for future VAMP studies.

### TABLE 5-1
**Coded Wire Tag Retention Rates and Effective Release Numbers for Juvenile Salmon Released as Part of VAMP 2001**

| RELEASE DATE | CWT CODE | RELEASE SITE | AVERAGE FL(mm) | NUMBER TAGGED | POND LOSS | EFFECTIVE MARKED | TAG RETENTION RATE | EFFECTIVE NUMBER RELEASED |
|---|---|---|---|---|---|---|---|---|
| 30-Apr | 06-44-29 | Durham Ferry | 88 | 25,899 | 97 | 25,802 | 90.55% | 23,363 |
| | 06-44-30 | Durham Ferry | 88 | 25,202 | 97 | 25,105 | 91.00% | 22,846 |
| | 06-44-31 | Durham Ferry | 88 | 24,822 | 97 | 24,725 | 91.00% | 22,500 |
| 1-May | 06-44-32 | Mossdale | 89 | 25,928 | 90 | 25,838 | 89.05% | 23,010 |
| | 06-44-33 | Mossdale | 88 | 26,199 | 92 | 26,107 | 85.00% | 22,191 |
| 4-May | 06-44-34 | Jersey Point | 89 | 25,761 | 30 | 25,731 | 95.00% | 24,444 |
| | 06-44-35 | Jersey Point | 88 | 25,792 | 26 | 25,766 | 97.00% | 24,993 |
| 7-May | 06-44-36 | Durham Ferry | 87 | 25,516 | 88 | 25,428 | 94.50% | 24,029 |
| | 06-44-37 | Durham Ferry | 87 | 25,386 | 88 | 25,298 | 95.00% | 24,033 |
| | 06-44-38 | Durham Ferry | 87 | 25,542 | 88 | 25,454 | 95.00% | 24,181 |
| 8-May | 06-44-39 | Mossdale | 89 | 25,602 | 60 | 25,542 | 93.50% | 23,882 |
| | 06-44-40 | Mossdale | 89 | 25,768 | 73 | 25,695 | 98.50% | 25,310 |
| 11-May | 06-44-41 | Jersey Point | 88 | 26,102 | 62 | 26,040 | 99.50% | 25,910 |
| | 06-44-42 | Jersey Point | 88 | 25,760 | 37 | 25,723 | 99.00% | 25,466 |

## CWT RELEASES

Two sets of CWT salmon releases were made as part of the 2001 VAMP experiment. The first set occurred on April 30 at Durham Ferry, May 1 at Mossdale and May 4 at Jersey Point. The second set of releases was made at Durham Ferry on May 7, at Mossdale on May 8, and at Jersey Point on May 11.

Approximately 75,000 salmon, in three distinct tag lots of about 25,000 fish, were released at Durham Ferry, while approximately 50,000 fish, in two tag lots, were used at each Mossdale and Jersey Point release (Table 5-1). Prior to VAMP 2000, each release was made such that all tag lots were trucked from the hatchery mixed and released as a single group. However, during VAMP 2000 and VAMP 2001, a new transport trailer with three tanks allowed each separate CWT lot to be transported to its release site in a separate tank and distinctly released. As mentioned earlier, the three tag lots comprising each of the groups released at Durham Ferry on April 30 and May 7 were already mixed at the hatchery and thus not transported separately by tag lot. Due to logistical difficulties getting the transport truck up the gravel road leading away from the Durham Ferry site, the May 7 release was made from the top of the levee using a combination of flexible aluminum pipe and vinyl hose. The issue of consistently releasing the Durham Ferry group from the top of the levee or near the river needs to be resolved prior to releasing groups in 2002. It is also of note that a nearby agricultural diversion was in operation during the May 7 Durham Ferry release.

In order to test the effectiveness of hydro-acoustic technology for monitoring movement of juvenile Chinook salmon past HORB, the releases at Mossdale were performed over a 12 hour period which was different than had occurred in past years. First, an alternate release site was chosen for delivery of the fish because it had more security and better facilities for watching the fish over the 12-hour period during release. This new site was a boat ramp at the Mossdale Trailer Park, approximately ½-mile upstream and on the opposite bank (west side) from the public ramp traditionally used at the Mossdale County Park. Prior to release, each 25,000 tag lot was taken from the transport truck via dip net and distributed into two large net pens (4' x 4' x 8'). When unloading was complete there were 4 large net pens, each with approximately 12,500 fish. These fish were then held for a few hours and allowed to acclimate to river conditions. Then, on specific points of the tidal cycle, a pen was floated downstream via a small boat, and the fish were freed into the river at approximately mid-channel near the historical release site at the Mossdale public boat ramp. Each group of approximately 12,500 salmon was released approximately 3 hours apart in a similar manner, in an attempt to time the arrival of each group at the HORB on a specific point on the tidal cycle (Table 5-2). These releases were also meant to help determine any day/night release time survival differences. Unfortunately, due to the number of agencies and individuals involved with the Mossdale release strategy, the information on the tag codes for each release time was not retained.

### TABLE 5-2
**Times of Release at Mossdale on 5/1 and 5/8 for the Four Groups (2 tag codes) Released.**

| MOSSDALE TIDAL RELEASES | | | | | |
|---|---|---|---|---|---|
| First Replicate | | | Second Replicate | | |
| 5/1/01 | 4:15 PM | Day | 5/8/01 | 5:53 | Day |
| | 8:35 PM | Night | | 8:56 PM | Night |
| 5/2/01 | 2:12 AM | Night | 5/9/01 | 2:00 AM | Night |
| | 7:00 AM | Day | | 7:12 AM | Day |

The release processes at Durham Ferry and Jersey Point were not changed from past years. Releases at Jersey Point were made at the beginning of the flood tide to increase dispersion of the tagged fish before they passed Antioch and Chipps Island. Releases at Mossdale and Durham Ferry were not made on any specific tidal condition.

The water temperature both in the hatchery truck and in the receiving waters was measured at the release site immediately prior to release. These, as well as additional release and recovery data, are provided in Table 5-3.

## WATER TEMPERATURE MONITORING

The water temperature was monitored during the VAMP 2001 study using individual computerized temperature recorders (e.g., Onset Stowaway Temperature Monitoring/Data Loggers). The water temperature was measured at locations along the longitudinal gradient of the San Joaquin River and interior Delta channels between Durham Ferry and Jersey Point-locations along the migratory pathways for the juvenile Chinook salmon released as

## TABLE 5-3

**Release and Recovery Information for Coded Wire Tag Groups Released as Part of VAMP in 2001.**

| CWT CODE | RELEASE SITE | RELEASE DATE | TRUCK TEMP C° | RELEASE TEMP C° | NUMBER RELEASED | AVERAGE FORK LENGTH (mm) | NUMBER RECOVERED AT ANTIOCH | PERCENT SAMPLED AT ANTIOCH | SURVIVAL INDEX AT ANTIOCH | GROUP SURVIVAL AT ANTIOCH | NUMBER RECOVERED AT CHIPPS | PERCENT SAMPLED AT CHIPPS | SURVIVAL INDEX AT CHIPPS | GROUP SURVIVAL AT CHIPPS | EXPANDED SALVAGE CVP | EXPANDED SALVAGE SWP | ABSOLUTE SURVIVAL ANTIOCH | ABSOLUTE SURVIVAL CHIPPS ISLAND |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 06-44-29 | | | 14.5 | 21.5 | 23,354 | 89 | 28 | 0.39 | 0.22 | | 14 | 0.28 | 0.28 | | 12 | | | |
| 06-44-30 | Durham Ferry | | 14.5 | 21.5 | 22,837 | 89 | 30 | 0.39 | 0.24 | | 22 | 0.28 | 0.45 | | 24 | | | |
| 06-44-31 | | | 14.5 | 21.5 | 22,491 | 89 | 18 | 0.39 | 0.15 | | 17 | 0.28 | 0.36 | | 48 | | | |
| Total | | 30-Apr | | | 68,682 | | 76 | 0.39 | | 0.20 | 53 | 0.28 | | 0.36 | | | 0.17 | 0.34 |
| 06-44-32 | Mossdale | | 15 | 19.5 | 23,000 | 91 | 18 | 0.39 | 0.14 | | 17 | 0.28 | 0.35 | | 24 | 12 | | |
| 06-44-33 | Mossdale | | 15 | 19.5 | 22,177 | 91 | 15 | 0.39 | 0.13 | | 14 | 0.28 | 0.30 | | 12 | | | |
| Total | | 1-May | | | 45,177 | | 33 | 0.39 | | 0.13 | 31 | 0.28 | | 0.32 | | | 0.11 | 0.31 |
| 06-44-34 | Jersey Point | | 15 | 20 | 24,443 | 88 | 156 | 0.39 | 1.18 | | 50 | 0.28 | 0.96 | | | | | |
| 06-44-35 | Jersey Point | | 15 | 20 | 24,992 | 88 | 173 | 0.39 | 1.27 | | 61 | 0.28 | 1.15 | | | | | |
| Total | | 4-May | | | 49,435 | | 329 | 0.39 | | 1.23 | 111 | 0.28 | | 1.06 | | | | |
| 06-44-36 | | | 14.5 | 19 | 24,025 | 85 | 8 | 0.40 | 0.06 | | 2 | 0.28 | 0.04 | | 12 | 9 | | |
| 06-44-37 | Durham Ferry | | 14.5 | 19 | 24,029 | 85 | 11 | 0.38 | 0.09 | | 4 | 0.28 | 0.08 | | | | | |
| 06-44-38 | | | 14.5 | 19 | 24,177 | 85 | 10 | 0.36 | 0.08 | | 2 | 0.28 | 0.04 | | 12 | 6 | | |
| Total | | 7-May | | | 72,231 | | 29 | 0.37 | | 0.08 | 8 | 0.28 | | 0.05 | | | 0.20 | 0.14 |
| 06-44-39 | Mossdale | | 15.5 | 21 | 23,878 | 89 | 8 | 0.40 | 0.06 | | 4 | 0.28 | 0.08 | | 12 | | | |
| 06-44-40 | Mossdale | | 15.5 | 21 | 25,308 | 88 | 11 | 0.41 | 0.08 | | 4 | 0.28 | 0.07 | | 12 | 12 | | |
| Total | | 8-May | | | 49,186 | | 19 | 0.40 | | 0.07 | 8 | 0.28 | | 0.08 | | | 0.18 | 0.19 |
| 06-44-41 | Jersey Point | | 16 | 22.5 | 25,909 | 88 | 43 | 0.40 | 0.30 | | 17 | 0.28 | 0.31 | | | | | |
| 06-44-42 | Jersey Point | | 16 | 22.5 | 25,465 | 87 | 53 | 0.35 | 0.43 | | 27 | 0.28 | 0.50 | | | | | |
| Total | | 11-May | | | 51,374 | | 96 | 0.35 | | 0.38 | 44 | 0.28 | | 0.40 | | | | |

*** For tag code, 06-44-37, one tag was found to be recovered at Chipps Island on May 9th, only two days after release. The tag was removed from the data set prior to calculating survival and is not included in this table or Appendix C-4.*

## TABLE 5-4

**Description of the Six Parameters Used to Assess Overall Condition of the Various Tag Groups Released as Part of VAMP in 2001.**

| | NORMAL | ABNORMAL |
|---|---|---|
| **Eyes** | Normally shaped | Bulging |
| **Color** | High contrast dark dorsal surface and light sides | Low contrast dorsal surface and sides, coppery color |
| **Fin Hemorrhaging** | No blood ore red at base of fins | Blood at base of fins |
| **Percent Scale Loss** | Lower relative numbers better based on 0-100% scale loss | Higher relative numbers worse based on 0-100% scale loss |
| **Gill Color** | Dark beet red to cherry red gill filaments | Light red to gray gill filaments |
| **Vigor** | Active swimming (prior to anesthesia) | Lethargic or motionless (prior to anesthesia) |

**FIGURE 5-1**

**Results of Water Temperature Monitoring at the Merced River Fish Hatchery.**

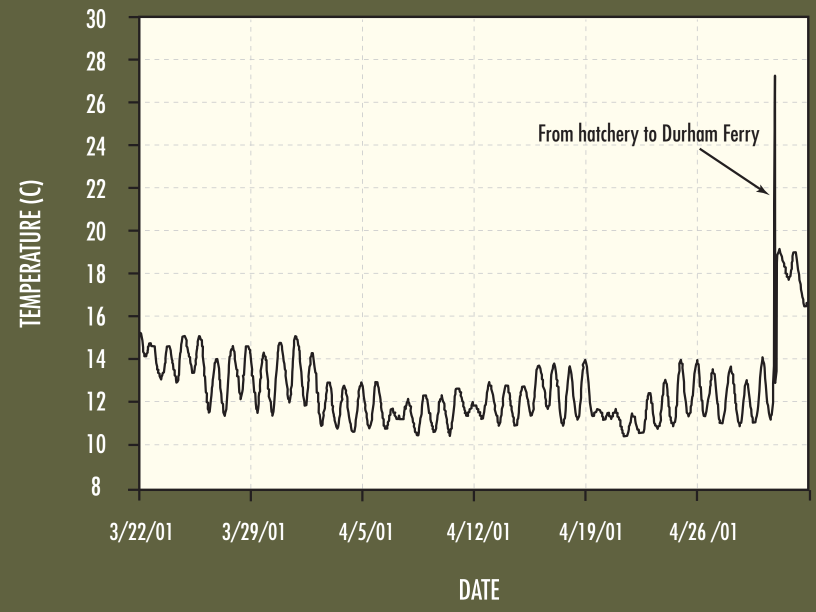



**FIGURE 5-2**

**Water Temperature Measured at Durham Ferry Immediately Following VAMP 2001 Release.**

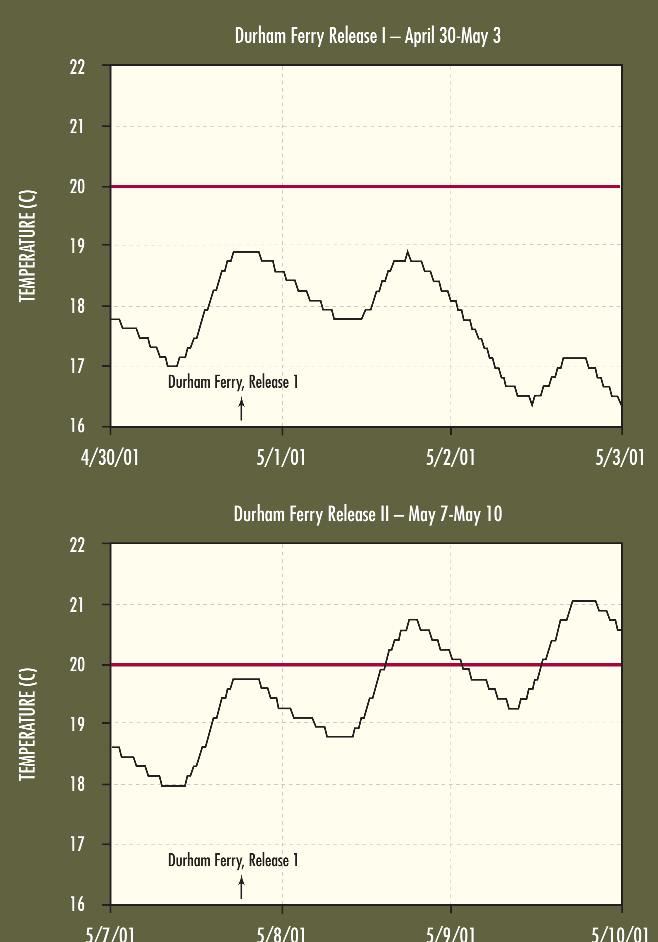
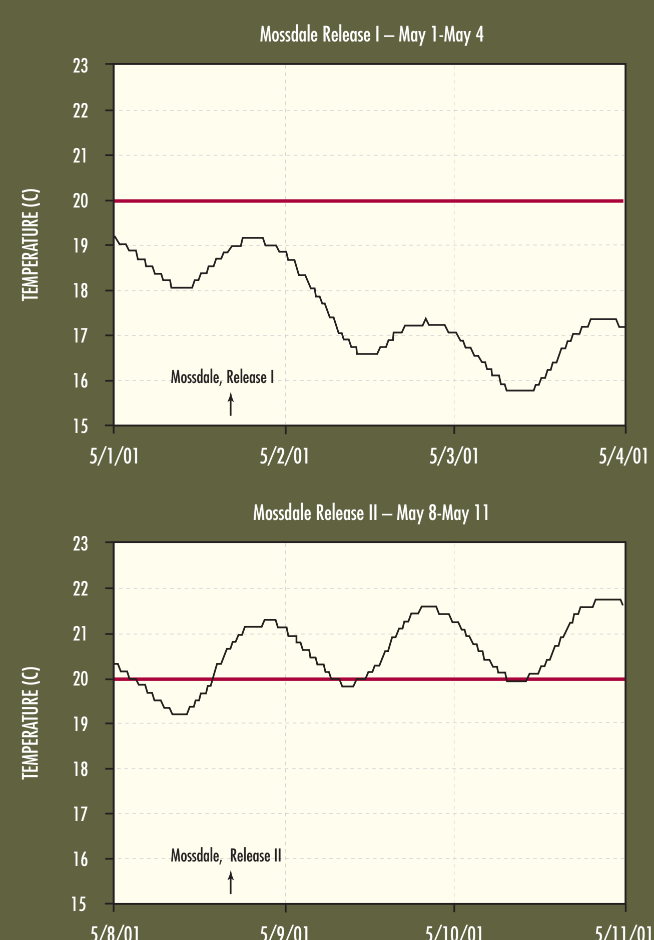



**FIGURE 5-3**

**Water Temperature Measured at Mossdale Immediately Following VAMP 2001 Release.**



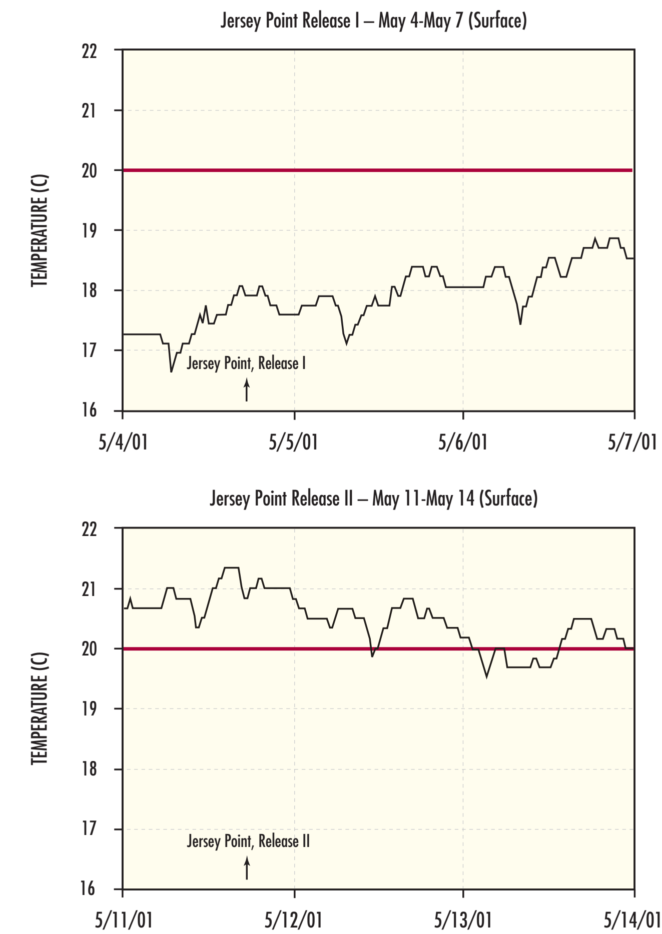



part of these tests (Appendix C-1). Water temperature was recorded at 24-minute intervals throughout the period of the VAMP 2001 investigations. Water temperature was also recorded within the hatchery raceways at the Merced River Hatchery coincident with the period when juvenile Chinook salmon were being tagged.

Results of water temperature monitoring within the Merced River Hatchery showed that juvenile Chinook salmon were reared in and acclimated to water temperatures of approximately 11.1–13.9 C (52-57 F) prior to release into the lower San Joaquin River (Figure 5-1). Results of water temperature monitoring at Durham Ferry, Mossdale, and Jersey Point following the first and second sets of VAMP 2001 releases are compared in Figures 5-2, 5-3 and 5-4. Results of water temperature monitoring showed that water temperatures at the release locations and throughout the lower San Joaquin River and Delta (Appendix C-2), were higher than those at the hatchery. Water temperatures at the release locations and throughout the lower San Joaquin River and Delta also showed water temperatures were greater coincident with the second VAMP 2001 release, which may have adversely affected juvenile Chinook salmon survival. Within the lower San Joaquin River and Delta, water temperatures during the second VAMP 2001 release and emigration period consistently exceeded 20 C (68 F). High temperatures were identified during the design of the VAMP experiment as an indicator of potential thermal stress adversely affecting juvenile Chinook salmon survival. These high temperatures during the second set of releases in 2001 could affect the interpretation of the flow-export relationship.

**FIGURE 5-4**

**Water Temperature Measured at Jersey Point Immediately Following VAMP 2001 Releases.**




## POST-RELEASE LIVE-CAR STUDIES

***Survival and Condition***

The post-release survival and condition of marked salmon was evaluated as part of the VAMP program using sub-samples of marked salmon from each release group. Approximately 200 salmon from each group were held at the respective release site in net pens for 48 hours after release and were evaluated for general condition and short-term mortality which might be associated with the handling, transport and release process. In addition to the 200 salmon held for 48 hours, 25 salmon from each tag group were evaluated for general condition immediately after release and another 25 salmon were held and similarly evaluated after the 48-hour holding period. To assess overall condition, fork length in millimeters, weight in grams, and six other characteristics were examined (Table 5-4). Obvious abnormalities or deformities were also noted.

Results of the evaluations of marked fish in the net pens, both immediately after release and 48 hours later, showed few abnormalities in the condition assessed characteristics which are shown in Appendix C-3. Scale loss ranged from 1-20%. All fish examined were noted to have normal coloration and normal eye characteristics. One fish from the May 8 Mossdale release had signs of fin hemorrhaging and 55 fish showed abnormally pale gills. Of the 1,433 salmon assessed, four ( 0.3%) were found to have a poor or incomplete fin clip. A total of three fish had some type of deformity, two of which had eroded pectoral fins (not uncommon for hatchery raised fish) and one that had a partial operculum. The percentage of salmon deformed within the sample group (0.2%) was within the normal range for hatchery-raised fish (S. Foott, Pers. com.).

A total of 19 mortalities were observed throughout the net pen experiments. Ten of these mortalities were observed in the pens immediately after the second Jersey Point release and were removed from the pens to avoid any possible contamination. The remaining nine mortalities were observed at the end of the 48-hour holding period, four at the first Durham release, one mortality at the first Jersey Point release, three at the second Durham release, and one at the second Mossdale release. There were no additional mortalities observed at the end of the 48-hour period at the second Jersey Point release. The higher incidence of pale gills and the observation of a few mortalities may indicate the juvenile salmon used as part of the VAMP experiments were under some level of stress.

*Comparison of Release Groups*

Results of previous salmon smolt survival studies have demonstrated a positive relationship between the length and condition of juvenile salmon and their survival. One of the underlying assumptions of the VAMP experimental design is that the length and condition of juvenile Chinook salmon released as part of the survival studies are comparable for fish released at Durham Ferry (treatment) and at Jersey Point (control). The experimental design also assumes that juvenile salmon released during the first set of studies each year are comparable in length and condition to the juvenile Chinook salmon in the second release group. Data on length, weight, and condition factor (length-weight relationship) developed from the sub-sample of fish collected for use in the net pen studies were used to test these underlying assumptions. For purposes of these statistical tests, data were selected from the sub-sample of fish measured at the time of release at both Durham Ferry and Jersey Point. If data was normally distributed, a t-test was used to determine if differences in sub-samples were significantly different. If data was not normally distributed, the non-parameter Mann-Whitney rank sum test was used. Results of these statistical comparisons of salmon released as part of the VAMP 2001 survival tests are summarized in Table 5-5.

Results of these tests showed statistically significant differences in both weight and condition factor in the first set of releases at Durham Ferry and Jersey Point. These statistically significant differences were also detected in the length of juvenile salmon released at Durham Ferry and Jersey Point during the second set of VAMP 2001 tests. Significant differences were also detected in both the length and weight of juvenile salmon released at Durham Ferry between the first and second release groups. Salmon were found to be significantly smaller (both length and weight) in the second set of VAMP 2001 releases at Durham Ferry. These statistical differences in size and condition among various test groups of salmon may or may not influence ultimate smolt survival to any meaningful degree. Future analysis of VAMP survival study results should take into account the potential affect of varying sizes of fish at the time of release at both Durham Ferry and Jersey Point as part of the overall analysis of survival study results.

## TABLE 5-5

### Statistical Analysis of the Size and Condition (Length-Weight Relationship) for Juvenile Chinook Salmon Released as Part of the VAMP 2001

| | DURHAM FERRY RELEASE 1 **MEAN** | JERSEY POINT RELEASE 1 **MEAN** | STATISTICAL TEST | PROBABILITY (P) | SIGNIFICANT DIFFERENCE |
|---|---|---|---|---|---|
| Length (mm) | 88.7 | 90.4 | t-test | 0.13 | No |
| Weight (g) | 7.3 | 7.9 | t-test | 0.03 | Yes |
| Condition factor | 2.6 | 2.1 | Mann-Whitney | 0.02 | Yes |
| | DURHAM FERRY RELEASE 2 **MEAN** | JERSEY POINT RELEASE 2 **MEAN** | STATISTICAL TEST | PROBABILITY (P) | SIGNIFICANT DIFFERENCE |
| Length (mm) | 84.6 | 87.8 | t-test | 0.03 | Yes |
| Weight (g) | 6.4 | 7.3 | t-test | 0.08 | No |
| Condition factor | 3.4 | 2.8 | t-test | 0.15 | No |
| | DURHAM FERRY RELEASE 1 **MEAN** | DURHAM FERRY RELEASE 2 **MEAN** | STATISTICAL TEST | PROBABILITY (P) | SIGNIFICANT DIFFERENCE |
| Length (mm) | 88.7 | 84.6 | t-test | 0.01 | Yes |
| Weight* (g) | 7.3 | 6.4 | t-test | 0.03 | Yes |
| Condition factor* | 2.6 | 3.4 | t-test | 0.08 | No |

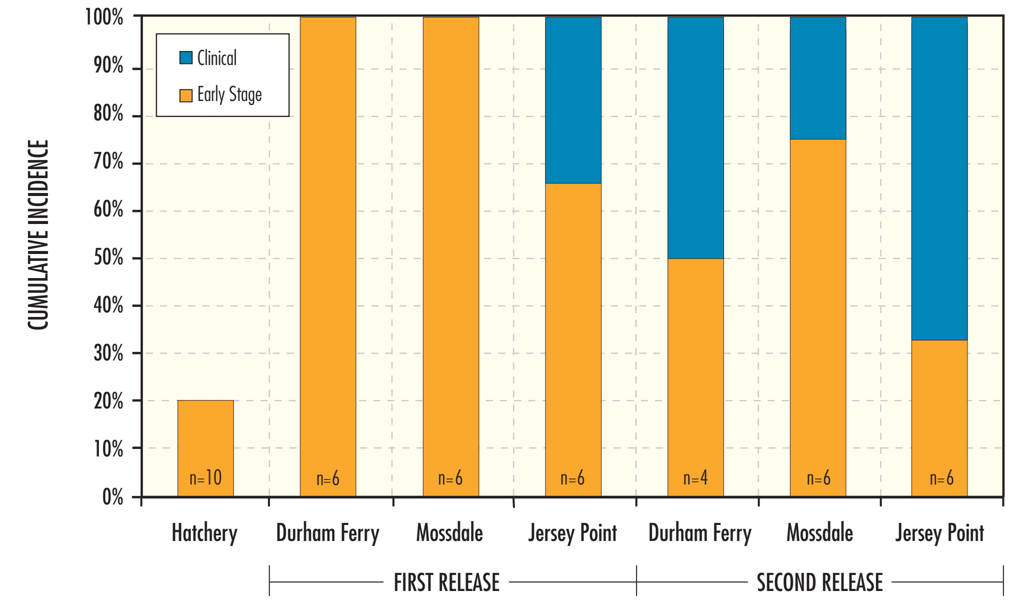
**NOTE:**
Analyses are based on measurements from net pen studies immediately following each release.

*Weight and condition factor were obtained on only 11 of 25 fish.

## FIGURE 5-5

### Incidence of Early Stage PKX infection (Early Stage) and Clinical Proliferative Kidney Disease (Clinical) in Posterior Kidney Samples.

*Early Stage indicates light presence of parasite, but no associated lesion. Clinical indicates presence of parasite with associated lesion likely impairing kidney function.*




*Tag Quality Control*

The subset of 25 salmon from each tag group (a total of 25 from each of the Durham Ferry releases) evaluated for condition as described above were sacrificed to verify purity of tag codes. The additional 200+ fish from each release that were held for condition and survival evaluations were archived in a freezer. Though rare, on few occasions in the past, salmon from different release groups have been mixed at some point prior to release. While performing quality control checks on the May 8 Mossdale releases, two errant tag codes were discovered. The remaining 210 tags were read to verify tag code purity. After reading all tags, it was determined that neither code was tainted. Upon further review, it appears that the original errant tag codes were the result of tags being lost and found, and not reported as lost, in the lab.

*Physiology*

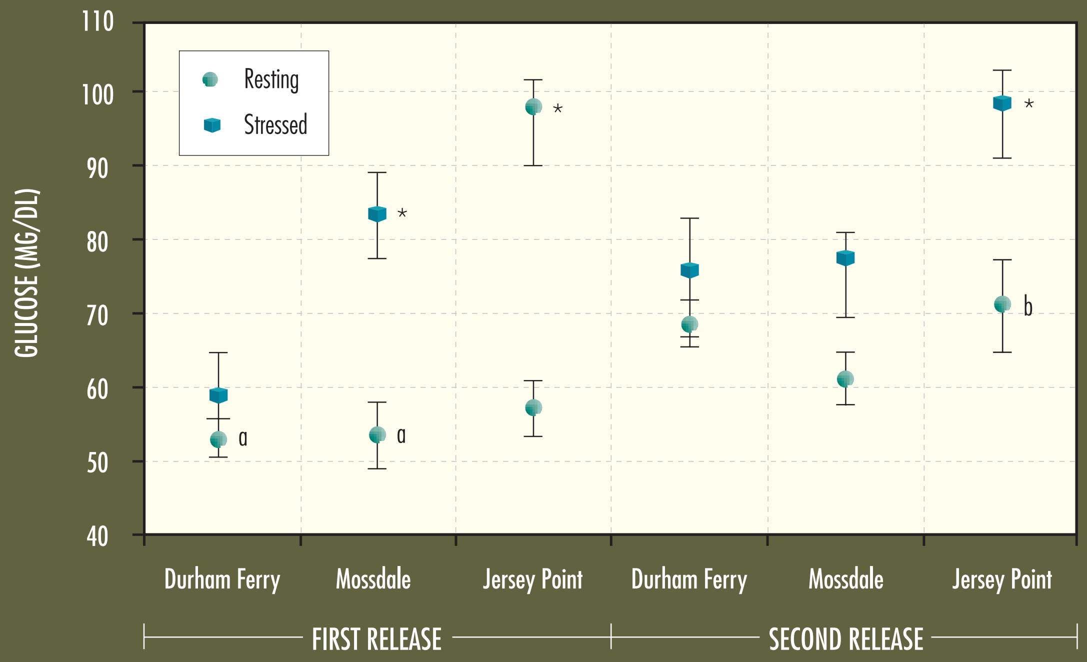
Physiological studies were conducted on a subset of the juvenile salmon used in the VAMP study by the USFWS California-Nevada Fish Health Center (Nichols et al. 2001). The results are briefly summarized below.

Physiological tests were conducted on a subset of the smolts released at Durham Ferry, Mossdale and Jersey Point after they had been held in the live cars for approximately 24 hours. Between 30 and 38 fish were sampled at each site. The fish were euthanized by an overdose of tricaine methane sulfonate (MS222), measured and assessed for external/internal abnormalities. Tissue samples were collected for pathogen and physiological assays. Kidney tissue was checked for bacterial pathogens. Internal organs were examined for parasites and abnormalities. Gill tissue was assayed for gill Na+, K+ - ATPase levels as an indicator of saltwater readiness (smolting). Plasma glucose and chloride levels were used to determine the ability of the fish to adapt to stress. Measurements were made with stressed and unstressed fish. The “unstressed” fish were removed from the net pen as quickly as possible and immediately euthanized. The stressed fish were held out of the water for 30 seconds, and sampled after they were allowed to recover for 30 minutes. To help establish baseline physiological conditions, sixty fish were sampled at random on April 9 from the Merced River Hatchery population. These fish were evaluated in terms of organosomatic analysis, ATPase levels, histology, bacteriology and virology. No stress physiology evaluation was conducted on the Merced River Hatchery fish. Results from the physiological tests indicated that the health of the release groups was poor and declined over time. No bacterial or viral pathogens were detected but infections of the PKX myxosporean parasite (the causative agent of Proliferative Kidney Disease) in the kidney were observed in 20% of Merced River Hatchery samples and 100% of all release groups (Figure 5-5). Infections had progressed to clinical disease in the first Jersey Point and all of the second set of release groups (Figure 5-5). Clinical signs of disease were evident during necropsy in 0-3% of the first release groups and 11-22% of the second release groups. Clinical signs of disease included pale gills, swollen kidney, and swollen spleen.

## FIGURE 5-6

**Resting and Stressed Plasma Glucose Concentrations in VAMP 2001 Release Groups.**

*Data given as Mean ± SE. Sample number is 12 for all groups except first Durham Ferry Resting (n=11).*

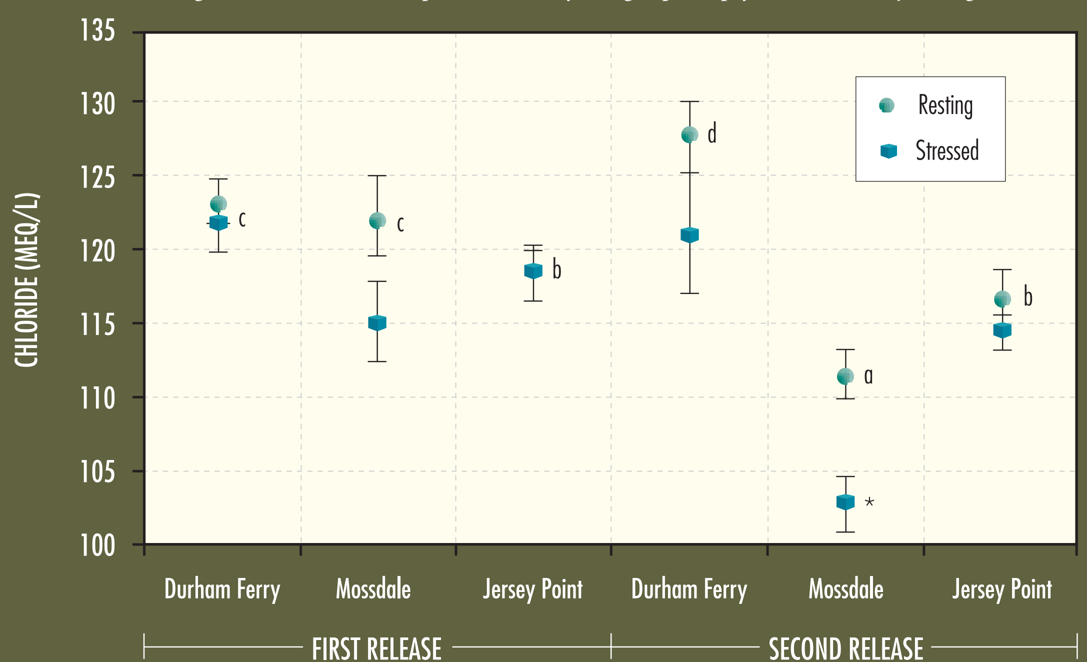



NOTES: * = difference between Resting and Stressed (P<0.05, t-test)
Resting levels labeled a are significantly lower than those labeled b (P<0.05, ANOVA)

## FIGURE 5-7

**Resting and Stressed Plasma Chloride Concentrations in VAMP 2001 Release Groups.**

*Data given as Mean += SE. Sample number is 12 for all groups except first Durham Ferry Resting (n=11).*




NOTES: * = difference between Resting and Stressed (P<0.05, t-test)
Resting levels labeled a are significantly lower than those labeled c or d (P<0.05)
Resting levels labeled b are significantly lower than those labeled d (P<0.05, ANOVA)



Stress treatments demonstrated healthy energy reserves in half of the release groups (Figure 5-6). Both Durham Ferry and the latter Mossdale groups either did not exhibit a significant glucose stress response or the stress treatment did not allow adequate time for the response to occur. The second Mossdale release demonstrated poor ion balance with low chloride values prior to stress and perilously low values following stress (Figure 5-7). Stress responses of fish from both Jersey Point releases were consistently different from the other groups. This difference was likely due to site conditions, and it was not evident if these differences would lead to increased or decreased survival.

In summary, all test groups showed signs of disease (not just infection) with the second set of release groups having a higher incidence of kidney disease. Stress response was not always healthy, but could have been due to holding conditions. Poor stress tolerance is also typical of PKX infections (Lom and Dyková 1995). Chronic PKX infection could desensitize the stress response of the fish making them more susceptible to the stress of transport and holding conditions.

It is possible that reduced health of the juvenile salmon used in the VAMP 2001 reduced their survival through the Delta. Possible bias in survival results due to reduced fish health was greater in the second set of releases and may be further confounded by exposure of these release groups to elevated water temperatures.

### CWT RECOVERY EFFORTS

CWT salmon were recaptured at Antioch and Chipps Island, at CVP and SWP fish salvage facilities and during sampling in upper Old River near the barrier (See Figure 1-1). CWT salmon released upstream of, and at, Mossdale were also recovered in DFG Kodiak trawls at Mossdale but are not discussed in this report. Juvenile Chinook salmon with an adipose fin clip (which identifies CWT salmon) caught at any of these sampling locations were sacrificed, labeled, and frozen pending CWT processing. Coded-wire tag processing was done by USFWS (Stockton) for fish recovered at Chipps Island, HORB, Antioch, and SWP/CVP salvage facilities.

Coded wire tag processing entails dissecting each tagged fish to obtain the half (0.5 millimeters) or full (1 millimeter) cylindrical tag from the snout. Most coded wire tags in 2001 were the newer generation decimal tags, which have the code imprinted several times on each tag, but the print is so small that the reading must be done under a microscope. Tags were read twice, with any discrepancies resolved by a third reader. All tags are archived for future reference. It should be noted that many tags recovered at Chipps Island, Antioch, SWP/CVP salvage, and other locations are from coded wire tag releases not affiliated with VAMP. Since the origin of the tag is unknown until after reading the tag, all tags recovered are read in order to identify the tag recoveries related to VAMP.

#### *SWP/CVP Salvage Recapture Sampling*

Sampling at the CVP and SWP fish salvage facilities was conducted approximately every two hours. The number of marked salmon collected (raw salvage) was "expanded" based on the number of minutes sampled during each two hour time period. The estimated expanded total number of CWT salmon, from each release group, was obtained by adding together the expanded number of each tag group for all time periods. Only the CWT salmon recovered in the raw salvage collections were sacrificed for tag decoding. Expanded salvage is only a portion of the direct loss experienced by juvenile salmon at the facilities as it does not include losses prior to, and associated with, pre-screen predation, screening, handling and trucking.

Expanded CVP and SWP salvage estimates of marked salmon released as part of the VAMP 2001 studies are shown in Table 5-3. Salvage numbers were low at both the SWP and CVP. These results are consistent with earlier studies showing that the HORB reduces the number of coded wire tagged salmon entrained at the fish facilities. It is interesting to note that 390 of the 25,000 coded wire tagged smolts released into upper Old River, were estimated to have been salvaged at the CVP. This is a much higher rate of salvage than for smolts released at Mossdale or Durham Ferry. It is likely that most of the salmon smolts released at Durham Ferry and Mossdale that were diverted into upper Old River were recovered and sacrificed in the fyke net sampling at the barrier. It is possible that a few of the recoveries at the CVP and SWP from the Durham Ferry and Mossdale releases could have been from smolts that migrated into upper Old River via the culverts that did not always have a fyke net attached (See Chapter 4).

Once in upper Old River these fish could have migrated downstream to the facilities. It is also possible that the smolts migrated back to the CVP and SWP via Turner or Columbia Cuts or river junctions off the San Joaquin River further downstream.

*Antioch Recapture Sampling*

Fishery sampling was conducted in the vicinity of Antioch on the lower San Joaquin River using a Kodiak trawl. The Kodiak trawl has a graded stretch mesh, from 2-inch mesh at the mouth to ½-inch mesh at the cod-end. Its overall length is 65 feet, and the mouth opening is six feet deep and 25 feet wide. The net was towed between two skiffs, sampling in an upstream direction. Trawls were performed parallel to the left bank, mid-channel, and right bank to sample CWT salmon emigrating from the San Joaquin River. Each sample was approximately 20 minutes in duration.

All fish collected were transferred immediately from the Kodiak trawl to buckets filled with river water, where the fish were held during processing. Data collected during each trawl included identification and measuring the fork length of fish collected, tow start time and duration and location in the channel. Mortality and damage to fish collected was documented to comply with the Endangered Species Act permit requirements.

Juvenile Chinook salmon with an adipose fin clip were retained for later CWT processing while unmarked salmon, steelhead, Delta smelt, splittail, and other fish were released at a location downstream of the sampling site immediately after identification, enumeration and measurement.

Sampling at Antioch was initiated May 1 and continued through May 25. Each day between 5:00 a.m. and 9:00 p.m., anywhere from 13 to 30, 20-minute tows were conducted. All told, 580 Kodiak trawl samples were collected, representing a total sampling duration of 11,545 minutes. During the sampling, a total of 6,373 unmarked juvenile Chinook salmon and 1,285 salmon with an adipose fin clip (CWT) were collected. In addition, 821 Delta smelt, 188 splittail, and 28 steelhead were caught in the sampling.

*Chipps Island Recapture Sampling*

As part of VAMP recovery efforts at Chipps Island, trawling was conducted daily between April 30 and June 19. This included at a minimum, a regular schedule of ten, 20-minute tows beginning at about 7:00 am each day, and ending about noon. Between May 3 and June 2, the effort was increased by adding a second shift of trawling in the afternoon/evening, bringing the trawling effort up to twenty, 20-minute tows per day. On these days the first shift was begun at dawn, while the second shift ended at or after sunset, to incorporate the crepuscular periods of Chinook movement. It is hypothesized, based on an analysis of salmon smolts caught during twenty-four hour sampling at Jersey Point in 1997, that a greater number of salmon would be caught around dawn and dusk. Both targeting this crepuscular period and doubling the total trawl effort at Chipps Island were intended to increase the numbers of CWT salmon recaptured and reduce the variability in VAMP survival indices. This second shift was also conducted in 1998, 1999, and 2000.

The trawl at Chipps Island was towed at the surface using a net with a mouth opening 10 feet deep by 30 feet wide, with a total net length of 82 feet. Aluminum hydrofoils were used on the top bridles and steel depressors along with a weighted lead line were used on the bottom bridles to keep the mouth of the net open. The net was variable mesh net starting with 4-inch mesh at the mouth and ending with a ¼-inch cod end.

To sample across the channel, trawling at Chipps Island was conducted in three distinct lanes, one each in the north, south and middle of the channel. Each lane was generally sampled at least three times per shift, with one lane sampled a fourth time during each shift. This lane was chosen at random or selected by the boat operator based on flow conditions.

Coded wire tagged salmon released as part of the VAMP program were recovered at Chipps Island between May 3 and June 2. A total of 256 CWT salmon were recovered at Chipps Island from the VAMP study. During the May 3 through June 2 VAMP recovery period, a total of 7,592 unmarked salmon, 574 CWT salmon from other non VAMP experiments, 165 Delta smelt, 360 Sacramento splittail, 4 clipped steelhead and 14 non-clipped steelhead were also collected at Chipps Island.

## VAMP Chinook Salmon CWT Survival Indices

Survival indices were calculated for marked salmon released at Durham Ferry, Mossdale, and Jersey Point and recovered at Antioch and Chipps Island. Survival indices were calculated by dividing the number of CWT salmon recovered by the effective number released and the fraction of time and channel width sampled. The fraction of the channel width sampled at Chipps Island (0.00769) was the net width (30 feet) divided by an estimate of the channel width (3900 feet). The fraction of the channel width sampled at Antioch (0.01388) was based on the net width (25 feet) used there and an estimate of the channel width (1,800 feet). The fraction of time sampled, at both locations, was calculated based on the number of minutes sampled, between the first and last day of catching each particular tag code or group, divided by the total number of minutes in the time period. The percent of time sampled for the VAMP 2001 release groups at Chipps Island was about 28 percent, while at Antioch it ranged between 35 and 40 percent.

Survival indices were calculated for each separate tag code to provide a sense of the variability associated with the overall group survival index. To generate the group survival index, the recovery numbers and release numbers are combined for the tag codes within a release group. This results in a slightly different index than would be generated by taking the mean of the survival indices of the individual tag codes within a group.

The individual and group survival indices to Antioch and Chipps Island of the CWT salmon released as part of VAMP 2001 are shown in Table 5-3. As in 2000, survival indices from the release locations to Antioch were sometimes lower than those at Chipps Island. It is expected that indices to Antioch would be greater than those to Chipps Island since Antioch is closer to the release locations than Chipps Island. Lower survival indices to Antioch may be a result of the marked salmon not being equally distributed or vulnerable to the trawls throughout the 24-hour period and the expansions for effort may be biasing the Chipps Island estimates high.

Differences between release groups were also evaluated statistically by comparing the recapture rates (the number recaptured divided by the number released) at Antioch or Chipps Island.

The first and second Durham Ferry releases had survival indices to Antioch of 0.20 and 0.08, respectively. Survival indices to Chipps Island were 0.36 and 0.06. The individual tag code survival indices at Antioch and Chipps Island did not overlap and there appeared to be a difference in survival between the first and second Durham Ferry groups. Results of statistical analysis of the Durham Ferry data showed that the proportion of CWT salmon recaptured from the second group was significantly lower ($P < 0.05$) than the proportion recovered from the first release group using the recovery information at both Antioch and Chipps Island.

The two Mossdale releases showed similar differences between the first and second releases. The first releases had survival indices to Antioch of 0.13 and 0.07 respectively and 0.32 and 0.08 to Chipps Island. Again none of the individual tag code survival indices overlapped between groups indicating a real difference between the two groups. Differences in the proportion of CWT salmon recaptured were statistically significant ($P < 0.05$) based on sampling at Chipps Island. Differences in the proportion recaptured based on sampling at Antioch were not significantly different between the first and second releases.

Similarly, the two Jersey Point groups also appeared to survive at different rates; with the first group surviving at a higher rate than the second. The first group released on May 4 had a survival index to Antioch of 1.23. The second group released on May 11 had an index to Antioch of 0.38. Chipps Island recoveries demonstrated the same apparent difference between groups with the first group having an index of 1.06 and the second group having an index of 0.40. Differences in proportion of CWT salmon recaptured were statistically significant at both recapture locations.

Why survival was so much lower for the second group (releases at Durham Ferry, Mossdale, and Jersey Point), relative to the first group is unknown. Flow and export conditions were similar for both groups. Water temperatures increased for some of the releases in the second group and likely contributed to the lower survival. A higher prevalence of PKD (Proliferative Kidney Disease) was also observed in the second set of releases in the physiological studies. Results of the net pen studies indicated a low level of mortality for all release groups, however it was not apparent that the second group had higher mortality in the net pens than the first group.

As part of the VAMP 2001 experimental design, releases were made at both Mossdale and Durham Ferry to determine how survival differed between these two locations. Results of the releases at Durham Ferry on April 30 and May 7 and Mossdale on May 1 and May 8, indicated survival from Durham Ferry and Mossdale was similar in 2001 even though Durham Ferry is 11 miles further upstream than Mossdale. Although the Durham Ferry group may have survived slightly better, indices were variable enough such that there was likely no real difference between the groups. No statistically significant ($P > 0.05$) difference in the proportion of CWT salmon recaptured was detected among salmon released at Durham Ferry and Mossdale based on recaptures at both Antioch and Chipps Island.

More important than the relative survival indices between locations are comparisons of survival indices within the same recovery location and the trends between the groups using the two recovery locations. The use of absolute survival estimates, where the survival index of the upstream release group is divided by the survival index of the downstream group (recovered at the same location), is most useful for within and between recovery locations and year comparisons.

### ABSOLUTE CHINOOK SALMON SURVIVAL ESTIMATES

Absolute survival rates were estimated using the ratio of the survival indices of smolts released at Durham Ferry and Mossdale in relation to those released at Jersey Point. These absolute survival estimates are more powerful for use in comparing survival rates, since the use of ratios between upstream and downstream groups theoretically standardizes for differences in catch efficiency between recovery locations and years. Two independent estimates of absolute survival have been calculated for the VAMP 2001 releases using recoveries at both Antioch and Chipps Island. An additional estimate of absolute survival will be possible from recoveries in the ocean fishery, 2 to 4 years following release. Absolute survival estimates for VAMP 2001 are shown in Table 5-3.

Statistical differences between groups, was also assessed based upon the ratio of CWT salmon released and recaptured from Durham Ferry and Mossdale relative to the proportion of CWT salmon released and recaptured from the downstream Jersey Point (control) releases.

Although the relative survival indices indicated that the first groups released survived at a higher rate than the second group, the absolute estimates of survival appear to give conflicting results. Survival between Durham Ferry and Mossdale and Jersey Point for the first group, was higher than the second group using Chipps Island recovery information. It was similar between the first and second releases using the Antioch recovery information. Differences in the proportions of recovery rates among the two test groups from Durham Ferry relative to Jersey Point groups were not found to be statistically significant based on sampling at Antioch. However, there was a statistically significant difference between the proportions of the two Durham Ferry releases relative to the Jersey Point controls using Chipps Island recovery information.

Differences in the proportion recovered of the combined Durham Ferry releases and the combined Mossdale releases were not found to be statistically significant ($p>0.05$) with recoveries from either sampling location.

Survival estimates in 2000 did appear less for the Durham Ferry group than the Mossdale group using recovery information at Antioch. This difference led to the recommendation of making releases at both Durham Ferry and Mossdale in 2001. Additional releases may be needed to fully understand if differences between these two groups are meaningful.

An alternative method for estimating survival from Durham Ferry to Mossdale and Mossdale to Jersey Point was developed by Dr. Ken Newman (See Chapter 6) based on the ratio of marked salmon recaptured from upstream and downstream release sites. Using this alternative calculation method, survival between Durham Ferry and Mossdale was 1.33 and 0.96 for the first and second groups, respectively. Since it is impossible to have over 100% survival between Durham Ferry and Mossdale, these data appear to show that survival was either very high between the two locations, or that the first group of smolts released at Durham Ferry survived at a higher rate than the first group released at Mossdale for some unknown reason. Survival between Mossdale and Jersey Point was 0.16 and 0.20 for the first and second groups released, respectively.

Variance and standard errors were also calculated based on the Delta method provided by Dr. Newman. The estimates of survival, plus or minus two standard errors, is roughly equivalent to the 95% confidence intervals. These confidence intervals are provided in Table 5-6 showing that there is a substantial variability around the survival estimates and that replicates (Durham Ferry to Mossdale and Mossdale to Jersey Point) were not significantly different from each other. These findings are not consistent with results of the statistical analysis using proportions that showed, when using Chipps Island data alone, that the survival rates for the first release groups were higher than the second.

*Transit Time*

Data on transit times for marked salmon from the release to recapture sites during VAMP 2001 is summarized in tabular and graphic form in Appendix C-4. CWT salmon released April 30 at Durham Ferry took between 5 and 11 days to arrive at Antioch and Chipps Island. The May 1 Mossdale release took between 4 and 11 days to arrive at Antioch and Chipps Island. Jersey Point release groups were recovered between 0 and 10 days after release at Antioch and between 1 and 7 days at Chipps Island. The May 7 Durham Ferry release group arrived at Antioch between 4 and 15 days and between 5 and 13 days at Chipps Island. The May 8 release group at Mossdale was recovered at Antioch between 4 and 12 days and between 5 and 10 days at Chipps Island. The second Jersey Point release group was recovered between 1 and 12 days after release at Antioch and 1 and 11 days after release at Chipps Island. The transit time from release location to Antioch and Chipps Island of both sets of releases was similar. The number of individual recoveries by tag code and the number of minutes towed per day for both Antioch and Chipps Island recoveries are shown in Appendix C-4.

## TABLE 5-6

**Estimates of Survival Between Durham Ferry and Mossdale (S DF TO MD) and Between Mossdale and Jersey Point (S MD TO JP), and Survival Minus (S-2se) and Plus (S +2se) two Standard Errors.**

| | REC. AT ANTIOCH | REC. AT CL | # RELEASED | A+C | A+C/R | S DF TO MD | S MD TO JP | S–2SD | S+2SD |
|---|---|---|---|---|---|---|---|---|---|
| Durham 1 | 28 | 14 | 23,354 | 42 | 0.001798407 | | | | |
| | 30 | 22 | 22,837 | 52 | 0.002277007 | | | | |
| | 18 | 17 | 22,491 | 35 | 0.001556178 | | | | |
| | 76 | 53 | 68,682 | 129 | 0.001878221 | 1.33 | | 1.12 | 1.53 |
| MD 1 | 18 | 17 | 23,000 | 35 | 0.001521739 | | | | |
| | 15 | 14 | 22,177 | 29 | 0.001307661 | | | | |
| | 33 | 31 | 45,177 | 64 | 0.00141665 | | 0.16 | -0.13 | 0.45 |
| JP 1 | 156 | 50 | 24,443 | 206 | 0.008427771 | | | | |
| | 173 | 61 | 24,992 | 234 | 0.009362996 | | | | |
| | 329 | 111 | 49,435 | 440 | 0.008900577 | | | | |
| Durham 2 | 8 | 2 | 24,025 | 10 | 0.000416233 | | | | |
| | 11 | 5 | 24,029 | 16 | 0.000665862 | | | | |
| | 10 | 2 | 24,177 | 12 | 0.000496339 | | | | |
| | 29 | 8 | 72,231 | 38 | | 0.96 | | 0.74 | 1.17 |
| MD 2 | 8 | 4 | 23,878 | 12 | 0.000502555 | | | | |
| | 11 | 4 | 25,308 | 15 | 0.000592698 | | | | |
| | 19 | 8 | 49,186 | 27 | 0.000548937 | | 0.20 | 0.00 | 0.40 |
| JP 2 | 43 | 17 | 25,909 | 60 | 0.002315798 | | | | |
| | 53 | 27 | 25,465 | 80 | 0.003141567 | | | | |
| | 96 | 44 | 51,374 | 140 | 0.002725114 | | | | |

## TABLE 5-7

**Absolute Survival Estimates for VAMP Survival Studies**

| | VAMP 2000 | | VAMP 2001 | |
|---|---|---|---|---|
| Vernalis Flow (cfs) | 5,869 | | 4,220 | |
| SWP/CVP exports (cfs) | 2,155 | | 1,420 | |
| Durham Ferry Survival | Release 1 | Release 2 | Release 1 | Release 2 |
| Antioch | 0.20 | 0.14 | 0.17 | 0.20 |
| Chipps Island | 0.31 | 0.19 | 0.34 | 0.14 |
| Mossdale Survival | Release 1 | Release 2 | Release 1 | Release 2 |
| Antioch | 0.34 | – | 0.11 | 0.18 |
| Chipps Island | 0.31 | – | 0.31 | 0.19 |



***Role of Flow and Exports on Absolute Survival***

Survival of juvenile Chinook salmon emigrating from the San Joaquin River system has been evaluated within the framework established by the VAMP experimental design during 2000 and 2001. Absolute survival estimates from these studies are summarized in Table 5-7 for the two San Joaquin River flow-export conditions tested.

Results of statistical analysis of these two years of data showed that the proportion of CWT salmon recovered were not significantly different (P > 0.05) from the combined Durham Ferry and Mossdale groups relative to the Jersey Point groups under the two flow-export conditions tested during VAMP 2000 and 2001. Given the relatively high variability inherent in conducting salmon smolt survival studies within the lower San Joaquin River and Delta, the lack of statistically significant differences in survival estimates between the two relatively close flow-export conditions tested was not unexpected. Results of these analysis underscore the importance of collecting salmon smolt survival data under the most extreme flow-export conditions identified as VAMP targets. The greater the separation between flow and export condition among tests, the greater the ability of these survival studies to detect the true effects of flow and/or export rate on juvenile Chinook salmon survival.

*The transit time from release location to Antioch and Chipps Island of both sets of releases was similar.*

The U.S. Fish and Wildlife Service has conducted a number of previous investigations on the effects of San Joaquin River flow and export conditions on juvenile Chinook salmon survival. Although these previous studies vary somewhat from the experimental design established by VAMP, results of these tests provide a useful context and foundation for evaluating and interpreting survival information collected as part of the VAMP investigations (San Joaquin River Group Authority 2000 Annual Technical Report and Appendix D).

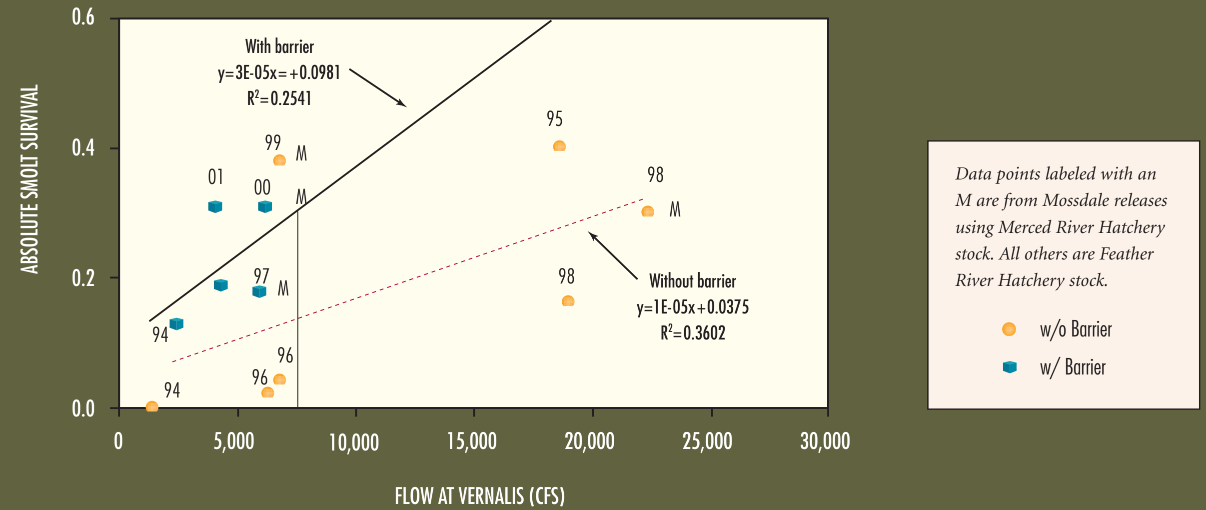
Survival estimates from Mossdale to Jersey Point (obtained using Chipps Island recovery information) gathered in 2001 are compared with past years survival data in Table 5-8. The absolute survival estimates obtained from the first groups in 2001 are similar to those obtained during the VAMP 2000 investigations and are relatively high in comparison to survival estimates from similar studies starting in 1994. Only 1999 and 1995 had higher absolute survival estimates between Mossdale and Jersey Point than those obtained in 2000 and for the first groups of 2001. Releases in 1995 were from Feather River Hatchery origin Chinook salmon, which have been shown to survive at lower levels than salmon from the Merced River Hatchery – thus the estimate in 1995 may be biased low. In contrast, data collected in 1999 is thought to be biased (high), based on potentially low recovery of Jersey Point released fish.

As in 2000, comparative releases in 2001 of CWT salmon were made at both Mossdale and Durham Ferry. Prior to 2000, all upstream releases had been made at Mossdale. Using the past data will help in evaluating the effects of SWP and CVP exports and San Joaquin River flow on salmon survival. If the survival estimates from the two release locations were found to be significantly different, then using only Durham Ferry releases would increase the number of years needed to complete the VAMP study. Results in 2001 indicated that survival was not significantly different for salmon smolts released at Durham Ferry and Mossdale and that the absolute survival between the two locations was relatively high.

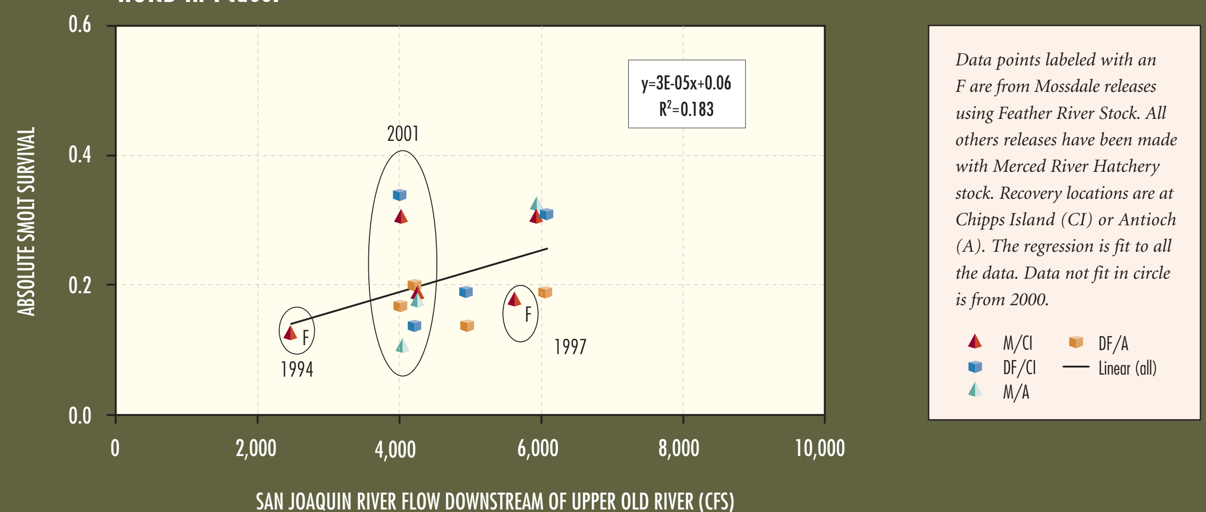
The relationship to date between absolute survival estimates between Mossdale and Jersey Point and San Joaquin River flow at Vernalis is shown in Figure 5-8. Linear regression analyses were used to assess the potential relationship between absolute survival estimates and river flow at Vernalis. Two regression lines have been developed based on survival data with and without the HORB. The barrier can not be installed and operated at flows greater than 7000 cfs. Statistically neither regression line is significant, although prior to adding the data from 1999, the without barrier relationship was significant ($R^2 = 0.75$, $P = 0.25$).

Figure 5-9 shows the relationship between absolute salmon smolt survival and flow with the HORB, but uses estimated net flow on the San Joaquin River downstream of upper Old River instead of the flow at Vernalis. Because the HORB has had different permeability (culvert operations) over the years, the estimated flow in the San Joaquin River downstream of upper Old River has been used to better reflect the river flow the juvenile salmon experience as they migrate down the San Joaquin River. This estimate is calculated by subtracting the estimated mean daily flow in upper Old River 840 feet downstream of the barrier from the USGS gauged mean daily flow at Vernalis. Figure 5-9 also includes survival estimates between Mossdale (and Durham Ferry) and Jersey Point using recovery information from the Antioch sampling. There is substantial variability at any one flow level based on this combined data from the variety of sources (Antioch and Chipps recoveries, Mossdale and Durham Ferry releases). Variation in estimates of survival

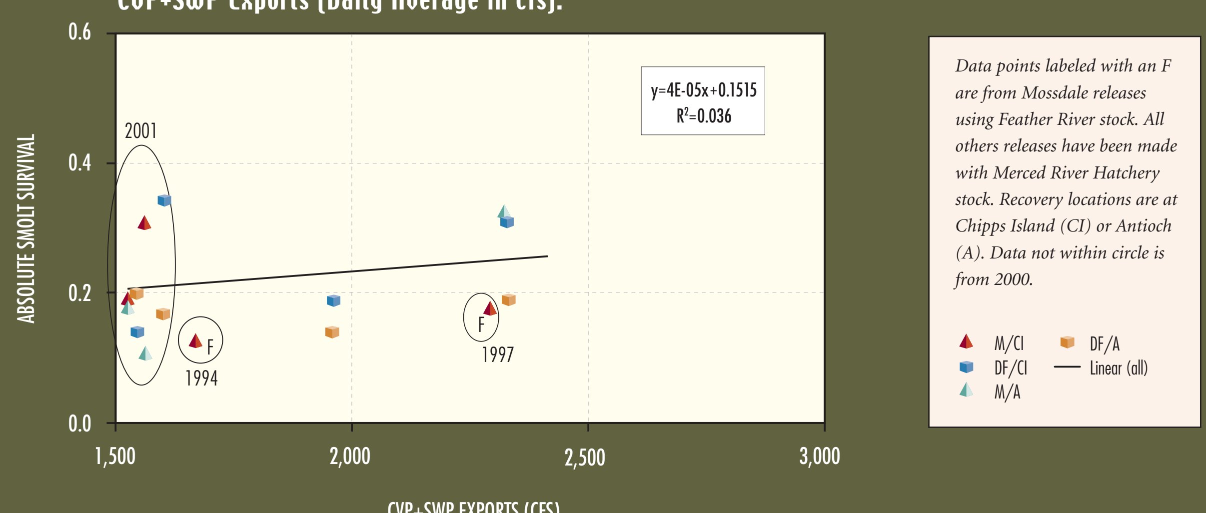
## FIGURE 5-8 Absolute Smolt Survival Between Mossdale and Jersey Point and San Joaquin River Flow at Vernalis, With and Without the HORB.




## FIGURE 5-9 Absolute Smolt Survival Between Mossdale (M)/Durham Ferry (DF) and Jersey Point and River Flow on the San Joaquin River Downstream of the Upper Old River With the HORB in Place.




## FIGURE 5-10 Absolute Smolt Survival Between Mossdale/Durham Ferry (DF) and Jersey Point and CVP+SWP Exports (Daily Average in cfs).




## TABLE 5-8
### Smolt Survival Data for Smolts Released at Mossdale, Durham Ferry (DF) and Jersey Point Between 1994 and 2000.

| YEAR | SURVIVAL INDEX | # FISH RECOV-ERED | RELEASE TEMP | SIZE AT RELEASE | SURVIVAL INDEX | # FISH RECOV-ERED | RELEASE TEMP | SIZE AT RELEASE | HATCHERY STOCK | RATIO | SJR FLOW DOWN-STREAM OF OLD RIVER (CFS) | FLOW AT VERNALIS | CVP+SWP EXPORTS | BARRIER STATUS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mossdale | | | | Jersey Point | | | | | | | | | |
| 1994 | 0 | 0 | 63 | 74 | 0.18 | 10 | 64 | 72 | FRH | 0.00 | 437 | 1,387 | 1,268 | no barrier |
| 1994 | 0.04 | 2 | 60 | 77 | 0.28 | 16 | 63 | 78 | FRH | 0.13 | 2,468 | 2,468 | 1,671 | barrier |
| 1995 | 0.19 | 20 | 57 | 70 | 0.48 | 26 | 60 | 70 | FRH | 0.40 | 7,363 | 18,450 | 3,666 | no barrier |
| 1996 | 0.02 | 2 | 59.5 | 78 | 0.5 | 25 | 62 | 78 | FRH | 0.04 | 2,631 | 6,673 | 1,651 | no barrier |
| 1996 | 0.01 | 1 | 64 | 81 | 0.45 | 24 | 64 | 87 | FRH | 0.02 | 2,475 | 6,269 | 1,517 | no barrier |
| 1997 | 0.19 | 10 | 60 | 100 | 1.03 | 55 | 63 | 99 | FRH | 0.18 | 5,605 | 5,905 | 2,302 | barrier (with 2 culverts) |
| 1998 | 0.1 | 7 | 66 | 84 | 0.63 | 40 | 66 | 78 | FRH | 0.16 | 7,692 | 18,850 | 2,004 | no barrier |
| 1998 | 0.56 | 88 | 57 | 86 | 1.84 | 187 | 62 | 89 | MRFF | 0.30 | 9,140 | 22,220 | 1,616 | no barrier |
| 1999 | 0.28 | 36 | 62 | 79 | 0.73 | 59 | 63 | 81 | MRFF | 0.38 | 3,161 | 6,762 | 3,161 | no barrier |
| 2000 | 0.19 | 18 | 56 | 79 | 0.62 | 65 | 64 | 82 | MRFF | 0.31 | 5,936 | 6,196 | 2,332 | barrier (with 2 open culverts |
| 2000 | 0.19 (DF) | 28 | 57 | 80 | 0.62 | 65 | 64 | 82 | MRFF | 0.31 | 6,077 | 6,339 | 2,335 | barrier (with 2 open culverts) |
| 2000 | 0.15 (DF) | 22 | 62 | 77 | 0.78 | 78 | 63 | 77 | MRFF | 0.19 | 4,959 | 5,702 | 1,964 | barrier (with 4 open culverts) |
| 2001 | 0.32 | 31 | 67 | 91 | 1.06 | 111 | 68 | 88 | MRFF | 0.31 | 4,011 | 4,126 | 1,567 | barrier (with 6 culverts open) |
| 2001 | 0.36 (DF) | 53 | 70 | 89 | 1.06 | 111 | 68 | 88 | MRFF | 0.34 | 4,013 | 4,125 | 1,609 | barrier (with 6 culverts open) |
| 2001 | 0.076 | 8 | 69.8 | 88.5 | 0.4 | 44 | 72.5 | 87.5 | MRFF | 0.19 | 4,225 | 4,337 | 1,529 | barrier (with 6 culverts open) |
| 2001 | 0.052 (DF) | 9 | 66.2 | 85 | 0.4 | 44 | 72.5 | 87.5 | MRFF | 0.13 | 4,206 | 4,297 | 1,548 | barrier (with 6 culverts open) |

between the two recovery locations (Antioch and Chipps Island) adds a level of uncertainty to the survival investigations, however, the benefit of having two rather than only one survival estimate per year is of major value.

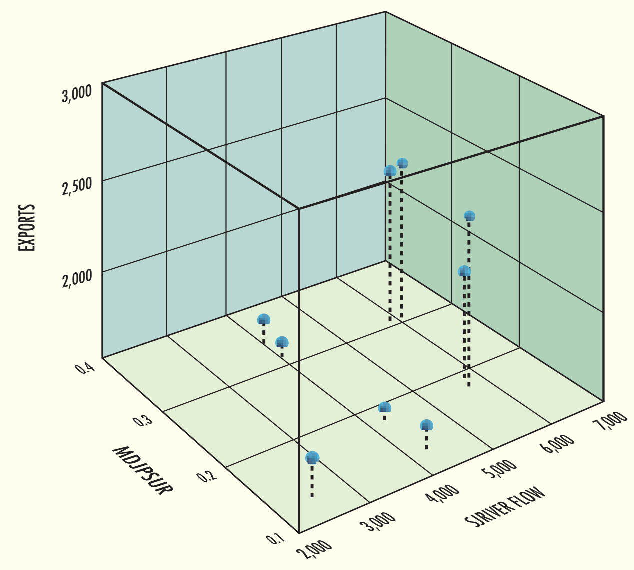
Figure 5-10 shows salmon smolt survival regressed against averaged CVP+SWP exports for the 10 days after release. The 10-day averaging period used in these analysis has been based on expected exposure periods during emigration as reflected in transit time estimates to the Antioch and Chipps Island recovery locations. In 2000, it was reported that absolute salmon survival appeared to increase as exports increased from 1600 to 2300 cfs. With the addition of the 2001 data the positive relationship between exports in this range and survival is less apparent. There is so much variability in the various estimates that a relationship is not clear.

Evaluating the role of SWP and CVP exports, the HORB, and flow on salmon smolt survival through the south Delta are key elements of VAMP. Presence of the HORB affects both the emigration route of salmon smolts and hydraulic conditions in the lower San Joaquin River and Delta that are thought to alter the vulnerability of juvenile salmon to export-related effects.

Figure 5-11 shows the relationship between salmon survival (between Mossdale and Jersey Point using survival estimates derived from Chipps Island recoveries), San Joaquin River flow downstream of upper Old River and SWP/CVP exports with the HORB in place. It appears that as flows increase, survival increases. High survival has been observed with lower (1,500 cfs) and somewhat higher exports (2,300 cfs).

## FIGURE 5-11

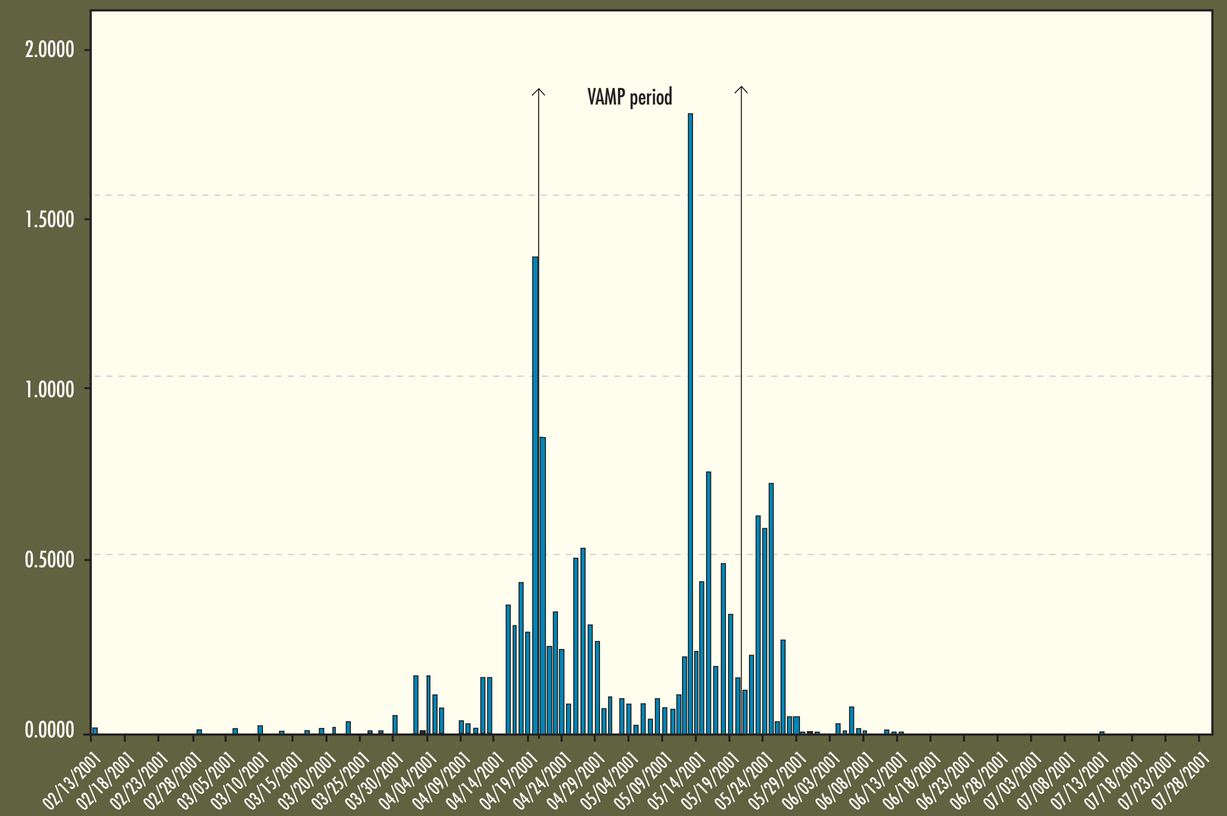
**Survival from Mossdale to Jersey Point (MDJPSUR) Versus San Joaquin Flow Downstream of Upper Old River (SJRIVERFLOW) and Average Daily Combined CVP+SWP Exports (EXPORTS).**




## FIGURE 5-12

**Average Catch/minute/day of all Non-clipped Chinook Per Day Captured in the Mossdale Kodiak Trawl Between February 13, 2001, and July 31, 2001.**

*Up to 20 tows per day were conducted between April 24, 2001, and May 28, 2001.*






The separate roles of SWP and CVP exports and San Joaquin River flow with the HORB in place is difficult to determine at this time as a result of (1) the few survival studies completed with the HORB in place; (2) variable permeability of the barrier within and among years, and 3) the lack of measuring survival at the extremes of the VAMP flow and export targets. Releases at both Mossdale and Jersey Point have only been made in four years when the HORB was in place. Also, during those four years the barrier design and permeability has changed. In 1994, the HORB was installed without culverts, while in 1997 the barrier had two open culverts that diverted approximately 300 cfs into upper Old River. In 2000, the HORB had six gated culverts, with two open during the Mossdale and first Durham Ferry release and four open during the second Durham Ferry release. In 2001, six culverts were installed and operated throughout the VAMP test period. The varying designs and changes in the culvert operations of the barrier add variability to the limited data, making it more difficult to detect the effects of flow and exports on salmon survival.

In the four years of measuring survival with the barrier in place, average total combined CVP/SWP exports have varied between 1,500 and 2,300 cfs. This is only an 800 cfs difference in exports—a relatively small difference in export rates. No data has been generated with the barrier at exports of 3,000 cfs—the highest export level under the VAMP targets. Gathering data at a 3000 cfs export level may help us further our understanding of the relationship between exports, with the barrier in upper Old River, and juvenile salmon smolt survival. Measuring survival with flows at 7,000 cfs and 3,200 cfs would also help for the same reasons. Future studies should prioritize, to the extent possible, VAMP target levels to be tested at 3,000 cfs exports and 7,000 cfs flow, and 1,500 cfs exports with 3,200 cfs and 7,000 cfs flow. Focusing our survival experiments on these extremes within the VAMP design will enable us to better determine the role of flow and export on salmon smolt survival.

Definitive conclusions about the respective roles of flow and exports on salmon smolt survival are not possible from the VAMP data at this time. It is recommended that further evaluation of VAMP 2000 and 2001 results occur prior to determining the study plan for VAMP 2002. It is also recommended that VAMP experiments continue. Results of these future studies will provide information to make the most appropriate management decisions to protect salmon smolts emigrating from the San Joaquin River basin.

### OCEAN RECOVERY INFORMATION FROM PAST YEARS

Ocean recovery data of CWT salmon groups can contribute to a more complete understanding and evaluation of salmon smolt survival studies. These data can provide another independent estimate of the ratio of survival of a test release group relative to a control release group, or "absolute survival", and can be compared with estimates based on juvenile salmon recoveries at Chipps Island and Antioch. Past recoveries at Jersey Point (1997–1999) can not be compared since the Jersey Point trawling site was located upstream of the Jersey Point release site and a ratio between the upstream and downstream sites can not be generated. The ocean harvest data may be particularly reliable due to the number of tag recoveries and the extended recovery period.

Adult recovery data are gathered from commercial and sport ocean harvest checked at various ports by DFG. The Pacific States Marine Fisheries Commission maintains the database of ocean recovery CWT data, which is current through 2000. The ocean CWT recovery data are usually recorded over a 1-4 year period after the year a study release is made as nearly all of a given year class of salmon have either been harvested or spawned by age 5. Consequently, these data are essentially complete for releases made through 1996 and partially available for CWT releases made through 1999, prior to the VAMP evaluations starting in 2000.

Survival estimates based on ocean recoveries for salmon produced at the Merced River Hatchery, and released as part of south Delta survival evaluations, were compared to survival estimates based on Chipps Island recoveries (Table 5-9). Releases were made at Dos Reis (on the San Joaquin River downstream of the upper Old River junction), Mossdale, and Jersey Point. Survival estimates are based on Mossdale or Dos Reis recovery rates relative to the Jersey Point recovery rates. Ocean absolute survival ratios were very similar to those at Chipps Island for the releases made in 1996 and 1999. And although ocean absolute survival ratios were higher than those to Chipps Island for releases in 1997 and 1998, they were generally similar (in the mid-range of survival). The ocean recovery data is incomplete for the 1997-99 releases. No data is yet available for releases made in 2000 and recovered at Chipps Island as well as Antioch. Once the data for these releases and for future releases is available it will be used to compare the three independent estimates of survival (using Antioch, Chipps Island and ocean recoveries).

Results of these comparative analysis of survival estimates for Chinook salmon produced in the Merced River Hatchery show (1) there is generally good agreement between survival estimates based on juvenile CWT salmon recoveries in Chipps Island trawling and adult recoveries from the ocean fishery, (2) survival estimates using Chipps Island recoveries were lower in some years than estimates based on ocean recoveries, and (3) additional comparisons need to be made, as data becomes available from VAMP releases, for recoveries at Antioch, Chipps Island, and the ocean fishery. Information on survival of juvenile salmon and the contribution to the adult salmon population will be valuable in evaluating the biological benefits of changes in flow and export rates under VAMP.

## TABLE 5-9

**Survival Estimates Based on Chipps Island and Ocean Recoveries of Merced River Hatchery Salmon Released as Part of South Delta Studies Between 1996 and 1999.**

| RELEASE YEAR | SAN JOAQUIN RIVER *(Merced River Origin)* TAG NO. | RELEASE NUMBER | RELEASE SITE | RELEASE DATE | CHIPPS IS. RECOVS. | EXPANDED ADULT OCEAN RECOVS. (AGE 1+ TO 4+) TOTAL | CHIPPS ISLAND | OCEAN CATCH |
|---|---|---|---|---|---|---|---|---|
| | | Juvenile Salmon CWT Releases | | | | | | |
| 1996 | H61110412 | 25,633 | DOS REIS | 01MAY96 | 2 | 3 | | |
| | H61110413 | 28,192 | DOS REIS | 01MAY96 | 3 | 37 | | |
| | H61110414 | 18,533 | DOS REIS | 01MAY96 | 1 | 8 | | |
| | H61110415 | 36,037 | DOS REIS | 01MAY96 | 5 | 10 | | |
| | H61110501 | 53,337 | JERSEY PT | 03MAY96 | 39 | 187 | | |
| | Effective Release | 107,961 | DOS REIS | | 11 | 58 | 0.14 | 0.15 |
| | Effective Release | 51,737 | JERSEY PT | | 39 | 187 | | |
| 1997 | H62545 | 50,695 | DOS REIS | 29APR97 | 9 | 178 | | |
| | H62546 | 55,315 | DOS REIS | 29APR97 | 7 | 167 | | |
| | H62547 | 51,588 | JERSEY PT | 02MAY97 | 27 | 349 | | |
| | Effective Release | 106,010 | DOS REIS | | 16 | 345 | 0.29 | 0.48 |
| | Effective Release | 51,588 | JERSEY PT | | 27 | 349 | | |
| | H62548 | 46,728 | DOS REIS | 08MAY97 | 5 | 91 | 0.28 | 0.48 |
| | H62549 | 47,254 | JERSEY PT | 12MAY97 | 18 | 191 | | |
| 1998 | 61110809 | 26,465 | MOSSDALE | 16APR98 | 25 | 52 | | |
| | 61110810 | 25,264 | MOSSDALE | 16APR98 | 31 | 39 | | |
| | 61110811 | 25,926 | MOSSDALE | 16APR98 | 32 | 56 | | |
| | 61110806 | 26,215 | DOS REIS | 17APR98 | 33 | 46 | | |
| | 61110807 | 26,366 | DOS REIS | 17APR98 | 23 | 35 | | |
| | 61110808 | 24,792 | DOS REIS | 17APR98 | 34 | 57 | | |
| | 61110812 | 24,598 | JERSEY PT | 20APR98 | 87 | 104 | | |
| | 61110813 | 25,673 | JERSEY PT | 20APR98 | 100 | 90 | | |
| | Effective Release | 77,655 | MOSSDALE | | 88 | 147 | 0.30 | 0.49 |
| | Effective Release | 77,373 | DOS REIS | | 90 | 138 | 0.31 | 0.46 |
| | Effective Release | 50,271 | JERSEY PT | | 187 | 194 | | |
| 1999 | 064606 | 25,005 | MOSSDALE | 20APR99 | 2 | 1 | | |
| | 062642 | 24,715 | MOSSDALE | 19APR99 | 8 | 12 | | |
| | 062643 | 24,725 | MOSSDALE | 19APR99 | 15 | 14 | | |
| | 062644 | 25,433 | MOSSDALE | 19APR99 | 13 | 0 | | |
| | 062645 | 25,014 | DOS REIS | 19APR99 | 20 | 9 | | |
| | 062646 | 24,841 | DOS REIS | 19APR99 | 19 | 18 | | |
| | 0601110815 | 24,927 | JERSEY PT | 21APR99 | 34 | 25 | | |
| | 062647 | 24,193 | JERSEY PT | 21APR99 | 25 | 19 | | |
| | Effective Release | 99,878 | MOSSDALE | | 38 | 27 | 0.32 | 0.30 |
| | Effective Release | 49,855 | DOS REIS | | 39 | 27 | 0.65 | 0.60 |
| | Effective Release | 49,120 | JERSEY PT | | 59 | 44 | | |

NOTE: Ocean recoveries are based on data through 2000



### SAN JOAQUIN RIVER SALMON PROTECTION

One of the VAMP objectives is to provide improved conditions and increased survival of juvenile Chinook salmon smolts produced in the San Joaquin River tributaries during their downstream migration through the lower river and Delta. To determine if VAMP in 2001 was successful in protecting juvenile salmon emigrating from the San Joaquin River tributaries, catches of unmarked salmon at Mossdale and in salvage at the CVP and SWP facilities were reviewed prior to and during the VAMP period.

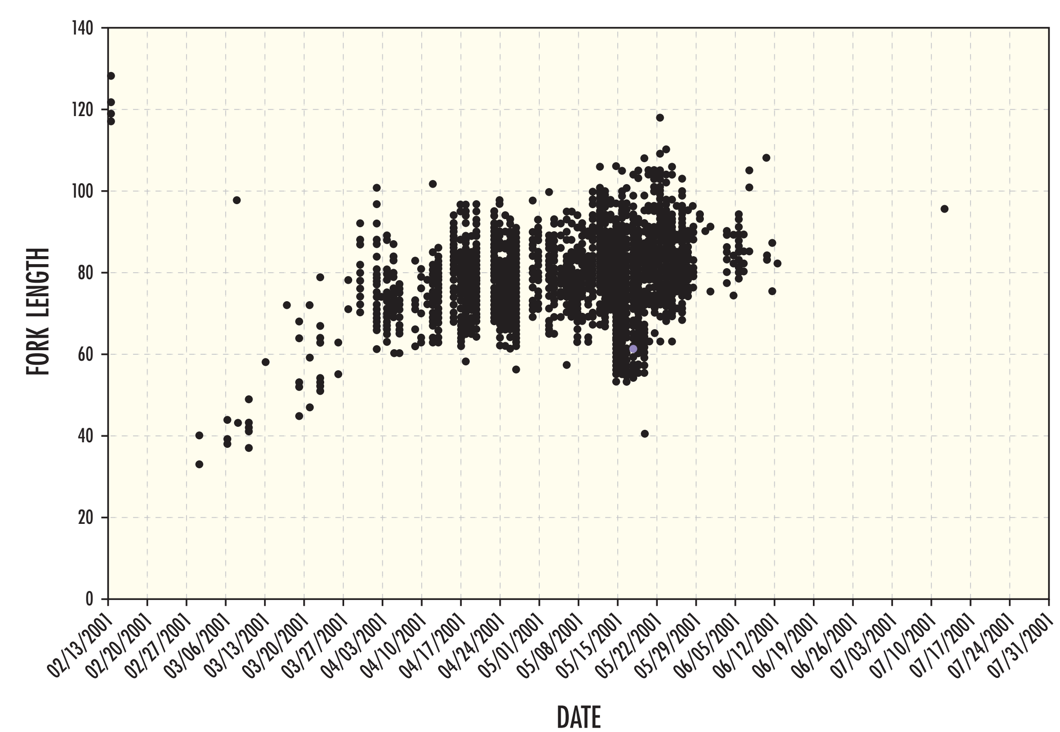
*Unmarked Salmon Recovered at Mossdale*

The original time period for VAMP (April 15 to May 15) was chosen based on historical data that indicated a high percentage of the juvenile salmon emigrating from the San Joaquin tributaries was passing into the Delta at Mossdale during that time period. In 2001, the VAMP period was delayed until April 20 due to permitting problems associated with installing the barrier at the HORB. Figure 5-12 shows the average catch per minute per day of unmarked juvenile salmon caught in kodiak trawling at Mossdale between February 13 and July 28, 2001. Unmarked salmon do not have an adipose clip and could be unmarked fish from the Merced River Hatchery or juveniles from natural spawning. Figure 5-12 indicates that the majority of juvenile salmon (65%) migrated past Mossdale during the VAMP period. Delaying removal of the HORB until May 26 and continuing export curtailments until early June affected an even greater percent of the population. Reducing flows while continuing the export curtailments and keeping the barrier in place for a week after the VAMP period may provide a way to stimulate movement of the juvenile salmon out of the system, while protecting these last remaining out-migrants. These additional protection measures after VAMP appear to have been beneficial to protecting a greater proportion of the population of unmarked juvenile salmon emigrating from the San Joaquin basin.

Most of the unmarked juveniles passing Mossdale during this time were between 60 and 100 mm in length, although there were a few below 60 mm observed towards the end of the VAMP period (Figure 5-13). It is also interesting to note that there were a few large juveniles (between 115 and 130 mm) migrating past Mossdale in mid-February. Although the VAMP period protects many of the juvenile salmon migrating during the time it is in place, it is also important to protect the diversity of emigration timing and life history expression in the basin.

## FIGURE 5-13

**Fork Lengths of all Non-clipped Chinook Per Day Captured in the Mossdale Kodiak Trawl Between February 13, 2001, and July 31, 2001.**




*Up to 20 tows per day were conducted between April 24, 2001, and May 28, 2001.*

*Salmon Salvage and Losses at Delta Export Pumps*

Fish salvage operations at the Central Valley Project (CVP) and State Water Project (SWP) export facilities capture unmarked salmon for transport by tanker truck and release downstream in the western Sacramento-San Joaquin Delta. The untagged salmon are either naturally produced or are untagged hatchery salmon, potentially from any source in the Central Valley. It is not certain which unmarked salmon recovered are of San Joaquin basin origin, although the timing of salvage and fish size can be compared with Mossdale trawl data and CWT recovery data at the facilities to provide some general indications. Data from 2000 are included here since they were not in the 2000 report and provide a comparison with the 2001 data.

*Results of these analyses showed that the VAMP 2001 test period coincided with much of the peak period of salmon smolt emigration.*

The salvage at the facilities is based on expansions from sub-samples taken throughout the day. Loss is estimated at approximately 4-5 salmon lost per salvaged salmon in the SWP Clifton Court Forebay based on high predation rates. The CVP pumps divert directly from the Old River channel and the loss estimates range from about 50–80% of the number salvaged, or about 6–8 times less per salvaged salmon than for the SWP. The loss estimates do not include any indirect mortality in the Delta due to water operations or additional export operations or additional mortality associated with trucking and handling. Salvage density of salmon is the number of salvaged per acre foot of water pumped.

The number of juvenile salmon that migrated through the system, the placement of the HORB, and the amount of water pumped by each facility are some of the factors that would influence the number and density of juvenile salmon salvaged and lost. Density may be the best indicator of when the most juvenile salmon were moving through the salvage system.

A review of the weekly salvage data around the 2001 VAMP period indicates that the highest salvage and losses occurred during the second week of the VAMP period at the SWP and in the week prior to VAMP at the CVP (Figures 5-14 and 5-15). Salmon density was highest in the first week of the VAMP period at both facilities, with the next highest density at CVP in the week before VAMP and at SWP in the second week of VAMP (Figure 5-16). This salvage, loss and density information indicates that delaying the VAMP period in 2001 may have resulted in higher impacts to juvenile salmon adversely affected by the CVP facility than would have occurred had the VAMP period started on April 15 as originally planned.

Comparable data for 2000 show a pattern of high salvage and loss at the CVP and SWP prior to the 2000 VAMP period (Figures 5-17 and 5-18). CVP density was highest prior to the VAMP period and SWP density was highest in the second week of the 2000 VAMP period (Figure 5-19). The data from 2000 also indicates that salvage numbers and densities were high at both facilities just prior to the VAMP period and initiating the VAMP earlier or extending the VAMP could have benefits by reducing the loss of juvenile salmon at the salvage facilities at this time. In 2000, the VAMP period started on April 15. Reducing exports during this earlier period of time would not only provide better conditions for juvenile salmon emigrating from the San Joaquin River basin, but from the Sacramento River basin as well. Juvenile spring-, winter-, and fall- run Chinook salmon migrate through the Delta in early April from the Sacramento River basin.

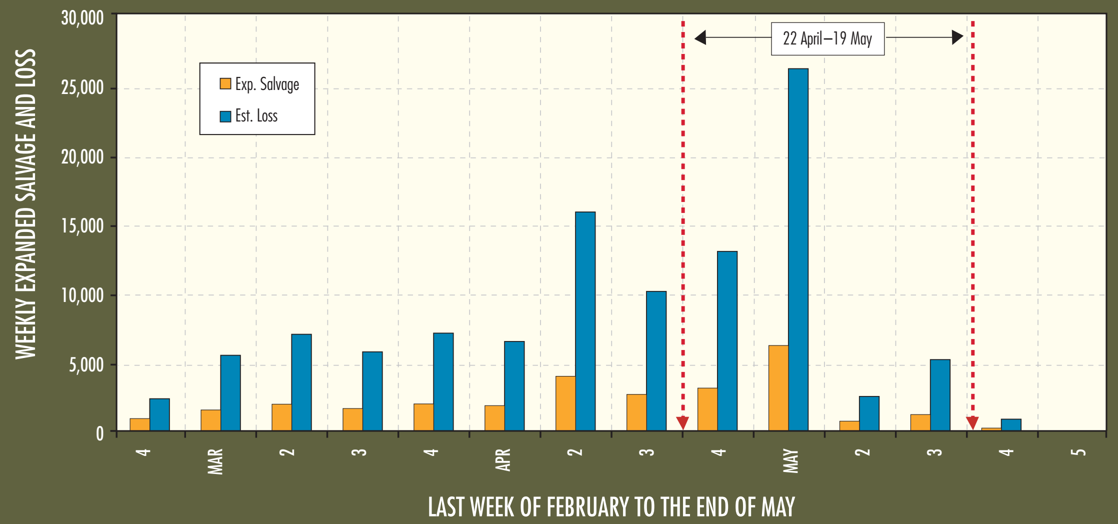
Salvaged salmon in 2001 showed a length pattern similar to 2000 during the VAMP period, although it generally appears there were more salmon less than 80 mm forklength and fewer greater than 100 mm forklength in 2001 (Figures 5-20 and 5-21).* The size distribution of unmarked salmon in the Mossdale trawl (Figure 5-13) and at the salvage facilities were similar in 2001.

Results of these analysis showed that the VAMP 2001 test period coincided with much of the peak period of salmon smolt emigration. Reductions in SWP and CVP exports and increased San Joaquin River flow provided improved conditions for salmon survival, although starting the VAMP period a week earlier may have had substantial benefits in both 2000 and 2001. Additional VAMP studies are required, however, to improve quantification of biological benefits over a broader range of environmental conditions.

** Provided by Sheila Greene, Department of Water Resources*

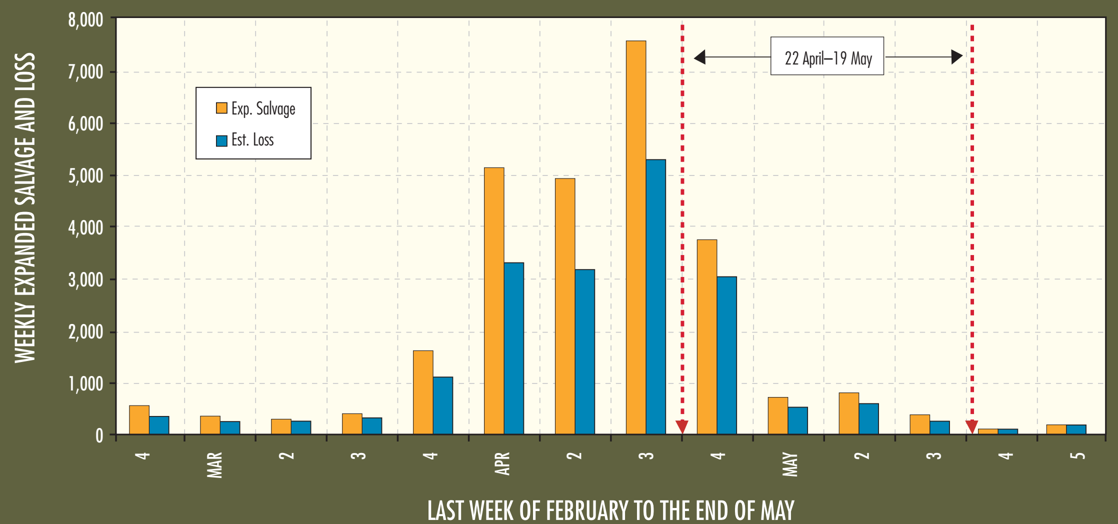
## FIGURE 5-14

2001 SWP Salmon Salvage and Loss.



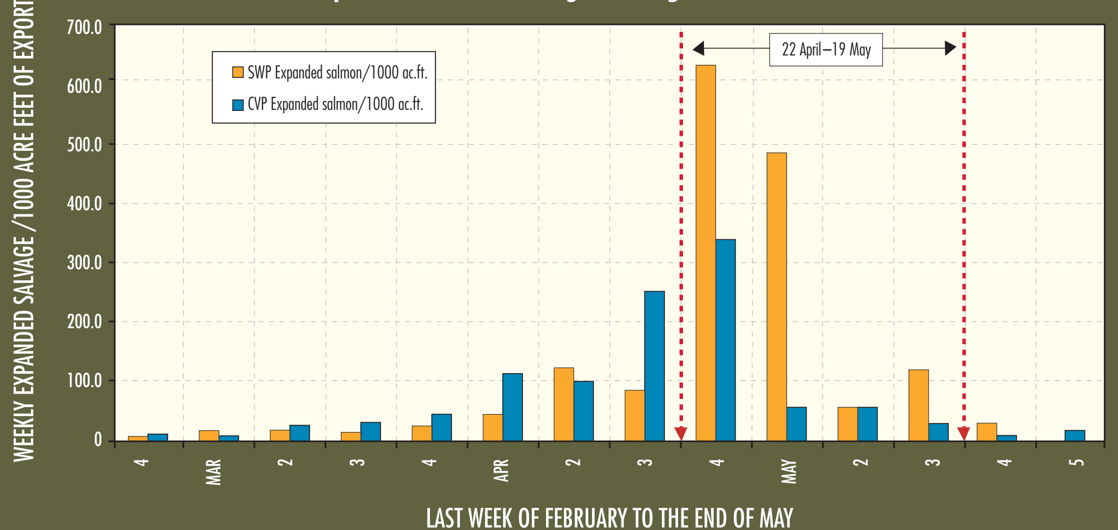

## FIGURE 5-15

2001 CVP Salmon Salvage and Loss.



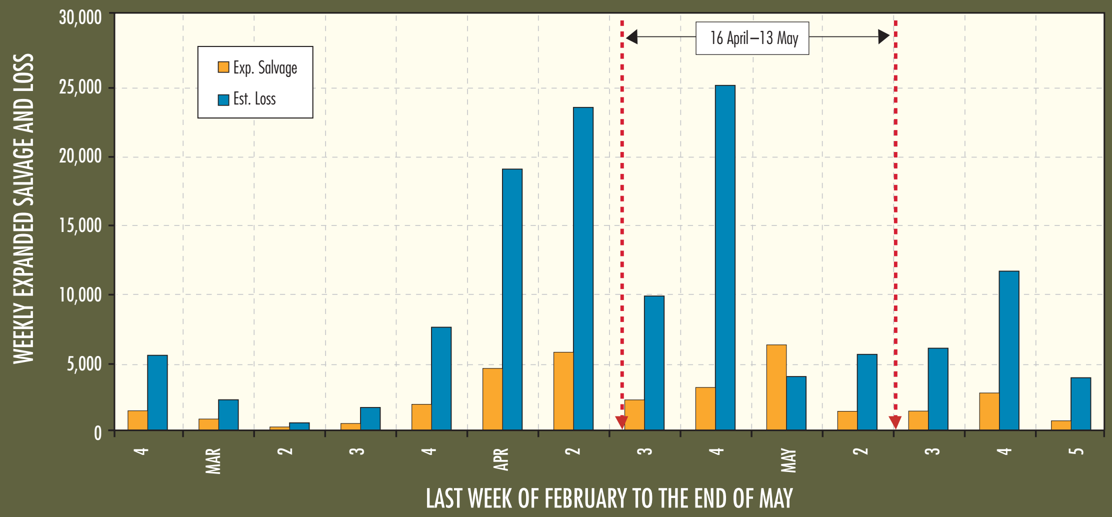

## FIGURE 5-16

2001 SWP & CVP Expanded Salmon Salvage Density.



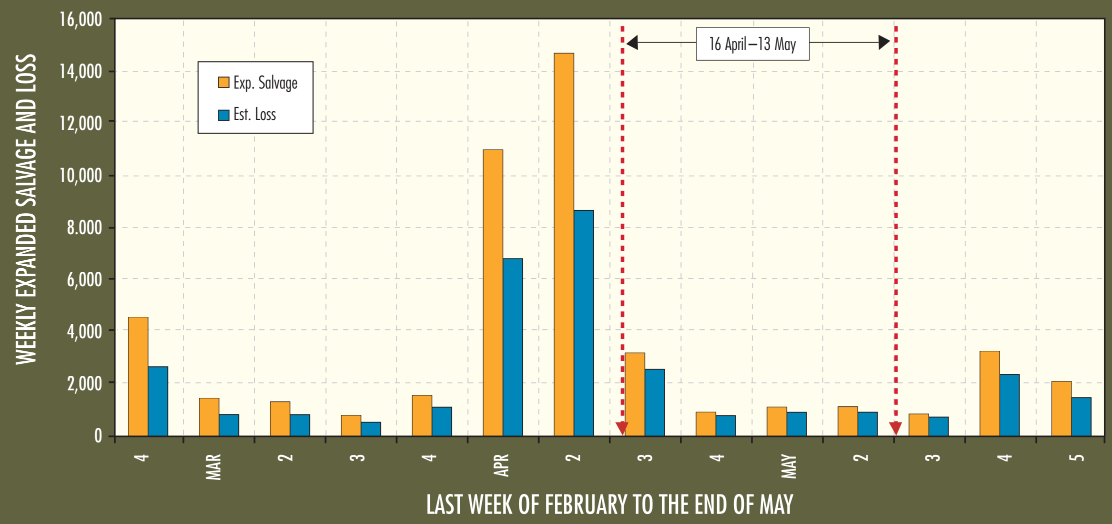

## FIGURE 5-17

2000 SWP Salmon Salvage and Loss.




## FIGURE 5-18

2000 CVP Salmon Salvage and Loss.




## FIGURE 5-19

2000 SWP & CVP Expanded Salmon Salvage Density.

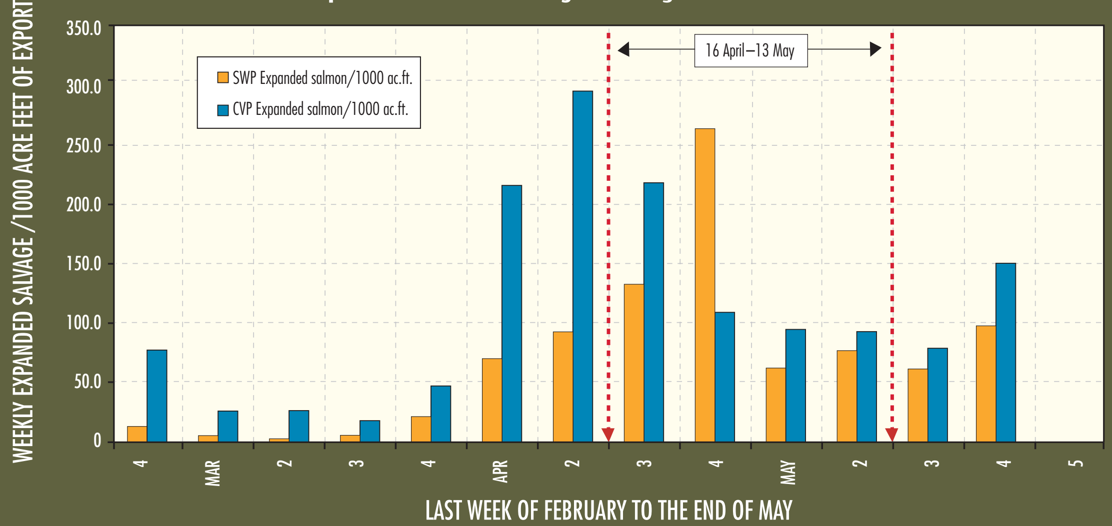
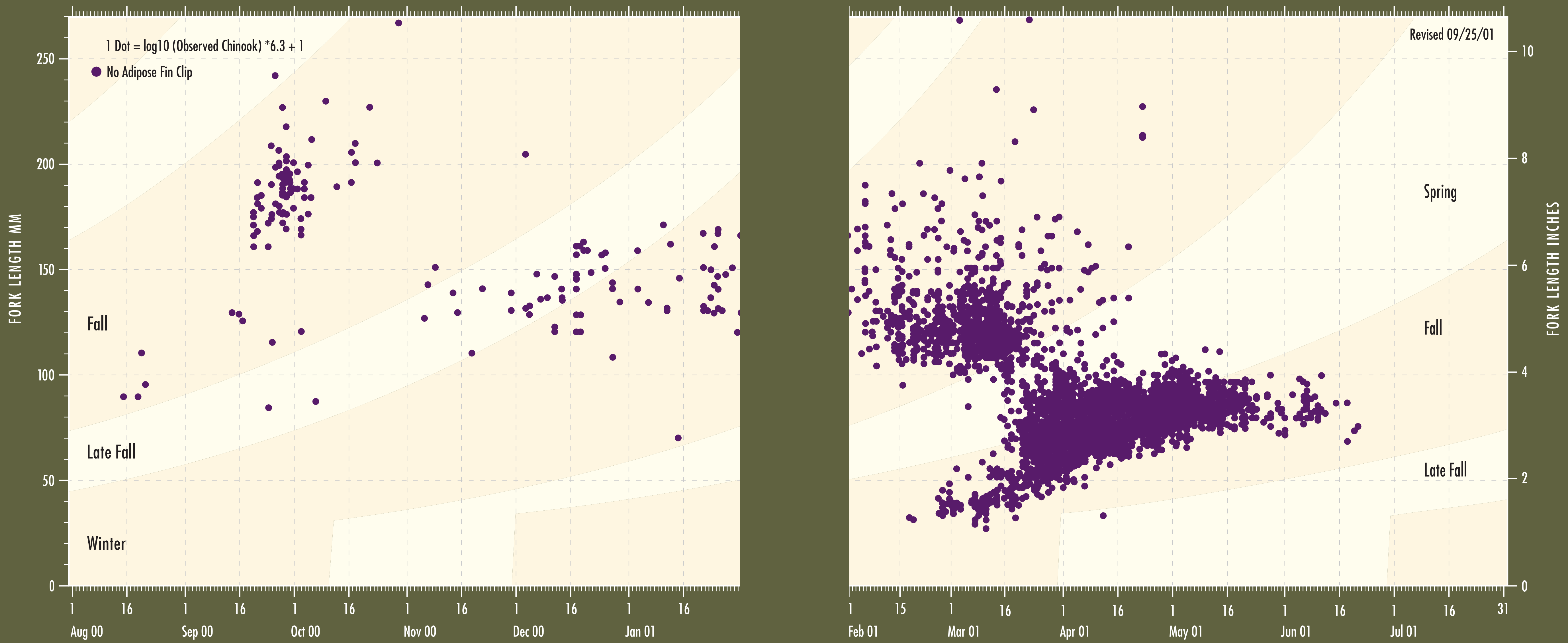


**FIGURE 5-20**

**Salvage Salmon Size Data and Export and Flow Data for 2000–2001 From DWR.**

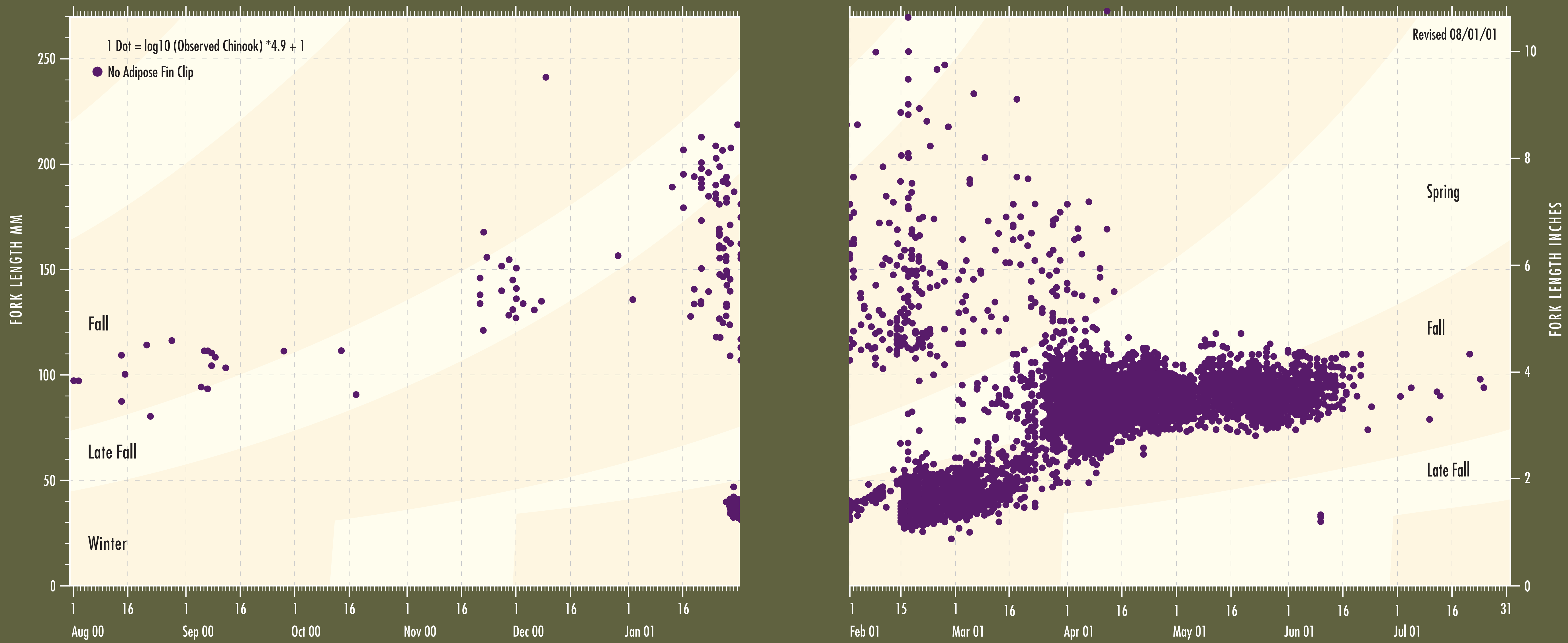
*Observed Chinook Salvage at the SWP & CVP Delta Fish Facilities 8/1/00 through 7/31/01.*



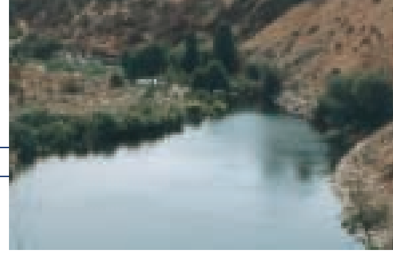
## FIGURE 5-21

**Salvaged Salmon Size Data and Export and Flow Data for 1999-2000 From DWR.**

*Observed Chinook Salvage at the SWP & CVP Delta Fish Facilities 8/1/99 through 7/31/00.*



# COMPLEMENTARY STUDIES RELATED TO VAMP



*During the VAMP 2001 test period, several complementary scientific investigations were also conducted to provide additional information on factors affecting survival of juvenile Chinook salmon emigrating from the San Joaquin River and Delta. These complementary investigations included (1) releases of coded-wire tagged juvenile Chinook salmon within San Joaquin River tributaries, which were subsequently recaptured as part of VAMP fisheries sampling, which can be used to provide estimates of salmon smolt survival, (2) results of in-situ toxicity testing within the San Joaquin River and Old River, (3) water velocity and current measurements within the San Joaquin River at the confluence with Old River in the vicinity of the HORB, and (4) pilot studies to investigate the potential use of hydro-acoustic technology to determine the seasonal distribution and density of juvenile Chinook salmon emigrating from the San Joaquin River system. Results of these complementary studies are briefly summarized below.*

## SURVIVAL ESTIMATES FOR JUVENILE CHINOOK SALMON EMIGRATING FROM THE SAN JOAQUIN RIVER TRIBUTARIES

CWT salmon releases were made in the San Joaquin River tributaries between April 21 and May 13 as part of independent (complementary) fishery investigations. Releases were made in the upper Merced River (Merced River Hatchery), lower Merced River (Hatfield State Park), upper Tuolumne River (La Grange), and on the mainstem San Joaquin River downstream of the confluence with the Tuolumne River (Old Fisherman's Club). Groups of CWT salmon were also released in the upper (Knights Ferry) and lower (Two Rivers) Stanislaus River in late May. Salmon released as part of these studies were produced in the Merced River Hatchery and coded wire tagged using methods similar to those described in Chapter 5.

Coded-wire tagged juvenile salmon released within the tributaries were subsequently recaptured as part of the VAMP sampling program at Antioch and Chipps Island (see Chapter 5). Based upon information regarding the number of coded-wire tagged salmon released, and the number recaptured, estimates of survival for each group of CWT salmon released in the tributaries were calculated.

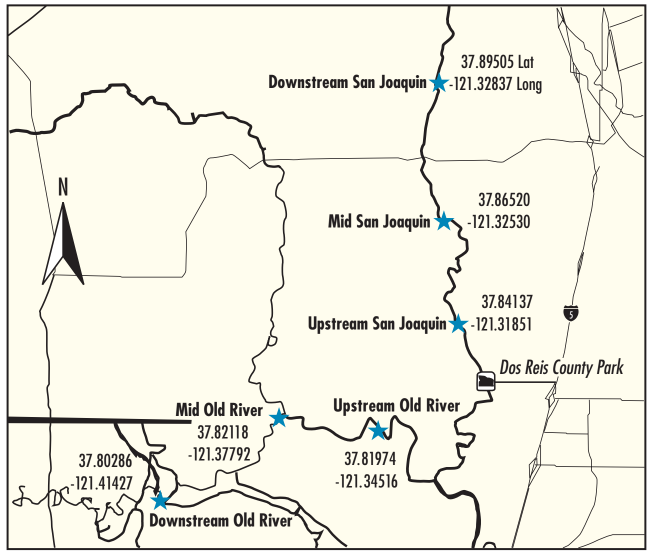
Group survival indices for salmon released in the tributaries and recovered at Antioch ranged between 0.04 and 0.30 (Appendix C-5). Since the groups released in the Stanislaus River were not released until late May, recoveries were not made at Antioch. Group survival indices ranged between 0.02 and 0.28 to Chipps Island and include the Stanislaus River releases (Appendix C-5). Comparisons of upstream groups relative to downstream groups provide a way to index survival through the tributaries (Appendix C-5). It appears that in 2001, survival through both the Merced and Tuolumne rivers was moderate and ranged between 17 and 52 percent. Estimates using recoveries from Antioch and Chipps Island were generally similar. No recoveries were made at Chipps Island from the Stanislaus River releases, even though two shifts of daily sampling continued through June 2 and one shift continued until June 15 (with the exception of June 10 when no sampling occurred). It is unclear from this result whether survival through the Stanislaus River and/or survival through the Delta was low for smolts released in the Stanislaus River. Releases in the Stanislaus were made later in the season than the rest of the releases, which could have adversely affected their survival through both the tributary and Delta.

Information on the transit time between release of CWT groups in the San Joaquin River mainstem and tributaries and recovery at Antioch and Chipps Island is summarized in Appendix C-6. As observed for VAMP releases, recovery times were generally similar between Antioch and Chipps Island for the various groups released upstream in the mainstem San Joaquin River and tributaries.

## EVALUATION OF CHINOOK SALMON SMOLT SURVIVAL IN OLD RIVER: BIOLOGICAL RESPONSES TO TOXICANTS

Results of previous salmon smolt survival studies have shown that the survival of fall-run Chinook salmon smolts is generally higher in the San Joaquin River as compared to Old River during their migration to Chipps Island in the western Delta. While it is known that a variety of toxicants are widespread in the Delta, their role in the decreased survival of salmon smolts passing down Old River as compared to the San Joaquin River is unknown. The objective of this complementary investigation is to determine if toxicants play a role in the decreased survival of Chinook salmon smolts that emigrate through Old River. Specific goals of this study were to (1) determine if there are biological effects (DNA strand breaks, acetylcholinesterase activity, stress protein expression, and cytochrome P450 expression) that correspond to chemical exposure in salmon smolts caged in Old River versus the San Joaquin River and (2) test the hypothesis that biomarker responses in salmon smolts vary temporally and spatially in this river system.

### FIGURE 6-1
**Salmon Caging Sites in the Old and San Joaquin Rivers.**




*Numbers located by caging sites indicate latitude (Lat) and longitude (Long) positions.*

In-situ field studies were scheduled to occur before and after the VAMP test period and during April–May when hydraulic and water quality conditions in south Delta channels vary as a result of VAMP. As described earlier, the VAMP program includes (1) construction of the HORB, (2) augmentation of the San Joaquin River flows by releasing water from reservoirs on upstream tributaries and (3) a reduction in SWP and CVP export rates. In addition to augmented San Joaquin River flows, these actions cause a reduction in Old River flow rates and water turnover. Thus, during the VAMP period of modified flows, toxicants from agricultural runoff or other sources are more concentrated in Old River than before or after and higher concentrations of toxicants in Old River are more likely to affect the survival of outmigrant salmon smolts than in the San Joaquin River. Before the VAMP period, 60% or more of the daily average flow of the San Joaquin River goes down Old River so that differences in toxicity and survival of salmon smolts between rivers should be minimal. After the VAMP period, opening of the Cross Channel gates (combined with a return to higher export rates) causes Sacramento River water to dominate the channels of Old River. As a result, water quality is likely to be less harmful in Old River than in the San Joaquin River, where reservoir releases and total flows decline and the contribution of agricultural return flows in the San Joaquin Valley dominate.

During each of three flow regimes (pre-VAMP, VAMP and post-VAMP) salmon smolts were delivered from the Merced River Hatchery to Dos Reis county park. Fish (n=12 per site) were transported to field sites, and caged at three sites in Old River (OR) and three sites in the San Joaquin River (SJR) for four days (Figure 6-1). Fish and fish cages were obtained, placed, monitored, and retrieved by USFWS personnel. After the four-day exposure, fish were removed from the cages and dissected. During each flow regime, composite water samples were collected for metals analysis (Desert Research Institute, Reno, NV) and pesticides including organophosphates and pyrethroids (USGS, Sacramento, CA). During the VAMP period (not pre- or post-VAMP), non-composite water samples were collected for analysis of organics (PCB, PAHs, and organochlorines, Severn Trent Laboratory, Sacramento, CA), analysis of dissolved and total copper (Desert Research Institute), and mercury analysis (Higashi Laboratory, UC Davis).

**FIGURE 6-2**

**Temperature in the San Joaquin River and Old River on Days in Which Fish Were Caged and Retrieved From Cages.**

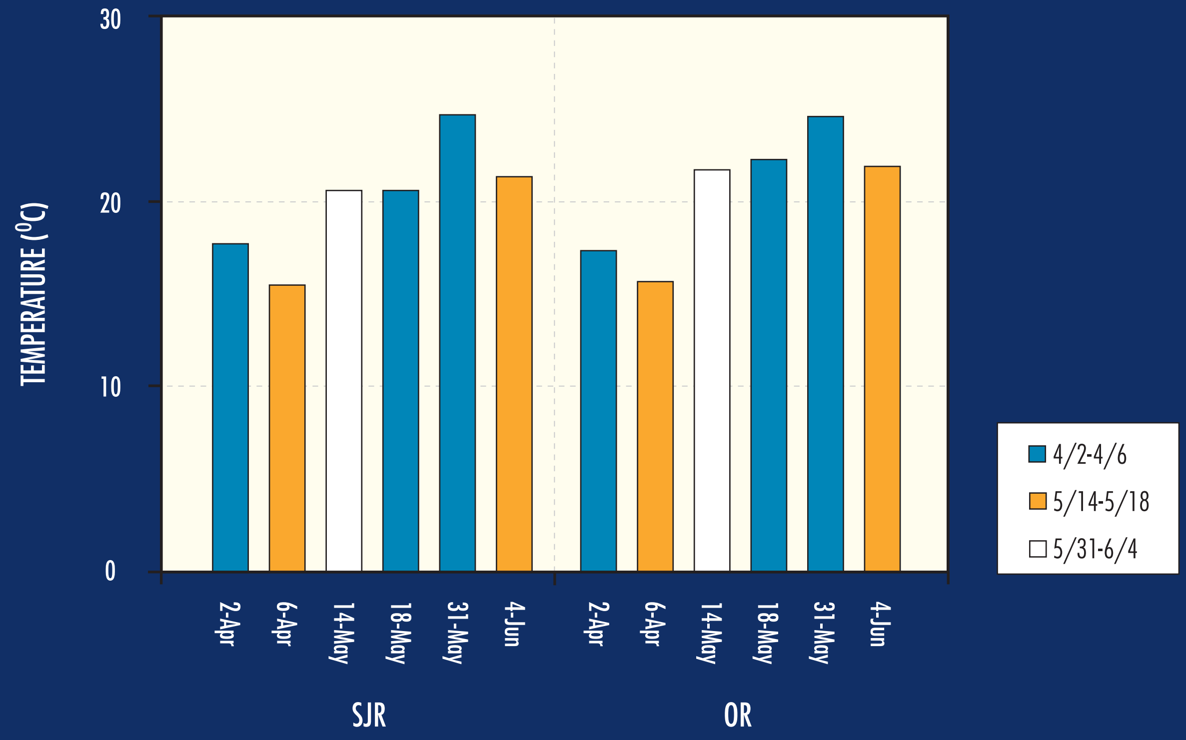
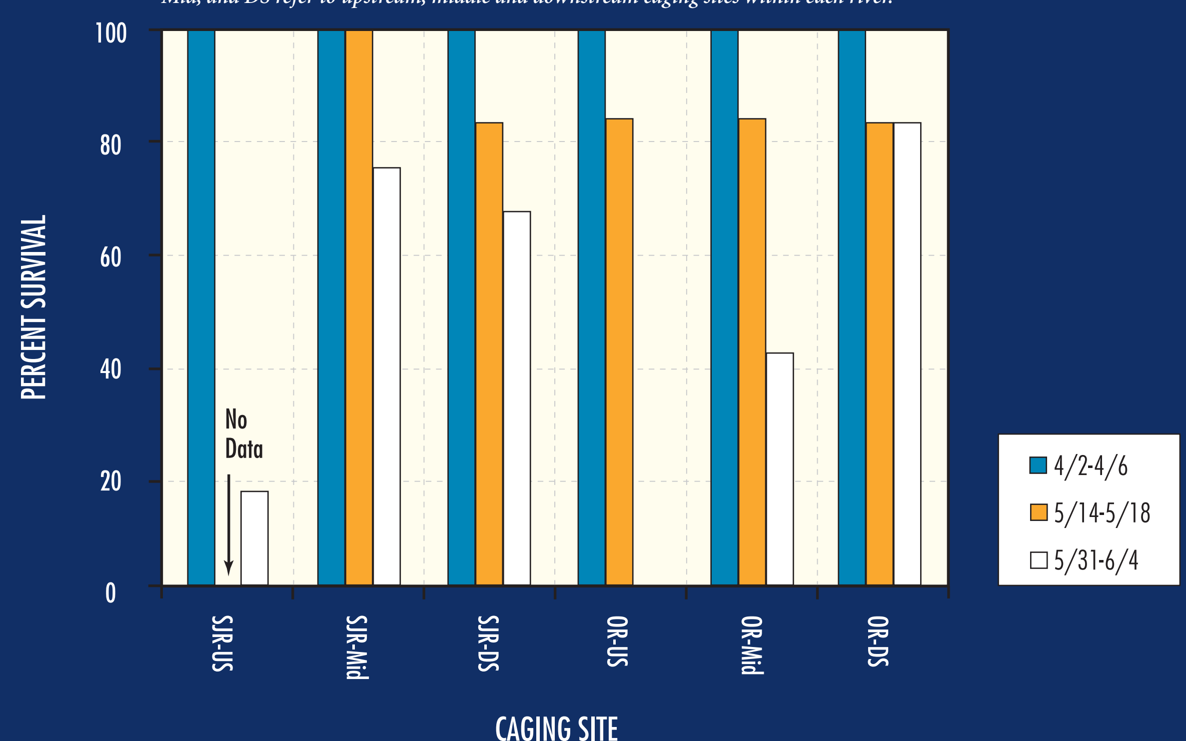



**FIGURE 6-3**

**Percent Survival of Chinook Salmon Smolts in Net Pens During Pre-VAMP (4/2-4/6), VAMP 5/14-5/18), Post-VAMP (5/31-6/4) Flow Regimes in the San Joaquin and Old Rivers.**

*Mid, and DS refer to upstream, middle and downstream caging sites within each river.*




During the pre-VAMP test period, water temperatures on April 2–6 were 15–17°C at all test sites (Figure 6-2). Because completion of the HORB was delayed, the VAMP test period was delayed to May 14–18, at which time water temperatures had reached at least 20°C at all test sites. During the post-VAMP period, temperatures were extremely high the day we placed our cages in both the San Joaquin and Old River sites; water temperatures reached as high as 24°C in both rivers. By the time we retrieved the fish (6/4/01), temperatures had dropped to about 21°C in both rivers (Figure 6-2).

Survival of salmon smolts in the net pens was 100% at all sites during pre-VAMP (4/2–4/6) and varied from 83% (San Joaquin River downstream, Old River all sites) to 100% (San Joaquin River middle site) during the VAMP period (5/14–5/18) as shown in Figure 6-3. During the post-VAMP test period, survival in net pens was 0% at the Old River upstream site, 42% at Old River middle site, 83% at the Old River downstream site, 17% at the San Joaquin River upstream site, 75% at the San Joaquin River middle site, and 67% at the San Joaquin River downstream site.

Analysis of the biological responses of juvenile salmon are currently underway and include acetylcholinesterase activity (Wilson Lab, UC Davis), DNA strand breaks (Anderson Lab, Bodega Marine Laboratory), cytochrome P450 expression (Snyder Lab, Bodega Marine Laboratory), and stress protein expression (Werner Lab, UD Davis). A portion of the controls for background DNA damage in Chinook salmon smolts have been completed (n=9 hatchery controls and n=8 transport controls from the post-VAMP flow regime). Hatchery and transport controls demonstrate 50% and 43% DNA damage levels, respectively, and there was no significant difference in mean DNA damage between treatments.

Analysis of water samples for pesticides is currently underway in the laboratory of Kathy Kuivila (USGS). Data from the analysis of PAHs, PCBs, and organochlorines has been received and shows non-detectable concentrations at all sites during the VAMP period at 1 ppb detection limits (Severn Trent Laboratory). The general metals analysis in water samples from both the San Joaquin River and Old River sites have been completed for all three flow regimes (Desert Research Institute). During the pre-VAMP period, Al levels were approximately 300 ppb at all sites in the SJR and OR. During the VAMP, all levels increased in the SJR sites to 900 or 1000 ppb (but not OR sites) and returned to pre-VAMP levels during the post-VAMP period. A similar trend was observed with Mn and Ni during all three time periods. Mn levels were approximately 100 ppb at all sites in both rivers and increased to 200 ppb in all SJR sites and the OR downstream site during VAMP. Ni levels were approximately 4 ppb or not detected prior to VAMP but increased at all SJR sites and at the OR downstream site to about 8 ppb during VAMP. Cu levels were about 2 ppb in all OR sites but increased to about 6 ppb in all SJR and the OR middle site during the VAMP. Additional metals were analyzed in water samples but did not fluctuate substantially during the three flow regimes or between the two rivers and include the following: Sb (<1 ppb), As (4-10 ppb), Ba (50-70 ppb), Be (<1 ppb), Cd (<1-4 ppb), Cr (1-3 ppb), Co (<1 ppb), Pb (<1 ppb), Mo (3-8 ppb), Se (<20 ppb), Ag (<1 ppb), Tl (<1 ppb), Th (<1 ppb), U (7-10 ppb), V (4-7 ppb), and Zn (4-10 ppb).

## HYDRAULIC INVESTIGATIONS ASSOCIATED WITH THE OLD RIVER BARRIER

As part of the VAMP 2001 test program, field measurements were made within the San Joaquin River at the confluence with Old River to evaluate hydraulic characteristics associated with operation of the HORB. Acoustic Doppler current meters and other field measurements were made to determine current patterns and water velocities. Hydraulic measurements were made over a variety of tidal conditions to assess the effects of changes in tidal hydrodynamics and water surface elevation on current patterns and velocities. Information from these field measurements is currently being compiled and analyzed and will be used in designing subsequent complementary field investigations to provide additional information useful in evaluating the role of the HORB on hydraulic conditions within the lower San Joaquin River, and potential effects on salmon smolt survival. One of the concerns that has been identified through field measurements and observations relates to eddies and hydraulic turbulence immediately adjacent to the confluence between the lower San Joaquin River and Old River, related to HORB operations, that may affect the behavioral response and emigration patterns for juvenile Chinook salmon. Turbulence and eddies in the area may also affect the vulnerability of juvenile Chinook salmon to predation mortality. Results of the VAMP 2001 hydraulic measurements will be used to help refine the design and measurement of hydraulic conditions during VAMP 2002, and will also be used to evaluate the affects of various culvert operational strategies as they relate to hydraulic conditions within the San Joaquin River.

### HYDRO-ACOUSTIC MONITORING OF JUVENILE CHINOOK SALMON EMIGRATION

A pilot study was designed and conducted as a complementary investigation during the VAMP 2001 test period to evaluate the potential application of hydro-acoustic technologies for monitoring the seasonal patterns in juvenile Chinook salmon movement and salmon densities within the lower San Joaquin River. Currently fisheries monitoring is conducted using conventional trawling methods, (e.g., Kodiak trawl, mid-water trawl) which requires extensive field effort and the capture and handling of juvenile Chinook salmon and other fish species. Development of an alternative fishery monitoring technique, such as hydro-acoustic technologies which have been used for fishery monitoring elsewhere, would offer the potential benefits of reduced monitoring costs, monitoring juvenile salmonid emigration continuously throughout an extended seasonal period, providing continuous monitoring during both day and nighttime conditions, and avoids concerns regarding the capture and handling of protected fish species including both steelhead and Sacramento splittail. Hydro-acoustic technologies, however, do not provide information on the species of fish detected and have not been demonstrated to provide reliable and quantitative information on juvenile salmonid emigration from the lower San Joaquin River. Results of the pilot scale hydro-acoustic studies conducted complementary to VAMP 2001 will be analyzed and evaluated. Results of these evaluations will be used, in part, to help design further field testing and validation of the application of alternative monitoring techniques such as hydro-acoustic technologies as part of the overall VAMP investigations. Results of the pilot scale study conducted during VAMP 2001 will be used to help evaluate and design additional field testing of the technology, if the VAMP 2001 results appear promising, as part of VAMP 2002.

### STATISTICAL ANALYSIS OF VAMP DATA

The U.S. Fish and Wildlife Service has contracted to have Dr. Ken Newman conduct various statistical analysis on VAMP salmon smolt survival data. During 2001, Dr. Newman evaluated several aspects of the VAMP data as briefly discussed below.

During his first evaluation, Dr. Newman used CWT salmon recoveries, at Antioch and Chipps Island, of releases made at Durham Ferry, Mossdale and Jersey Point in 2000 to estimate survival between Durham Ferry and Mossdale and between Mossdale and Jersey Point (Newman, Ken,. Pers. com. (a)). He also estimated the standard errors associated with the estimates of survival. The number of recoveries at Antioch and Chipps Island were modeled as trinomial random variables. Implicit in this modeling is the assumption that the three releases have the same survival probabilities over identical reaches of the river and the same capture probabilities. Maximum likelihood estimates for survival in each reach and variances were calculated. The standard errors were the square roots of the estimated variances.

Survival was estimated to be 0.329 between Mossdale and Jersey Point in 2000. Standard errors ranged between 0.031 and 0.054, respectively. Survival (and standard error) between Durham Ferry and Mossdale was estimated at 0.73 (0.145). These estimates compare to survival estimates using the ratio of survival indices of the Mossdale group to the Jersey Point group of 0.33 and 0.31 for the Antioch and Chipps Island recoveries respectively. These two independent methods seem complementary since estimates are very similar using both methods. The maximum likelihood estimates are more informative since they provide standard errors and a way to assess if differences between survival estimates are significant.

It was concluded that maintaining a uniform recovery effort at any given recovery site is crucial to minimizing the bias in estimating survival. Variation in capture probabilities between recovery locations, however, is not a problem. Increasing capture probability lowers the standard error of estimates of survival. Capture probability can be increased by increasing the number of salmon released or increasing the recapture effort. Use of replicate tag codes is valuable for detecting over dispersion, which is a violation of the assumptions underlying the trinomial distribution used for parameter estimation.

In his second evaluation, Dr. Newman conducted a power analysis to determine the probability of detecting flow and export effects on juvenile Chinook salmon survival in the VAMP experiments (Newman, Ken,. Pers. com. (b)). Using 1997, 1998, and 2000 CWT recovery data at Chipps Island, the survival in each year between Mossdale and Jersey Point was estimated. (The 1999 data was not used as it appeared to be an "outlier".) These estimates were used to fit a logistic regression model of survival to flow at Vernalis, export pumping and the presence or absence of the HORB. This analysis also simulated the effect of changing the number of fish released and the recapture rates at Antioch and Chipps Island to detect statistically significant differences in survival for the different VAMP export and flow targets experiments. The probability of detecting a significant difference between targets was greater as release numbers and capture probability increased. The probability of detecting significant differences is greater when the underlying differences are greater between the two different flow and export combinations.

Table 6-1 shows the probabilities that an observed difference in survival for two flow and export combinations would be significantly different at the 0.05 level. It is clear that significant differences are more likely when flow and export target extremes are compared.

This model was then used to compare estimates of survival observed in 2001 to those predicted by the model. The model estimated survival between Mossdale and Jersey Point to be 0.47 for the first group and 0.57 for the second group of releases. This compared to observed estimates of 0.16 and 0.20 (Table 5-6). It appears, from these comparisons, that the model is not tracking the observed data well. The increase from the first group to the second group seems consistent between the model and the data.

Further statistical and power analysis of the available salmon smolt survival data are planned to help in the design of the VAMP 2002 experiments.

## TABLE 6-1

**Probability That an Observed Difference in Survival for two Flow and Export Combinations is Found Significantly Different at the 0.05 Level.**

*The probability is labeled Pr, where R is the number released per group, and p equals the capture probability.*

| | | | | | p=0.001 | | | p=0.002 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| COMBINATION 1 | | COMBINATION 2 | | | R=50K | R=100K | R=150K | R=50K | R=100K | R=150K |
| Flow | Exp | Flow | Exp | Diff. | Pr | Pr | Pr | Pr | Pr | Pr |
| 3,200 | 1,500 | 4,500 | 1,500 | 0.372 | 0.846 | 0.993 | 1.000 | 0.988 | 1.000 | 1.000 |
| 3,200 | 1,500 | 5,700 | 2,250 | 0.018 | 0.058 | 0.048 | 0.056 | 0.059 | 0.078 | 0.072 |
| 3,200 | 1,500 | 7,000 | 1,500 | 0.666 | 0.994 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 3,200 | 1,500 | 7,000 | 3,000 | 0.125 | 0.389 | 0.669 | 0.834 | 0.627 | 0.928 | 0.983 |
| 4,500 | 1,500 | 5,700 | 2,250 | -0.354 | 0.797 | 0.982 | 0.819 | 0.984 | 1.000 | 1.000 |
| 4,500 | 1,500 | 7,000 | 1,500 | 0.294 | 0.390 | 0.649 | 0.997 | 0.659 | 0.898 | 0.987 |
| 4,500 | 1,500 | 7,000 | 3,000 | -0.497 | 0.996 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 5,700 | 2,250 | 7,000 | 1,500 | 0.649 | 0.992 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 5,700 | 2,250 | 7,000 | 3,000 | -0.143 | 0.501 | 0.781 | 0.906 | 0.740 | 0.968 | 0.995 |
| 7,000 | 1,500 | 7,000 | 3,000 | -0.791 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |

CHAPTER 7

# CONCLUSIONS & RECOMMENDATIONS

The VAMP experimental investigation of juvenile Chinook salmon survival was implemented during spring 2001. The Vernalis target flow was 4,450 cfs, with SWP and CVP export flow of 1,500 cfs. The HORB was successfully installed and maintained throughout the VAMP test period. Estimates of juvenile Chinook salmon smolt survival were calculated based upon releases of CWT juvenile salmon produced in the Merced River Hatchery and released at Durham Ferry, Mossdale, and Jersey Point. Marked salmon were subsequently recaptured in sampling at the HORB, SWP and CVP export facility salvage, and through intensive fisheries sampling at Antioch and Chipps Island. Based upon the data and experience gained during the VAMP 2001 investigations, conclusions and recommendations have been developed, as summarized in Table 7-1. The conclusions and recommendations include both technical and policy/management issues that will affect the design and implementation of VAMP 2002 operations and investigations.



## TABLE 7-1
### Summary of VAMP 2001 Conclusions and Recommendations

| CONCLUSIONS | RECOMMENDATIONS |
|---|---|
| The quality of the real-time flow data at Vernalis was improved by weekly measurements. | Continue weekly measurements. Investigate alternative flow measurement methods and/or locations. |
| Estimation of ungauged flow (accretions, depletions) at Vernalis should be improved. | Continue hydrology investigation to improve predictions. |
| Coordination with upstream tributary operations was successful. | Continue coordination among tributary operators. |
| Design of the HORB was improved, however debris accumulation on trash screens was a problem. | Modify trash screen design to facilitate trash removal and provide routine maintenance. |
| Operation of the HORB was successful in maintaining south Delta water levels. | Continue to refine operational criteria for culverts. |
| Permitting delayed HORB installation. | Secure all permits early and schedule construction to avoid delay in installation. |
| Hydraulic measurements of flow through HORB culverts need to be taken. | Take flow measurements within each culvert. |
| HORB has limited impacts on seepage. | Continue monitoring. |
| Sampling using fyke nets was successful in collecting entrained fish at the culverts. | Continue monitoring culverts using fyke nets to document entrainment. |
| Experimental design for barrier evaluation did not support consistent quantitative hypothesis testing. | Re-design experimental design of barrier investigations. |
| CWT retention rate was relatively low. | Investigate CWT quality control to improve retention rates. |
| Problem with logistics of release at Durham Ferry. | Modify release procedures. |
| Water temperatures were elevated during the second set of releases and may have adversely affected survival. | Avoid seasonal delays in barrier installation and survival testing. |
| Results of net pen studies showed evidence of disease and reduced condition of test fish. | Continue net pen studies and fish health inspections. |
| Results showed substantially lower survival for the second set of releases at all locations compared to the first release. Disease and temperature stress were identified as factors potentially affecting survival. | Do not delay releases otherwise high temperatures may affect results. Second set of CWT survival indices are not comparable to the first set of indices. |
| Differences in survival between Durham Ferry and Mossdale were not found to be statistically significant. | Continue statistical analysis of survival data. Continue to evaluate need for releases at both Durham Ferry and Mossdale. |
| Differences in survival from Durham Ferry in 2001 were not significantly different from 2000. | Conduct survival testing at VAMP flow and export extremes. |
| Flow in the lower San Joaquin River downstream of upper Old River appears to be more relevant than Vernalis flow because of flow through the HORB culverts. | Measure the flow in the San Joaquin River downstream of upper Old River. |
| Hydrologic conditions during 2001 were close to the threshold separating two alternative flow targets. | If hydrologic conditions are close to a decision threshold, select target flow representing a new VAMP test condition rather than repeating a previously tested flow/export case. |
| Complementary studies to evaluate mechanisms affecting survival were conducted. | Encourage an expansion of complementary studies to provide additional information on factors and mechanisms affecting salmon survival. |
| Relatively few CWT salmon from VAMP releases were recovered at the SWP and CVP salvage facilities. | Continue salvage monitoring to document direct losses. |
| Conclusions are not yet possible on the respective roles of San Joaquin River flow and SWP/CVP exports on juvenile Chinook salmon smolt survival. | Continue VAMP test program. |

# LITERATURE CITED


**Foott, S., Pers. com., U.S. Fish and Wildlife Service, California-Nevada Fish Health Center, Anderson, CA.**

**Lom, J. and I. Dyková. 1995.** *Myxosporea (Phylum Myxozoa). Pages 97–148 in PTK Woo (ed). Fish Disease and Disorders, Vol 1. CAB International, Wallingford, UK.*

**Newman, K., Pers. com. (a), University of Idaho. Memo, March 19, 2001. Revised November 2, 2001.** *"Analysis of downstream recoveries of CWT releases from Durham Ferry, Mossdale and Jersey Point in 2000."*

**Newman, K., Pers. com. (b), University of Idaho. Memo, November 2, 2001.** *"Analyses of the probability of detecting flow and export effects on juvenile Chinook salmon survival in the VAMP experiments."*

**Nichols, K., R. Burmester and J. Scott Foott.** *2001 Health Assessment of VAMP Release Groups–FY 2000 Investigational Report US Fish and Wildlife Service, California-Nevada Fish Health Center, Anderson, CA. October 2001.*

**San Joaquin River Group Authority.** *"2000 Annual Technical Report on Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan." Sacramento, CA. January 2001.*




# CONTRIBUTING AUTHORS


**MICHAEL ARCHER**
MBK Engineers, Sacramento

**PATRICIA BRANDES**
U.S. Fish and Wildlife Service, Stockton

**PAUL CADRETT**
U.S. Fish and Wildlife Service, Stockton

**TIM FORD**
Modesto and Turlock Irrigation Districts, Turlock

**CHARLES HANSON**
Hanson Environmental, Inc., Walnut Creek

**MARK HOLDERMAN**
California Department of Water Resources, Sacramento

**WILLIAM JOHNSTON**
San Joaquin River Group Authority, Modesto

**SIMON KWAN**
California Department of Water Resources, Sacramento

**KEN NICHOLS**
U.S. Fish and Wildlife Service, Anderson

**MARK PIERCE**
U.S. Fish and Wildlife Service, Stockton

**TOBI ROSE**
California Department of Fish and Game, Stockton

**WENDY ROSE**
University of California, Davis

# SIGNATORIES TO THE SAN JOAQUIN RIVER AGREEMENT

**U.S. BUREAU OF RECLAMATION**

**U.S. FISH AND WILDLIFE SERVICE**

**CALIFORNIA DEPARTMENT OF WATER RESOURCES**

**CALIFORNIA DEPARTMENT OF FISH AND GAME**

**OAKDALE IRRIGATION DISTRICT***

**SOUTH SAN JOAQUIN IRRIGATION DISTRICT***

**MODESTO IRRIGATION DISTRICT***

**TURLOCK IRRIGATION DISTRICT***

**MERCED IRRIGATION DISTRICT***

**SAN JOAQUIN RIVER EXCHANGE CONTRACTORS WATER AUTHORITY***

- San Luis Canal Company
- Firebaugh Canal Water District
- Central California Irrigation District
- Columbia Canal Company

**FRIANT WATER USERS AUTHORITY***

25 agencies including:

- Delano-Earlimart Irrigation District
- Lower Tule River Irrigation District
- South San Joaquin Municipal Utility District
- Madera Irrigation District

**METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA**

**NATURAL HERITAGE INSTITUTE**

**SAN JOAQUIN RIVER GROUP AUTHORITY**

*San Joaquin River Group Authority Members

# APPENDIX TABLE OF CONTENTS

## APPENDIX A



## APPENDIX B



## APPENDIX C



## APPENDIX D

SAN JOAQUIN RIVER GROUP AUTHORITY

P.O. Box 4060, Modesto, CA  95352 • (209)526-7405 • FAX (209)526-7315

Modesto Irrigation District
Turlock Irrigation District
Oakdale Irrigation District
Merced Irrigation District
Friant Water Users Authority
City and County of San Francisco
South San Joaquin Irrigation District
San Joaquin River Exchange Contractors