# SUMMARY REPORT OF THE VERNALIS ADAPTIVE MANAGEMENT PLAN (VAMP) FOR 2000-2008

**PREPARED BY:**
**SAN JOAQUIN RIVER TECHNICAL COMMITTEE**
**December 22, 2008**

**Prepared for the Advisory Panel Review Conducted by the Delta Science Program**

# TABLE OF CONTENTS

# LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| BKD | Bacterial Kidney Disease |
| CDEC | California Data Exchange Center |
| CDFG | California Department of Fish and Game |
| CDRR | Combined Differential Recovery Rate |
| cfs | Cubic Feet per Second |
| CVP | Central Valley Project |
| CVPIA | Central Valley Project Improvement Act |
| CWT | Coded-Wire Tag |
| DCC | Delta Cross Channel |
| DIC | Deviance Information Criterion |
| dpe | days post-exposure |
| DSM2 | DWR’s Delta Simulation Model |
| DWR | California Department of Water Resources |
| EWA | Environmental Water Account |
| FHC | USFWS California/Nevada Fish Health Center |
| FL | Fork Length |
| FRH | Feather River Hatchery |
| GLC | Grant Line Canal |
| HOR | Head of Old River |
| HORB | Head of Old River Barrier |
| IEP | Interagency Ecological Program |
| MeID | Merced Irrigation District |
| MID | Modesto Irrigation District |
| MR | Middle River |
| MRH | Merced River Hatchery |
| MSL | Mean Sea Level |
| NMFS | National Marine Fisheries Service |
| NOAA | National Oceanic and Atmospheric Administration |
| OCAP | Operations and Criteria Plan |
| OID | Oakdale Irrigation District |
| ORT | Old River near Tracy |
| PG&E | Pacific Gas and Electric Company |
| PKD | Proliferative Kidney Disease |
| POD | Pelagic organism Decline |
| PTM | Particle Tracking Models |
| QAQC | Quality Assurance/Quality Control |
| RST | Rotary Screw Traps |
| SDIP | South Delta Improvement Program |
| SDWA | South Delta Water Agency |
| SJR | San Joaquin River |
| SJRA | San Joaquin River Agreement |
| SJRECWA | San Joaquin River Exchange Contractors Water Authority |
| SJRGA | San Joaquin River Group Authority |
| SJRTC | San Joaquin River Technical Committee |
| SLDMWA | San Luis Delta Mendota Water Authority |
| SSJID | South San Joaquin Irrigation District |
| SWC | State Water Contractors |
| SWP | State Water Project |
| SWRCB | State Water Resources Control Board |
| TBP | Temporary Barriers Program |
| TID | Turlock Irrigation District |
| USBR | United States Bureau of Reclamation |
| US EPA | United States Environmental Protection Agency |
| USFWS | United States Fish and Wildlife Service |
| USGS | United States Geological Survey |
| VAMP | Vernalis Adaptive Management Plan |
| WQCP | 1995 Water Quality Control Plan |
| WWTP | Wastewater Treatment Plant |
| WY | Water Year |

# LIST OF FIGURES

# LIST OF TABLES

# 1.0 DEVELOPMENT OF THE VERNALIS ADAPTIVE MANAGEMENT PLAN (VAMP)

*Contributed by Bruce Herbold, United States Environmental Protection Agency (US EPA)*

In 1994 a long process of developing new water quality standards for the Sacramento-San Joaquin Delta culminated in an agreement, the Delta Accord. This Delta Accord was proposed to the State Water Resources Control Board (SWRCB) and became the basis for their 1995 Water Quality Control Plan (WQCP). This plan specified a variety of San Joaquin River (SJR) flows at Vernalis and limited total State Water Project (SWP) and Central Valley Project (CVP) exports to 100% of the inflow of the San Joaquin River at Vernalis.

Although flows on the lower San Joaquin were a part of the Delta Accord, many water right holders on the San Joaquin had not been involved in the agreement and their concerns threatened the viability of the plan. In addition, both the National Marine Fisheries Service (NMFS) and the US Fish and Wildlife Service (USFWS) were concerned that the conditions specified in the Delta Accord might not adequately protect species listed under the federal Endangered Species Act. In particular the USFWS, in their Biological Opinion for Delta smelt, specified that total exports should be no more than half of the San Joaquin flow requirement.

Many studies had been done to examine the survival of salmon in the delta, but the results did not provide much detail for management recommendations. For most studies, flows had been either the minimum required under earlier rules or had been very high as a result of flood operations. Export rates had varied in most studies in ways that made statistical conclusions about their effects difficult.

To address these concerns Drs. Bruce Herbold of the United States Environmental Protection Agency (US EPA) and Charles Hanson of Hanson Environmental, Inc. were asked by the United States Bureau of Reclamation (USBR) and the Metropolitan Water District of Southern California to develop a plan that would address the various concerns surrounding the lower San Joaquin conditions in a scientific fashion that could be appended to the earlier agreement. Generally Dr. Herbold led the effort in experimental design aspects and Dr. Hanson developed field sampling aspects.

The result of the Hanson/Herbold effort was an adaptive management plan to protect both San Joaquin Basin salmon and delta smelt in keeping with the scientific knowledge at the time and to simultaneously develop scientific information that would fill the missing gaps in regard to flow and export impacts on salmon. This became the Vernalis Adaptive Management Plan (VAMP). The San Joaquin River Agreement provided the funding and framework to implement the VAMP.

# 2.0 GOAL, OBJECTIVES AND DESIGN OF VAMP

*Contributed by Bruce Herbold, United States Environmental Protection Agency (US EPA)*

The VAMP had three major objectives:

- Implement protective measures for San Joaquin River fall–run Chinook salmon within the framework of a carefully designed management and study program which is designed to achieve, in conjunction with other non-VAMP measures, a doubling of natural salmon production by improving smolt survival through the Delta although the VAMP study is not designed to evaluate other factors which may be limiting future salmon production.

- Gather scientific information on the relative effects of flows in the lower San Joaquin River, CVP and SWP export pumping rates, and operation of a fish barrier at the head of Old River on the survival and passage of salmon smolts through the Delta.
- Provide environmental benefits on the lower San Joaquin River and Delta during the April-May Pulse Flow Period at a level of protection equivalent to the Vernalis flow objective of the 1995 Water Quality Control Plan (WQCP) and implement the remaining San Joaquin River Portion of the 1995 WQCP.

To achieve the goal of assessing the relative impacts of changes in Vernalis flow and SWP and CVP export rates on the survival of San Joaquin salmon smolts passing through the delta, survival was estimated for salmon smolts released upstream of Vernalis relative to those released at Jersey Point using recaptures at sampling locations in the western delta under consistent flow and export conditions that would vary from year to year. As part of the design of VAMP, a barrier at the Head of Old River (HORB) was assumed to be in place, although it was recognized that in some years the barrier would not be in place and that valuable data could still be collected.

Experimental design of VAMP was constrained by a number of factors. Earlier studies had developed considerable support for the construction of a barrier at the Head of Old River to keep salmon smolts away from the export facilities. The 1995 WQCP supported the concept of such a barrier but did not require its installation. However, such a barrier would cause flood risks at river flows over 7,000 cubic feet per second (cfs) and could not be installed at river flows over 5,000 cfs. In addition, some export water was required by local cities without any storage capacity, particularly Tracy, to meet their needs for municipal safety.

Thus, maximum experimental flows were set at 7,000 cfs and minimal exports were set at 1,500 cfs. These constraints, coupled with the Biological Opinion requirement that flows should be at least double export rates, resulted in maximum export rates of 3,000 cfs and minimum flows of 3,200 cfs. These maxima and minima yielded three experimental conditions that would compare the effects on survival for two levels of export at one flow and for two levels of flow at one export rate (Table 1).

**Table 1: Original Experimental Flow and Export Levels in Cubic Feet per Second (cfs)**

| | Delta Export Target Rate 1,500 cfs | Delta Export Target Rate 3,000 cfs |
|---|---|---|
| **VAMP Target Flow at Vernalis 3,200 cfs** | *X* | |
| **VAMP Target Flow at Vernalis 7,000 cfs** | *X* | *X* |

Consultation with project operators, agency biologists, consultants and university statisticians led to two important conclusions:

- a wider range of flow conditions was desirable from a statistical viewpoint and was achievable within a range of variability of about 10% and
- an intermediate combination of flows and exports was needed to discern any curvilinear responses to either parameter.

These needs led to a re-design of Table 1 to a final set of five (5) targeted experimental conditions (Table 2).

**Table 2: Redesigned Experimental Flow and Export Target Rates in Cubic Feet per Second (cfs)**

| | **Delta Export Target Rate 1,500 cfs** | **Delta Export Target Rate 2,250 cfs** | **Delta Export Target Rate 3,000 cfs** |
|---|---|---|---|
| **VAMP Target Flow at Vernalis (cfs)** | | | |
| **3,200** | ***X*** | | |
| **4,450** | ***X*** | | |
| **5,700** | | ***X*** | |
| **7,000** | ***X*** | | ***X*** |

To implement this study plan, triggering criteria to set flow targets were developed. Predicted baseline flows at Vernalis on April 15 are increased by two steps up the range of targeted flows (e.g. if baseline flows were 3,600 cfs, the targeted VAMP flow would be 5,700 cfs). However, if the current and previous year averaged out to below normal or drier, the targeted flow would only be the next higher experimental flow (e.g. if the current and previous years had both been dry or critically dry and baseline Vernalis flows were predicted to be 2,700 cfs, then the required flow would be only 3,200 cfs). Comparison with the historical record of Vernalis flows suggested that all of the flow conditions would be achieved over a span of ten to twelve years.

Export rates in most years would be set by the triggered flow rates. For years when flow targets would be 7,000 cfs, two export rates were available. It was agreed that in years with 7,000 cfs, export targets would alternate between 1,500 an 3,000 cfs, starting with the lower value.

To meet these flow targets the San Joaquin River Group Authority (SJRGA) members, the State Water Contractors (SWC), the San Luis and Delta Mendota Water Authority (SLDMWA), the USBR, and other water and environmental organizations developed and signed the San Joaquin River Agreement (SJRA). The SJRA assigned responsibilities and payments for providing the target flows, with the understanding that payment was intended to fund irrigation improvements that would reduce the economic impacts of any future regulations. When necessary the costs of export reductions have been covered through use of Central Valley Project Improvement Act (CVPIA) and Environmental Water Account (EWA) water.

The method of setting Vernalis flows has not yielded the higher experimental flow conditions. Given the extreme variability in precipitation patterns, it may not be possible to mandate high flows in dry years. The eight years of the VAMP have been very diverse hydrologically but we have so far only achieved three experimental conditions; flows of 3,200 and 4,450 cfs with export of 1,500 cfs; and flows of 5,700 cfs with exports of 2,250 cfs. This limited range of experimental conditions has greatly limited the conclusions that can be drawn, as will be described at greater length later in this report.

# 3.0 CHALLENGES ENCOUNTERED DURING VAMP STUDIES

*Contributed by Pat Brandes, US Fish and Wildlife Service (USFWS)*

## 3.1 LOW PRECISION WITH CODED WIRE TAGS

One limitation of the coded wire tag studies conducted during VAMP has been their lack of precision. This was especially true in the earlier years of analyses, prior to combining recoveries from Antioch, Chipps Island and the ocean fishery. However, the uncertainty or lack of an ocean fishery (in 2008) would have reduced the recoveries and again decreased the variance associated with our estimates. Without the ocean recoveries included or lack of ocean recoveries, it is likely that survival between target conditions can not be statistically differentiated because confidence intervals overlap (SJRGA, 2005). A full discussion of the Coded Wire Tag studies is presented in 4.0 of this report.

## 3.2 NARROW RANGE OF TARGET CONDITIONS

The ability to detect differences between target conditions is a function of the magnitude of effects and the environmental and sampling noise associated with measuring survival. One way of increasing the ability to detect changes in survival due to flows and exports would be to measure survival at the extremes of flow and export conditions. With a HORB in place, VAMP is limited to flows of less than 7,000 cfs and exports were limited to no more than half the flow, due to the delta smelt biological opinion operating at the time the VAMP agreement was established. The narrow range of flows and exports with the HORB in place, contained within the VAMP framework, make detecting the effects of flow and exports difficult.

Flow conditions have varied over the course of the studies and survival has been measured over a broad range of flows without the HORB in place. However, exports have generally been limited to less than 3,000 cfs, per the VAMP agreement to make better direct comparisons with data obtained with the HORB at lower flows. The one exception was in 2006, where flows were high and survival was measured under two export conditions, (1,500 and 6,000 cfs).

The modeling done by the USFWS (Newman, 2008) incorporated some of the data from early studies where releases were made at Dos Reis and into upper Old River because survival was measured under high export conditions. This may overcome some of the problems with the narrow range of export conditions, without the HORB in place – however it assumes that the model is able to adequately estimate survival in the reaches where it was not measured in those years. A description of the HORB is in Section 4.0 of this report and results from survival studies are in Section 5.0.

## 3.3 CONTINUING VAMP WITH A DIFFERENT STUDY TECHNIQUE

The VAMP study as originally envisioned is incomplete. The data has not been obtained for the five flow and export targets with the HORB installed, identified in the original study plan. VAMP is a twelve-year study and after five years only three of the five targets had been achieved.

In addition, several logistical and institutional issues have been encountered that has required modification to the study plan to attempt to complete the VAMP. These limitations include the lack of study fish for coded wire tag studies, lack of a HORB (in 2008), potential inability to recover coded wire tagged fish due to limiting trawling at Chipps Island and Antioch and the reduction/suspension of an ocean fishery (2008). To address the issues identified above we modified the study plan of VAMP in 2007 and 2008 to use micro-acoustic tags to estimate survival through the Delta. Logistical and equipment failures in the initial years have limited our ability to estimate survival through the Delta. However, conceptually the acoustic methodology appears sound and if equipment failures can be overcome, it seems possible that survival through the Delta could be measured using this technology and the remaining years of VAMP could be completed.

One of the questions is how could the data obtained from coded- wire-tagged juvenile salmon be compared to that developed using the acoustic tags. While the data are from two different methodologies, both have been designed to estimate survival through the Delta, from Mossdale or Durham Ferry to Jersey Point. The ratios of recovery rates from the coded wire tag releases assumes that within a paired group, probability of capture (and recovery) at Chipps Island, Antioch and in the ocean is the same, thus the ratio of recovery rates equals the ratio of survival probabilities. Similar survival probabilities can be estimated using mark-recapture model structures such as Cormack (1964), Jolly (1965) and Seber (1965). Modeling route specific survival is based on Skalski et al., (2002). Thus the two types of estimates with their respective confidence intervals can be estimated and compared.

The benefit of using acoustic tags is that survival can be measured more precisely and modeled using route and reach modeling approaches. This approach can identify specific reaches of the Delta where the tagged fish experience high mortality and which routes are used to migrate through the Delta. This added information will help sort out potential mechanisms for whatever survival is measured- something that was limited using coded wire tags. The liability of acoustic tags is the short battery life (11 days in 2008) of acoustic tags small enough to use to tag fall run smolts from the San Joaquin basin.

In 2008, the study design was developed to estimate survival between Durham Ferry and Mossdale and Jersey Point using tagged fish released at Durham Ferry and receivers deployed at Jersey Point and Chipps Island (Mallard Island). The dual array of receivers at Chipps Island allowed survival to also be measured to Chipps Island and allow any fish that entered the system downstream of Jersey Point and Three-Mile Slough (via trucking from the fish facilities) to be included in survival estimates. A second release group was used at Stockton to assure that at least some fish survived to Chipps Island. By having a receiver at Mossdale, survival could be estimated from Durham Ferry to

Mossdale. In addition, the model could estimate the proportion of fish diverted into upper Old River and survival in the various reaches of the mainstem San Joaquin River and in the central Delta.

## 3.4 ABSENCE OF A ROCK BARRIER AT HEAD OF OLD RIVER

In the original VAMP design, a rock barrier in upper Old River was assumed to be in place during the VAMP period when target flows were 7,000 cfs or less. In most years since 2000, this was the case, with the exception of 2008. The rock barrier at the head of Old River was not installed in 2008 due to a court decision regarding the protection of delta smelt. Without the rock barrier installed at the head of Old River, a part of the foundation associated with the VAMP study was changed. Survival through the Delta at low flows, without the rock barrier at the HOR, is likely different than it would be at low flows with the HORB. Thus comparing past data obtained with the HORB to that obtained in the future without the HORB will make isolating the effects of flow and exports on survival more difficult.

# 4.0 VAMP STUDIES TO DATE

*Contributed by: Mike Archer, MBK Engineers; Pat Brandes, USFWS; Andrea Fuller, FISHBIO Environmental, LLC; and Jeff Stuart, National Marine Fisheries Service (NMFS) of the National Oceanic and Atmospheric Administration (NOAA)*

This section of the report summarizes the hydrology and survival studies associated with the VAMP. It will also include summaries on pre-VAMP studies; USFWS modeling work using the VAMP and pre-VAMP data; the results of acoustic tag experiments in 2006 and 2007 and what information is available from the 2008 acoustic experiments; the south Delta temporary barriers, which includes the HORB; and complementary studies.

## 4.1 HYDROLOGY RELATIVE TO VAMP

*Contributed by Mike Archer, MBK Engineers*

### *4.1.1 Hydrology Overview*

The VAMP provides for a steady 31-day pulse flow (target flow) at the Vernalis gage on the San Joaquin River during the months of April and May, along with a corresponding reduction in SWP and CVP Sacramento-San Joaquin Delta exports. The VAMP target flow and reduced Delta export are determined based on a forecast of the San Joaquin River flow that would occur during the pulse flow period absent the VAMP (Existing Flow) as shown in Table 3. The supplemental water needed to achieve the target flow, up to a limit of 110,000 acre-feet, is provided by the following SJRGA member agencies: Merced Irrigation District (MeID), Oakdale Irrigation District (OID), South San Joaquin Irrigation District (SSJID), San Joaquin River Exchange Contractors Water Authority (SJRECWA), Modesto Irrigation District (MID) and Turlock Irrigation District (TID). The allocation of responsibility between these agencies for the VAMP supplemental water is governed by a Division Agreement, which is summarized in Table 4. Achieving the target flow in the San Joaquin River requires the coordinated operation of the three major San Joaquin River tributaries upstream of Vernalis: the Merced River, the Tuolumne River and the Stanislaus River.

The planning and implementation for the VAMP hydrologic operation is undertaken by the Hydrology Group of the San Joaquin River Technical Committee (SJRTC). Implementation of VAMP is guided by the framework provided in the SJRA and the 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 which is 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 supplemental flow to meet the target flow: MeID, TID, MID, OID, SSJID, SJRECWA, and the USBR. Though not a water provider, the California Department of Water Resources (DWR) is closely involved with the coordination of operations relating to the potential installation of the HORB and the planning of Delta exports consistent with the VAMP.

**Table 3. VAMP Flow and Delta Export Target Flow Rates in Cubic Feet per Second (cfs)**

| Forecasted Existing Flow (cfs) | SJRGA Supplemental Water Target Flow (cfs) | VAMP Target Flow (cfs) | Delta Export Target Rate (cfs) |
|---|---|---|---|
| Less than 2,000 [1] | 2,000 | | 1,500 |
| 2,000 to 3,199 | 3,200 | 3,200 | 1,500 |
| 3,200 to 4,449 | 4,450 | 4,450 | 1,500 |
| 4,450 to 5,699 | 5,700 | 5,700 | 2,250 |
| 5,700 to 7,000 | 7,000 | 7,000 | 1,500 or 3,000 |
| Greater than 7,000 | N/A | Provide stable flow to extent possible | 1,500, 2,250 or 3,000 [2] |

[1] If the Existing Flow is less than 2,000 cfs, then the SJRGA is required to provide supplemental water to achieve a target flow rate of 2,000 cfs with the USBR responsible for obtaining water to fulfill the requirement of existing biological opinions.

[2] Suggested rates

**Table 4. VAMP Supplemental Water Division Agreement in Acre-Feet**

| Priority in Descending Order | First 50,000 acre-feet | Next 23,000 acre-feet | Next 23,000 acre-feet | Next 23,000 acre-feet | Totals (acre-feet) |
|---|---|---|---|---|---|
| MeID | 25,000 | 11,500 | 8,500 | 10,000 | 55,000 |
| OID/SSJID | 10,000 | 4,600 | 3,400 | 4,000 | 22,000 |
| SJRECWA | 5,000 | 2,300 | 1,700 | 2,000 | 11,000 |
| MID/TID | 10,000 | 4,600 | 3,400 | 4,000 | 22,000 |

### *4.1.2 Historical VAMP Hydrologic Operation*

The VAMP operation in compliance with SWRCB Decision 1641 (D-1641) was initiated in the year 2000. The year 2008 marks the ninth year of VAMP operation. A summary of the historical VAMP flows and exports is provided in Table 5. A summary of the historical VAMP supplemental water contributions is provided in Table 6.

The Hydrology Group monitors the cumulative impact of the SJRA on reservoir storage and stream flows. The MeID VAMP supplemental water is provided from storage in Lake McClure on the Merced River and the MID/TID VAMP supplemental water is provided from storage in Don Pedro Lake, thereby resulting in potential impacts on reservoir storage as a result of the VAMP operation. Any storage impacts, though, would be offset by any water conservation measures that have been instituted as a result of the SJRA and that result in a reduced reliance on river diversions. The OID/SSJID VAMP supplemental water is made available from their diversion entitlements and therefore there are no storage impacts in New Melones Reservoir on the Stanislaus River due to the SJRA. Due to the extended nature of the VAMP, a 12-year plan, the storage impacts can potentially carry over from year to year. Conversely, these reservoir storage impacts are reduced or eliminated when the reservoirs make flood control releases. The cumulative impacts of the SJRA on reservoir storage and stream flows are shown graphically in Figures 1 through 4. It should be noted that the Merced River impacts shown in Figures 1 and 2 assume that the MeID river diversions are the same with and without the SJRA. However, MeID has undertaken a number of SJRA related conservation measures that have resulted in a reduced reliance on Merced River diversions. That is, as a direct result of the SJRA, the MeID river diversions are less than they would be without the SJRA. The amount of reduction in river diversion has not yet been quantified, therefore the impacts are shown assuming no change in the river diversions.

## Table 5. Summary of Historical VAMP Period Flows, 2000-2008, in Cubic Feet per Second

| Year | Year Type [a] | VAMP Period | San Joaquin River at Vernalis Flow, VAMP Period Average (cfs) | | Delta Export, VAMP Period Average (cfs) | |
|---|---|---|---|---|---|---|
| | | | Target | Observed | Target | Observed |
| **2000** | Above Normal | 4/15-5/15 | 5,700 | 5,869 | 2,250 | 2,155 |
| **2001** | Dry | 4/20-5/20 | 4,450 | 4,224 | 1,500 | 1,420 |
| **2002** | Dry | 4/15-5/15 | 3,200 | 3,301 | 1,500 | 1,430 |
| **2003** | Below Normal | 4/15-5/15 | 3,200 | 3,235 | 1,500 | 1,446 |
| **2004** | Dry | 4/15-5/15 | 3,200 | 3,155 | 1,500 | 1,331 |
| **2005** | Wet | 5/1-5/31 | >7,000 | 10,390 | 2,250 | 2,986 [b] |
| **2006** | Wet | 5/1-5/31 | >7,000 | 26,020 | 1,500/6,000 [c] | 1,559/5,748 [c] |
| **2007** | Critical | 4/22-5/22 | 3,200 | 3,263 | 1,500 | 1,486 |
| **2008** | Critical | 4/22-5/22 | 3,200 | 3,163 | 1,500 | 1,520 |

[a] San Joaquin Valley Water Year Hydrologic Classification originally specified in the 1995 SWRCB WQCP and implemented in SWRCB D-1641.

[b] Exports were increased starting May 26 in conjunction with increasing existing flow. May 1st through May 25th average flow was 2,260 cfs; May 26th through May 31st average flow was 6,012 cfs.

[c] "First fish release-recapture period" (May 3rd – 17th)/"Second fish release-recapture period" (May 18th- June 2nd)

**Figure 1**
SJRA Cumulative Storage Impacts – Lake McClure, Merced River

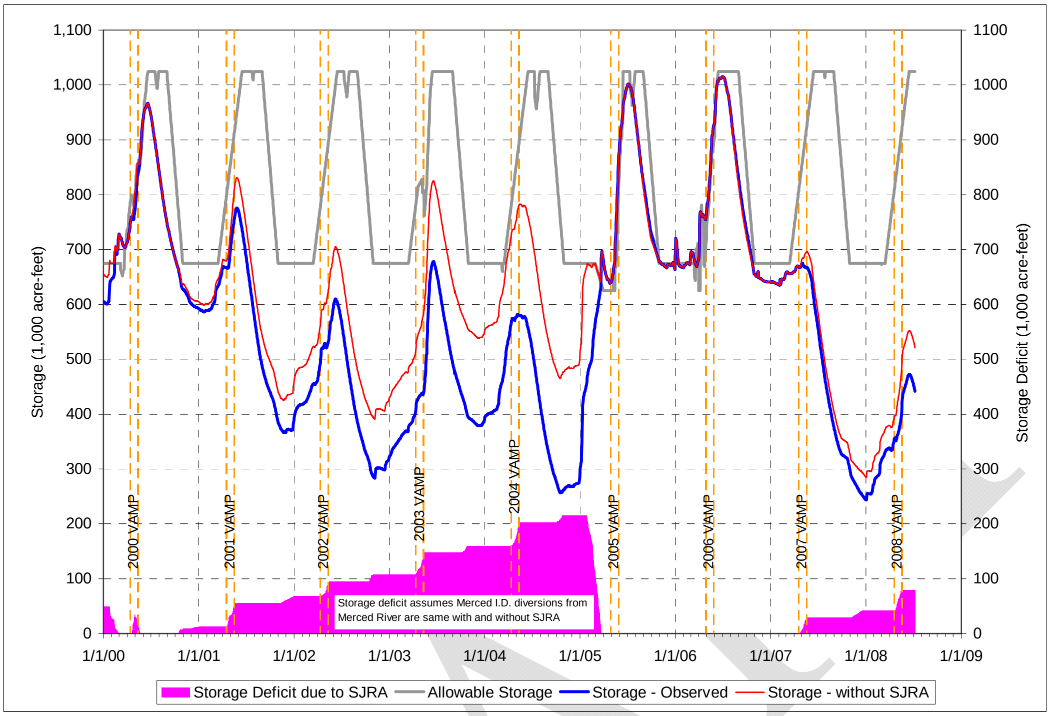



**Figure 2**
SJRA Flow Impacts – Merced River

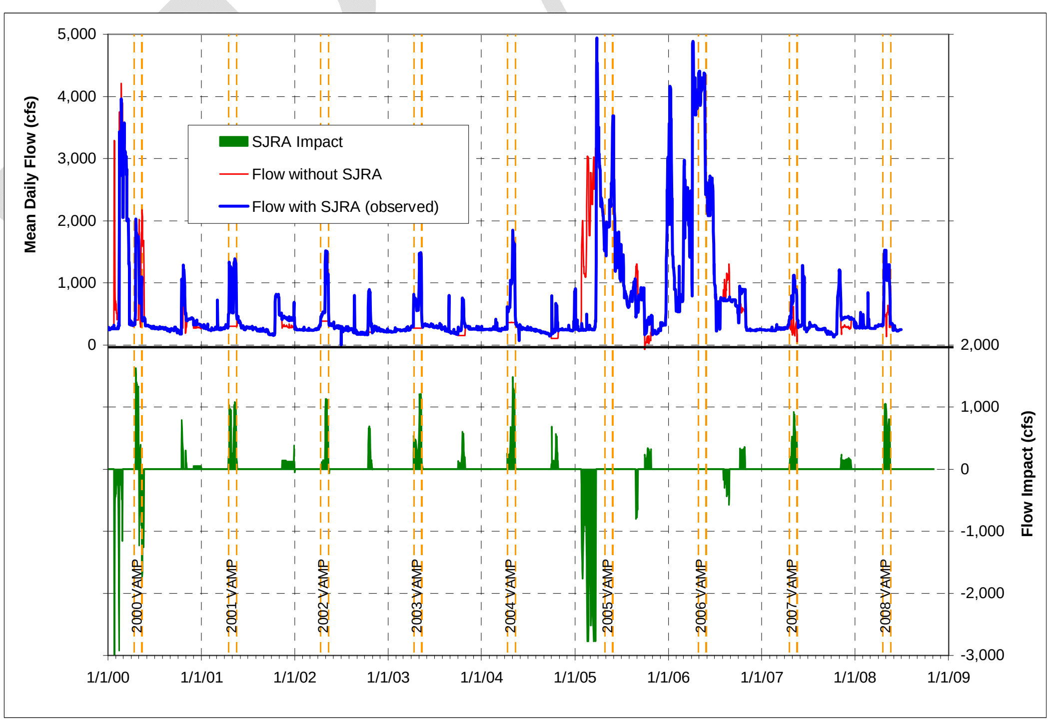


**Figure 3**
SJRA Cumulative Storage Impacts – Don Pedro Reservoir, Tuolumne River

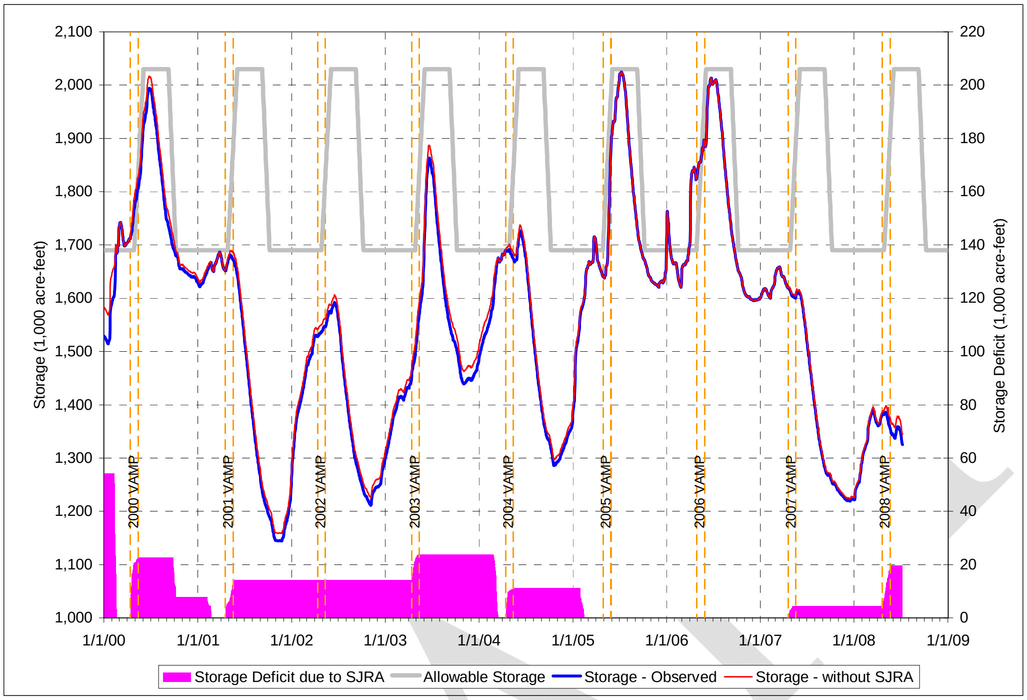



**Figure 4**
SJRA Flow Impacts – Tuolumne River

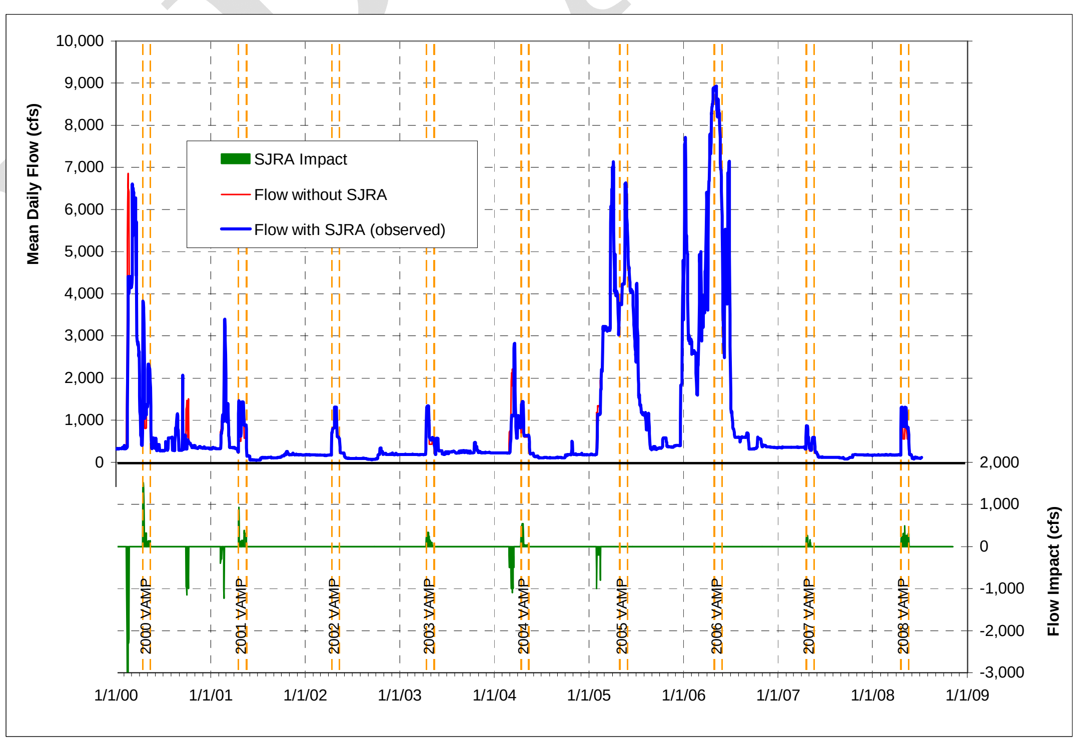


**Table 6. Summary of Historical VAMP Supplemental Water Contributions, 2000-2008 in Acre-Feet**

| Year | Total Supplemental Water Volume (acre-feet) | Supplemental Water Contribution (acre-feet) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Merced I.D. | Oakdale I.D. | South San Joaquin I.D. | SJRECWA | Modesto I.D. | Turlock I.D. |
| **2000** | 77,680 | 42,770 | 7,300 [a] | 7,300 [b] | 8,280 | 5,580 | 6,450 |
| **2001** | 78,650 | 42,120 | 7,365 | 7,365 | 7,740 | 7,030 | 7,030 |
| **2002** | 33,430 | 25,840 | 3,795 | 3,795 | 0 | 0 | 0 |
| **2003** | 58,065 | 33,257 | 5,039 | 5,039 | 5,000 [c] | 4,864.5 | 4,864.5 |
| **2004** | 65,591 | 37,680 | 5,880 | 5,880 | 5,000 [c] | 5,575.5 | 5,575.5 |
| **2005** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **2006** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **2007** | 33,330 | 28,960 | 2,185 [d] | 2,185 [d] | 0 | 0 | 0 |
| **2008** | 75,250 | 38,150 | 7,260 | 7,260 | 7,300 [c] | 7,640 | 7,640 |

[a] Provided by MID due to flow constraints on the Stanislaus River.
[b] Provided by MeID (54.55%), OID (15.91%), MID (15.91%) and TID (13.64%) due to flow constraints on the Stanislaus River.
[c] Provided by MeID
[d] Provided by MID and TID due to flow constraints on the Stanislaus River.

#### *4.1.3 Hydrologic Operation Issues*

The VAMP hydrologic operation can be boiled down to the following basic steps:

1. Determine the VAMP target flow and supplemental water needs.
2. Prepare flow schedules for the Merced, Tuolumne and Stanislaus Rivers to achieve the VAMP target flow.
3. Implementation of flow schedule.

However, inherent in these seemingly straightforward and simple steps are a number of challenges, which are briefly discussed here.

<u>Determine VAMP Target Flow</u>

The VAMP target flow is determined by estimating the mean flow that would occur at Vernalis during the VAMP target flow period without the VAMP, which is referred to as the "existing flow" (see Table 3). To do this, forecasts of the expected tributary operations are needed along with estimates of the San Joaquin River flow upstream of the Merced River and of the ungaged flow[1] in the San Joaquin River at Vernalis. The tributary operations on the Tuolumne and Stanislaus Rivers are tied to the current and forecasted hydrologic conditions; therefore the forecasts of the tributary

[1] The ungaged flow in the San Joaquin River at Vernalis is the difference between the reported flow at the Vernalis gage and the sum of the reported flows at the tributary measurement points and the estimated upper San Joaquin River flow.

operations will change if the hydrologic conditions change. There is some uncertainty associated with the forecast of the upper San Joaquin River flow, but it tends to have a somewhat predictable recession pattern in the April-May period. The forecast of the ungaged flow is the factor with the most uncertainty. Review of historical data shows little correlation between the ungaged flow and the hydrologic conditions and that the best predictor appears to be the value occurring at the beginning of the period. Comparisons of the forecasted and observed upper San Joaquin River flows and ungaged flow at Vernalis are provided in Table 7 for the VAMP study period.

**Table 7. Comparison of Forecasted and Observed Upper San Joaquin River Flow and Ungaged Flow at Vernalis in Cubic Feet per Second (cfs)**

| Year | VAMP Period | Forecast Date | Upper San Joaquin River Flow, VAMP Period Mean (cfs) | | Ungaged Flow at Vernalis, VAMP Period Mean (cfs) | |
|---|---|---|---|---|---|---|
| | | | Forecast | Observed | Forecast | Observed |
| **2000** | 4/15-5/15 | 4/13 | 395 | 496 | 550 | 784 |
| **2001** | 4/20-5/20 | 4/16 | 375 | 350 | 650 | 368 |
| **2002** | 4/15-5/15 | 4/9 | 248 | 230 | 400 | 424 |
| **2003** | 4/15-5/15 | 4/9 | 388 | 276 | 300 | 362 |
| **2004** | 4/15-5/15 | 4/9 | 254 | 362 | 500 | 127 |
| **2005** | 5/1-5/31 | 4/28 | 693 | 1,629 | 400 | 337 |
| **2006** | 5/1-5/31 | 4/25 | 9,652 | 9,283 | 2,000 | -109 |
| **2007** | 4/22-5/22 | 4/18 | 183 | 268 | 300 | 69 |
| **2008** | 4/22-5/22 | 4/18 | 259 | 252 | 0 | -56 |

<u>Prepare Tributary Flow Schedules</u>

The amount of flow expected on the tributaries is determined in the previous step. In this step the primary challenge is developing a daily schedule of flows that satisfies the needs or requirements on the individual tributaries while achieving a relatively stable flow in the San Joaquin River at Vernalis. This step is undertaken in close coordination between the fisheries agencies and operators to coordinate desired pulse flows and ramping rates on the tributaries.

<u>Implementation of Flow Schedule</u>

The previous planning steps are essentially paper exercises in which the greatest challenges are tied to forecasting. During the implementation phase the main challenges involve uncertainty related to real-time flow data and limited ability to make operational adjustments when observed ungaged and/or upper San Joaquin River flows start to deviate significantly from the forecasted values.

The real-time flows reported by the United States Geological Survey (USGS) and California Data Exchange Center (CDEC) are dependent on the most current rating shift. Flow measurements are made at stream gage sites periodically and if the flow differs significantly from that resulting from the existing rating shift, an adjustment is made to the rating shift which results in the reported flow being adjusted as well. As an example, during the 2007 VAMP operation the USGS measured a flow of 3,800 cfs at Vernalis on April 25th when the corresponding real-time flow was being reported as

3,210 cfs. Subsequently, on April 30th the USGS measured a flow of 3,280 cfs at Vernalis when the corresponding real-time flow was being reported as 3,700 cfs. Both of these measurements resulted in sudden and significant changes in the reported real-time flow. Examples of the differences between real-time flow data and final published flow data are presented in Figures 5 and 6.

Another potential challenge with respect to the use of real-time flow data would be a situation where a gage or the gage data transmission malfunctions or fails. Fortunately, this situation has not occurred at any of the main measurement sites during the VAMP periods to date.

The ability to make flow adjustments in response to deviations from the forecasted flow schedule are limited by the distance of the tributary points of control to Vernalis (see Table 8). Additionally, MeID has a requirement to notify Pacific Gas & Electric (PG&E) at least 48 hours in advance of any changes to schedules reservoir releases.

**Table 8. Distances and Travel Times From Control Points to Vernalis**

| | Approximate Distance (miles) | Estimated Travel Time |
|---|---|---|
| **Merced River at Exchequer Dam to Vernalis** | 108 | 5 days [1] |
| **Tuolumne River at Lagrange Dam to Vernalis** | 64 | 2 days |
| **Stanislaus River at Goodwin Dam to Vernalis** | 61 | 2 days |

[1] The Merced River response is further constrained by a 48 hour notification requirement with PG&E for changes to Exchequer Dam scheduled releases.

## 4.2 SUMMARY OF HEAD OF OLD RIVER BARRIER OPERATIONS AND MONITORING OF FISH ENTRAINMENT

*Contributed by Jeff Stuart, National Marine Fisheries Service (NMFS) of the National Oceanic and Atmospheric Administration (NOAA) and Pat Brandes, US Fish and Wildlife Service (USFWS)*

### *4.2.1 Introduction*

The installation of the Head of Old River Barrier (HORB) is a component of the South Delta Temporary Barriers Program (TBP). The Vernalis Adaptive Management Plan (VAMP) experimental studies incorporate the installation of the spring HORB by the DWR to redirect emigrating fall-run Chinook salmon down the San Joaquin River instead of into Old River, to minimize their movement into Old River where survival has been shown to be lower. The South Delta TBP is an ongoing project which installs up to four rock barriers in channels located in the southern portion of the Sacramento - San Joaquin Delta near the cities of Tracy and Lathrop in San Joaquin County, California. The South Delta TBP was initiated in 1991 in response to a lawsuit filed by the South Delta Water Agency (SDWA) in 1982 against DWR. DWR agreed to install these four

**Figure 5**
Comparison of Real-time and Published Flow Data, San Joaquin River near Vernalis

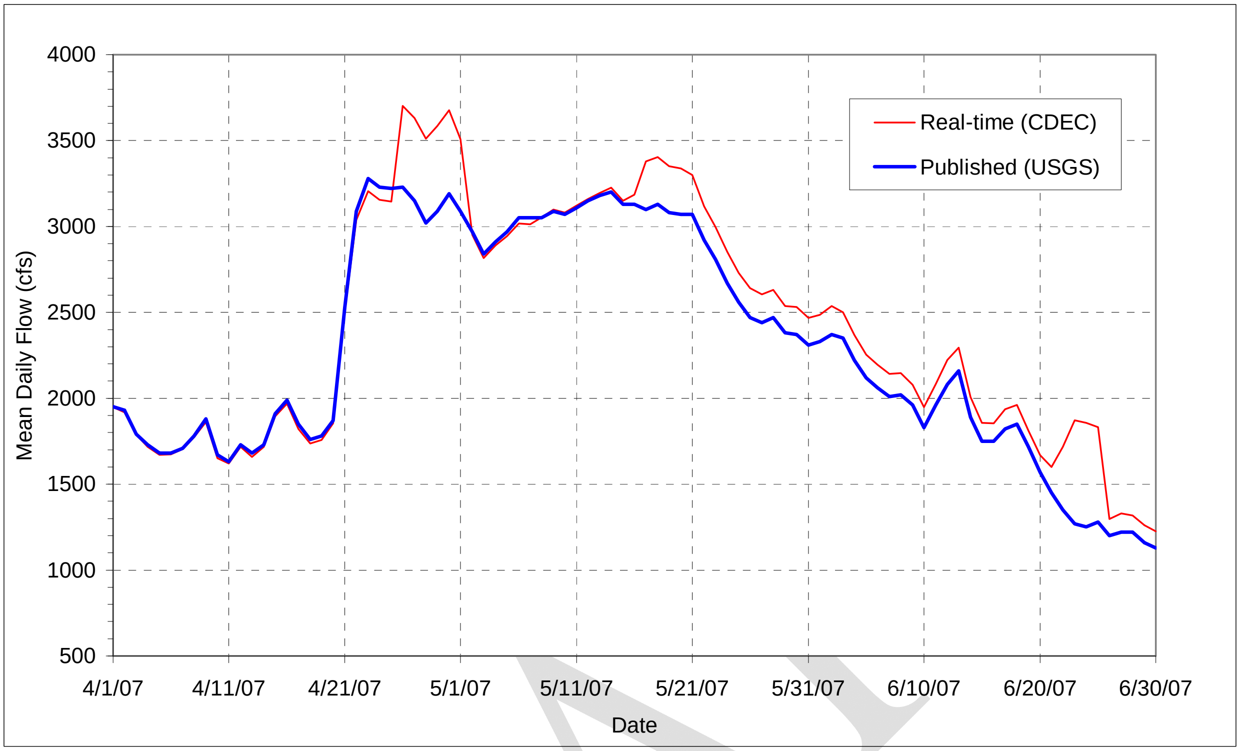
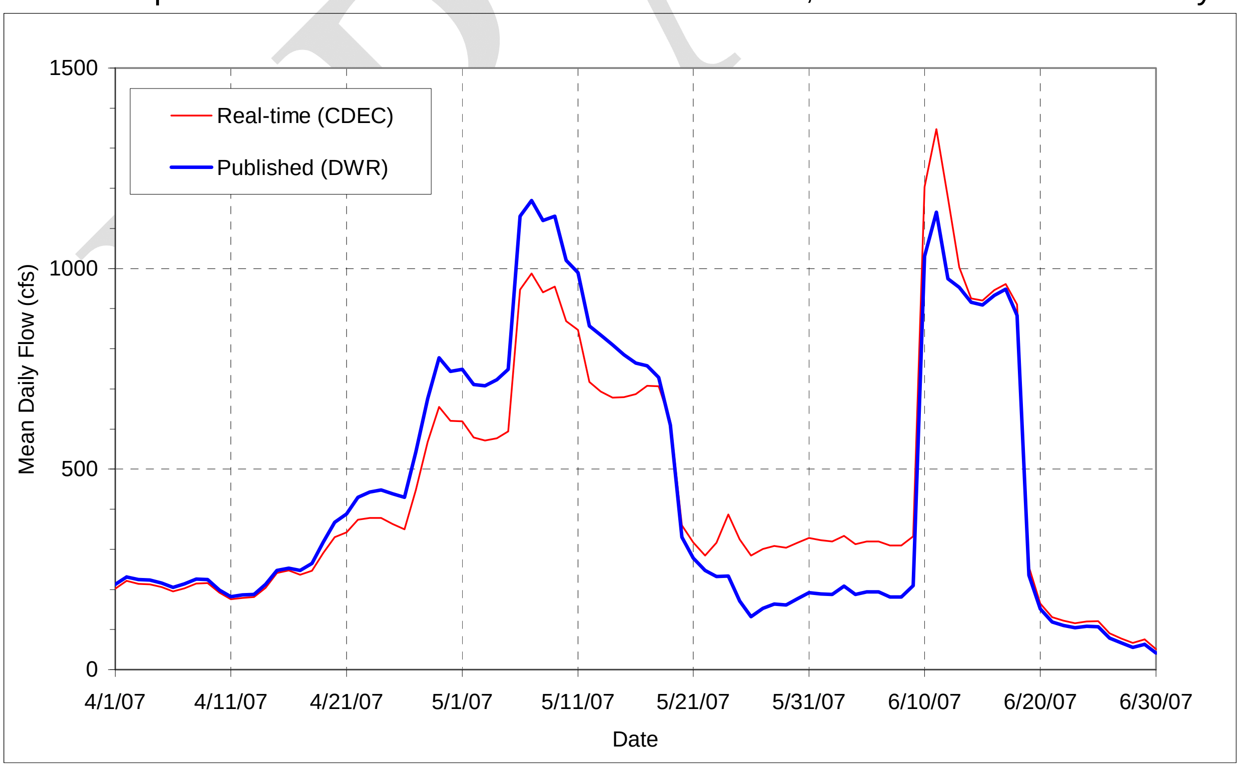



**Figure 6**
Comparison of Real-time and Published Flow Data, Merced River near Cressey



barriers to ensure that local agricultural diverters within the SDWA service area did not experience adverse water level and circulation impacts caused by the SWP and CVP. The first installation of the HORB occurred in 1992. Subsequent barrier installations have occurred in 1994, 1996, 1997, 2000, 2001, 2002, 2003, 2004, and 2007. High flows in the San Joaquin River prevented installation of the HORB in 1993, 1995, 1998, 2005 and 2006 (see table 9). Installation in 1999 was precluded due to the inability to obtain permission to access the installation site from the adjoining landowner.

The TBP installs three rock barriers in Old River near Tracy (ORT), Middle River (MR), and Grant Line Canal (GLC) near the Tracy Boulevard Bridge which are designed to act as flow control structures, "trapping" tidal waters behind them following a high tide. These barriers improve water levels and circulation for local South Delta farmers. The fourth barrier, the HORB is designed to improve migration conditions for Central Valley fall-run Chinook salmon (*Oncorhynchus tshawytscha*) originating in the San Joaquin River watershed during adult and juvenile migrations (*i.e.*, fall and spring) by "blocking" migratory movements into the Old River channel from the mainstem San Joaquin River (see Figure 7). The spring HORB is the barrier that is a key component of the VAMP experimental design.

The spring HORB is typically installed during the period between April 1st and May 31st (typically for only 31 days but sometimes for longer periods based on request from the fish agencies) to provide a measure of protection for anadromous fish species emigrating through the San Joaquin River corridor towards the ocean. It is designed to reduce the loss of outmigrating San Joaquin River basin Central Valley fall-run Chinook salmon smolts by significantly decreasing their diversions down Old River, consequently reducing their entrainment at the SWP and CVP pumps. Central Valley steelhead is also believed to benefit from this protective action, although maybe not to the same extent as fall-run Chinook salmon because of their more prolonged emigration times.

### *4.2.2 Construction Of The Barriers*

The TBP entails the placement of rock barriers within the channels of Old River (ORT; 37.8100 N, -121.5427 W), middle River (MR; 37.8856 N, -121.4799 W), Grant Line Canal (GLC; 37.8198 N; -121.4477 W), and Old River near Mossdale (HOR; 37.8082 N, -121.3287 W). Quarry rock is stockpiled alongside the sections of river adjacent to the barrier installation sites on the waterside of the levee crown. Each spring, heavy construction equipment is mobilized to move the stockpiled rock from its storage location adjacent to the river channel and into the channel to form the barriers. Large front loaders, dump trucks, and long-reach excavators are used to move and place the materials. Typically, machinery works from both banks of the channel to place the rock material, as well as any additional materials such as culverts, flashboard structures, concrete reinforcing mats, or other structures. Depending on the individual design of each barrier, the 48-inch diameter steel pipes used as culverts are placed by crane after the bed of the barrier is constructed. If the barrier abutments remain in place over the winter, the culverts are typically left in place also. As the rock barrier is extended into the channel, machinery can utilize the crown of the barrier to move farther into the channel on top of the barrier to place additional materials. Construction typically takes 1-2 weeks to complete for each barrier. Removal of the barriers occurs in the fall and the installation procedure is reversed.

**Table 9. Spring Head of Old River Barrier (HORB)**

| Year | Installation | | | Removal | | |
|---|---|---|---|---|---|---|
| | Date Started | Date Closed | Date Completed | Date Started | Date Breached | Date Completed |
| **1992** | 15-April | | 23-April @ 4ft<br>26-April @ 6ft | 2-June | | 8-June |
| **1993** | (1) | | | | | |
| **1994** | 21-April | | 23-April @ 10ft | 18-May | | 20-May |
| **1995** | (1) | | | | | |
| **1996** | 6-May | | 11-May | 16-May | | 3-Sept (2) |
| **1997** | 9-April | | 16-April | 15-May | | 19-May |
| **1998** | (1) | | | | | |
| **1999** | (1) | | | | | |
| **2000** | 5-April | | 16-April | 19-May | | 2-June |
| **2001** | 17-April | | 26-April | 23-May | | 30-May |
| **2002** | 2-April | | 18-April | 22-May | 24-May | 7-June |
| **2003** | 1-April | 15-April | 21-April | 16-May | 18-May | 3-June |
| **2004** | 1-April | 15-April | 21-April | 19-May | 24-May | 10-June |
| **2005** | (1) | | | | | |
| **2006** | (1) | | | | | |
| **2007** | 11-April | 20-April | 26-April | 19-May | 22-May | 6-June |

(1) Barrier not installed due to high San Joaquin River flows.

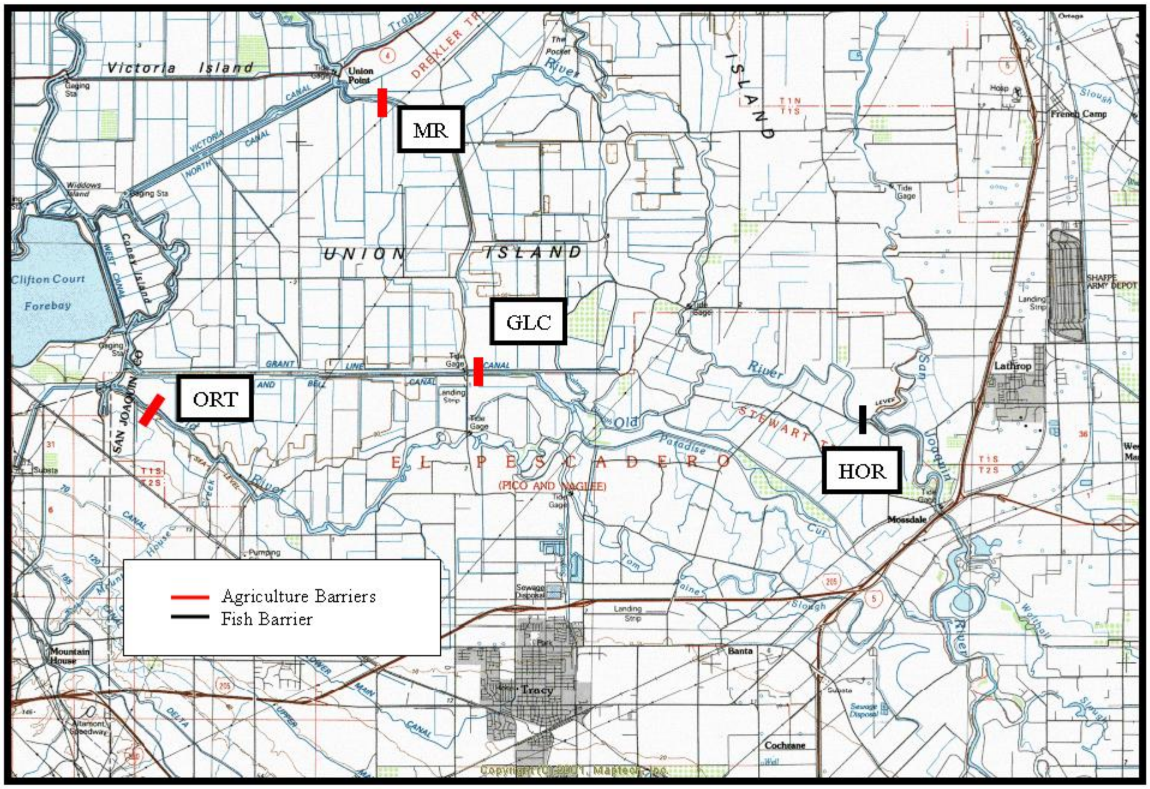
(2) Barrier was breached on 5/16/96 on an emergency basis, but complete removal was not accomplished until 9/3/96 after the US Army Corps of Engineers demanded compliance with the permit.



### *4.2.3 Physical Description of the HORB*

This barrier is located at the divergence of Old River from the SJR near the City of Lathrop. The spring HORB was originally designed to withstand SJR flows of about 3,000 cfs. However, through the years, an alternate design was developed to include flows higher than the benchmark 3,000 cfs. A "low flow" barrier would be built to an elevation of +10 feet mean sea level (MSL) when the target flows during the VAMP are below 7,000 cfs. A "high flow" barrier would be built to an elevation of +11 feet MSL for San Joaquin River target flows above 7,000 cfs and additional rock material would be placed on the abutments to raise their elevations to +13 feet MSL. Both of these current designs are equipped with six 48-inch operable culverts with slide gates which are placed adjacent to the south abutment of the barrier, parallel to the flow of water in the Old River channel. The gates can be operated to allow differential amounts of SJR water to flow into Old River to facilitate the maintenance of water elevations in the South Delta channels during the spring VAMP actions. These operable culverts were added starting in 1997 in response to complaints from farmers in the SDWA that the installation of the HORB negatively impacted the water elevations in the South Delta. Initially, two culverts were installed, but the number of culverts was subsequently increased to six in the year 2000 to supply a sufficient volume of water to irrigators in the South Delta. The steel frames of the slide gates on the culverts also enable fyke nets to be attached to the culverts to monitor fish entrainment through them during the spring installation. The HORB is approximately 225 feet long, 85 feet wide at the base of the barrier, and is composed of approximately 12,500 tons of quarry rock. The middle section of the barrier has been backfilled with clay and armored with concrete mats to protect it against scouring during overtopping flows. The HORB is installed when ambient flows in the SJR are below 5,000 cfs. Installation can not be carried out when flows exceed 5,000 cfs.

**Figure 7**
Location of Temporary Barriers in the South Delta




### *4.2.4 Barrier Operations and Monitoring for Fish Entrainment*

The flows within the channels of the mainstem San Joaquin River and Old River are continuously monitored during the VAMP experimental period for flow, stage, and velocity within the vicinity of the HORB and within selected culverts (acoustic Doppler current meters – ADCMs). Although the HORB was originally designed to block all of the flow into Old River, the permeability of the HORB has been modified over the years. Due to complaints of lowered surface water elevations in the South Delta by the SDWA, up to 6 culverts have been installed in the HORB since the year 2000 (2 culverts from 1997 to 2000). These culverts permit a fraction of the SJR water to pass through the barrier and alleviate water elevation problems in the South Delta during the operational periods of the HORB in spring and fall. The operation of these culverts has increased the potential for a fraction of the outmigrating fish (both fall-run Chinook salmon and Central Valley steelhead) to be entrained into the culverts and passed into Old River below the barrier during spring operations. In order to ascertain the level of entrainment, the VAMP experiment has placed fyke nets over the outlets of the culverts during the operations of the HORB. Mark and recapture experiments utilizing Chinook salmon smolts from the MRH have been carried out by the USFWS and CDFG during the VAMP experiments. Based on the data collected, the USFWS and CDFG estimate that this entrainment is approximately 0.5 to 1.5 percent of the fish passing by the barrier as reflected by the recovery of marked fish released upstream of the barrier's location. This data was collected as part of the VAMP experiments during the period from the year 2000 to 2006 (SJRGA 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008; DWR 2002, 2003, 2005, 2006, 2007). These data also indicated that there are distinct differences between nighttime and daytime entrainment rates, and less so with the status of the tides. The highest entrainment rates occur during the night as compared to the day. Flood tides following the low tide appear to have a greater entrainment rate than ebb tides following the high tide, but this relationship is weaker than the nighttime/daytime effect.

## 4.3 VAMP SALMON SMOLT SURVIVAL INVESTIGATIONS

*Contributed by Pat Brandes, US Fish and Wildlife Service (USFWS)*

Juvenile salmon smolt survival through the south Delta has been measured under the framework of VAMP since the year 2000. Previous to that similar south Delta studies were conducted at various flow and exports levels and for the remainder of this report they will be referred to as pre-VAMP studies. The primary objectives of conducting the VAMP study was to determine the effects of San Joaquin River flows, SWP and CVP water exports, and HORB placement on survival through the Delta of Chinook salmon smolts emigrating from the San Joaquin River. In 2005 and 2006 flows were too high to install the HORB. Therefore the VAMP study design was modified in those two years to accommodate the lack of HORB. Prior to the year 2000, the study design in the pre-VAMP studies was similar, although the flow and export levels tested were not the same as those contained within the VAMP framework that has been used since the year 2000. The HORB was installed in some of the pre-VAMP years (1992, 1994 and 1997). Data from the pre-VAMP studies were used in conjunction with that obtained with the VAMP to increase sample sizes when assessing the relative roles of exports and flows on survival through the Delta for juvenile salmon originating from the San Joaquin tributaries.

This section summarizes the methods used to conduct the Chinook salmon smolt survival investigations associated with VAMP (and pre-VAMP) and the estimates of survival. It will also summarize the modeling of the VAMP and pre-VAMP data that has recently been conducted by the USFWS. For more detailed information on each of the study years please refer to the corresponding annual reports (USFWS, 1992, 1993, 1994 and 1998; IEP, 1996-1998; Brandes, 2000; SJRGA, 2001 – 2008). Further information is provided in Brandes and McLain, 2001 and Newman, 2008 (tables listing the number of fish released and locations of releases and recoveries).

### *4.3.1 Conceptual Model*

One of the objectives of the VAMP was to better understand the relationship between smolt survival through the Delta and San Joaquin River flows, combined CVP and SWP exports and installation of the HORB. Survival during the smolt life-stage was assumed to be the mechanism behind two statistically significant relationships between escapement and 1) San Joaquin River flow at Vernalis and 2) the flow/export ratio, 2 ½ years earlier (SJRGA, 2007) (Figures 8 and 9). Both relationships (without the years when a HORB were installed) were statistically significant at the $p<0.01$, with flow/exports accounting for somewhat more of the variability (($r^2 = 0.56$) than the relationship with flow alone ($r^2 = 0.40$). While years with the HORB in place are noted in the graphs, the HORB was not in place for the entire migration period in each of the years and the resulting escapement would represent juveniles migrating with and without the HORB in place.

To determine whether flow or flow/exports was better at predicting escapement 2 ½ years later, Dr. Newman conducted a K-fold cross validation where K equaled 5. Essentially this analysis breaks the data down into five random groups and uses data not used to fit the model to validate the model. In this analysis, it was found that the total absolute prediction error was about 15% less using the model that incorporated the flow/export variable, indicating that it better predicts the data than the model using flow alone (SJRGA, 2007).

It is these relationships between flow and flow/exports and escapement that are the basis for the hypothesis that increasing flow and decreasing exports during the smolt outmigration will increase adult escapement to the San Joaquin basin. The strength of using adult escapement is that there are more data gathered and it is over a broader range of conditions than that obtained with smolt survival under the pre-VAMP and VAMP studies. On the other hand, there is some uncertainty and noise in these relationships because escapement does not separate fish of different ages contained within annual escapement estimates, reflect the impact of declining ocean harvest in recent years or the uncertainty associated with the escapement estimates themselves.

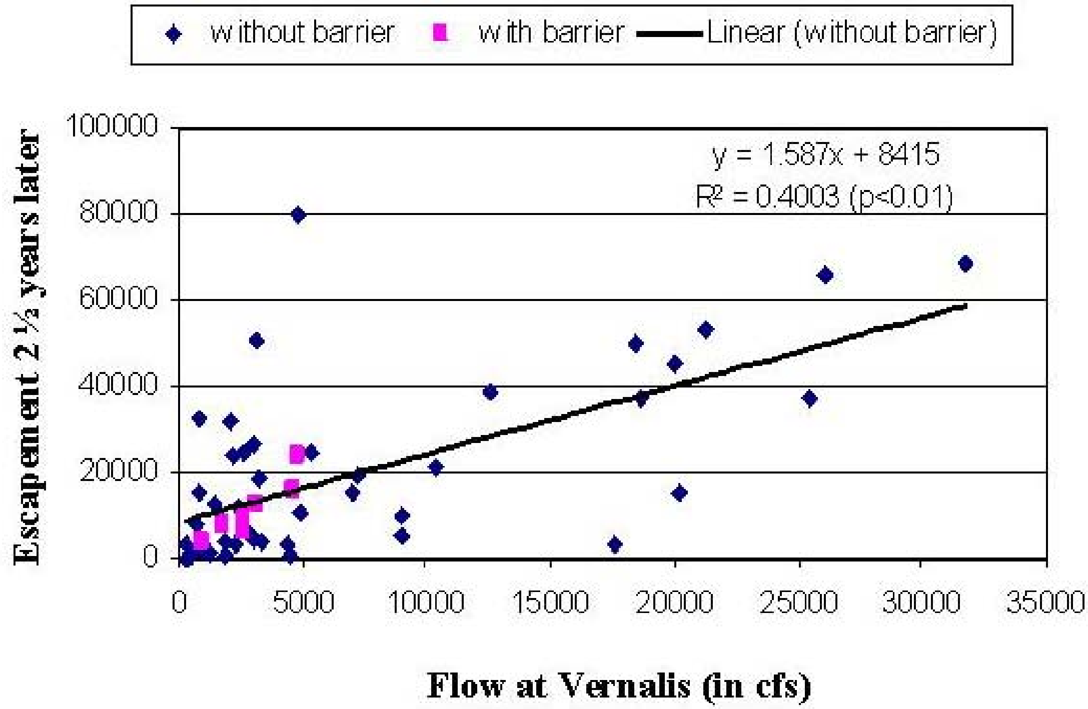
Perhaps a more appropriate way to assess relationships between adult escapement and flow, exports, and/or HORB would be to use brood year production cohorts which have been developed for San Joaquin River fall-run Chinook salmon as described in Mesick et al. (2007). In an analysis using estimates of cohorts produced each year, Mesick and Marston found that spring flows at Vernalis explained 60% of the variability in cohort trends, while exports alone explained 8% of the variability, and the export/inflow ratio explained 63% of the variability (Figures 10 and 11). These analyses using cohorts instead of escapement seems to show a smaller incremental improvement in explaining the variability in escapement using an export/flow ratio rather than using flow alone (CDFG, unpublished data).

### *4.3.2 Coded-wire Tagging*

Between 2000 and 2006 juvenile salmon from Merced River Hatchery (MRH) were marked with coded wire tags (CWT) and released to estimate survival through the Delta. The full study plan required the use of 400,000 CWT Chinook, but in nearly every year the full allocation was not provided due to limited numbers of fish available and competition with other studies. In each year, salmon were marked by clipping their adipose fin and inserting a CWT into their snout. After marking and tagging, groups of fish were generally held, separately by tag code, for approximately three to four weeks before release. Each group was tagged with CWT's with distinct tag code. Sub-samples of tagged salmon were examined at the hatchery to obtain estimates of the mean size of individuals at release within groups and CWT retention rates. CWT retention is typically high and salmon from the sub-samples that did not have a tag detected were sacrificed to determine if these fish contained an undetected, non-magnetized tag. No sub-sampled fish were found to contain non-magnetized tags. Average tag retention documented by MRH was generally high across years.

**Figure 8**

Vernalis flows (April 15 – June 15) versus escapement 2 ½ years later in years with and without the HORB between 1951 and 2003




Prior to the year 2000, CWT fish used in the pre-VAMP studies were from either MRH (1986-1989, 1996-1999) or Feather River Hatchery (FRH) (1989-1998). Pre-VAMP studies were also conducted in 1985 using fish from MRH, but fish that were marked using spray-dye.

### *4.3.3 Effective Release Numbers*

Each year the CDFG calculated the number of fish released for VAMP and pre-VAMP studies by tag code using a multi-step process. First the pond loss at the hatchery (HL) was subtracted from the total number tagged (TM) by tag code to obtain the hatchery release number (HR). Secondly, the mortalities from the quality control (QCL), loading (LL) and transportation (TL) processes were subtracted from the HR to obtain the number released at the site (SR). Lastly, the number released at the site (SR) was then corrected for the tag retention rate (TRR) to obtain the number of fish with tags released at the site (ST). The following equations restate this:

$$HR = TM - HL$$
$$SR = HR - QCL - LL - TL$$
$$ST = SR * TRR$$

The total number of fish released at the site with tags was approximately accurate even in 1996 and 1997 when sub-samples of fish from some of the release groups were released after they were held in net pens for assessing fish condition and short term mortality. However, starting in 1998, the sub-samples of fish used for the condition assessments and net pen studies were sacrificed.

Because not all of the tags were read from the sacrificed fish, in order to estimate the effective number of fish released by group, we first had to combine the numbers released with tags (ST) from multiple tag codes within the same release group before subtracting the number of sacrificed fish estimated to have had tags (PT) from the same release groups. Once the sacrificed fish with tags in the net pens (PT) were subtracted from the number estimated to be at the site with tags (ST) we obtained the effective release number (ER).

$$ER = \sum ST - PT$$

Prior to 1996, the ER and ST were equal. In past annual reports, the number of fish sacrificed was not always subtracted from the number estimated to be at the site with tags (ST). The release numbers used in Newman (2008) were updated to attempt to subtract the fish that were sacrificed in the net pens although the release numbers still do not take into account the nominal number of fish sacrificed for the fish health studies. We do not expect the relatively few fish sacrificed and not subtracted from the release numbers to affect our estimates of survival in any meaningful way.

There were two instances that we are aware of over the period of record, where tag mixing occurred at FRH and/or MRH (in 1997 and in 2006). In 1997 it was determined that the mixing would not have affected the survival indices that year (Bill Loudermilk, Mark Pierce, CDFG, personal communication). In contrast, the effective number released for the second Jersey Point group in 2006 was corrected to adjust for the mixing (SJRGA, 2007).

### *4.3.4 Pre-VAMP and VAMP Fish Releases*

CWT salmon were released at various locations over the course of the studies between 1985 and 2006 and reflect the evolution of different study designs. Marked fish releases were made in Old River, at Jersey Point and on the San Joaquin River at Durham Ferry, Mossdale and Dos Reis (Figure 11). The pre-VAMP studies are described in detail in Brandes and McLain, 2001.

Initially, pre-VAMP studies compared survival between marked hatchery smolts released into upper Old River and those released on the mainstem San Joaquin River (Dos Reis). These studies were conducted between 1985 and 1990 and suggested that survival was better for fish released on the mainstem San Joaquin River than for fish released into Old River, although differences were not statistically significant (Brandes and McLain, 2001). These studies were the basis for recommending a full rock barrier at the head of Old River (HORB) to prevent juvenile salmon from migrating down Old River where their survival appeared to be less. However, the principal investigators recognized that the survival difference between upper Old River and the San Joaquin River might be less than that anticipated with an actual HORB in place due to the change in hydrology with the full HORB in place. A full barrier at the Head of Old River (HOR) would increase the amount of water diverted into Turner and Columbia Cuts from the mainstem San Joaquin river under equal export demands.

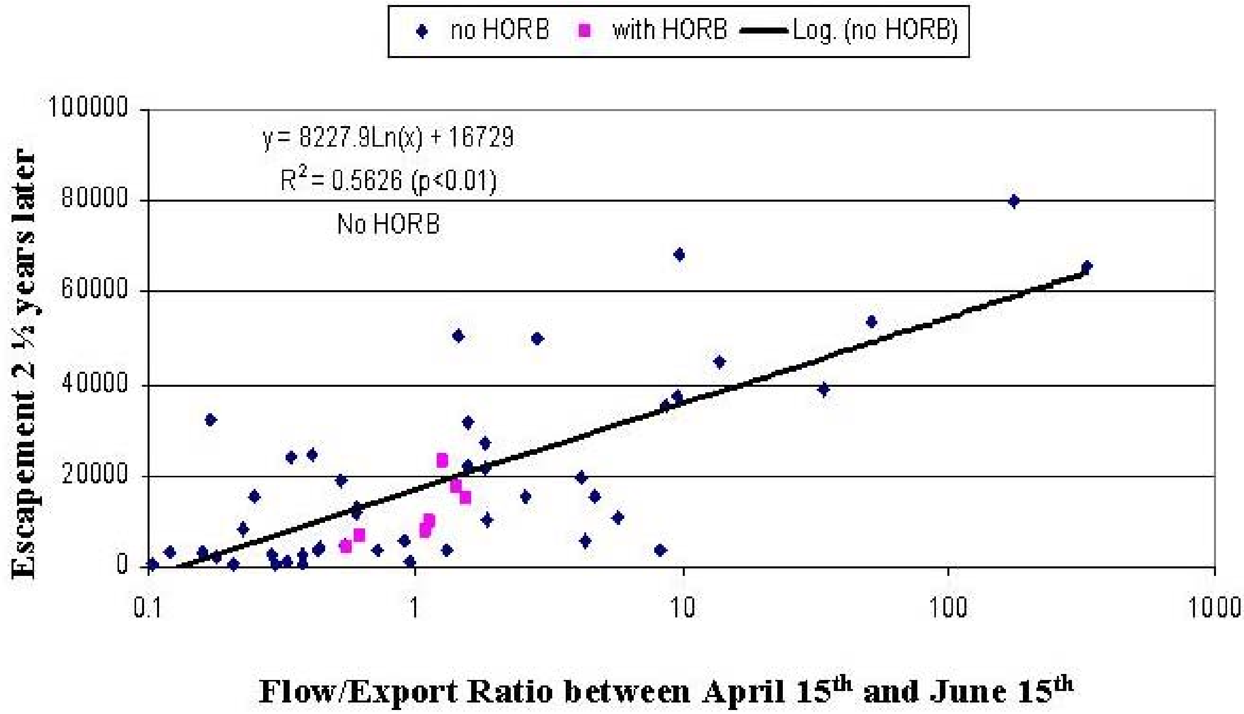
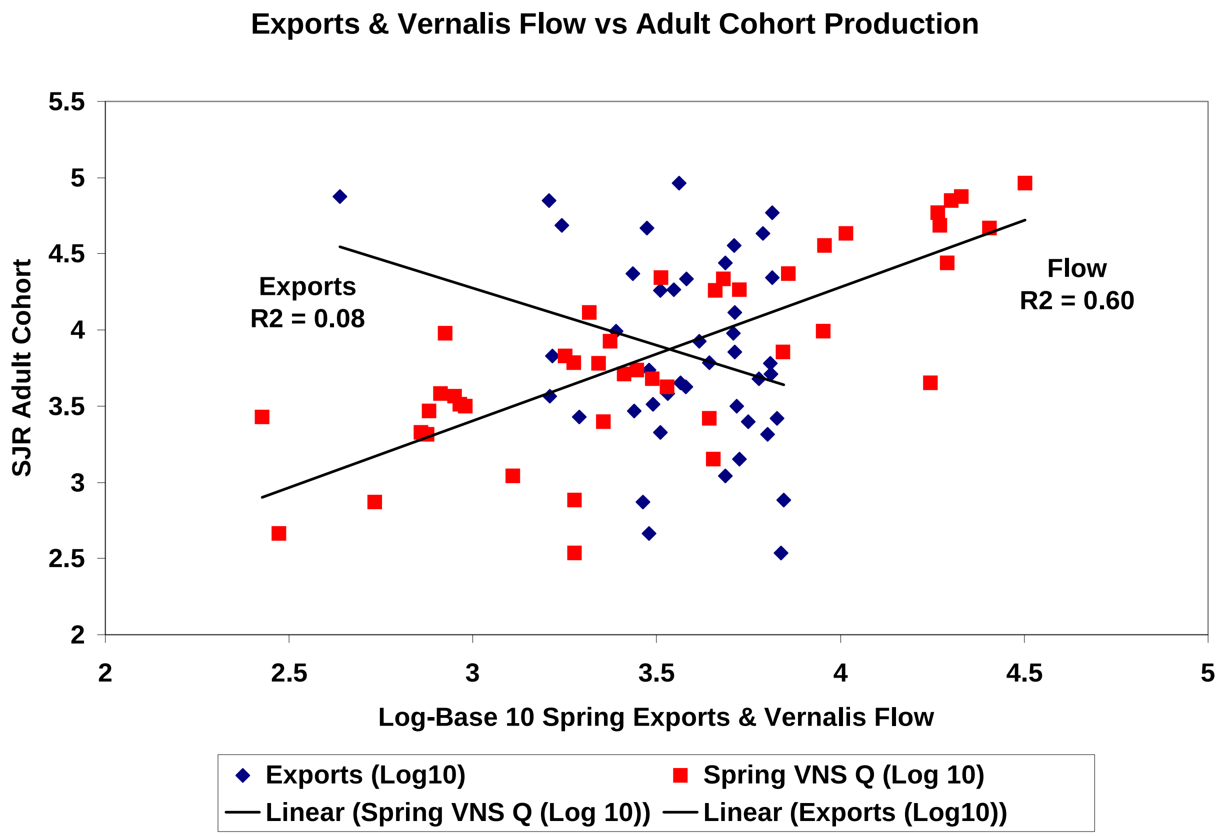



**Figure 9**
Vernalis flow/export ratio versus adult escapement 2 ½ years later in years with and without the HORB in place between 1951 and 2003

During the spring of 1992 a full rock barrier was installed at the HOR and attempts were made to confirm the benefits of the HORB to salmon survival by making CWT releases at Mossdale with and without the HORB installed (Brandes and McLain, 2001). Due to the logistics of installing a HORB, releases were made without the HORB first, which resulted in survival indices to Chipps Island that were higher than with the HORB, likely due to the lower water temperatures (17.2° and 17.8° C) relative to those after installation of the HORB (20.6, 21.7, 22.2° C.) (USFWS, 1992 and Brandes and McLain, 2001). A similar experiment was conducted in 1994, but survival indices to Chipps Island were so low for all releases made at Mossdale that year, both those with and without the HORB in place, that conclusions on the benefits of the HORB could not be estimated (USFWS, 1994).

In 1993, 1995, 1998, 2005 and 2006 CWT releases were made without the HORB in place because flows were too high for installation and in 1999 the HORB wasn't installed due to landowner access problems. In 1996, the HORB was installed late due to permitting issues (May 11th) and partially breached early due to flooding concerns (May 16th) (IEP, 1996). CWT releases in 1996 included in this report were made prior to the installation of the HORB that year.

**Figure 10**
The log base 10 of April – June exports and Vernalis flows versus adult cohorts estimated to have been produced from juveniles migrating during the period of exports and spring flows (CDFG, unpublished data)




In 1997 the HORB was installed with two culverts and between 2000 and 2004 it was installed with six culverts. The culverts allowed San Joaquin River flow to enter Old River. In each of these years survival was measured using CWT fish. Between 1996 and 1998, hatchery fish from MRH were paired with those from FRH and after 1999 only MRH stock were used in the experiments.

Between 1994 and 2006 marked fish were released on the San Joaquin River at Mossdale and Jersey Point. Starting in the year 2000, releases were also made at Durham Ferry to allow the fish to distribute prior to reaching the junction with Old River. To assess the mortality between Durham Ferry and Mossdale, in most years since 2000, releases were made at both locations. In 2006, San Joaquin River flows were so high that part of the flow was diverted into Paradise Cut (a flood bypass), which is upstream of Mossdale, but downstream of Durham Ferry. To better compare results to other years, when San Joaquin flow was not diverted into Paradise Cut, the upstream release site was changed from Durham Ferry to Mossdale in 2006. Releases were made at Jersey Point in all years.

CWT releases were made at Jersey Point as a control for upstream releases (i.e. Mossdale, Durham Ferry and Dos Reis) starting in 1994. There were also a few releases made at Jersey point earlier (1989 and 1990). The releases were generally made on a flood tide at Jersey Point to increase fish dispersion throughout the channel before they migrated downstream and encountered the recovery trawls at Antioch and Chipps Island. Releases at other locations generally did not incorporate the tides for determining release times.

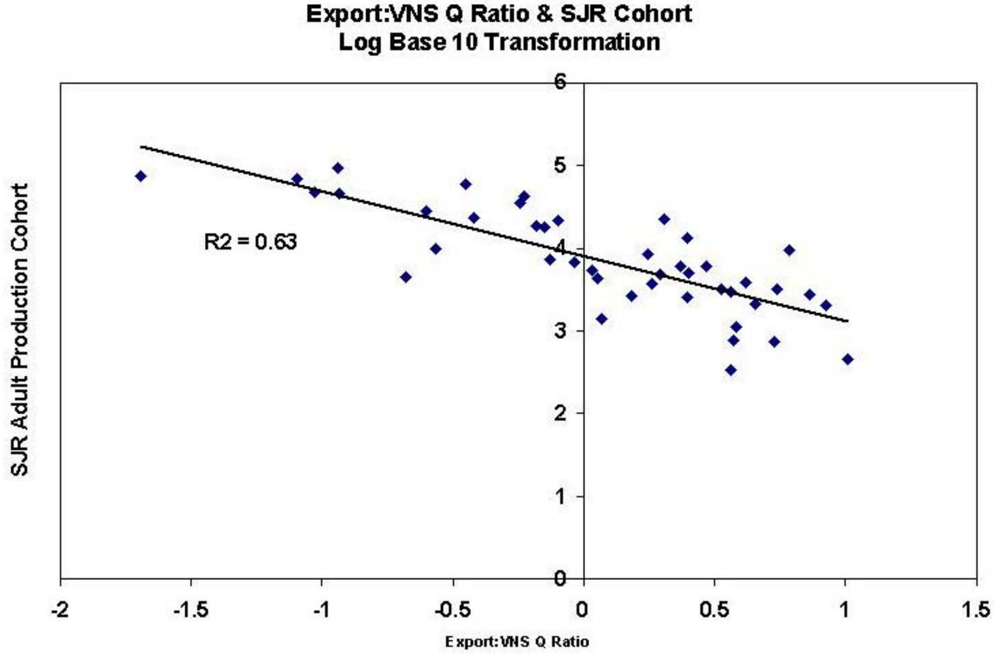
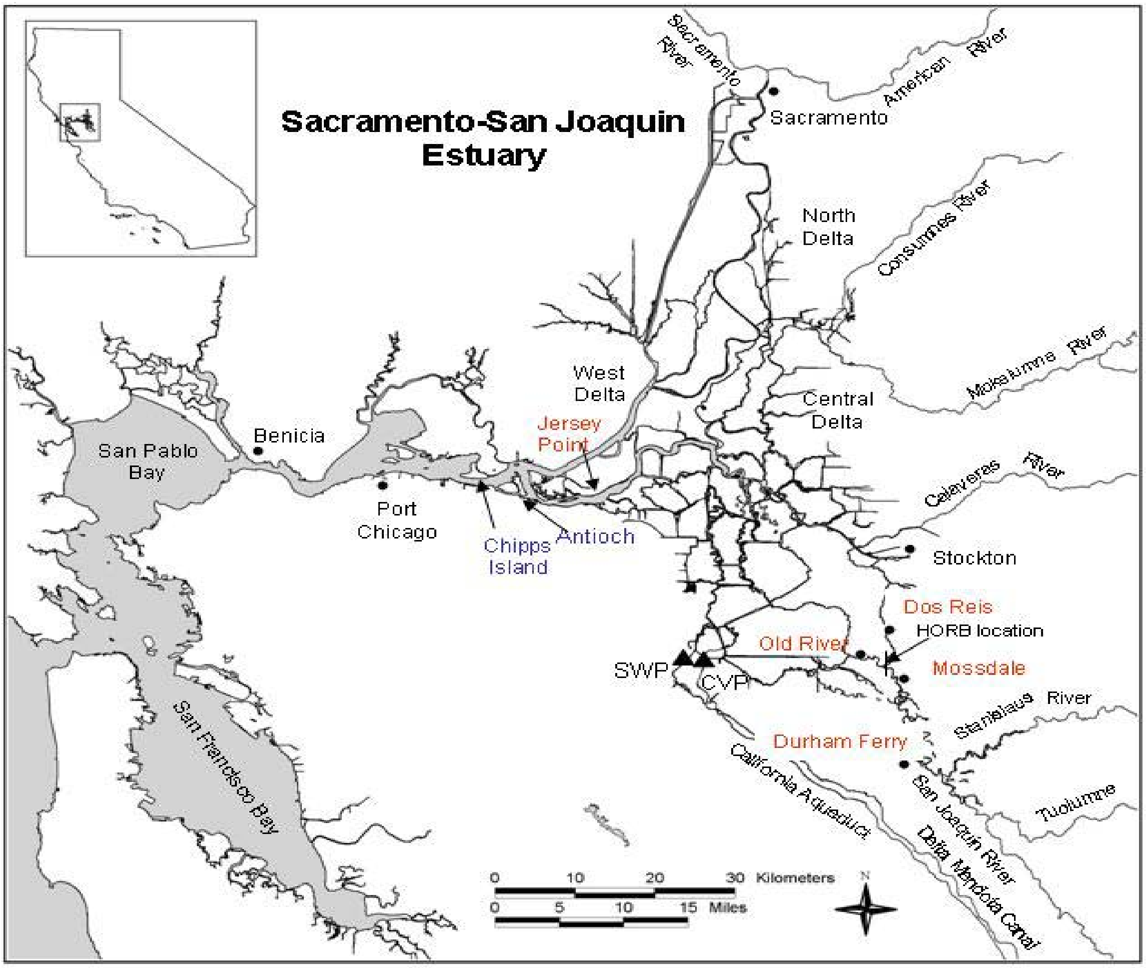



**Figure 11**
Export/Vernalis flow ratio during the spring period the juveniles migrated through the Delta versus adult cohorts (CDFG, unpublished data)

In some years CWT releases were also made at Dos Reis which is located on the San Joaquin River downstream of the HOR and was used to help assess the mortality of marked salmon from the Mossdale/Durham Ferry releases that were diverted into Old River when there was no HORB in place. An exception was in 1997, when releases were made at Dos Reis with the HORB in place. Comparison of survival indices or recovery rates of fish released at Dos Reis when compared to those indices or recovery rates based on fish released at Mossdale or Durham Ferry, assuming that survival would have been similar for Dos Reis and the Mossdale or Durham Ferry groups if a portion of the groups did not migrate into upper Old River, allows a qualitative assessment of the impact of diversion into upper Old River. Some of the fish from the Mossdale or Durham Ferry groups likely migrated into upper Old River without the HORB.

**Figure 12**

Release locations for coded wire tag and spray-dye releases as part of the VAMP and pre-VAMP salmon survival studies in the Sacramento-San Joaquin Estuary, California




The VAMP study design was intended to estimate survival between Mossdale or Durham Ferry and Jersey Point under specific flow and export levels with the HORB installed. When the initial plan was developed it was acknowledged that the HORB could not be installed due to high flows thus in those years the experimental fish were released at both Mossdale and Dos Reis to determine if there was differences in survival for smolts released at Mossdale versus those released at Dos Reis, without the HORB in place. Although it was assumed that fish released at Dos Reis migrated downstream, on the mainstem San Joaquin River, there is the potential for fish released at Dos Reis to move upstream into Old River on flood tides, especially during periods of low San Joaquin River flows and high exports.

### *4.3.5 Flow and Export Conditions*

For the VAMP period starting in the year 2000, flow and export targets were prescribed in the VAMP study plan based on the hydrology (earlier chapter). Between the year 2000 and 2004, San Joaquin River flows at Vernalis ranged between 3,200 and 5,700 cfs and exports ranged between 1,450 and 2,250 cfs with the HORB in place. During the pre-VAMP studies with the HORB (1994 and 1997), San Joaquin River flows at Vernalis were lower (less than 2,500 cfs) than they were during the VAMP studies (2000-2004) with the HORB was in place.

VAMP and pre-VAMP studies without the HORB in place had exports that ranged between 1,400 and 3,700 cfs, with the exception of the year 2006, when they were 6,000 cfs for the latter two weeks of the VAMP period (Newman, 2008). Prior to 1994, exports were at times higher than 3,700 cfs. In 1989 and 1990, studies targeted both a high (~10,000 cfs) and low (~2,000 cfs) export for each of the releases under low flows (Brandes and McLain, 2001). In 2006 survival was measured under both a high (6,000 cfs) and low export (1,500 cfs) with high flows (> 20,000 cfs) (SJRGA, 2007). Between 1985 and 1987 and in 1991, exports ranged between about 4,000 and 7,000 cfs.

For some of the relationships and modeling discussed in this report, the flow in the San Joaquin River just downstream of the HOR junction (Stockton flow) and the proportion of water diverted into upper Old River from the San Joaquin River was estimated. To estimate Stockton flow one of three equations were used, depending on the proportion of exports to Vernalis flow minus a fraction (0.03) of the channel depletion. Channel depletion was estimated at 1,500 cfs for the April $15^{th}$ - May $15^{th}$ period and 0.03 of the channel depletion was 45. The three equations were obtained from a memo from DWR to SWRCB dated December 22, 1986. These specific equations are:

1) If exports/(vernalis-45) < or = to 3 then the equation was:

(Vernalis flows - (0.4184(Vernalis) -0.0186 (Channel Depletion) - 0.0971(exports)))/Vernalis

2) If exports/(vernalis-45) > 3 but less than 10 then the equation was:

(Vernalis flows - (0.3137(Vernalis) – 0.0156(Channel Depletion) - 0.0625(exports)))/Vernalis

3) If exports/(vernalis-45) > 10 then the equation was:

(Vernalis flows - (0.1114(Vernalis) – 0.00950(Channel Depletion) - 0.0432(exports)))/Vernalis

The flow in upper Old River was derived by subtracting Stockton flow from Vernalis flow. The proportion of flow in upper Old River relative to that at Mossdale was estimated by dividing upper Old River flow by Vernalis flow. When exports and flow were equal, the proportion diverted was estimated to be 65% into upper Old River. For the modeling, the proportion of fish diverted into upper Old River from the upper release sites (Durham Ferry and Mossdale) was assumed to be the same as the proportion of water diverted into upper Old River.

### *4.3.6 Water Temperature Monitoring*

Water temperature has been monitored during the VAMP since the year 2000 using individual computerized temperature recorders (e.g., Onset Stowaway Temperature Monitoring/Data Loggers). For these years, water temperatures were measured at locations along the longitudinal gradient of the San Joaquin River and interior Delta channels – locations along the migratory pathway for the juvenile Chinook salmon released as part of the tests. Water temperatures were also recorded within the hatchery raceways at MRH coincident with the period when juvenile Chinook salmon were being tagged and held. These temperature recorders were later transported with the juvenile salmon to some of the release locations to estimate temperatures at the release locations at the time of release.

Results of water temperature monitoring within the MRH showed that juvenile Chinook salmon were reared in, and acclimated to, water temperatures of approximately 10° - 12° C prior to release into the lower San Joaquin River. Results of water temperature monitoring at Durham Ferry, Mossdale Dos Reis, and Chipps Island during the April-May period showed that water temperatures throughout the lower San Joaquin River and Delta were higher than those at the hatchery, which is usually always the case. Water temperatures measured within the lower San Joaquin River and Delta usually increased over the period of mid-April to June and may have, in some years, reduced the survival of emigrating juvenile Chinook salmon released as part of the VAMP and south Delta investigations. Prior to the year 2000, only temperatures at release and in the hatchery truck were obtained. Temperatures at each of the release sites ranged from 13 to 22° C (Newman, 2008).

The water temperature in the hatchery truck was usually about 10 degrees lower than that at the release site. This differential in water temperature between the hatchery truck and release site has been a concern for many years. Increasing the water temperatures in the trucks by adding warmer water did not seem prudent as the process alone would cause stress and potential mortality to the fish. In 1996 it was noted that for the first release at Mossdale there was only a 1° C differential between the hatchery truck and the river, but survival was still extremely low and worse than for the Mossdale release made 2 weeks earlier when the differential was 6° C. To try to assess the effect on survival of test fish from temperature differences between the hatchery truck and the release site, a sub-set of fish were held in net pens and assessed using health/physiological study techniques starting in 1996 and have continued throughout the VAMP.

### *4.3.7 Short-Term Survival Study (Net Pen Studies)*

Since 1996, short term survival studies were conducted to determine if handling, transport, temperature differential and release processes affected the immediate and 48-hour (short term) survival and general condition of the experimental fish used in the VAMP and pre-VAMP experiments. Subsets of approximately 200 CWT salmon were taken from the hatchery truck and placed in net pens (volume ~ $1m^3$; mesh size ~3 mm) just prior to release for most of the groups since 1996.

Once placed into the pens, a sub-sample of 25-30 fish from each pen were examined for swimming vigor then euthanized for measuring and documenting general condition. Each fish was measured, weighed and examined qualitatively in the field for percent scale loss, body color, fin hemorrhaging, eye quality, and gill coloration. Additionally, quality of adipose fin clip was documented. The sub-sampled fish were also used for tag code verification. After 48-hours post release, an additional 25-

30 fish from each pen were measured, weighed, and examined for condition, as described above. The remaining fish from each pen were then examined for mortalities, and for studies after 1997, the fish were euthanized, counted, measured, weighed, and retained for additional tag code verification if needed. Prior to 1997, the fish were released at the net pen site.

Sub-samples of fish in the net pens for all years were generally in good condition. In most years, between 0 and 19 fish were observed to be dead after 48 hours in the subsets of approximately 1,200 fish examined per year. Mortality in 1998 was higher and was estimated to be as great as 9.2% for the Jersey Point release made on April 28, 1998 (Table 10) (IEP, 1999a). In contrast, the health assessments conducted in 1998 concluded that the overall health of the fish examined as part of the pre-VAMP study appeared good (IEP, 1999b).

**Table 10: Total Percent Mortality for Juvenile Chinook Salmon Held in Net Pens in 1998 - Total Mortality is Based on the Total Number of Fish in the Net Pen After 48 Hours**

| Hatchery Source | Release Site | Release Date | Total Percent Mortality |
|---|---|---|---|
| Merced | Mossdale | 4/16/98 | 0 |
| Merced | Dos Reis | 4/17/98 | 0 |
| Merced | Jersey Point | 4/20/98 | 1.6 |
| Feather | Mossdale | 4/23/98 | 7.2 |
| Feather | Dos Reis | 4/24/98 | 2 |
| Feather | Jersey Point | 4/28/98 | 9.2 |

### *4.3.8 Heath and Physiology*

Starting in 1996, the USFWS California/ Nevada Fish Health Center (FHC) has provided a health and physiological assessment of pre-VAMP and VAMP release groups. The purpose of these assessments was to rule out survival differences due to differential health between release groups and between years. The FHC looked at health (bacterial, viral, and parasitic infections), smolt development, and stress response to determine if there were significant differences which might affect survival of one group over another. While differences in smolt development and stress response each year were noted, the FHC believes the most significant factor affecting survival for the fish used in the VAMP and pre-VAMP studies was infection with *Tetracapsuloides bryosalmonae* (the myxosporean parasite which causes Proliferative Kidney Disease (PKD)). Incidence of infection in MRH salmon ranged from 0 to 100% in annual pre-VAMP/VAMP study releases between 1996 and 2004 (Table 11). Most of these infections were identified early in the disease progression and fish were asymptomatic (Foott and Stone, personal communication, 9/11/06).

**Table 11. Prevalence of *Tetracapsula bryosalmonae* Detected in Merced River Fish Hatchery Chinook Salmon Smolts 1996-2004[1]**

| Year | Sample Date(s) | Prevalence |
|---|---|---|
| 1996 | 5/01 | 5/8 (63%) |
| 1997 | 5/01 | 0/10 (0%) |
| 1998 | 4/17 | 0/6 (0%) |
| 1999 | 4/20 | 0/6 (0%) |
| 2000 | 4/18 – 5/02 | 2/45 (4%) |
| 2001 | 5/01 – 5/12 | 34/34 (100%) |
| 2002 | 4/19 – 5/01 | 92/201 (46%) |
| 2003 | 4/21 – 5/02 | 30/48 (63%) |
| 2004 | 4/22 – 4/26 | 33/66 (50%) |

[1] All samples were taken from VAMP (and precursor project) release groups. Fish were assayed by histopathological examination of posterior kidney by the CA-NV Fish Health Center

In 2005, sub-samples of MRH smolts were moved to the FHC and monitored for 50 days. Over the course of the 50 days, smolts progressed from the asymptomatic stage of PKD to clinical infection and mortality. The level of clinical PKD, as demonstrated by a combined kidney lesion and anemia score, markedly increased starting at 29 days post-exposure (dpe). A total of 76 study salmon (27% cumulative mortality) died due to PKD beginning at 36 dpe through the final sample at 50 dpe. There was no observed PKD effect on time to exhaustion during a 120-minute swim challenge until 50 dpe. Similar to swim performance, saltwater adaptation was not impaired until 50 dpe.

In addition to examining MRH salmon held at the FHC, selected salmon recovered at Chipps Island in 2005 were also examined for the presence of PKD. *T. bryosalmonae* was observed in 40% (17 of 43) of the kidney imprints collected from VAMP salmon recovered in the Chipps Island trawl in 2005. From the laboratory experiments, severe disease was not detected until 29 dpe which was after the last VAMP CWT recovery at Chipps Island. These results indicate that while PKD was prevalent in VAMP out-migrating salmon, it may not have reduced their survival to Chipps Island. However PKD could be a significant mortality factor for VAMP salmon smolts during their early seaward entry phase (Foott et al., 2005).

An infection of *T. bryosalmonae* can reduce a fish's performance due to associated kidney dysfunction and anemia. However, infection with the parasite does not necessarily kill the fish. Researchers have found that over 90% of infected juvenile Chinook salmon were able to survive after being transferred into full seawater under laboratory conditions (Hedrick and Aronstien, 1987 as reported in Nichols and Foott, 2002). For the VAMP studies, it does not appear that MRH smolts have advanced PKD by the time they are collected at Chipps Island. It is uncertain whether they would recover once they enter the Bay and ocean, but there is the possibility that in some years PKD could have reduced the survival of smolts used in the VAMP studies after they migrated past Chipps Island. But of note is that testing did not show any marked difference in severity or incidence of Tb infection between groups in a given year (Scott Foott, personal communication).

It has also been reported that *T. bryosalmonae* has been at MRH since the 1980's (Hendrick et al., 1986, reported in Nichols and Foott, 2002) and in California since at least 1966 (Hendrick et al. 1985 reported in Nichols and Foott, 2002). In 2001, *T. bryosalmonae* was found in over 90% of the samples tested from naturally spawned Chinook salmon on the Merced River. *T. bryosalmonae* was also found in one of eighteen Chinook salmon sampled on the Tuolumne River in 2001, but in none of eighteen sampled on the Stanislaus River.

Scott Foott, pathologist from the FHC provided the following information on PKD at a technical meeting of the VAMP group a few years ago. "Water temperature is a major factor affecting the development of clinical PKD" (Longshaw, et al., 2002). PKD is a progressive disease at water temperatures greater than 15 degrees C. and at water temperatures of 9 degrees C. the parasite can infect fish but it can't multiply. Depending on the temperature, 10 to 90 minute exposure can lead to clinical disease, and the clinical stage lasts between 8 and 12 weeks. Recovery is between 12 and 20 weeks. The parasite's primary host is bryozoan (Okamura and Wood., 2002). FHC made some suggestions for reducing the infection by *T. bryosalmonae* such as killing macrophytes near the upstream water supply at MRH, and making sure pipes supplying water to the MRH had completely dried when not in use to minimize macrophyte and bryozoan colonization.

In 2006, similar health assessments were conducted but based on the inability to detect *T. brysalmonae* in both histological and cytological sample types it did not appear that MRH juvenile Chinook population was infected with *T. bryosalmonae* in 2006. Instead Bacterial Kidney Disease was detected. While the fish were asymptomatic for Bacterial Kidney Disease (BKD), the 23% detection rate indicates that MRH juvenile Chinook contained a high number of R. *salmoninarum* infected fish. R. *salmoninarum* infections have been documented for MRH Chinook juveniles in previous years. It is unclear whether such infection later develops into clinical disease and is a health problem for the population (Foott and Stone, personal communication, 9/11/06).

#### *4.3.9 Coded-wire Tag Recovery Efforts*

CWT salmon were recaptured in culverts at the HORB (2000- 2006), in trawling at Old River (2005 and 2006), Mossdale (since 1989), Jersey Point (1997-1999), Antioch (2000-2006), and Chipps Island (all years), and in sampling at the fish facilities of the CVP and SWP (all years). They are also recovered in later years, as adults, in the ocean fishery. CWT salmon recovered in CDFG Kodiak trawls since the year 2000 were discussed in Chapters 4 and 6 of the various annual reports.

Juvenile Chinook salmon caught at these locations with an adipose fin clip caught were processed to identify the tag code. CWT processing consists of dissecting each tagged fish to obtain the 1-mm cylindrical tag from the snout. Tags were then placed under a dissecting microscope and the numbers or series of notches were read and recorded in a database and archived. All tags were read twice, with any discrepancies resolved by a third reader.

Antioch Recapture Sampling

Fish sampling was conducted in the spring near Antioch on the lower San Joaquin River using a Kodiak trawl between 2000 and 2006. 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 6 feet deep and 25 feet wide. The net was towed between two skiffs, sampling in an upstream direction. Trawls were performed near 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, however the number of samples each day varied somewhat and ranged from approximately 6 to 30. Prior to the year 2000, a similar sampling effort was conducted during the spring at Jersey Point (which was downstream of the Jersey Point release site). The sampling site was moved from Jersey Point to Antioch in the year 2000 to allow catches of both the upstream (Durham Ferry, Mossdale and Dos Reis) and Jersey Point release groups. Recoveries at Jersey Point have not been included in this report.

Chipps Island Recapture Sampling

Sampling at Chipps Island was conducted using a mid-water trawl towed at the surface. The trawling net is 82 feet in length and has an opening that is 30 feet wide by 10 feet deep. Mesh size of the net is variable and ranges from 4-inch mesh at the mouth to 5/16-inch mesh at the cod end. The net size of the cod end of the net was changed to 5/16" from ¼" during the period from 1997 and 2001, to reduce the incidental catches of delta smelt at Chipps Island.

Sampling prior to 1998 consisted of 10, twenty minute tows per day, for seven days a week for the period after the marked fish were released until several weeks later for each of the pre-VAMP and VAMP years. In 1998, and for the years between 1999 and 2006, sampling was doubled during the time period the VAMP fish were in the Delta. Greater recoveries of Chinook salmon smolts were reported to be caught at Jersey Point during sunrise and sunset (Hanson Environmental, unpublished data) thus the trawling at Chipps Island was increased and broken up into two shifts per day to cover both sunrise and sunset in an attempt to increase the recovery of Chinook salmon smolts and reduce the variability in calculated survival indices and recovery rates at Chipps Island. Each shift consisted of ten 20-minute tows with approximately equal number conducted across the channel (north, middle, and south sections of the channel parallel to the shore). Generally, three tows are conducted in each section of the channel with the section of the channel selected randomly for the last tow. After six weeks, the majority of VAMP Chinook salmon smolts had migrated past Chipps Island, and sampling was reduced to one shift per day, three days per week.

CVP and SWP Salvage Recapture Sampling

CVP and SWP fish facilities salvage fish on a continuous basis. To estimate the total number of fish salvaged, sub-samples (raw salvage) were collected approximately every two hours during the VAMP and pre-VAMP studies. The raw salvage was expanded by the time sampled to provide an estimate of the total number of fish salvaged (expanded salvage). Expanded salvage does not take into account the loss of Chinook salmon smolts at the facilities from pre-screen predation, screening, handling, and trucking. Raw and expanded CVP and SWP salvage estimates have been reported each year in the various annual reports. Expanded salvage is also reported in Newman, 2008.

Ocean Recovery

Ocean recovery of CWT salmon groups can provide an additional source of data for estimating survival through the Delta. The ocean harvest data may be more reliable due to the greater number of estimated CWT recoveries and the extended recovery period.

Adult ocean recovery data are gathered from commercial and sport ocean harvest checked at various ports by CDFG. The Pacific States Marine Fisheries Commission's Regional Mark Processing Center maintains a database of ocean harvest CWT which was the source of recoveries through 2004. The ocean CWT recovery data accumulate over a one to four year period after the year a study release is made as nearly all of a given year-class of salmon have been either harvested or spawned by age five. Consequently, these data are essentially complete for releases made through 2002 and partially available for CWT releases made from 2003 to 2004. At the time of writing of this report, no recoveries are yet available for releases made in 2005 and 2006.

### *4.3.10 VAMP Chinook Salmon CWT Survival*

Survival Indices and Recovery Rates

Survival in many of the past VAMP reports was initially estimated using differential survival indices of upstream to downstream groups, to Antioch and Chipps Island (SJRGA, 2007). Survival indices attempted to correct for effort and expanded the number recovered by the proportion of time and channel width sampled at Antioch and Chipps Island. However based on recommendations from Dr. Ken Newman, the more recent calculations to estimate survival have been based on differential recovery rates of the upstream to downstream groups. The recovery rates have been generated by combining the number of recoveries at Antioch, Chipps and in the ocean fishery, prior to dividing by the number released for each group shown in the equation:

Differential Recovery Rate = (Combined Ocean, Antioch and Chipps Island Recoveries for Upstream Group) * (Combined Ocean, Antioch and Chipps Island Recoveries for Downstream Groups)

Recoveries are not available from each recovery location for all years so only those that are available have been used.

Combined recoveries from Chipps Island and the ocean fishery are available for releases made between 1985 and 1999, combined recoveries from Chipps Island, Antioch and the ocean fishery are available for releases made between 2000 and 2005 and releases made in 2006 only have Chipps Island and Antioch recoveries available. For the modeling done by Newman (2008), ocean recoveries were not available for 2005 and 2006. In graphs and tables obtained from the 2006 Annual Report (SJRGA, 2007), ocean recoveries were not available for 2004-2006.

The doubling of effort at Chipps Island since 1998 would be of little consequence relative to comparing survival estimates between years because in theory such a change in effort would be reflected by an increase in the number recovered from both the upstream as well as the downstream groups and not effect the overall point estimate of survival between the upstream and downstream release locations. The increased recovery rate of both groups would result in more precision associated with the point estimates.

Sampling at Antioch was less regular within days within a season, and potentially added noise in estimating survival. However, the timing of the Mossdale and Jersey Point groups past Antioch appeared similar enough over the entire recovery period that Dr. Newman concluded that there appeared to be no substantial bias in the recoveries from Antioch (SJRGA, 2007).

### Chinook Salmon Survival Estimates

To estimate survival through the Delta for smolts released at Durham Ferry, Mossdale, and Dos Reis (and sometimes upper Old River), a control group was released at Jersey Point. The survival between the upstream and downstream location, estimated by dividing the recovery rate of the upstream group by the recovery rate of the downstream group, should be more robust for comparing survival between groups and years, since using ratios theoretically standardizes for differences in catch efficiency of recovery locations within and between years.

Standard errors of point estimates of survival were calculated based on the Delta method (K. Newman, personal communication). Plus or minus two standard errors are roughly equivalent to the 95% confidence intervals around the estimate. In comparing survival between reaches, the confidence intervals were used to determine if survival estimates were significantly different from one another. If the 95% confidence intervals overlapped, survival estimates were not considered statistically different from each other. If the 95% lower confidence level was less than zero it was truncated at zero.

Survival in the most recent VAMP report (SJRGA, 2007) was analyzed by reach. In this report we will initially discuss survival through the entire Delta; from Durham Ferry or Mossdale to Jersey Point, and then discuss survival by smaller reaches within the Delta: between Durham Ferry or Mossdale and Dos Reis; Dos Reis and Jersey Point; and Old River to Jersey Point.

### Survival Between Durham Ferry or Mossdale and Jersey Point

Smolt survival between Durham Ferry and Mossdale and Jersey Point has ranged considerably between 1994 and 2006 with differential recovery rates ranging from 0.01 to 0.79 (SJRGA, 2007). The year with the highest survival was 1995 and the years with the lowest survival were 2003 and 2004. Since 1997, there has been a general decline in survival (Figure 13). Survival rebounded slightly in 2005 and 2006 (Figure 13).

In most years since 2000, releases were made at both Durham Ferry and Mossdale. In addition replicate releases were made with one group released about a week earlier than the second release group (there was a 2 week difference in 2006). Pretty consistently, the second set of release groups within a year, survived at a lower rate than the first group, although not statistically different (Figure 13). Flow and exports conditions were generally the same for both groups within a year, with the exception of 2006, where exports were 1,500 cfs for the first release and 6,000 cfs for the second release. Durham Ferry and Mossdale groups seemed to generally survive at similar rate within a year (Figure 13).

### Survival Between Durham Ferry /Mossdale and Dos Reis

Between 1995 and 2006, there were ten releases made to assess the difference in survival between Mossdale or Durham Ferry and Dos Reis. It was assumed that without a HORB a portion of the group released at Mossdale or Durham Ferry would migrate down upper Old River, while those released at Dos Reis would migrate down the mainstem San Joaquin River. Mossdale and Dos Reis are relatively close (about 5 miles apart) and without a diversion into upper Old River, survival between the two locations would likely be similar. Durham Ferry is approximately 12 miles upstream from Mossdale. Results indicated that survival between the Durham Ferry or Mossdale to Dos Reis has varied, with average survival at 0.73 (Table 12, SJRGA, 2007).

In comparing the recovery rates of the ratios of the Mossdale or Durham Ferry release groups relative to the Dos Reis groups, half of the release groups had survival ratio's of significantly less than 1.0 ($p<0.05$), suggesting that in these years, some of the fish released at Mossdale or Durham Ferry were diverted into upper Old River where survival was less (Table 12, SJRGA, 2007). It also indicates that in the other half of the years that perhaps 1) survival in Old River was comparable to that at Dos Reis, or 2) most fish migrated down the mainstem San Joaquin River or 3) most of the fish from the Dos Reis release moved upstream, on a flood tide, into upper Old River. One of the years, that survival was similar between Mossdale and Dos Reis was in 2006, when flows were extremely high ((~25,000 cfs), and it is unlikely fish released at Dos Reis moved upstream that year. It appeared from acoustic information that many of the fish migrated into upper Old River in 2006, and if most of the CWT fish released at Mossdale that year also primarily migrated into Old River, survival was similar between the two routes (between Old River and Jersey Point and between Dos Reis and Jersey Point). For that particular group in 2006 exports were low (1,500 cfs).

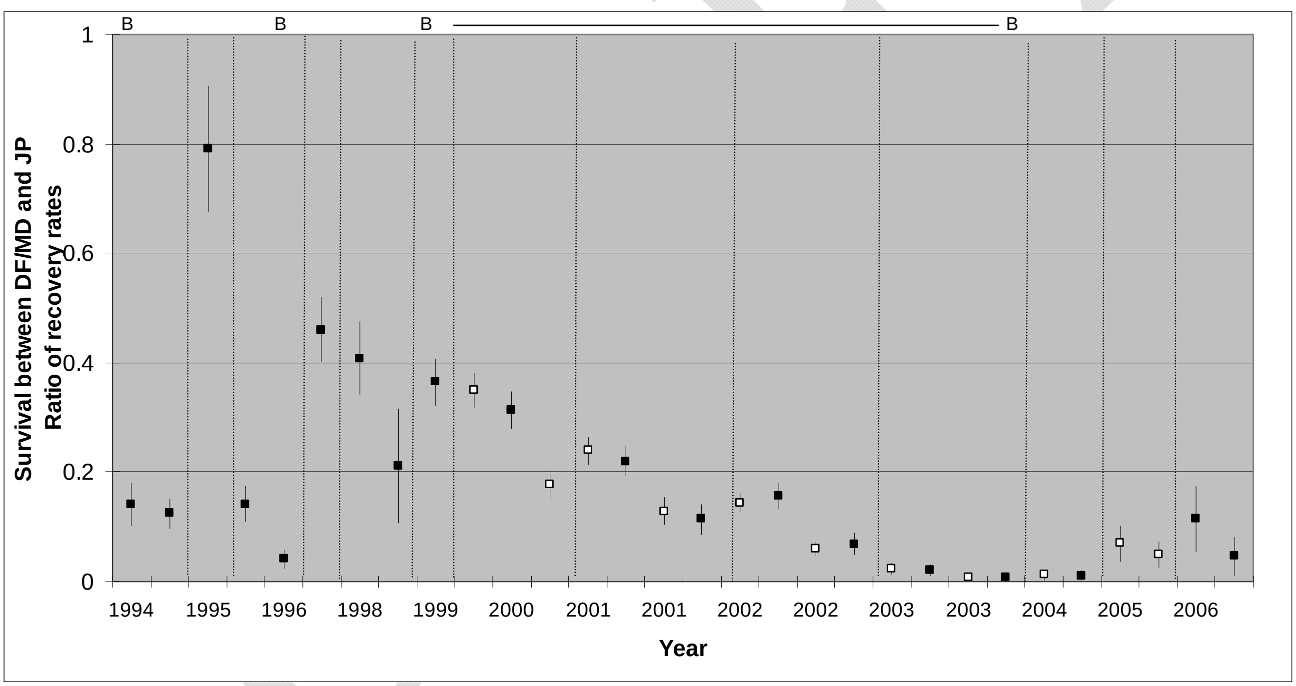



**Figure 13**

Survival estimates from Durham Ferry (open space) and Mossdale (closed squares) to Jersey Point (+/- 2 SE) between 1994 and 2006. B= HORB installed

Only once were releases made at Mossdale and Dos Reis with the HORB in place. That was in 1997 and the point estimate of survival between the two locations was 1.29 using combined Chipps Island and ocean recoveries (SJRGA 2007). These data reinforce that the temporary HORB on average provides protection to juvenile salmon migrating from the San Joaquin basin by preventing the fish from migrating into upper Old River.

**Table 12. Combined Differential Recovery Rates (CDRR) for Experimental Fish Released at Mossdale (MD) or Durham Ferry (DF) and Dos Reis between 1995 - 1999 and 2005- 2006[1,2,3,4]**

| Year | Date | Release site | Chipps + Ocean CDRR | Chipps + Antioch CDRR | |
|---|---|---|---|---|---|
| **1995** | 17-Apr | Mossdale | 0.99 | | |
| **1995** | 05-May | Mossdale | 0.31 | | |
| **1995** | 17-May | Mossdale | 0.44 | | |
| **1996** | 30-Apr | Mossdale | 0.37 | | |
| **1998** | 16-Apr | Mossdale | 1.05 | | |
| **1998** | 23-Apr | Mossdale | 0.42 | | |
| **1999** | 19-Apr | Mossdale | 0.69 | | |
| **2005** | 02-May | Durham Ferry | | 1.32 | |
| **2005** | 09-May | Durham Ferry | | 0.75 | |
| **2006** | 04-May | Mossdale | | 0.94 | |
| **Average for all years** | | | | | 0.73 |

1 Years 1995 - 1999 do not have Antioch recoveries

2 Years 2005 and 2006 do not have ocean recovery data available

3 Survival reach is between Durham Ferry or Mossdale and Dos Reis

4 Those shaded are significantly different (95% confidence interval) from 1.0



Survival Between Dos Reis and Jersey Point

Survival in the reach from Dos Reis to Jersey Point is generally much lower than survival from Mossdale to Dos Reis. There have been 16 experiments where releases have been made at Dos Reis and Jersey Point, with three of these made in 1997 with the HORB in place. The remaining data was gathered without the barrier in place between 1989 and 1991, 1995 and 1999 and during 2005 and 2006. Survival ranged between 0.05 and 0.79 and averaged 0.28 (Table 13). Additional data obtained in 1991, indicated that the highest salmon smolt mortality (lowest survival per mile) on the San Joaquin River between Dos Reis and Jersey Point occurred between Stockton and Empire Tract and the mouth of the Mokelumne River, although mortality between Dos Reis and Stockton, and between Stockton and Empire Tract was also high (Brandes and McLain, 2001).

Survival Between Old River and Jersey Point

Survival from Old River to Jersey Point could only be estimated in 1989 and 1990, as those were the only two years when releases were made at both locations. Estimates of survival ranged from 0.02 to 0.20 and averaged 0.07 (Table 14).

**Table 13: Combined differential recovery rates (CDRR) using recoveries from Chipps Island and the ocean fishery or Chipps Island and Antioch to estimate survival from Dos Reis (DR) and Jersey Point (JP) between 1989 and 2005[1, 2] (SJRGA, 2007). The 1997 data was obtained with the Head of Old River Barrier in place and the 2005 and 2006 data do not have ocean recoveries available.**

| DR - JP Survival Year | Date | Stock[3] | CDRR Ocean + Chipps | CDRR Chipps + Antioch |
|---|---|---|---|---|
| **1989** | 20-Apr | FRH | 0.19 | |
| **1990** | 16-Apr | FRH | 0.05 | |
| **1990** | 02-May | FRH | 0.07 | |
| **1991** | 15-Apr | FRH | 0.12 | |
| **1995** | 17-Apr | FRH | 0.79 | |
| **1996** | 01-May | FRH | 0.11 | |
| **1996** | 01-May | MRH | 0.15 | |
| **1997** | 29-Apr | FRH | 0.36 | |
| **1997** | 29-Apr | MRH | 0.48 | |
| **1997** | 08-May | MRH | 0.47 | |
| **1998** | 17-Apr | MRH | 0.4 | |
| **1998** | 24-Apr | FRH | 0.54 | |
| **1999** | 19-Apr | MRH | 0.53 | |
| **2005** | 03-May | MRH | | 0.05 |
| **2005** | 10-May | MRH | | 0.06 |
| **2006** | 05-May | MRH | | 0.12 |

1 The barrier was in, in all years except 1997
2 Average for all years is 0.28
3 Stock is either Feather River (FRH) or Merced River Hatchery (MRH)

More data is available to evaluate the relative difference in survival between fish released into upper Old River relative to those released on the San Joaquin River at Dos Reis. As mentioned earlier in this report, these paired studies were conducted between 1985 and 1990. It has previously been published that survival appeared to be about twice that for smolts migrating down the mainstem San Joaquin versus those migrating down upper Old River, however differences were not statistically significant (Brandes and McLain, 2001).

In reanalyzing the upper Old River and Dos Reis paired data, with combined recoveries at Chipps Island and in the ocean fishery, four of the seven years tested showed the 95% confidence interval around the ratio of the recovery rate of the Dos Reis group relative to the Old River group was significantly greater than 1.0 indicating the survival for smolts released at Dos Reis in those years was higher than for those released in upper Old River. (Table 15). The average ratio (Dos Reis to upper Old River) was similar to that reported in the past at 2.2. Confidence intervals around the average ratio also indicate that it was significantly greater than 1.0, and survival was significantly higher for smolts released at Dos Reis compared to those released into upper Old River.

**Table 14: Recovery Rates from CWT Groups Released into Upper Old River (UOR) and Jersey Point (JP) in 1989 and 1990. Survival Between UOR and JP Was Calculated by Dividing the Combined Recovery Rate of the UOR Group by the Recovery Rate of the JP group. Stock is Feather River Hatchery (FRH) or Merced River Hatchery (MRH)**

| TAG CODE | RELEASE SITE/(STOCK) | DATE | NUMBER RELEASED | NUMBER RECOVERED at Chipps | EXPANDED OCEAN RECOVERIES | Combined Recovery Rate | Survival UOR->JP |
|---|---|---|---|---|---|---|---|
| 6-1-14-1-6 | Upper Old River (FRH) | | 52,954 | 0 | 5 | | |
| 6-1-14-1-5 | Upper Old River (FRH) | | 53,313 | 2 | 9 | | |
| | **Total** | 04/17/90 | 106,267 | 2 | 14 | 0.0002 | 0.03 |
| 6-1-14-1-9 | Jersey Point (FRH) | 04/18/90 | 52,962 | 32 | 224 | 0.0048 | |
| 6-1-14-1-12 | Upper Old River (FRH) | | 51,521 | 1 | 5 | | |
| 6-1-14-1-13 | Upper Old River (FRH) | | 52,074 | 0 | 6 | | |
| | **Total** | 05/03/90 | 103,595 | 1 | 11 | 0.0001 | 0.02 |
| 6-31-19 | Jersey Point (FRH) | 05/04/90 | 50,143 | 56 | 204 | 0.0052 | |
| 6-31-13 | Upper Old River (FRH) | 04/21/89 | 51,972 | 5 | 38 | 0.0008 | 0.20 |
| 6-1-11-1-11 | Jersey Point (FRH) | | 27,758 | 26 | 83 | | |
| 6-1-11-1-12 | Jersey Point (FRH) | | 29,058 | 27 | 97 | | |
| | **Total** | 04/24/89 | 56,816 | 53 | 180 | 0.0041 | |
| 6-1-11-1-4 | Upper Old River (MRH) | | 25,087 | 2 | 5 | | |
| 6-1-11-1-5 | Upper Old River (MRH) | | 24,472 | 1 | 0 | | |
| 6-1-11-1-6 | Upper Old River (MRH) | | 24,782 | 1 | 11 | | |
| | **Total** | 05/03/89 | 74,341 | 4 | 16 | 0.0003 | 0.04 |
| 6-1-11-1-9 | Jersey Point (FRH) | | 27,525 | 32 | 144 | | |
| 6-1-11-1-10 | Jersey Point (FRH) | | 28,708 | 24 | 139 | | |
| | **Total** | 05/05/89 | 56,233 | 56 | 283 | 0.0060 | |
| | | | | | **Average** | | **0.07** |

**Table 15: Ratio Between Recovery Rates of Marked Smolts Released at Dos Reis and Upper Old River Between 1985 and 1990[1] (SJRGA, 2007)**

| Year | DR/UOR Ratio | SE | "+ 2SE | "-2 SE |
|---|---|---|---|---|
| 1985 | 0.99 | 0.01 | 1.00 | 0.97 |
| 1986 | 1.90 | 0.07 | 2.04 | 1.76 |
| 1987 | 2.48 | 0.13 | 2.74 | 2.22 |
| 1989 | 0.96 | 0.21 | 1.37 | 0.54 |
| 1989 | 4.35 | 1.08 | 6.50 | 2.20 |
| 1990 | 1.70 | 0.53 | 2.77 | 0.63 |
| 1990 | 3.17 | 1.05 | 5.27 | 1.07 |
| | | | | |
| Mean | 2.22 | | 2.68 | 1.76 |

[1] **Highlighted rows identify where ratio is significantly different from one using confidence intervals (+/- 2 standard errors (SE))**



### *4.3.11 The Role of Flow, Exports and the HORB on Smolt Survival Through the Delta*

In past VAMP annual reports the data has been segregated and analyzed in two groups, depending on whether the Head of Old River Barrier (HORB) had been installed or not. Then the data was analyzed using simple linear regressions between survival and flows and survival and exports.

<u>Evaluation of Flow With the HORB</u>

In the 2006 Annual Report, a statistically significant relationship was reported between San Joaquin River flow at Vernalis and survival from Durham Ferry or Mossdale to Jersey Point with the HORB in place (Figure 14, $r^2 = 0.73$, $p<0.01$) (SJRGA, 2007).

<u>Evaluation of Flow Without HORB</u>

In contrast, the relationship between flow at Vernalis and the relative recovery rates of the Durham Ferry and Mossdale releases relative to those at Jersey Point (combined differential recovery rate (CDRR)) without the HORB was much more variable and no real trend was evident (Figure 15). The 2005 and 2006 data were much lower than what previous estimates had been at similar flow levels. Fish released at Mossdale or Durham Ferry without a HORB could migrate either down upper Old River or via the mainstem San Joaquin River. It is not surprising that there is more variability associated with smolt survival at any given flow at Vernalis without the HORB since the flow and proportion of marked fish moving into HOR would vary more without the HORB. The proportion of juvenile salmon that migrate down upper Old River relative to the number that stay in the mainstem San Joaquin River has been a critical uncertainty for many years.

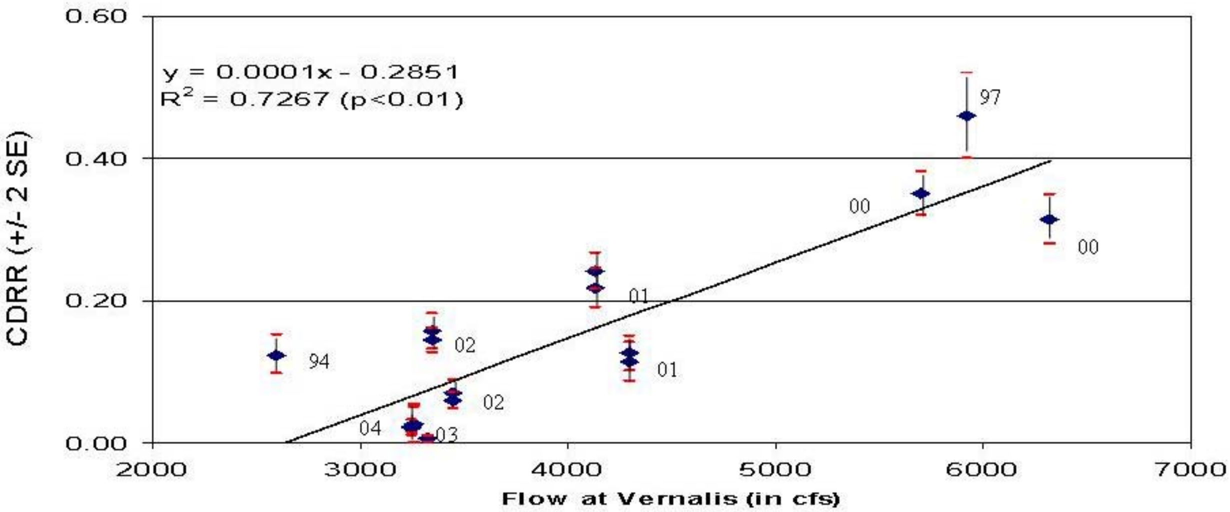



**Figure 14**

Combined Differential Recovery Rate (CDRR) (point estimates of survival) plus and minus 2 standard errors using Chipps Island, Antioch and ocean recoveries, for groups released at Mossdale or Durham Ferry and Jersey Point in 1994, 1997, 2000-2004 and average flow at Vernalis in cfs for 10 days starting the day of the Mossdale release or the day after the Durham Ferry release with the HORB in place. Ocean recoveries are not yet available for 2004 releases (SJRGA, 2007)

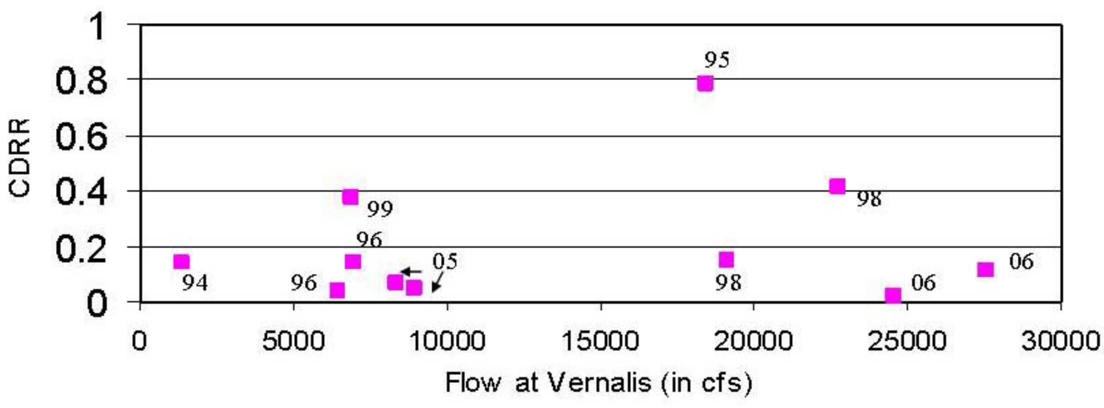



**Figure 15**

Recovery rates of the Durham Ferry and Mossdale release groups relative to Jersey Point groups using combined Chipps Island, Antioch and ocean recoveries and average flow at Vernalis in cfs for 10 days starting the day of the Mossdale release or the day after the Durham Ferry release without the HORB in place. Data in 2005 and 2006 only include recoveries from Antioch and Chipps Island (SJRGA, 2007)

If the juvenile salmon migrate downstream on the mainstem San Joaquin River, their survival would be approximated by those fish released at Dos Reis. There does appear to be a weak relationship between the survival of fish released on the San Joaquin River downstream of upper Old River (at Dos Reis) and flow in the San Joaquin River (estimated at Stockton) ($p<0.10$, Figure 16, SJRGA, 2007). The estimates in 2006 appeared much lower than historical estimates at the same flow (Figure 16). The relationship excluding the 2005 and 2006 estimates was statistically significant for the remaining data without the HORB in place ($p<0.01$) (SJRGA 2007). It is unclear why estimates of survival in 2006, in particular, were so low compared to that observed in the past, although survival has been extremely low and lower than expected since 2003. It appears this trend has continued in 2005 and 2006 without the HORB in place, even though flows were higher.

Evaluation of Exports on Survival

Another goal of the VAMP program is to identify the role of exports on juvenile salmon survival through the Delta. VAMP limits combined CVP and SWP exports to between 1,500 and 3,000 cfs depending on the flow target, because of its dual protective purpose for naturally spawned juvenile salmon and to meet the terms of the delta smelt biological opinion. Prior to 1994, exports were generally much greater than 3,000 cfs during the spring period. The VAMP design includes examining the role of exports with the HORB at flows of 7,000 cfs by experimenting at exports of 1,500 and 3,000 cfs. As conditions have not yet provided a 7,000 cfs flow with a HORB to test either export level, assessing the role of exports with a HORB is limited at this time.

In years when the HORB could not be installed it was recommended in the VAMP framework agreement to limit exports to either 1,500 or 3,000 cfs to make better comparisons with and without the HORB. In 2006, export levels were 1,500 and 6,000 cfs at high San Joaquin River flows (~25,000 cfs) for the two sets of VAMP releases. We were able to recommend such an experimental design because flows were deemed high enough to provide adequate protection for delta smelt even with the 6,000 cfs exports. Additional tests of this type may help us better identify the role of exports on smolt survival without the HORB in place.

Role of Exports With HORB

The relationship between San Joaquin River flow relative to exports and survival between Durham Ferry and Mossdale and Jersey Point, while statistically significant ($p<0.05$, Figure 16, SJRGA, 2007), does not appear to explain the variability in smolt survival as well as flow alone with the HORB in place (Figure 14). The flow/export variable is the 10 day mean of the ratio. One potential explanation for these results is that level of exports were low and did not vary enough during these experiments to provide a sufficient difference to be detected by our measurements of smolt survival. Exports ranged between 1,450 and 2,350 cfs during these experiments which is much lower than those incorporated into the adult escapement relationships to flow at Vernalis during the spring. Another complication is that exports and San Joaquin River flows were correlated; higher exports were observed during times of higher flows (SJRG, 2006).

The VAMP experimental design incorporated flow targets of 7,000 cfs with the HORB at two export levels (1,500 and 3,000 cfs) to better define the export effect on smolt survival with the HORB in place. Experimenting at flows of 7,000 cfs with 1,500 cfs exports would help decouple the effects of flows and exports with the HORB in place (Figure 18).

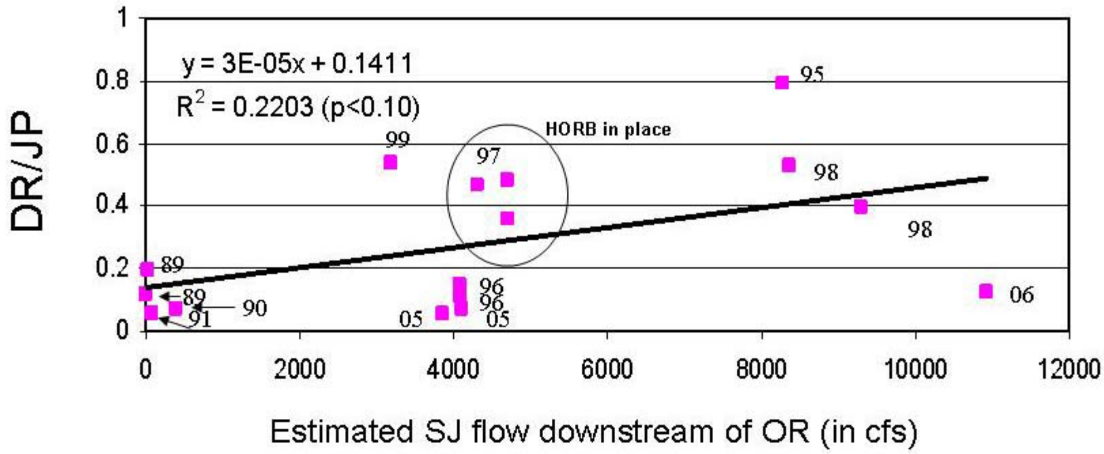



**Figure 16**

Survival between Dos Reis and Jersey Point (with recoveries at Chipps Island and the ocean fishery) with and without the HORB and estimated/modeled San Joaquin flows downstream of Old River between 1989-1991, 1995-1999, 2005 and 2006. 1997 data was gathered with the HORB in place. 2005 and 2006 data only has Chipps Island and Antioch recoveries available at this time (SJRGA, 2007)



HORB in place (Figure 17). The flow/export variable is the 10 day mean of the ratio. One potential explanation for these results is that level of exports were low and did not vary enough during these experiments to provide a sufficient difference to be detected by our measurements of smolt survival. Exports ranged between 1,450 and 2,350 cfs during these experiments which is much lower than those incorporated into the adult escapement relationships to flow at Vernalis during the spring. Another complication is that exports and San Joaquin River flows were correlated; higher exports were observed during times of higher flows (SJRG, 2006).

The VAMP experimental design incorporated flow targets of 7,000 cfs with the HORB at two export levels (1,500 and 3,000 cfs) to better define the export effect on smolt survival with the HORB in place. Experimenting at flows of 7,000 cfs with 1,500 cfs exports would help decouple the effects of flows and exports with the HORB in place (Figure 17).

Role of Exports Without HORB

The role of exports on smolt survival without the HORB in place is also difficult to identify at this time. Similar limitations, to those with HORB, occur with this data. Exports have been limited to between 1,400 and 3,700 cfs, with the exception of 6,000 cfs for the second experiment conducted in 2006. As mentioned earlier, there is not a clear relationship between smolt survival and flow without the HORB (Figure 13). Regressions between survival from Mossdale and Durham Ferry to Jersey Point using Chipps Island, Antioch and ocean recoveries also do not show a clear relationship with flow/export ratios (Figure 16). This is counter to our conceptual model based on the higher $r^2$ value of the relationship of flow/exports between 1951 and 2003 and San Joaquin basin escapement 2 ½ years later ($r^2$ = 0.56) relative to the $r^2$ (0.40) from the relationship of the same years of escapement and flow alone.

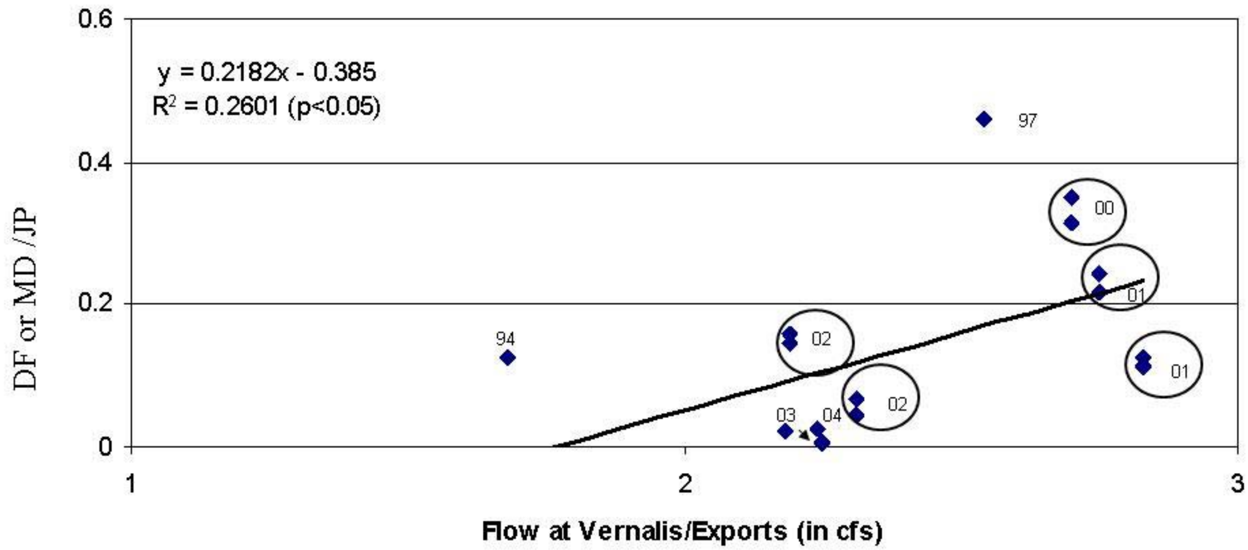



**Figure 17**

Recovery rates using recoveries at Chipps Island, Antioch (2000-2004 only) and in the ocean (1994, 1997, 2000-2003), for groups released at Mossdale or Durham Ferry relative to those released at Jersey Point and average flow at Vernalis/Exports in cfs for 10 days starting the day of the Mossdale release or the day after the Durham Ferry release with the HORB in place (SJRGA, 2007)



In the modeling work by Dr. Ken Newman, data from 1989 and 1990, (pre-VAMP) studies have been included specifically to address this weakness. In these two years, the studies were designed specifically to assess two extreme export levels on survival between Dos Reis and Jersey Point and Old River and Jersey Point. Flows were low in those two years (1,400 – 2,500 cfs at Mossdale) and exports were around 2,000 and 10,000 cfs for the two experiments within each of the years. Results showed that survival in Old River may have been higher at the higher exports in one of the two years, but the data was potentially biased because in one of the sets released in 1989, the Old River group was from MRH and paired with a group released at Jersey Point from FRH (Brandes and McLain, 2001)(Table15).

Studies in 2006 (VAMP) were again specifically designed to address the role of exports on survival from Mossdale to Jersey Point. In 2006, flows were high (> 20,000) and survival was measured under two export conditions (1500 and 6000 cfs). Point estimates of survival from Mossdale to Jersey Point were relatively low for both sets of releases, but lower for the second release when exports were higher (Figure 13). However the confidence levels around each estimate and around the difference in the point estimates, under the two different export levels, indicated that the difference was not statistically significant at the $p<0.05$ level. The 2006 data is limited in its precision because it still relies only on recoveries at Chipps Island and Antioch because ocean recoveries are not yet available. Without a commercial fishery in 2008, very few fish may be recovered in the ocean from releases made in 2006.

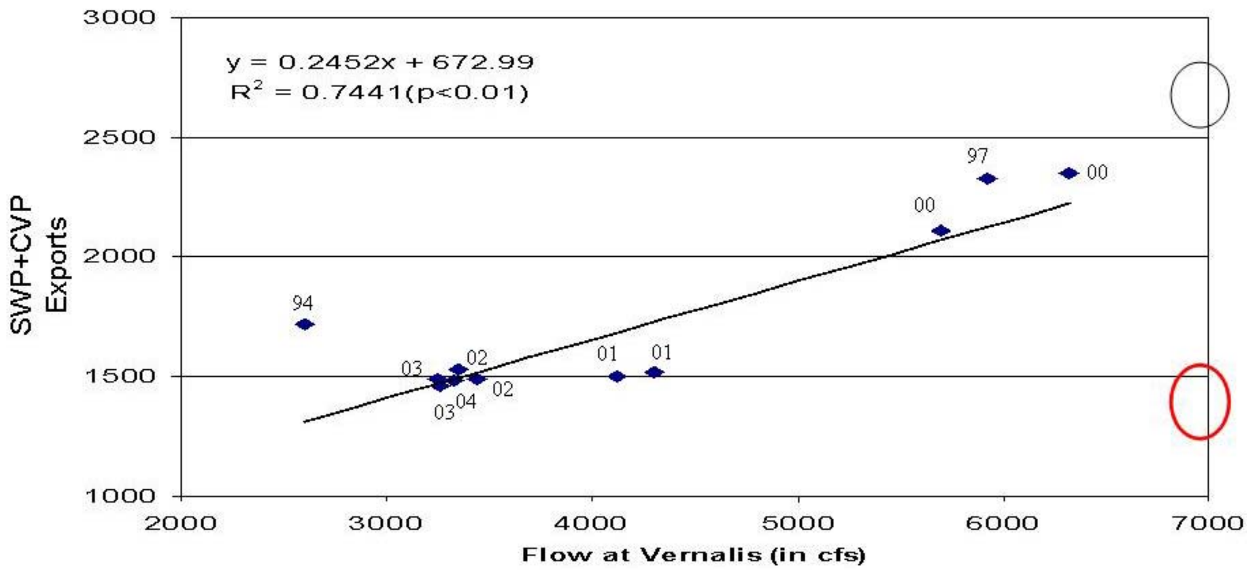



**Figure 18**

The relationship between flow and exports during VAMP tests with the Head of Old River Barrier (HORB) in place (SJRGA,2007)

<u>The Role of the HORB on Survival Through the Delta</u>

Comparing survival through the Delta with and without the HORB using the recoveries from Chipps Island, Antioch, and the ocean fishery, indicates that there may be, on average, value in installing the HORB at flows between about 4,000 and 7,000 cfs (Figure 18).

<u>The Role of Temperature on Smolt Survival</u>

One parameter that appears to be an important component in determining survival is water temperature. Without the HORB, survival from Mossdale or Durham Ferry to Jersey Point was highest in the years that had the lowest temperature at release (Figure 21). Water temperature at release has also been shown to be an important factor in survival for smolts migrating through the Delta from the Sacramento Basin (Newman, 2003).

<u>Summary</u>

The smolt survival data obtained without the HORB do not show a clear relationship to flow, especially with the 2005 and 2006 data included. With the HORB in place we have demonstrated statistically significant relationships between smolt survival and flow at Vernalis and flow/exports, although exports are correlated to flow. The relationship between survival of the Dos Reis groups relative to the Jersey Point groups and San Joaquin River flow downstream of upper Old River

(Stockton) indicates that survival will generally improve as flows increase for smolts that migrate downstream on the mainstem San Joaquin River. The role of exports on smolt survival within the VAMP (with HORB) and without a HORB is more difficult to define based on the limited data. To identify the role of exports with a HORB it would be informative to measure survival with export rates at 1,500 and 3,000 cfs with San Joaquin River flows of 7,000 cfs. Experiments like those conducted in 2006 can help assess the role of exports without the HORB. It is unclear why smolt survival between 2003 and 2006 has been so low. While this analyses is intended to give some assessment of how the various factors effect survival, a better analyses of the data can be done using modeling, where the data can be comprehensively analyzed together.

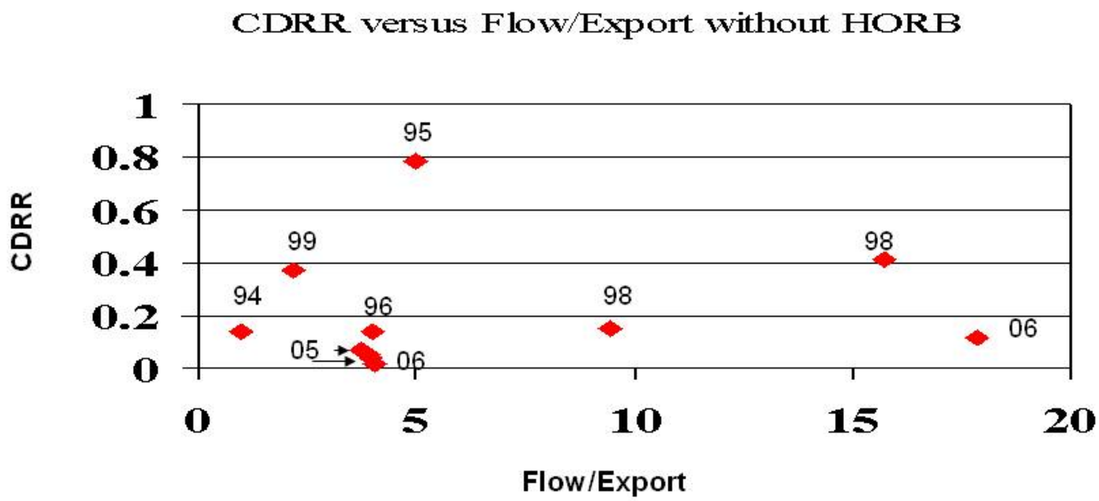



**Figure 19**

Combined Differential Recovery Rate (CDRR) for fish released at Mossdale and Durham Ferry relative to Jersey Point between 1994-1996, and in 1998, 1999, 2005 and 2006 versus the Median Flow/Export Ratio during the VAMP Test Period for the 10 days after release without the Head of Old River Barrier (HORB) in place

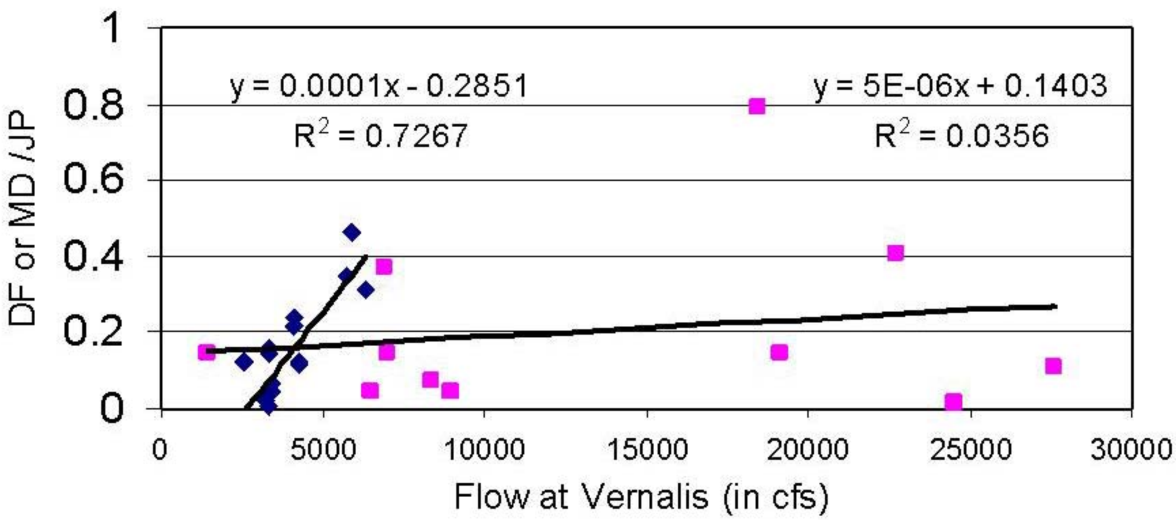



**Figure 20**

Recovery rates using recoveries from Chipps Island, Antioch and the ocean for Durham Ferry or Mossdale releases relative to those at Jersey Point and average flow at Vernalis in cfs for 10 days starting the day of the Mossdale release or the day after the Durham Ferry release with and without the HORB in place between 1994-2006. Data in 2004, 2005 and 2006 only include recoveries from Antioch and Chipps Island. Diamonds are data gathered with the HORB ($r^2$=0.73) and squares are data gathered without the HORB ($r^2$=0.03) (SJRGA, 2007)

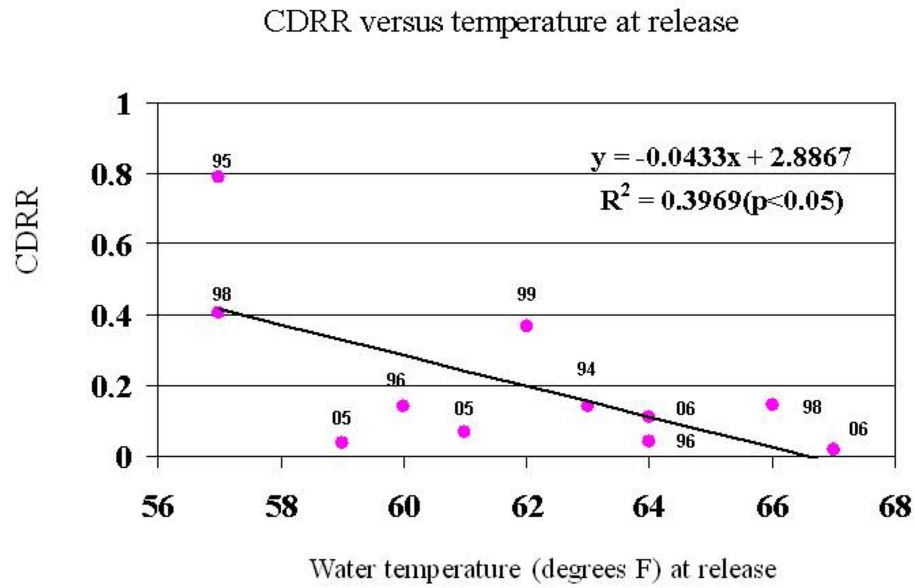



**Figure 21**

Combined Differential Recovery Rate (CDRR) for Smolts Released at Durham Ferry and Mossdale Relative to Those Released at Jersey Point without the Head of Old River Barrier (HORB) Versus Water Temperature at Release Site for Smolts Released at Durham Ferry and Mossdale

#### *4.3.12 Modeling Efforts With Coded Wire Tag Data*

Coded wire tag experiments conducted as part of VAMP and pre-VAMP studies were part of a CALFED Science review of four coded wire tag experiments conducted in the Delta. The review was conducted by Dr. Ken Newman of the USFWS Stockton office, with peer review by three selected colleagues: Dr's Brian Manly, Dave Hankin and Russell Millar. The review (Newman, 2008) assessed the studies, made recommendations and fitted models to the data. The VAMP (including pre-VAMP studies) was by far the most complex of the four studies reviewed.

In the review, Bayesian hierarchical models were used to fit the VAMP and pre-VAMP data. Survival probabilities by reach were linked for four reaches; Durham Ferry to Mossdale, Mossdale to head of Old River (HOR), Dos Reis to Jersey Point, Old River to Jersey Point. It was determined that survival probabilities could be estimated by assuming recovery probabilities (a combination of survival and capture probabilities) were identical for groups within a paired set of upstream and downstream releases (Durham Ferry and Mossdale relative to Jersey Point releases). Survival probabilities between Old River and Jersey Point were also estimated, but, as discussed earlier in the report, are based on less actual data. Although the pairing was not always consistent for all releases in all years, estimates of survival could be made because paired releases at those locations were made at some time during the study. For releases made upstream of Old River when the HORB was not in place (Mossdale) survival probabilities were estimated using a weighted estimate of survival from Old River to Jersey Point and from Dos Reis to Jersey Point. The proportion of fish going into each reach was based on the proportion of water split at the junction. For one alternative model, the proportion was fixed but unknown. With the HORB in place the probability of going into upper Old River was set at 0.

The models assume that the fish go from Durham Ferry to Mossdale and then from Mossdale to the HOR junction. Once the fish arrive at the Old River junction they either 1) stay on the mainstem San Joaquin River and go to Dos Reis and then on to Jersey Point, or they 2) enter Old River, pass the Old River release site and continue on to Jersey Point. After the fish arrive at Jersey Point, they pass Antioch, Chipps Island and enter the ocean. An additional assumption of the model is that survival is 100% between the HOR junction and both a) Dos Reis (about 3 miles) and b) the Old River release site (about ¼ mile).

Survival and recovery probabilities were transformed (logit) and modeled with random effects, and various covariates. The selection of the "best" model was based primarily on the lowest deviance information criterion (DIC) (Newman, 2008). Including random effects improved the DIC value of the model considerably (from 25000 to 1500).

The quality of fit was similar for the two models with different proportions of flow diverted into upper Old River. The model with the known and varying proportion of fish going into Old River (DIC = 1499) was just slightly higher than the one with the unknown and fixed proportion (DIC = 1496). The expected survival probability was always higher in the San Joaquin River than in Old River and the final models were fit using the known and varying proportions of fish going into upper Old River.

The model with the lowest DIC (1474.8) incorporated both flow and exports into estimating survival down both reaches: Dos Reis to Jersey Point; and upper Old River to Jersey Point. The surprising result is that survival improved in both reaches with increased exports. While this was the "best" model, the posterior probabilities suggested only weak export effects in both reaches and weak flow effects between upper Old River and Jersey Point.

The model that only included flow to determine survival between Dos Reis and Jersey Point (and not exports in either reach) had a slightly higher DIC of (1491.4). A model that incorporated flow as a covariate for survival between Dos Reis and Jersey Point and a stock effect had a DIC of 1494.5. The only other model presented did not have any coefficients and had a DIC of 1499.1.

The models were further evaluated by removing data since 2003 to determine the sensitivity of the model to recent data when survival was extremely low. Results were similar to those with the full model although the flow effects between Dos Reis and Jersey Point and between upper Old River and

Jersey Point were stronger, with the probability of a positive coefficient being 100% for the reach between Dos Reis and Jersey Point and 97% for the reach between Old River and Jersey Point.

The role of water temperature on survival was evaluated by comparing random effects residuals to water temperature at release. The results suggested perhaps, a slightly negative relationship between water temperature at release and the random effects for Durham Ferry releases.

The one other issue of concern addressed in the modeling was the differing hatchery stocks used in the experiments. There was some evidence for a stock effect and an alternative model was fit (reported above). The DIC was slightly higher than the "best" model but results were similar suggesting that incorporating a stock effect into the model did not change the general conclusions about flow and exports.

For the various models fitted, two robust conclusions were identified: 1) flow is positively related to survival between Dos Reis and Jersey Point; and 2) survival is higher from Dos Reis to Jersey Point relative to that from upper Old River to Jersey Point.

One additional issue evaluated was the sample size needed to estimate effects of flows, exports and a HORB. The analyses were based on earlier versions of the models. As with the other coded wire tag studies, the number of replications has a larger effect on the precision, than the number released and the relative error tends to decrease for downstream releases, suggesting that fewer releases should be made downstream relative to upstream.

## 4.4 ACOUSTIC TELEMETRY STUDIES

*Contributed by Andrea Fuller, FISHBIO Environmental, LLC*

### *4.4.1 Background*

Acoustic telemetry studies were initiated in 2006 to determine if the equipment, techniques, and results would be a valuable complement to existing VAMP studies in future years. During 2007 and 2008 sufficient numbers of fish were not available to implement the VAMP coded wire tag (CWT) study design in these years. Following successful demonstration of the technology during 2006, acoustic telemetry studies were expanded during 2007 and 2008 to serve as an alternative means of estimating survival through the Delta.

### *4.4.2 Results of Acoustic Telemetry Studies*

<u>2006 Pilot Acoustic Telemetry Study</u>

During the 2006 VAMP, a pilot study was initiated to monitor the migration of juvenile Chinook salmon smolts using acoustic telemetry. The objective of the short-term, small-scale pilot effort during 2006 was to determine if the equipment, techniques, and results would be a valuable complement to existing VAMP studies in future years. A total of 100 MRH smolts with surgically implanted acoustic transmitters were released at Mossdale and Dos Reis (Table 16), and movement of tagged smolts was monitored at 5 stationary receiver locations (Figure 22) between May 8th and May 19th. Flood control releases upstream provided flows at Vernalis that ranged from 24,800 cfs to

27,600 cfs during the acoustic study period, while exports were held at 1,500 cfs through May 17th and increased to 6,000 cfs during the last two days of the acoustic study period (Table 17). The HORB was not installed during 2006.

Results of the pilot study demonstrated that the use of acoustic telemetry would be a feasible and valuable complement to existing VAMP studies, providing a level of detail that cannot be achieved through CWT releases. Of the 61 tags that were released at Mossdale and not diverted down Old River or released at Does Reis during 2006, 13 (21%) were found in scour holes or associated with pump station structures between Mossdale and Brandt Bridge suggesting a high rate of predation in this reach. Using CWTs these losses would have been reflected in the overall survival estimate, but the specific locations and cause of mortality would not have been identified.

The pilot acoustic telemetry work during 2006 also corroborated findings from previous CWT studies regarding the importance of operating the HORB to protect San Joaquin salmon from entrainment into Old River. During the 2006 pilot study under flood conditions and low exports, it is estimated that at least 58% of the acoustically tagged smolts released at Mossdale were diverted into Old River. At the times when fish approached the flow split, it is estimated that approximately 51-53% of the mainstem San Joaquin River flow was diverted into Old River.

<u>2007 Acoustic Telemetry Study</u>

During 2007, coded wire tag releases for VAMP were not feasible due to a limited number of smolts available from Merced River Hatchery, and the acoustic study was expanded to serve as an alternative means of estimating survival through the Delta. Due to logistical challenges, stationary receivers could not be installed at Chipps Island and Jersey Point which precluded estimation of survival through the Delta during 2007. A total of 970 MRH smolts with surgically implanted acoustic transmitters were released at five locations (Table 16), and movement of tagged smolts was monitored at 10 stationary receiver locations in the south and central Delta (Figure 23) between May 3rd and 21st.

Detections at the stationary receiver locations during 2007 indicated an average 45% loss between Durham Ferry and Bowman Road, which does not account for losses within the migratory pathways of the greater Delta that may be used by salmon after they pass Bowman Road. An area adjacent to a railroad bridge and the Stockton Waste Water Treatment Plant (WWTP) was identified as a possible area of high predation through mobile tracking. Fifteen percent (n=116) of the 776 tags released at four upstream locations were found motionless at this location indicating that the tags were either in dead fish or had been defecated by a predator. The actual proportion of fish lost in this area may have been higher since some tags may not have been detected due to expired batteries, and no adjustment was made to subtract fish that did not survive to this point. Such detailed information regarding the specific location of fish mortality would not have been revealed through CWT releases, and more information could have been available from the 2007 study had tag detections at some of the stationary receiver sites not been compromised by unexpected equipment malfunction.

<u>2008 Acoustic Telemetry Study</u>

During VAMP 2008, the acoustic study design was revised and expanded to provide estimates of survival through the Delta and route selection probabilities at several junctions. The study design was also refined to include measures to address challenges with equipment malfunction observed during 2007. Previous logistical challenges with stationary receiver deployment were surmounted and receivers were installed at all 24 locations designated in the study plan for 2008 (Figure 24). A preliminary total of 835 MRH smolts[2] with surgically implanted acoustic transmitters were released at two locations (Table 16) and movement of tagged smolts was monitored at 16 stationary receiver locations between April 29th and June 1st.

Although results are not yet available, unforeseen problems with tag and receiver performance are expected to preclude estimation of survival to Chipps Island during 2008. Tag life studies were conducted during 2008 to evaluate premature tag failure rates and data suggest that 40% of the original study tags failed to program or stopped functioning during the minimum expected lifespan of the tags (11 days). A fundamental assumption of mark-recapture survival models is that no tags cease operation during the study period or within the study region. Premature tag failure results in biased survival estimates because such failure cannot be separated from fish mortality. In response to problems with tag failure identified during quality assurance and quality control (QA/QC) protocols implemented during the first week of the 2008 field study, the manufacturer provided additional replacement tags for the field study and for another tag life study. In contrast to the original study tags, 15% of the replacement study tags failed to program or stopped functioning during the minimum expected lifespan of the tags. The difference in tag failure rates is likely due to the fact that the replacement tags used in the tag life study originated from a different manufacturing lot than the original tags used in the initial tag life study. Additionally, replacement tags used in the tag life study may have undergone more extensive QA/QC by the manufacturer prior to delivery. Protocols were not in place to confirm tag function prior to releases in 2007 so comparison cannot be made.

During 2008 some of the measures intended to address previous challenges with receiver malfunction could not be employed due to logistical constraints. For example, remote access to monitor receiver function and to download data from the receivers via telemetry was only implemented near Chipps Island and Jersey Point but could not be employed at any of the other stations. Therefore, problems with some stations could not be determined and remedial actions could not be implemented until after weekly data downloads occurred. Problems with some of the receiver arrays and, primarily, tag failure issues are likely to preclude calculation of survival estimates during 2008.

It is common to experience unexpected problems with new technology utilized for field studies and acoustic technology shows promise to greatly improve our understanding of the mechanisms influencing San Joaquin salmon survival through the Delta. All of the challenges encountered during 2008 can be resolved by working with the manufacturer to improve QA/QC at the factory, and by designing and implementing additional QA/QC protocols during future field studies.

During the 2008 VAMP, intensive water quality monitoring was conducted by the University of the Pacific to investigate potential causes of the high mortality observed near the Stockton WWTP during 2007. Grab samples were collected daily on the outgoing tide at four sites along the San Joaquin River (SJR), one upstream background site (Brandt Bridge), a site directly above the WWTP (Garwood), at the WWTP outfall (Outfall), and a site downstream of the WWTP (Burns Cutoff). Samples of the WWTP effluent were also collected. Continuous monitoring was also conducted at four SJR sites. Results of water quality analysis showed that the background site above the WWTP

[2] Total excludes non-functioning tags that were not detected at the hatchery after tagging and prior to transport.

was significantly lower than the downstream site with respect to nitrogen compounds concentration, total and dissolved organic carbon, volatile suspended solids, soluble phosphate, specific conductance and turbidity. Levels of ammonia were below US EPA guidelines for the duration of the study, but in combination with other stressors, may have been at a level to affect fish behavior.

### Table 16. Release Data for Acoustically Tagged Salmon During 2006, 2007, and 2008

| Year | Release Date | Release Location | Number Released[1] | Tag weight (g)[2] |
|---|---|---|---|---|
| 2006 | May 8 | Mossdale | 32 | 0.8 |
| | May 15 | Mossdale | 35 | |
| | | Dos Reis | 33 | |
| | | **2006 TOTAL** | 100 | |
| 2007 | May 3 | Durham Ferry | 98 | 0.65 |
| | | Mossdale | 99 | |
| | May 4 | Bowman Road | 99 | |
| | | Stockton | 100 | |
| | | D/S HORB | 99 | |
| | May 10 | Durham Ferry | 96 | |
| | | Mossdale | 97 | |
| | May 11 | Bowman Road | 95 | |
| | | Stockton | 92 | |
| | | D/S HORB | 95 | |
| | | **2007 TOTAL** | 970 | |
| 2008 | April 29 | Durham Ferry | 246 | 0.65 |
| | May 1 | Stockton | 166 | |
| | May 6 | Durham Ferry | 266 | |
| | May 8 | Stockton | 147 | |
| | | **2008 TOTAL** | 835 | |

1 Preliminary data
2 Weight in air

### Table 17. Flow, Barrier, and Export Conditions During the 2006, 2007, and 2008 Acoustic Tag Study Periods

| Year | Study Period | River Flow at Vernalis (cfs) | Combined CVP/SWP Export Target (cfs) | HORB |
|---|---|---|---|---|
| **2006** | May 8-19 | 24,800–27,600 | 1,500; 6,000[1] | No |
| **2007** | May 3-21 | 3260[2] | 1,500 | Yes |
| **2008** | Apr 29 – Jun 1 | 3,163[2] | 1,500 | No |

[1] With the exception of May 18 and 19 when exports increased to 6,000 cfs, combined exports were 1,500 cfs during the study period.
[2] Flows at Vernalis during the VAMP period, which is different than the reported study period.

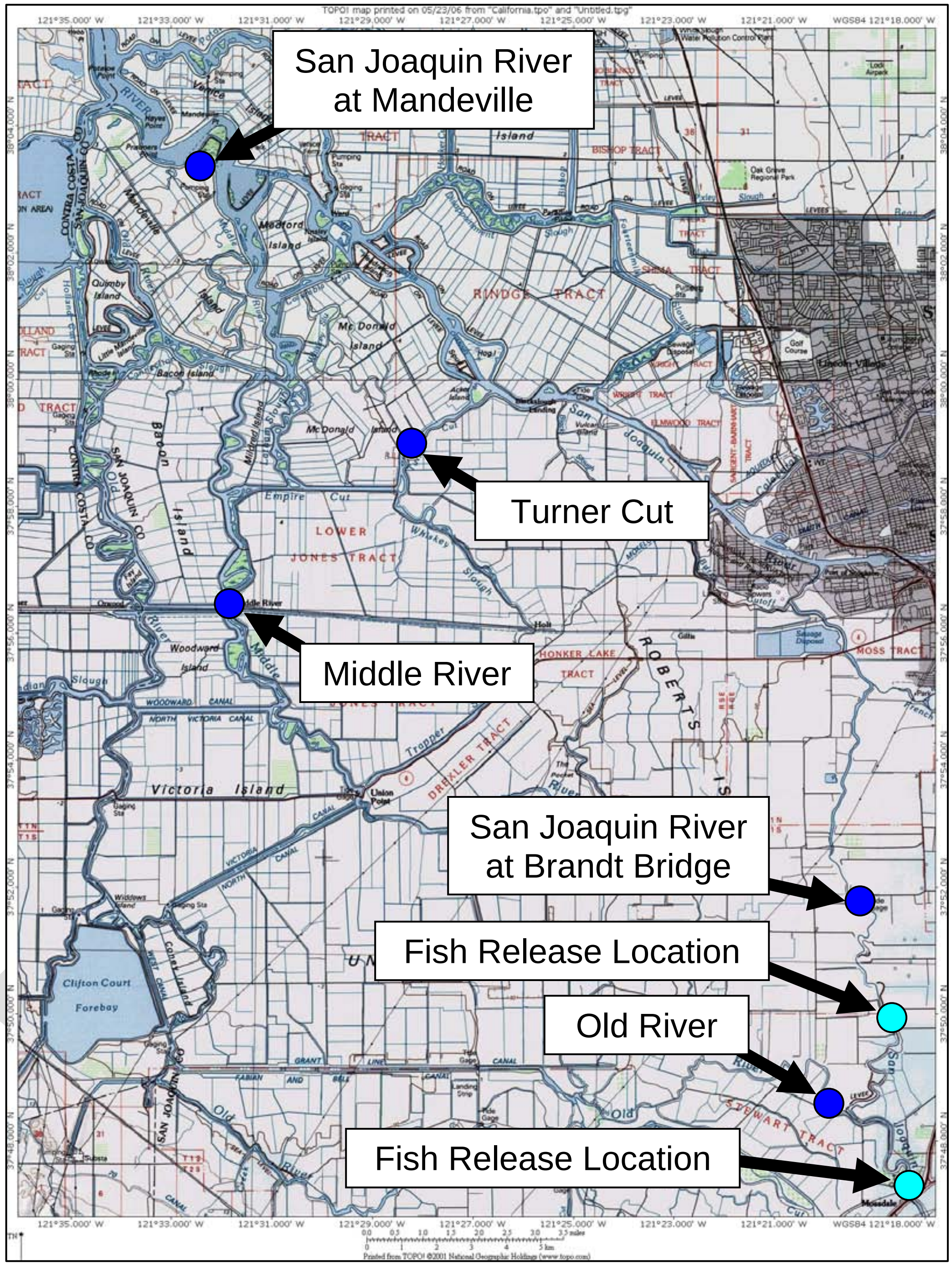



**Figure 22**
Location of acoustic detection stations during 2006

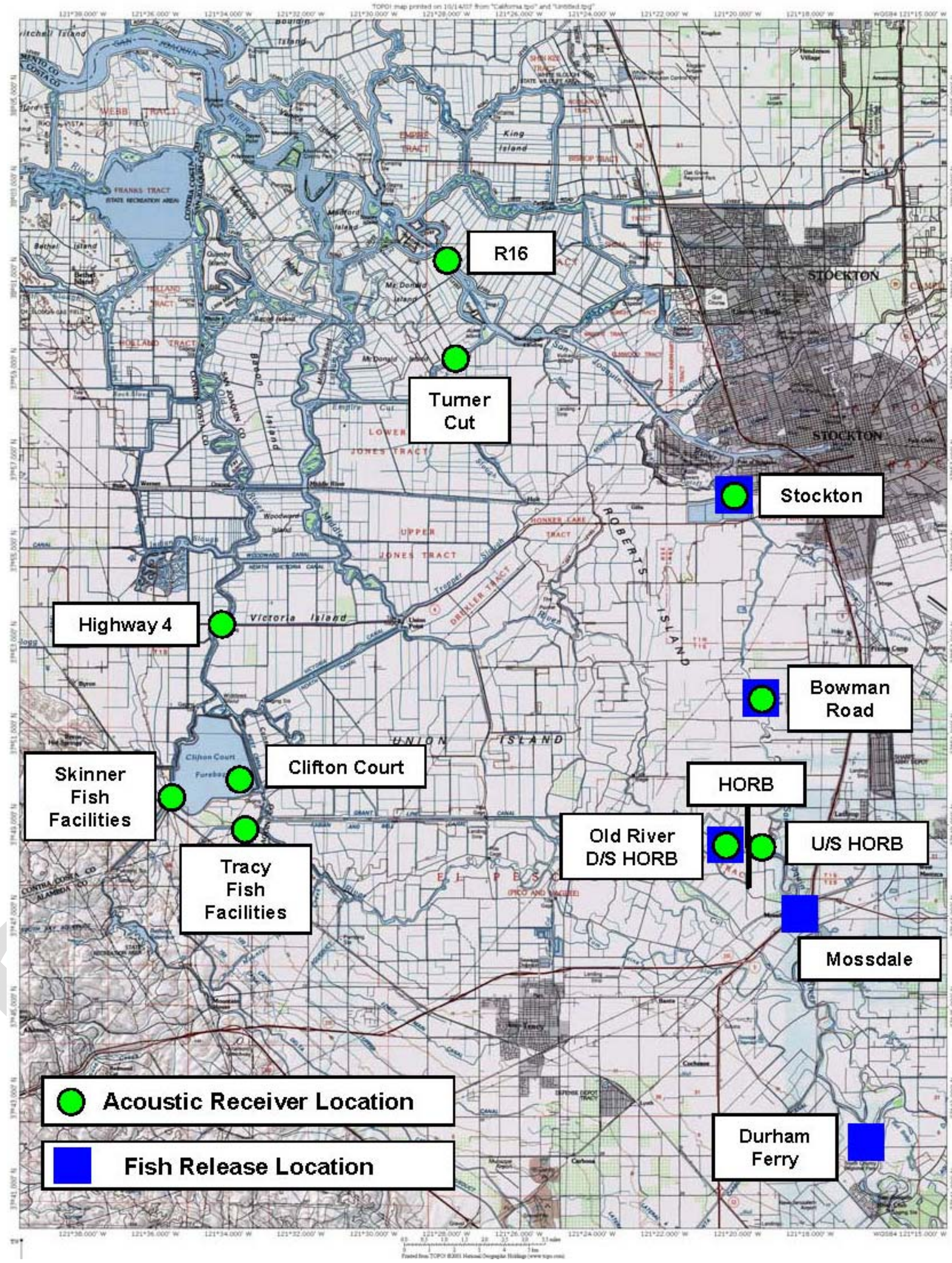
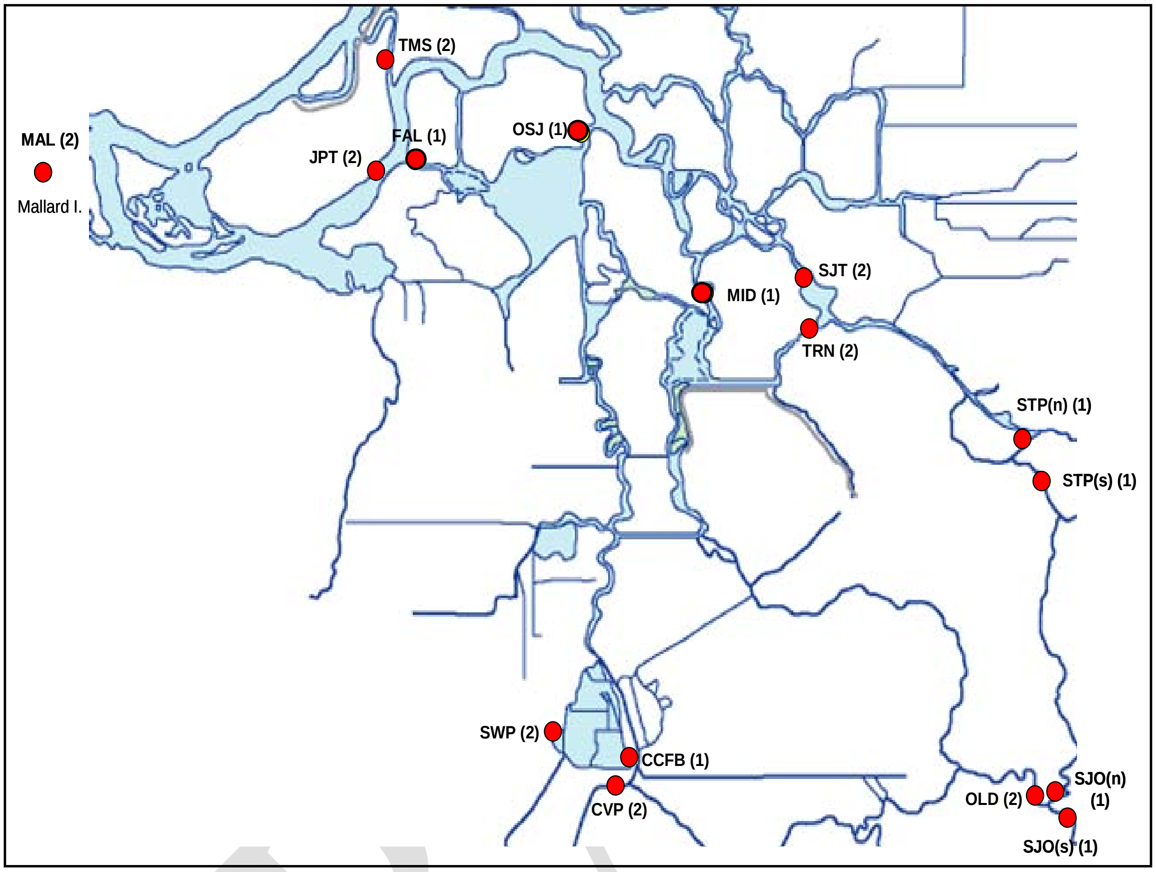



**Figure 23**
Location of acoustic detection stations during 2007

**Figure 24**
Location of acoustic detection stations during 2008




## 5.0 COMPLEMENTARY STUDIES

*Contributed by Pat Brandes, US Fish and Wildlife Service (USFWS)*

A variety of complementary studies have been conducted during the years the pre-VAMP and VAMP studies have been implemented. Several of these complementary studies have been summarized in the each of the VAMP annual reports. For example, studies included in the 2006 Annual Report (Chapter 6) includes: Review of Juvenile Salmon Data from the San Joaquin River Tributaries to the South Delta During January through mid-July, 2006 contributed by Tim Ford, Turlock and Modesto Irrigation Districts and Andrea Fuller, FISHBIO Environmental; 2006 Mossdale Trawl Summary, contributed by Jason Guignard, CDFG; 2006 VAMP Pilot Study to Monitor the Migration of Juvenile Chinook Salmon Using Acoustic Telemetry, contributed by Dave Vogel, Natural Resource Scientists, Inc.; Survival Estimated for CWT Releases Made in the San Joaquin Tributaries and Comparison of VAMP Releases with Sacramento River Delta Releases contributed by Pat Brandes, USFWS.

One goal of the VAMP was to "*... implement protective measures for San Joaquin River fall-run Chinook salmon within the framework of a carefully designed management and study program which is designed to achieve, in conjunction with other non-VAMP measures, a doubling of natural salmon production by improving smolt survival through the Delta*" (Appendix A, SJRA, March 20, 1998). Escapement in the San Joaquin River tributaries since 2002 would be the result of changes in spring conditions associated with the implementation of VAMP (starting in 2000). Combined escapement in the three San Joaquin tributaries since 2000 has not doubled from the average during the 1967-1991 period per the goal of the CVPIA's Anadromous Fish Restoration Program, but has significantly declined since the fall of 2000 (Figure 25). In the fall of 2007 fewer than 1,000 adult Chinook salmon returned, which represents a reduction of over 97% in the last seven years. While the low numbers of spawners in 2007 was experienced by fall run salmon populations through- out the Central Valley and West Coast in general, the longer term decline in the San Joaquin River basin has not stopped since the implementation of the VAMP.

## 5.1 VAMP AND SAN JOAQUIN RIVER UNMARKED SALMON

*Contributed by Pat Brandes, US Fish and Wildlife Service (USFWS)*

One of the VAMP objectives is to provide improved conditions to increase the survival of juvenile Chinook salmon smolts produced in the San Joaquin River tributaries during their downstream migration through the lower river and Delta. It is hypothesized that these actions to improve conditions for the juveniles will translate into greater adult abundance and escapement in future years than would otherwise occur without the actions. The ultimate goal of VAMP is to gather the information necessary to learn about the respective roles of flow, exports and a HORB on survival, to provide the most efficient means of protection in the future. The main purpose of WQCP standards is to protect beneficial uses. One of those beneficial uses is to assure adequate survival for juvenile Chinook salmon migrating through the Delta from the San Joaquin tributaries.

VAMP is incorporated into a 31-day period roughly between April 15th and May 15th. This time-period was chosen because it was predicted from past monitoring data at Mossdale that a majority of the smolts migrating through the Delta would enter the Delta during that time. Since 2000 the VAMP period has been shifted to start later than April 15th in five of the nine years since VAMP has been implemented. The timing of the VAMP was later in 2001, and in all years between 2005 and 2008, with the latest shifts in time starting the VAMP on May 1st. The shifts were made to provide better protection for the unmarked fish in wet years (2005 and 2006), to allow the fish used for acoustic experiments to grow to a larger size before tagging (2007 and 2008) and to resolve permitting issues associated with installing the HORB (2001)( SJRGA, 2002)).

Although a high proportion of the smolt outmigration has migrated through the Delta during the VAMP period, there is a component of the population that either immigrates into the Delta as fry in February and March or as smolts prior to and after the VAMP period (~ March 15th to April 14th and ~May 16th to June 15th).

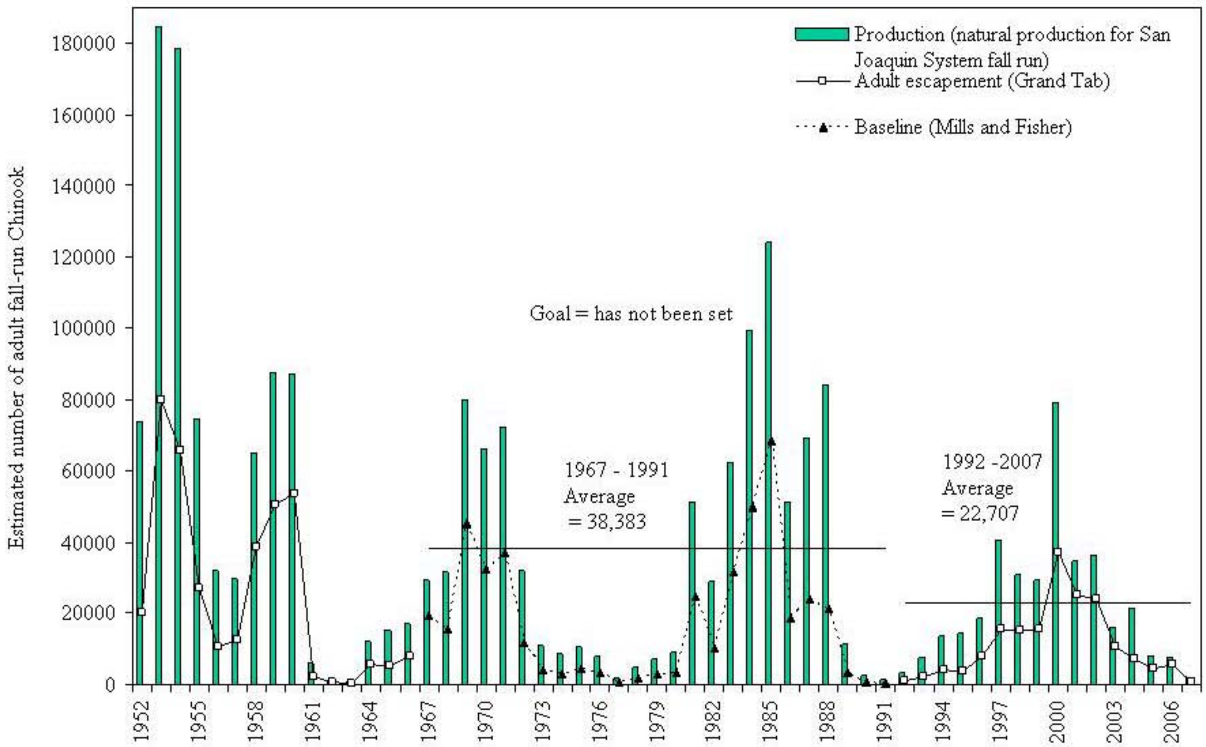



**Figure 25**

Estimated yearly natural production and in-river escapements of San Joaquin System adult fall-run Chinook salmon. The San Joaquin System is the sum of the Stanislaus, Tuolumne and Merced Rivers. 1952 – 1996 and 1992 – 2006 data are from CDFG Grand Tab (August 20, 2007). Baseline numbers (1967 – 1991) are from Mills and Fisher (CDFG, 1994)



### *5.1.1 Survival of Chinook Salmon*

To determine if survival for natural juvenile Chinook salmon migrating through the Delta with VAMP was better than that with conditions identified in the 1995 WQCP, the "best" model developed by the USFWS (Newman, 2008) (discussed in an earlier chapter) was used to estimate survival under the two scenarios. The model was also used to estimate survival with the VAMP flows and exports, without the HORB installed, since it appears the HORB will not likely be installed in the future due to delta smelt concerns.

The model estimated survival under the five VAMP flow and export targets with the HORB installed. The flows ranged from 3,200 to 7,000 cfs and exports ranged between 1,500 and 3,000 cfs as specified in the SJRA and the VAMP study plan. The alternative case was with the flow and export levels specified in the 1995 WQCP. In the WQCP two flow ranges are listed for each water year type in the 1995 WQCP. For this comparison the higher flow listed in the plan was used and would be used when X2 (2ppt isohaline) is required to be at or west of Chipps Island. In addition, the WQCP was interpreted to set export levels equal to the San Joaquin River flow at Vernalis during the April 15th to May 15th (assumed VAMP period).

The median survival estimate, with the 1st and 3rd quartiles and essentially the range are shown for each flow and export target under the two alternative set of standards (Table 18 and Figure 26). A dashed line at survival of 0.5 is shown on both graphs to show the relative differences between the two alternative conditions. The VAMP conditions with the HORB installed result in median survival estimates that range from 0.163 for a dry water year type to 0.241 and 0.273 in wet water year types, with exports of 1,500 and 3,000 cfs in the wet year water type, respectively. Median estimates under conditions with the 1995 WQCP range from 0.152 in a critical water year type to 0.251 in a wet water year type, and were slightly less than those obtained with conditions associated with the VAMP, but generally similarly.

The median survival estimates for the VAMP without the HORB were lower for each flow and export target than either the VAMP with the HORB or the 1995 WQCP standards, with values ranging from 0.141 in a dry water year type to 0.164 and 0.170 in a wet water year type (Figure 26). The probability distribution of median estimates of survival for the VAMP with and without the HORB and the 1995 WQCP under the five combinations of flow at Vernalis and CVP/SWP exports (scenarios) are shown in Figure 27.

The model used for estimating smolt survival, the "best" model, includes a positive coefficient for exports and flow into upper Old River, even though there is relatively more uncertainty on the effects of exports and flow in Old River on salmon smolt survival than the effect of the HORB or flow on the survival between Dos Reis and Jersey Point.

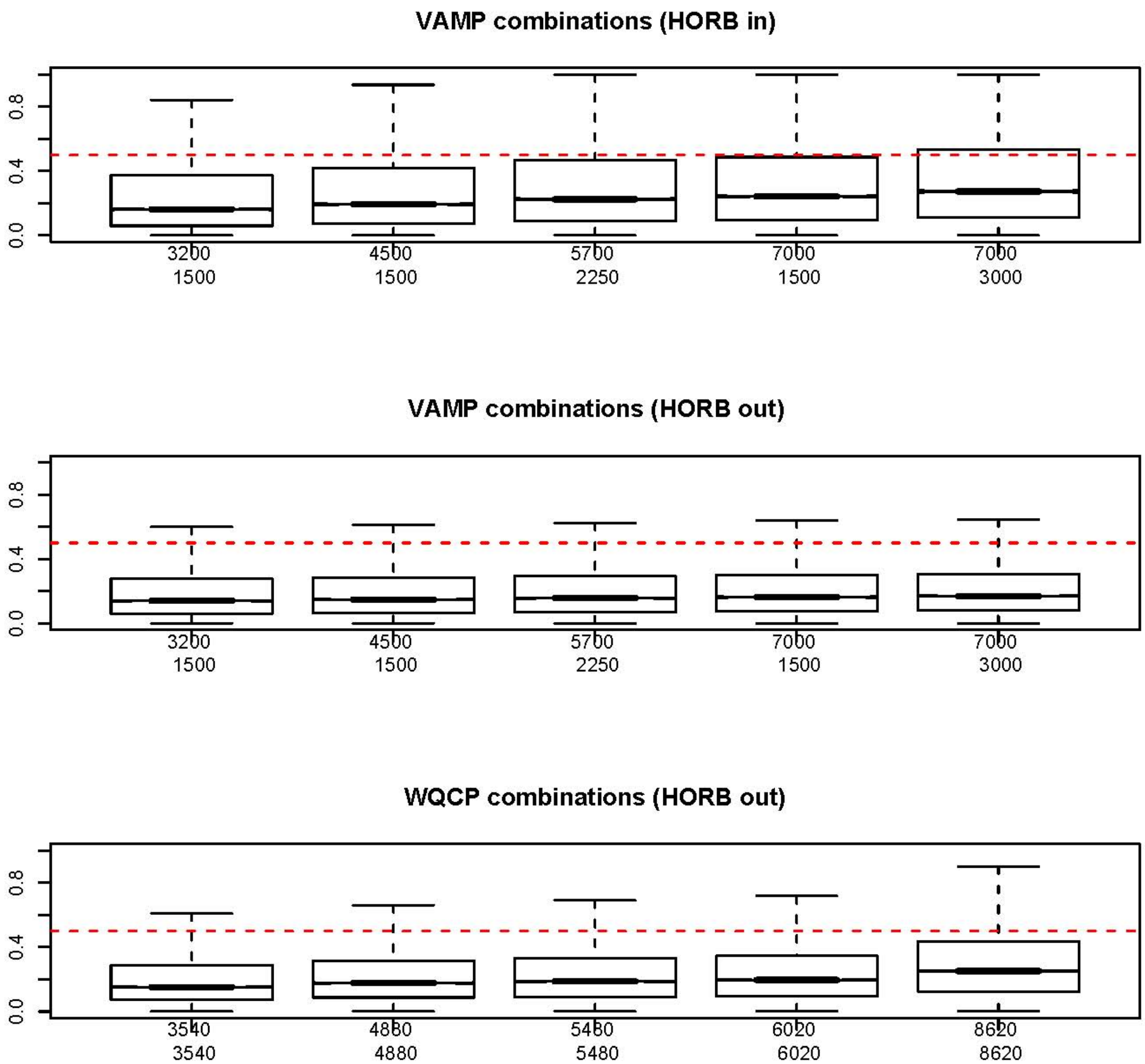
It should be noted that under all cases, that median survival is estimated to be well below 50% in all cases. The highest median survival in any of the three cases: VAMP with HORB; VAMP without HORB; and the WQCP; only ranges between 17% and 27%.

### *5.1.2 VAMP and Protection of Unmarked Juvenile Salmon Migrating Through the Delta*

To determine how successful VAMP has been in targeting the migration period of unmarked juvenile salmon smolts (salmon >70 mm fork length (FL)), catches of unmarked salmon at Mossdale were reviewed. To determine what proportion of the smolt population actually experienced conditions (potentially improved survival) associated with VAMP, the VAMP period was shown on plots of the catch per minute or catch per 10,000 cubic meters at Mossdale between March 15th and June 30th (Figures 28a-f). The proportion of juvenile salmon migrating during the VAMP period relative to the primary smolt migration period (April 15th to June 30th) was also estimated. The proportion migrating during the VAMP period of managed flow years of 2000-2004 and 2007-2008 was estimated to be between 31% in the year 2000 and 76% (in 2003) between 2000 and 2005.

**Figure 26**

Estimated median survival (with 1st and 3rd quartile and range) using Newman's "Best" model for VAMP combinations (With the Head of Old River Barrier (HORB) in shown in the top graph, HORB out shown in the middle graph and Water Quality Control Plan (WQCP) combinations with the HORB out shown in the bottom graph). Red line is 50% survival.



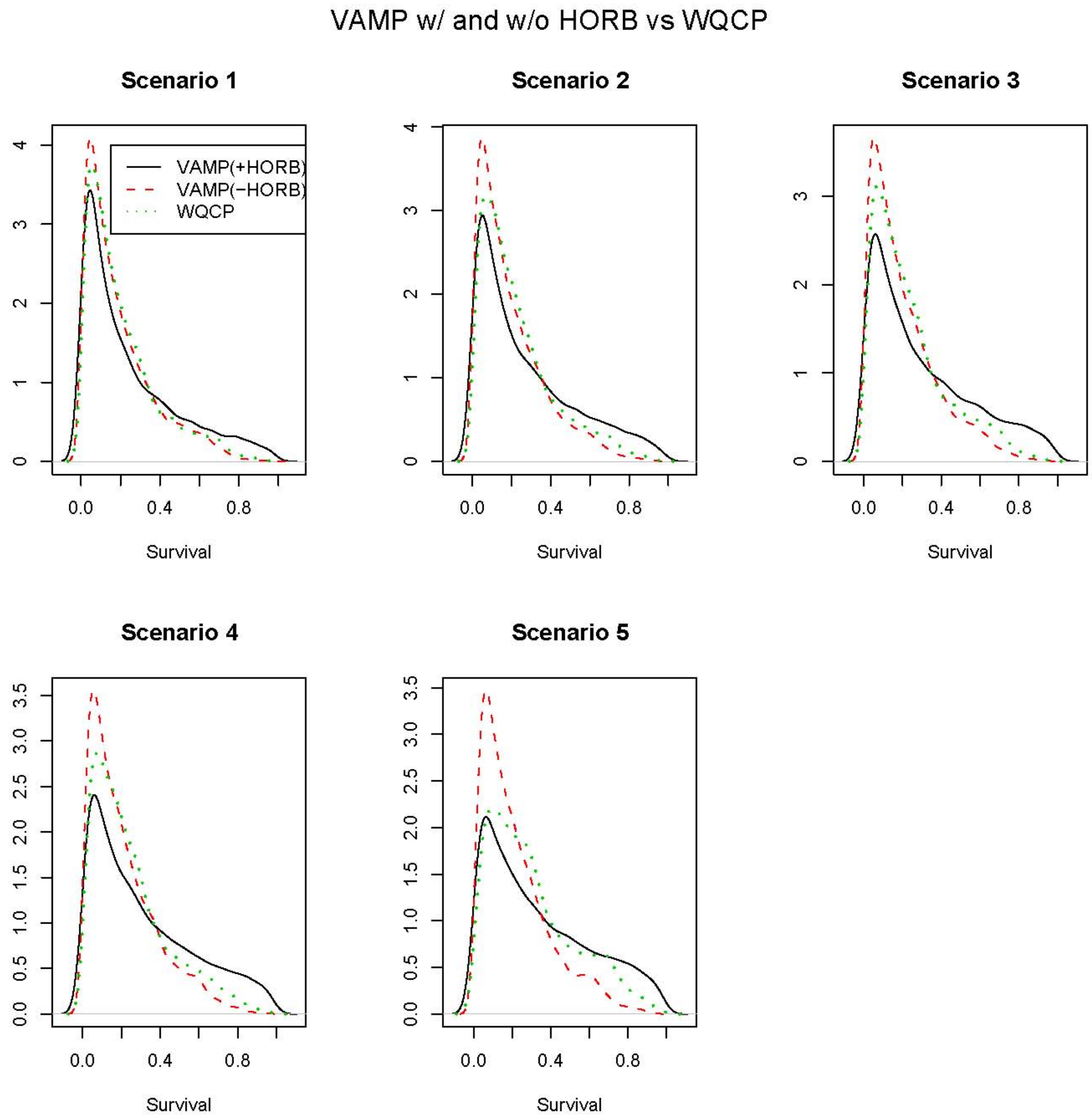



**Figure 27**

Probability distribution for survival under three conditions (VAMP with HORB, VAMP without HORB, or WQCP (without HORB) for five different combinations (scenarios) of flow and exports

**Table 18. Median estimates of juvenile salmon survival using the USFWS "best model" (Newman, 2008)**

| Water Year Type | VAMP With HORB | WQCP Without HORB | VAMP Without HORB |
|---|---|---|---|
| Critical | 0.163 | 0.152 | 0.141 |
| Dry | 0.193 | 0.177 | 0.148 |
| Below Normal | 0.224 | 0.187 | 0.157 |
| Above Normal | 0.241 | 0.196 | 0.164 |
| Wet | 0.273 | 0.251 | 0.170 |

Flood years (2005-2006) have somewhat different migration characteristics and 2006 was unique in that it had two differing export levels within the VAMP period. Thus the VAMP period was broken into two halves for the plot of the year 2006 (Figure 29).

The WQCP standards for the periods before and after VAMP resulted in flows ranging between 710 and 3,420 cfs, depending if the water year was critical, dry, below normal, above normal or wet and whether the 2 ppt isohaline was required to be at or west of Chipps Island. The WQCP requires that exports be limited to 35% of total Delta inflow (includes Delta inflow from the Sacramento basin) between February and June, excluding the pulse flow period. Exports have been lower than required after the VAMP (approximately May 15$^{th}$) until early June, to reduce take of delta smelt and to improve smolt survival for the remaining juvenile salmon migrating through the San Joaquin basin. In addition, in 2008, exports were limited due to Delta smelt concerns and a court ordered action to limit negative flows in Old and Middle Rivers, which was met principally through reduced exports.

Survival during the period outside of VAMP was not modeled for any of the years, although it could be done. The flows and exports would be the same either with the VAMP or the 1995 WQCP during this time period, so modeled survival would be the same under either case.

The most important question relative to VAMP is whether the conditions it provides, results in adequate protection through the Delta for juvenile salmon migrating from the San Joaquin tributaries. Modeling suggests that both with VAMP (with the HORB) and the 1995 WQCP standards (without the HORB) that survival is on average roughly 20% under either scenario (Newman, 2008). The 3$^{rd}$ quartile of the data is nearly always below 50%. The only condition that incorporates 50% survival in the 3$^{rd}$ quartile is the VAMP conditions (with the HORB) of flows of 7,000 cfs with exports at either 1,500 or 3,000 cfs. The low and declining numbers of adults returning to the San Joaquin basin to spawn indicate that, on average, survival over the entire life-cycle for San Joaquin basin Chinook salmon is not great enough to replace the previous cohort. Unless something else changes to overcome the decline of adult production and the survival in the Delta since 1997, survival will be too low, in either case, to increase the population.

### *5.1.3 VAMP and Having Adequate Scientific Information on Which to Support Current WQCP Objectives or Changes to the Objectives*

The VAMP study plan (Appendix A, SJRA, 1998) originally planned for a twelve year study with expectations that over the 12 years, two replicates of survival would be obtained each year and each of the five combinations of flows and exports would be achieved with the HORB installed.

VAMP target flows, exports and installation of the HORB were achieved in six (2000-2004 and 2007) of the nine years VAMP has been conducted (2000- 2008). In the remaining three years since VAMP started the HORB was not installed due to high flows (2005 and 2006) or due to a court order for the protection of delta smelt (2008). Study fish for the traditional VAMP CWT studies were not provided during one (2007) of the six years that VAMP target conditions with the HORB were met. In three of the five years (2002-2004), when VAMP target conditions were met and study fish were available for CWT studies, flow and export targets were the same (3,200 flow and 1,500 exports), thus only three of the five target conditions contained within the VAMP study design were actually tested.

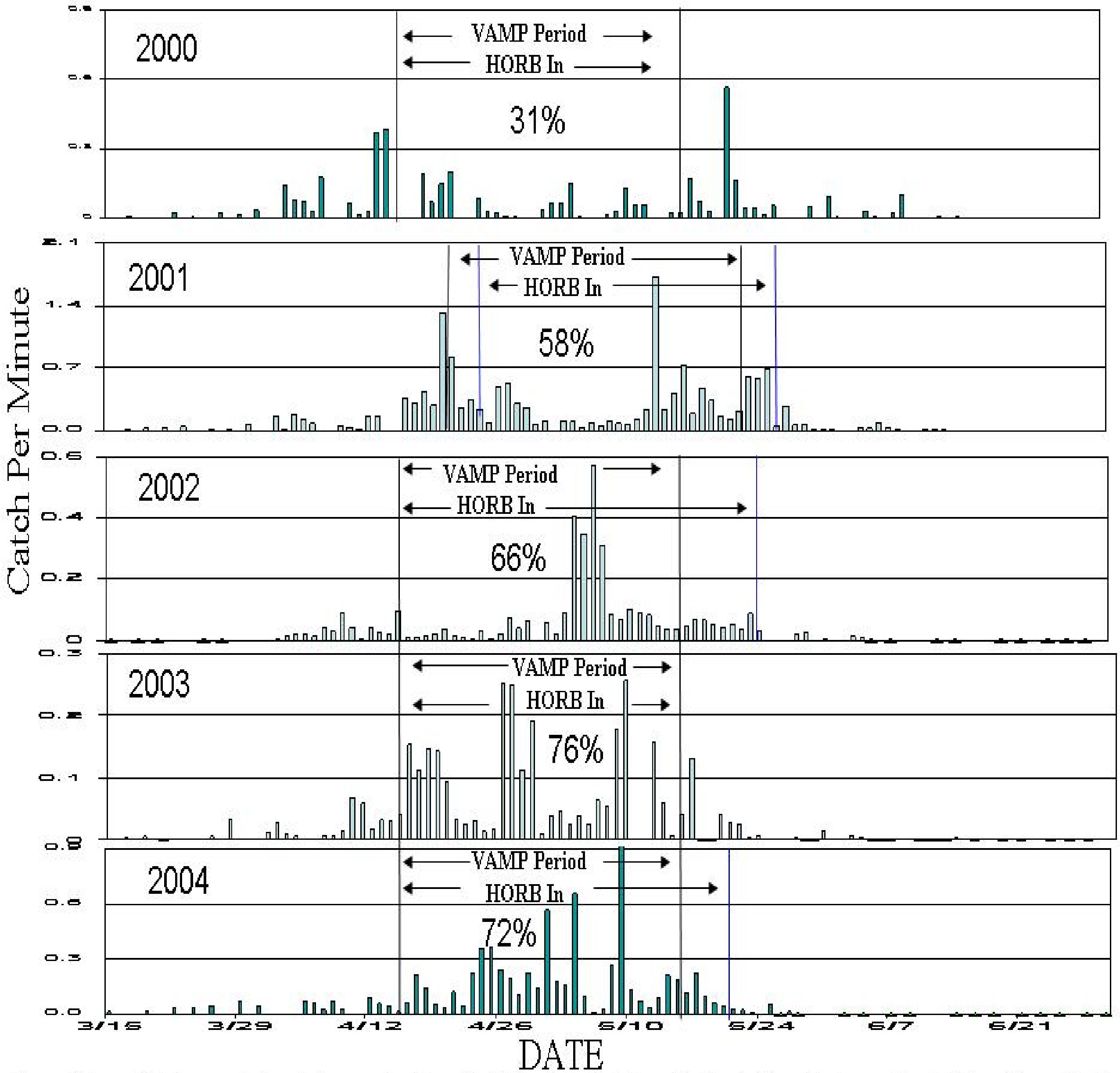
While, pilot efforts of acoustic studies were attempted in 2007 and 2008, equipment failures limited us from estimating survival through the entire Delta in those years. Flows and export targets in 2007 and 2008 were 3,200 and 1,500 cfs, and similar to what they were in 2002-2004. While the HORB was installed in 2007, a court order for the protection of delta smelt precluded the installation of the HORB in 2008. Finally, an additional limitation was realized in the spring of 2007 and during periods of 2008, when trawling at Chipps Island was suspended or reduced to limit delta smelt catches, precluding our ability to consistently sample for CWT fish, if they had been available in those years.

It is uncertain if completing VAMP by obtaining all of the flow and export targets as originally envisioned would have provided the data needed to develop new or support current water quality standards. To complete the VAMP a key data point is needed at flows of 7,000 cfs and exports at 1,500 cfs with the HORB installed. This key data point is needed to decouple the role of exports and flows because during the VAMP, with the HORB, higher exports always occurred during times of higher flow. Thus, measuring survival under this particular flow and export condition would be helpful. Measuring survival at a target of 3,000 cfs exports with 7,000 cfs flow would further help separate the roles of flow and exports (Figure 21).

It is uncertain whether a 7,000 cfs flow with a HORB could have, in reality, occurred at the frequency needed for the VAMP, given that the hydrology needed to produce a 7,000 flow (e.g. wet years) typically produces flood control releases from the San Joaquin River tributaries which preclude the installation of the HORB at Vernalis at flow levels exceeding approximately 5,000 cfs (e.g. the maximum level at which the HORB can be installed). One possible exception to this would be the instance where a “double-step” VAMP study year occurred such that a less than wet year followed a wet year providing sufficient water supply enabling controlled releases pre-VAMP allowing installation of the HORB and a controlled 7,000cfs flow level during VAMP. The potential toward more, lower flow years within the VAMP range of conditions may have ultimately precluded VAMP from achieving the needed data points to complete the VAMP and in potentially identifying the role of exports.

**Figure 28 a-e**

Catch per minute of all unmarked juvenile Chinook in the Mossdale Kodiak trawl between March 15th and June 30th. The Head of Old River Barrier was in for the total VAMP periods in 2000 and 2003. The HORB stayed in after the VAMP period in 2001, 2002 and 2004. In 2001 the HORB was installed after the VAMP period started.



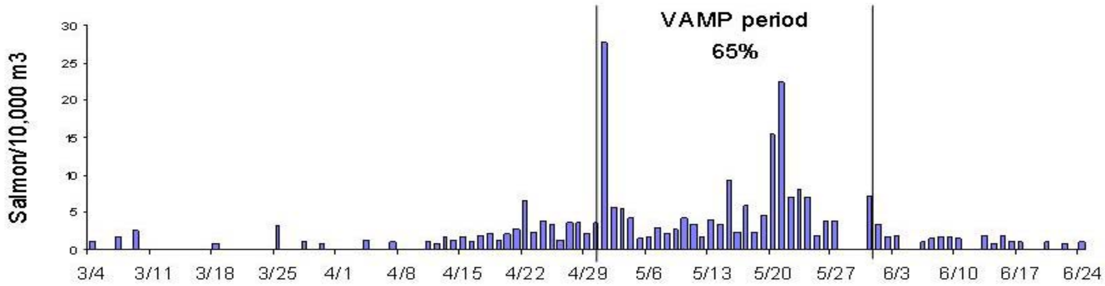



**Figure 28f**

The average daily densities of unmarked salmon caught in the Mossdale Kodiak trawl on the San Joaquin River between March 4th and June 24th of 2005 and the percent of smolts in the March 15th to June 30th period that were estimated to migrate during the VAMP period (May 1st – May 31st)

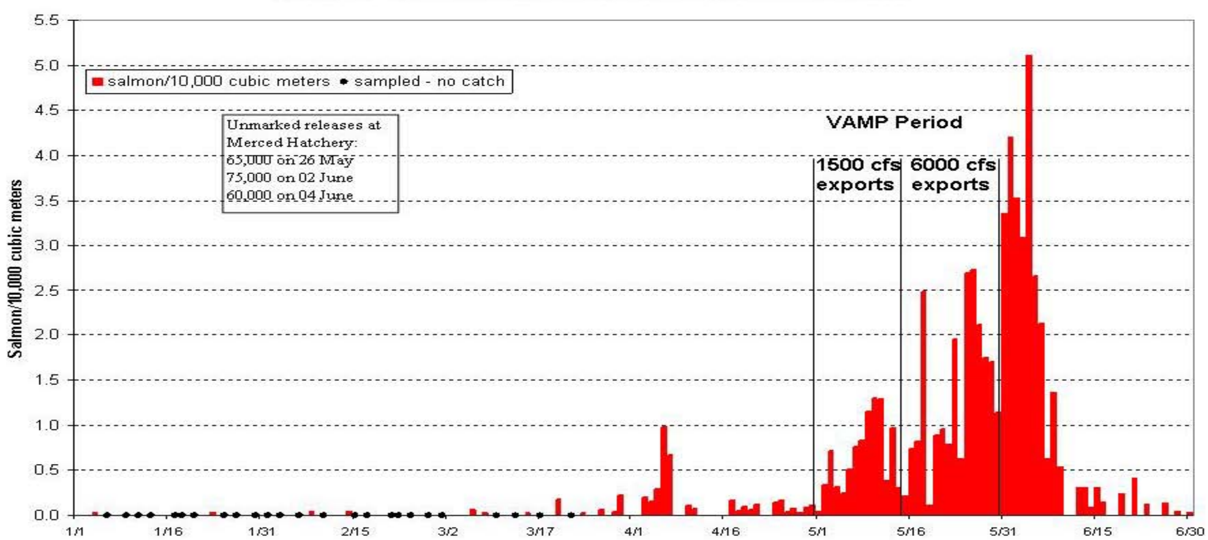



**Figure 29**

Unmarked juvenile salmon catch per 10,000 cubic meters at Mossdale between January 1st and June 30th, 2006

As with the case with many scientific studies, the studies associated with VAMP have resulted in knowledge that without a structured study plan could not have been achieved. For instance, flows and exports targets were similar (3,200 cfs flow and 1,500 cfs exports) in 2002-2004, but survival in 2003 and 2004 were much lower than 2002, indicating that some other factor, other than flow or exports reduced survival in 2003 and 2004. We did see survival increase somewhat in 2005 and 2006 with flood flows, but estimates were much lower than in many of the past years with higher flows. When we incorporate data from pre-VAMP studies, we observe that survival through the Delta has declined since 1997 (Figure 12). In addition, the loss of so many acoustically tagged fish near the Stockton wastewater treatment plant in 2007 may provide some indication that water quality or conditions that allow excessive predation to occur in some parts of the Delta may be limiting survival in some years.

## 5.2 VAMP and Protection of Steelhead from the San Joaquin River Basin

*Contributed by Jeff Stuart, National Marine Fisheries Service (NMFS) of the National Oceanic and Atmospheric Administration (NOAA)*

Several monitoring programs in the San Joaquin River basin designed to estimate the population and spatial timing of fall-run Chinook salmon smolt outmigrations have given valuable information as to the timing and relative annual size of the Central Valley steelhead outmigration. The USFWS and CDFG conduct trawls at the Mossdale site on the San Joaquin River, covering the river reach adjacent to the HOR. Trawls begin in January and continue through the end of June with the frequency of trawls increasing during the VAMP experimental period. Each year these trawls routinely capture outmigrating steelhead smolts, yet the frequency of capture is often quite low, ranging from one or two fish to as many as 40 fish (2007) annually. Typically, the frequency of capture is higher during the VAMP period (April through May) however; this may be an artifact of the increased level of trawl monitoring effort applied during the time span. Trawls, including the currently used Kodiak trawl, are inefficient in capturing the larger, more elusive steelhead smolts. Steelhead smolts typically range in length from 200 to 250 mm.

Data collected from rotary screw traps (RSTs) located on the Stanislaus River at Oakdale and farther downstream at Caswell State Park for the 10-year period between 1996 and 2006, indicate that steelhead smolt downstream migration begins as early as December on the Stanislaus River when individuals are collected at the Oakdale RST. Smolt-sized fish are collected in higher numbers from January through May. By June the outmigration has essentially ceased for the year, although fish have been collected in June and July in some years (1998, 2000, and 2001). This pulse of outmigrating fish is subsequently seen at the Caswell Park RSTs about one month later. Captures at Caswell begin to increase in February, peak in March and April, before tapering off with the onset of summer conditions. Collections of smolts in the Mossdale fish monitoring trawls typically see peaks in the April and May time frame, although some fish are collected prior to April (pre-VAMP pulse flow conditions). Based on these cursory observations, the VAMP pulse flows and closure of the HORB benefit a large proportion of the smolts emigrating from the Stanislaus River. It is also assumed that smolts emigrating from the Tuolumne and Merced River systems would follow a pattern similar to that seen on the Stanislaus River watershed, and would likewise benefit from the VAMP pulse flows and closure of the HORB during the 31-day period during April and May.

## 5.3 VAMP and Protection of Delta Smelt

*Contributed by Bruce Herbold, United States Environmental Protection Agency (US EPA)*

VAMP appears to be an essential element in the survival of the delta smelt population in recent years. Work by Bill Bennett and Jim Hobbs has examined the early life history of delta smelt (July 3 report to Pelagic Organism Decline (POD) management Team, May 2008 presentation to IEP Estuarine Ecology Team, other public presentations and pers. comm.). By examining smelt otoliths these authors have determined the birthdates of smelt that survive to the fall. Despite smelt spawning throughout most spring months, the ones that survive to become adults, since the year 2000 when VAMP began, have been spawned during VAMP (Figure 30). This strongly suggests that the higher San Joaquin flows or the reduced export impacts, or both have substantially contributed to survival of the remaining delta smelt population. In his 2008 court decision regarding the USFWS Biological Opinion for smelt, federal Judge Wanger explicitly called for continuation of VAMP as part of his interim requirements.

Protection of delta smelt in recent years has included reducing the risk of entrainment at the CVP and SWP by requiring positive (or mildly negative) flows in lower Old and middle rivers. When there is no HORB, these flows can be roughly estimated by subtracting total export rates plus in-delta diversions from the inflow at Vernalis. The VAMP requirements of exports being no more than half of Vernalis flows virtually guarantees that flows during VAMP will be positive.

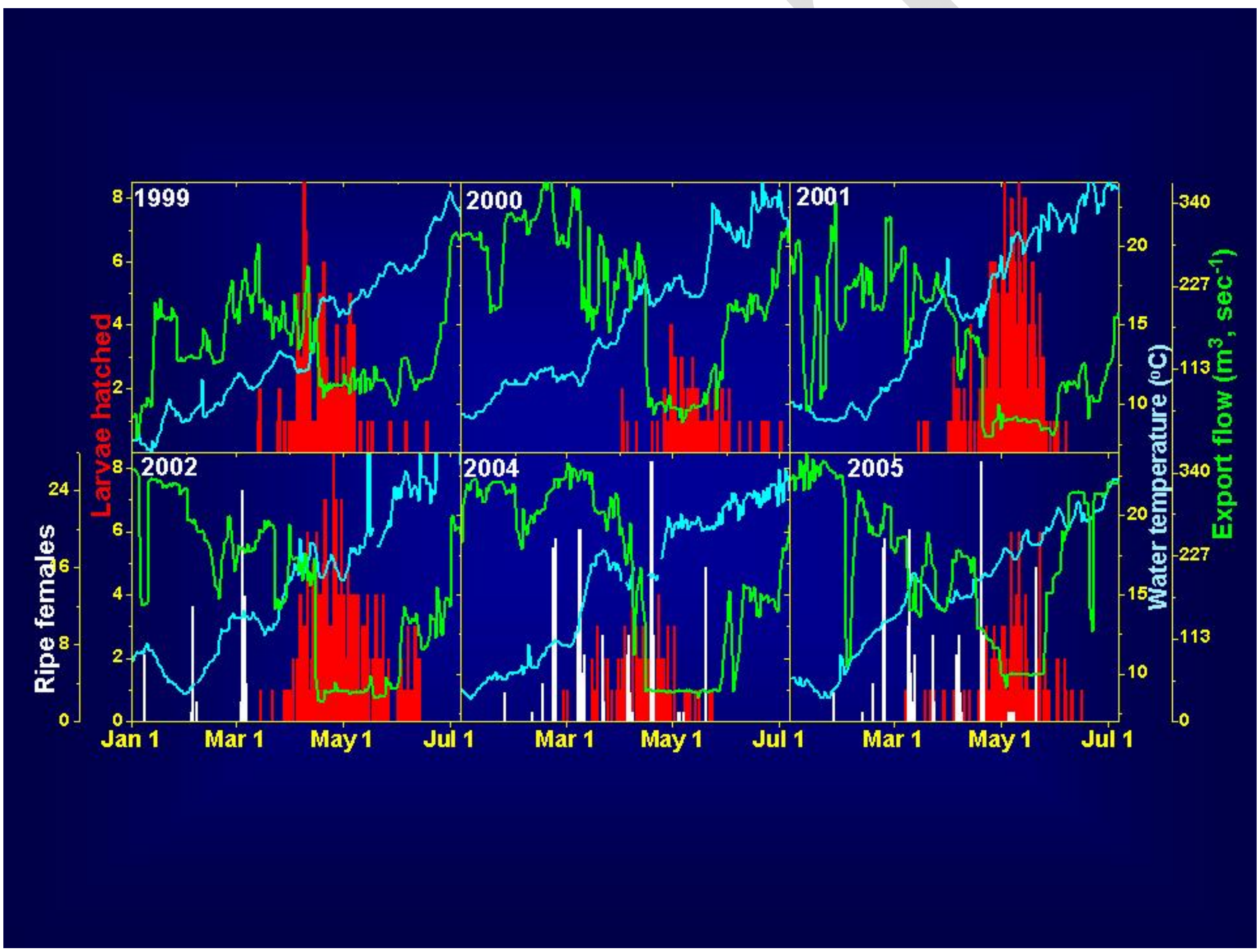



**Figure 30**

Delta smelt hatch dates in relationship to export rates between1999 and 2005. Source: B Bennett, UC Davis.

VAMP was designed with the assumption that a HORB would be in place, but in recent years the barrier has not been installed. Installation of the HORB can reduce flows in Old and Middle Rivers and presumably increase the entrainment risk of delta smelt. Thus, VAMP as originally conceived may not be as protective as it has been in recent years. Nevertheless, VAMP indirectly produces the same conditions that have been required at other times of year to minimize water project impacts. The evidence of the surviving fish suggests that VAMP has been an important protective element for the delta smelt population.

## 5.4 POTENTIAL FOR ENTRAINMENT AT THE CVP AND SWP FACILITIES – PARTICLE TRACKING MODELS

*Contributed by Jeff Stuart, National Marine Fisheries Service (NMFS) of the National Oceanic and Atmospheric Administration (NOAA)*

Particle tracking models (PTMs) were generated by the Department of Water Resources in 2004 for the South Delta Improvement Program (SDIP) using modeling assumptions utilized in the 2004 Operations and Criteria Plan (OCAP) consultations with the NOAA's National Marine Fisheries Service (NMFS). These studies were originally produced by DWR's CALSIM II model for statewide monthly operations and then further processed in DWR's Delta Simulation Model 2 (DSM2) to generate hydrodynamic outputs at 15-minute intervals for the Delta region. As a component to the DSM2, the PTM module simulates the transport and fate of individual neutrally buoyant particles and uses the hydrodynamics determined in the HYDRO module of DSM2 to calculate the movement of each individual particle. At each injection point, 1,000 particles were injected evenly over the course of a day and tracked for 30 days. PTM results were plotted at 5 days, 10 days, and 30 days post release for each of these injection points. NMFS requested that the PTMs be run for the months of January through June, and cover critical (water year [WY] 1988), below normal (WY 1979), and wet (WY 1988) hydrological water years. During the course of the 30-day period, the fate of the particles was determined. Particles could leave the system by several routes such as: transport through the Delta system past Chipps Island, diversion at the CVP or SWP facilities, loss to agricultural diversions in the Delta, or other diversions (Contra Costa Canal, North Bay Aqueduct, and Vallejo). In addition, some particles were still present in the Delta 30-days after injection and were reported as "in-Delta" in the PTM reports.

The PTM results for the periods between April and June over the three water year types bracket the months that the effects of VAMP actions would be observed. Under the modeling assumptions, the barriers were installed according to table 19.

The Delta Cross Channel (DCC) was closed for the months of April and May and open for the month of June in all water years. River flows in the San Joaquin River were similar for WY 1979 and 1984, peaking at approximately 7,000 cfs for the period between mid-April and mid-May, before falling into the range between 2,100 cfs (WY 1979) and 2,600 cfs (WY 1984). In the critically dry year of 1988, the San Joaquin River flow peaked at 2,000 cfs in the mid-April to mid-May time period, before falling to approximately 1,300 cfs through June. Pumping rates at the CVP and SWP for WY 1979 and WY 1984 were 1,500 cfs each during the period between mid-April and the end of May. Pumping rates in WY 1988 had a combined CVP and SWP rate of 1,500 cfs for the 30-day VAMP period.

**Table 19. Dates of barrier installation for HORB, Middle River (MR), Old River at Tracy (ORT), and Grant Line Canal (GLC) used in particle tracking modeling**

| Site | WY 1979 | | WY 1984 | | WY 1988 | | |
|---|---|---|---|---|---|---|---|
| | May | June | May | June | April | May | June |
| HORB | | | | | Apr 15 – May 15 | | |
| MR | May 17 to June 30 | | May 17 to June 30 | | Apr 16 to June 30 | | |
| ORT | May 17 to June 30 | | May 17 to June 30 | | Apr 16 to June 30 | | |
| GLC | May 17 to June 30 | | May 17 to June 30 | | | May 16 to June 30 | |

Results from the PTM indicate that there is a consistent risk to particles injected at Mossdale of entrainment at the CVP and SWP facilities, often reaching 50 to 60 percent of the injected particles by the end of the 30-day study period. The CVP typically entrains the greater share of particles and usually does so more quickly than the SWP. Entrainment values at the CVP reach near maximal levels within 5-days of injection, while the entrainment values at the SWP generally do not show increases until 15 days after injection. This lag may be due to particles which remain in the mainstem of the San Joaquin River after passing the HOR bifurcation eventually being drawn towards the SWP through one of the channels branching off the lower San Joaquin River (*i.e.*, Turner and Columbia Cuts, Middle River, and Old River). In the PTM study run for 1988, in which the HORB is installed, a pattern begins to emerge that indicates the beneficial effects of the HORB. Entrainment of particles by the CVP is markedly reduced, to approximately 50 percent of the pre-HORB values in April (Figure 31a –c)). The SWP is also reduced and delayed. On inspection of the particle entrainment levels, the CVP does not increase markedly after the HORB is installed and the SWP shows minimal entrainment until after the barrier is removed and pumping rates are increased post-VAMP. An additional element that can be seen in the PTM results is the increase in particle losses to agricultural diversion in the south Delta during this period, and the increase in particles remaining in the Delta after the 30-day study period ends. Essentially, no particles escape the Delta to be measured at Chipps Island after their injection at Mossdale, according to this PTM study (see Tables 20, 21, and 22).

## Table 20. Water Year 1979 PTM results for the period between April and June

| Apr-79 | Chipps Island | In-Delta | Ag Diversions | Other Diversions | SWP | CVP |
|---|---|---|---|---|---|---|
| Day 5 | | | | | | |
| Mossdale | 0.00% | 53.30% | 0.70% | 0.00% | 3.40% | 42.60% |
| UpStreamDCC | 0.00% | 100.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Freeport | 0.00% | 99.80% | 0.20% | 0.00% | 0.00% | 0.00% |
| Day 15 | | | | | | |
| Mossdale | 0.00% | 33.40% | 1.20% | 0.00% | 15.80% | 49.60% |
| UpStreamDCC | 44.70% | 49.60% | 0.20% | 0.00% | 2.70% | 2.80% |
| Freeport | 51.70% | 43.80% | 0.20% | 0.00% | 1.90% | 2.40% |
| Day30 | | | | | | |
| Mossdale | 0.60% | 26.60% | 1.70% | 0.00% | 21.50% | 49.60% |
| UpStreamDCC | 73.50% | 18.10% | 1.10% | 0.00% | 4.50% | 2.80% |
| Freeport | 78.40% | 14.20% | 1.20% | 0.50% | 3.30% | 2.40% |
| May-79 | | | | | | |
| Day 5 | | | | | | |
| Mossdale | 0.00% | 71.00% | 2.70% | 0.00% | 5.70% | 20.60% |
| UpStreamDCC | 0.00% | 99.70% | 0.30% | 0.00% | 0.00% | 0.00% |
| Freeport | 0.00% | 99.50% | 0.50% | 0.00% | 0.00% | 0.00% |
| Day 15 | | | | | | |
| Mossdale | 0.00% | 57.70% | 4.10% | 0.00% | 17.40% | 20.80% |
| UpStreamDCC | 58.90% | 40.40% | 0.50% | 0.20% | 0.00% | 0.00% |
| Freeport | 58.90% | 39.80% | 1.30% | 0.00% | 0.00% | 0.00% |
| Day30 | | | | | | |
| Mossdale | 2.90% | 29.00% | 6.60% | 0.30% | 36.50% | 24.70% |
| UpStreamDCC | 76.30% | 18.60% | 1.10% | 0.70% | 2.20% | 1.10% |
| Freeport | 77.10% | 17.10% | 2.50% | 0.90% | 1.80% | 0.60% |
| Jun-79 | | | | | | |
| Day 5 | | | | | | |
| Mossdale | 0.00% | 61.90% | 13.90% | 0.00% | 0.00% | 24.20% |
| UpStreamDCC | 0.00% | 98.30% | 1.70% | 0.00% | 0.00% | 0.00% |
| Freeport | 0.00% | 98.60% | 1.40% | 0.00% | 0.00% | 0.00% |
| Day 15 | | | | | | |
| Mossdale | 0.00% | 45.10% | 21.60% | 0.00% | 0.30% | 33.00% |
| UpStreamDCC | 10.60% | 65.80% | 4.80% | 2.70% | 8.10% | 8.00% |
| Freeport | 11.20% | 74.00% | 4.60% | 1.90% | 4.10% | 4.20% |
| Day30 | | | | | | |
| Mossdale | 0.00% | 10.00% | 27.50% | 0.00% | 15.90% | 46.60% |
| UpStreamDCC | 26.60% | 21.70% | 8.20% | 3.80% | 21.30% | 18.40% |
| Freeport | 36.40% | 26.20% | 7.90% | 3.50% | 14.20% | 11.80% |

## Table 21. Water Year 1984 PTM results for the period between April and June

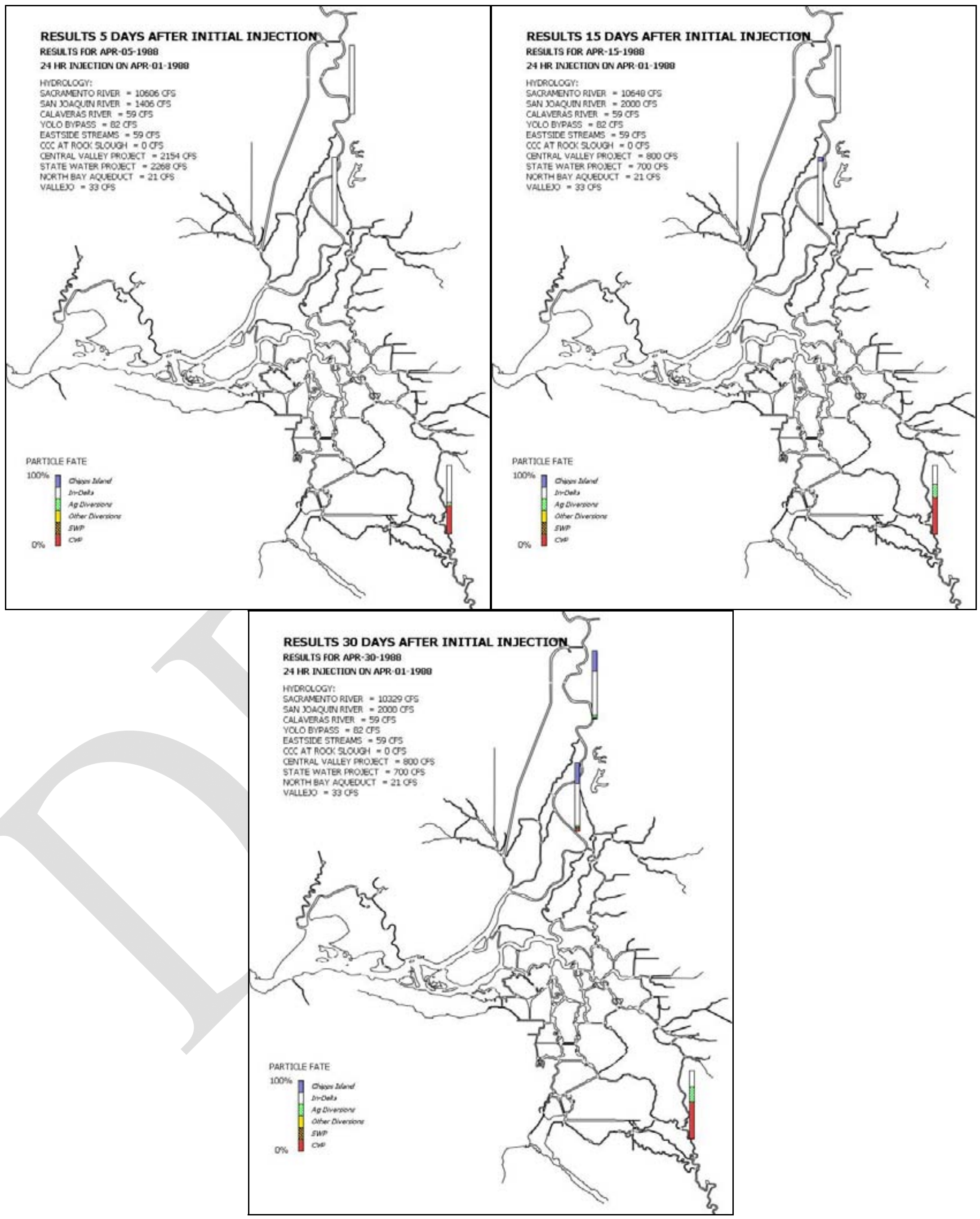
| Apr-84 | Chipps Island | In-Delta | Ag Diversions | Other Diversions | SWP | CVP | |
|---|---|---|---|---|---|---|---|
| Day 5 | | | | | | | |
| Mossdale | 0.00% | 53.40% | 1.70% | 0.00% | 0.50% | 44.40% | 100.00% |
| UpStreamDCC | 0.00% | 99.90% | 0.10% | 0.00% | 0.00% | 0.00% | 100.00% |
| Freeport | 0.00% | 100.00% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| | | | | | | | |
| Day 15 | | | | | | | |
| Mossdale | 0.00% | 37.60% | 3.20% | 0.00% | 6.50% | 52.70% | 100.00% |
| UpStreamDCC | 33.30% | 57.30% | 0.60% | 0.00% | 4.70% | 4.10% | 100.00% |
| Freeport | 34.30% | 60.30% | 0.00% | 0.00% | 2.70% | 2.70% | 100.00% |
| | | | | | | | |
| Day30 | | | | | | | |
| Mossdale | 0.10% | 32.20% | 4.50% | 0.00% | 10.50% | 52.70% | 100.00% |
| UpStreamDCC | 61.70% | 25.90% | 1.50% | 0.00% | 6.80% | 4.10% | 100.00% |
| Freeport | 69.00% | 21.90% | 0.80% | 1.20% | 4.40% | 2.70% | 100.00% |
| | | | | | | | |
| May-84 | | | | | | | |
| | | | | | | | |
| Day 5 | | | | | | | |
| Mossdale | 0.00% | 68.40% | 4.70% | 0.00% | 4.90% | 22.00% | 100.00% |
| UpStreamDCC | 0.00% | 99.80% | 0.20% | 0.00% | 0.00% | 0.00% | 100.00% |
| Freeport | 0.00% | 99.50% | 0.50% | 0.00% | 0.00% | 0.00% | 100.00% |
| | | | | | | | |
| Day 15 | | | | | | | |
| Mossdale | 0.00% | 55.00% | 7.30% | 0.00% | 15.70% | 22.00% | 100.00% |
| UpStreamDCC | 30.00% | 69.30% | 0.70% | 0.00% | 0.00% | 0.00% | 100.00% |
| Freeport | 27.60% | 70.90% | 1.50% | 0.00% | 0.00% | 0.00% | 100.00% |
| | | | | | | | |
| Day30 | | | | | | | |
| Mossdale | 1.10% | 39.40% | 10.10% | 0.90% | 23.30% | 25.20% | 100.00% |
| UpStreamDCC | 59.80% | 37.70% | 1.60% | 0.40% | 0.40% | 0.10% | 100.00% |
| Freeport | 57.00% | 36.30% | 3.50% | 2.90% | 0.20% | 0.10% | 100.00% |
| | | | | | | | |
| Jun-84 | | | | | | | |
| | | | | | | | |
| Day 5 | | | | | | | |
| Mossdale | 0.00% | 54.10% | 11.80% | 0.00% | 0.00% | 34.10% | 100.00% |
| UpStreamDCC | 0.00% | 98.80% | 1.20% | 0.00% | 0.00% | 0.00% | 100.00% |
| Freeport | 0.00% | 98.80% | 1.20% | 0.00% | 0.00% | 0.00% | 100.00% |
| | | | | | | | |
| Day 15 | | | | | | | |
| Mossdale | 0.00% | 35.90% | 24.70% | 0.00% | 3.10% | 36.30% | 100.00% |
| UpStreamDCC | 4.00% | 75.20% | 4.40% | 2.50% | 8.10% | 5.80% | 100.00% |
| Freeport | 4.50% | 79.70% | 4.70% | 1.60% | 5.70% | 3.80% | 100.00% |
| | | | | | | | |
| Day30 | | | | | | | |
| Mossdale | 0.00% | 8.50% | 29.50% | 0.00% | 20.00% | 42.00% | 100.00% |
| UpStreamDCC | 18.90% | 31.60% | 7.90% | 4.00% | 23.90% | 13.70% | 100.00% |
| Freeport | 22.40% | 35.10% | 9.30% | 3.00% | 20.10% | 10.10% | 100.00% |

**Table 22. Water Year 1988 PTM results for the period between April and June**

| Apr-88 | Chipps Island | In-Delta | Ag Diversions | Other Diversions | SWP | CVP |
|---|---|---|---|---|---|---|
| Day 5 | | | | | | |
| Mossdale | 0.00% | 53.70% | 5.50% | 0.00% | 0.00% | 40.80% |
| UpStreamDCC | 0.00% | 99.80% | 0.20% | 0.00% | 0.00% | 0.00% |
| Freeport | 0.00% | 99.90% | 0.10% | 0.00% | 0.00% | 0.00% |
| Day 15 | | | | | | |
| Mossdale | 0.00% | 27.30% | 19.40% | 0.00% | 0.00% | 53.30% |
| UpStreamDCC | 6.20% | 89.80% | 0.60% | 0.00% | 1.30% | 2.10% |
| Freeport | 2.90% | 95.50% | 0.60% | 0.00% | 0.30% | 0.70% |
| Day 30 | | | | | | |
| Mossdale | 0.00% | 23.90% | 22.20% | 0.00% | 0.00% | 53.90% |
| UpStreamDCC | 30.00% | 61.10% | 2.00% | 0.00% | 2.60% | 4.30% |
| Freeport | 29.60% | 63.20% | 4.10% | 0.00% | 1.30% | 1.80% |
| May-88 | | | | | | |
| Day 5 | | | | | | |
| Mossdale | 0.00% | 96.90% | 3.10% | 0.00% | 0.00% | 0.00% |
| UpStreamDCC | 0.00% | 98.90% | 1.10% | 0.00% | 0.00% | 0.00% |
| Freeport | 0.00% | 99.40% | 0.60% | 0.00% | 0.00% | 0.00% |
| Day 15 | | | | | | |
| Mossdale | 0.00% | 78.90% | 12.60% | 0.00% | 0.00% | 8.50% |
| UpStreamDCC | 4.50% | 93.30% | 1.90% | 0.30% | 0.00% | 0.00% |
| Freeport | 3.70% | 93.40% | 2.50% | 0.40% | 0.00% | 0.00% |
| Day 30 | | | | | | |
| Mossdale | 0.00% | 48.90% | 16.90% | 0.30% | 10.60% | 23.30% |
| UpStreamDCC | 16.70% | 68.60% | 4.00% | 1.50% | 3.80% | 5.40% |
| Freeport | 16.10% | 70.30% | 5.70% | 2.00% | 2.00% | 3.90% |
| Jun-88 | | | | | | |
| Day 5 | | | | | | |
| Mossdale | 0.00% | 77.80% | 22.20% | 0.00% | 0.00% | 0.00% |
| UpStreamDCC | 0.00% | 97.40% | 2.60% | 0.00% | 0.00% | 0.00% |
| Freeport | 0.00% | 98.10% | 1.90% | 0.00% | 0.00% | 0.00% |
| Day 15 | | | | | | |
| Mossdale | 0.00% | 54.10% | 45.90% | 0.00% | 0.00% | 0.00% |
| UpStreamDCC | 0.00% | 91.00% | 6.80% | 0.70% | 0.00% | 1.50% |
| Freeport | 0.00% | 91.80% | 6.20% | 0.70% | 0.00% | 1.30% |
| Day 30 | | | | | | |
| Mossdale | 0.00% | 29.70% | 54.50% | 0.00% | 0.00% | 15.80% |
| UpStreamDCC | 7.00% | 66.60% | 11.00% | 2.60% | 0.30% | 12.50% |
| Freeport | 7.60% | 68.00% | 11.80% | 2.40% | 0.30% | 9.90% |

**Figure 31a**

Particle tracking results from a model run of April 1988 with HORB in April 15 through May 15



## Figure 31b

Particle tracking results from a model run of May 1988 with HORB in April 15 through May 15

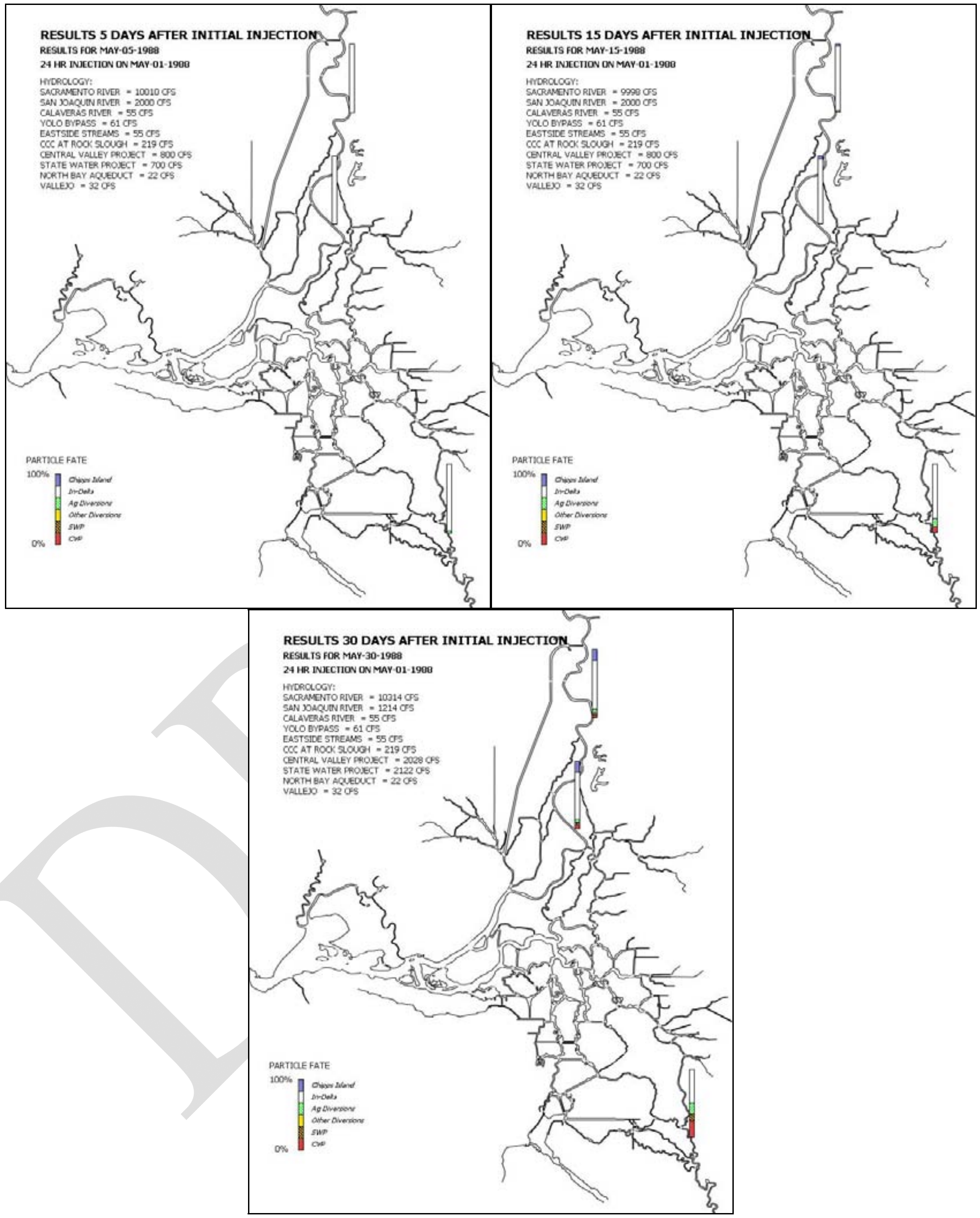
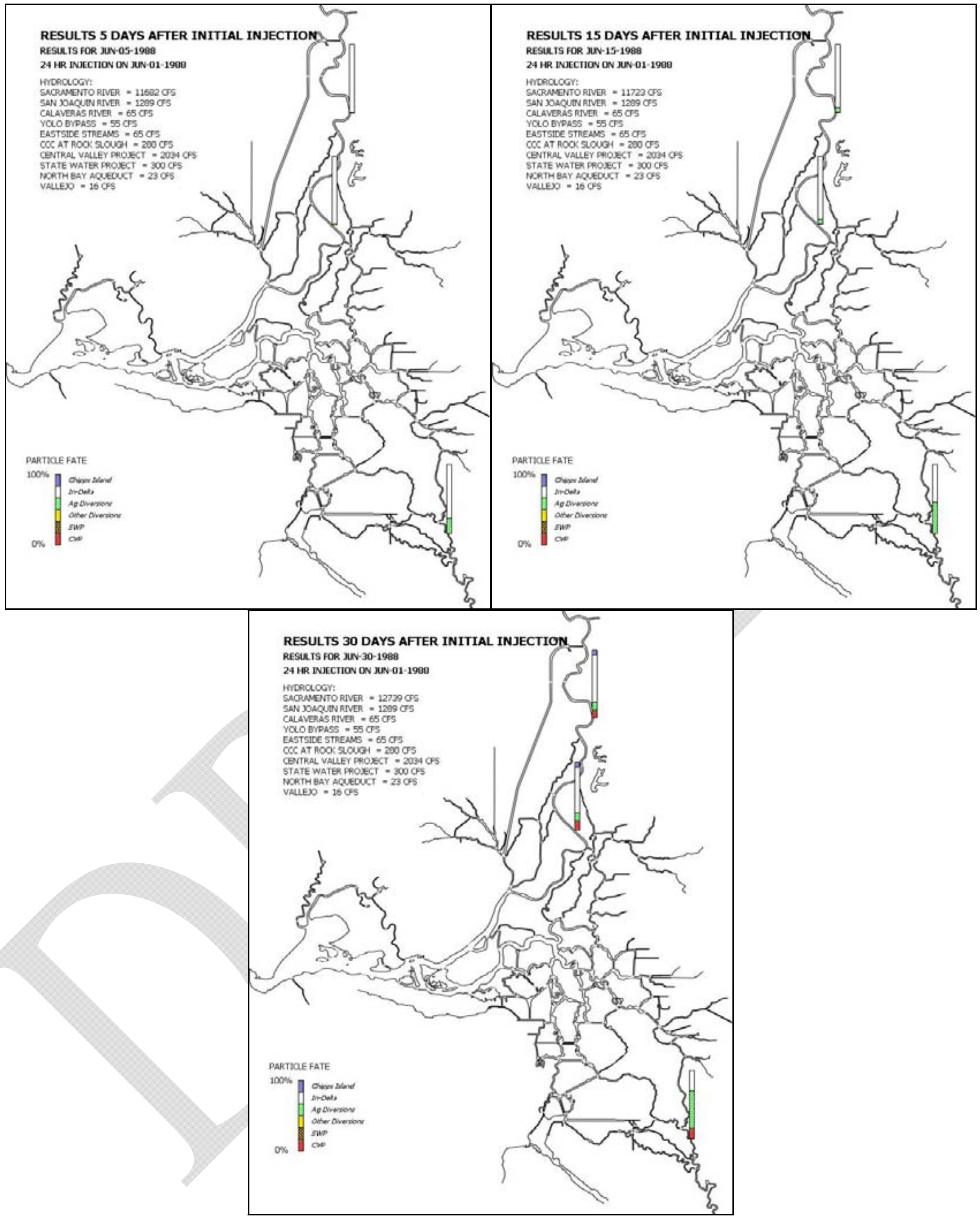


**Figure 31c**
Particle tracking results from a model run of April 1988 with HORB in April 15 through May 15



# 6.0 REFERENCES CITED


Bradford, M.J. 1995. Comparative review of Pacific salmon survival rates. Canadian Journal of Fisheries and Aquatic Sciences 52 (6): 1327-1338

Brandes, P.L. 2000. 1999 South Delta Salmon Smolt Survival Studies. 5/26/00. Can be obtained from USFWS, 4001 N. Wilson Way, Stockton, CA 95205

Brandes P.L, McLain J.S. 2001. Juvenile Chinook Salmon Abundance, Distribution, and Survival in the Sacramento-San Joaquin Estuary. In: Brown RL, editor. Contributions to the Biology of Central Valley Salmonids. Fish Bulletin 179. Volume 2. Sacramento (CA): California Department of Fish and Game. p 39-136. On website: http://www.delta.dfg.ca.gov/usfws/Reports/SSJEFRO_Reports.html

Cormack, R.M. 1964. Estimates of survival from the sighting of marked animals. Biometrika 51:429-438.

Department of Water Resources, personal communication. December 22, 1986. State of California Memo; File No: Delta Flow Equations. To Richard Satkowski, SWRCB from Jim Snow, Chief, Compliance Monitoring Unit, Division of Operations and Maintenance.

Foott., S. and R. Stone, personal communication, U.S. Fish and Wildlife Service: US Government Memo to Pat Brandes on "Health Monitoring of 2006 VAMP marked MRH Chinook salmon. Received 9/11/06.

Foott S., R. Stone and K.Nichols. 2005. FY2005 Investigational report: Proliferative Kidney Disease effects on blood constituents, swimming performance and saltwater adaptation in Merced River Hatchery juvenile Fall-run Chinook Salmon used in the 2005 VAMP study. U.S. Fish & Wildlife Service California – Nevada Fish Health Center, Anderson, CA.

Healey, M.C. 1991. Life History of chinook salmon (Oncoryhynchus tshawytscha). *In* Pacific salmon Life Histories. *Edited by* Groot and L. Margolis. UBC Press, Vancouver, B.C. pp. 310-393.

Hedrick,R.P., M.L. Kent, J.S. Foott, R. Rosemark and D. Manzer. 1985. Proliferative kidney disease(PKD) among salmonid fish is California, U.S. A.; a second look. Bulletin of the European Association of Fish Pathologists. 5:36-38.

Hedrick,R.P., M.L. Kent and C.E. Smith. 1986. Proliferative kidney disease in salmonid fishes. United States Fish and Wildlife Service, Fish Disease Leaflet 74. Washington,DC. 9 pp.

IEP, 1996. Results of 1996 Coded Wire Tag Smolt Survival Experiment in the San Joaquin River Delta Interagency Ecological Program for the Sacramento-San Joaquin Estuary. Vol 9, Number 4, Autumn 1996. pages 13- 16.

IEP, 1998. 1997 Salmon Smolt Survival Studies in the South Delta. Interagency Ecological Program for the Sacramento-San Joaquin Estuary. Vol 11, Number 1, Winter 1998. pages 29- 38.

IEP, 1999a. Results of 1998 Complementary VAMP Salmon Smolt Survival Evaluation. . Interagency Ecological Program for the Sacramento-San Joaquin Estuary. Vol 12, Number 1, Winter 1999. pages 49- 56.

IEP, 1999b. Health Assessment of Merced River Fish Facility and Feather River Hatchery Juvenile Fall –run Chinook Salmon Released at Mossdale and CWT Fish Recovered at Chipps Island – 1998. Interagency Ecological Program for the Sacramento-San Joaquin Estuary. Vol 12, Number 1, Winter 1999. pages 34-36.

Jolly,G.M. 1965. Explicit estimates from capture-recapture data with both death and immigration-stochastic model. Biometrika 52:225-247.

Longshaw, R-M Le Deuff, A.F. Harris and S.W. Feist, 2002. Development of proliferative kidney disease in rainbow trout, *Oncorhynchus mykiss (Walbaum)*, following short-term exposure to *Tetracapsula bryosalmonae* infected bryozoans. Journal of Fish Diseases 2002. 25; 443-449

Mesick, Carl, D. Marston, and T. Heyne. 2007. Provisional Draft San Joaquin River Fall-run Chinook Salmon Age Cohort Reconstruction. Can be obtained from USFWS, 4001 N. Wilson Way, Stockton CA 95205.

Newman, K.B. 2003. Modeling paired release-recovery data in the presence of survival and capture heterogeneity with application to marked juvenile salmon. Statistical Modeling 2003; 157-177.

Newman, K.B. 2008, An Evaluation of four Sacramento-San Joaquin River Delta juvenile salmon survival studies. March 31, 2008. 180 pgs. A final report submitted to CALFED Science. Available on the web at: http://www.science.calwater.ca.gov/pdf/psp/PSP_2004_final/PSP_CalFed_FWS_salmon_studies_final_033108.pdf

Okamura B., and T S Wood., 2002. Bryozoans as hosts for *Tetracapsula bryosalmonae*, the PKX organism. Journal of Fish Diseases 2002, 25: 469-475

Skalski,J.R. R. Townsend, J. Lady, A.E. Giorgi, J.R. Stevenson, and R.D. McDonald. 2002. Estimating route-specific passage and survival probabilities at a hydroelectric project from smolt radiotelemetry studies. Canadian Journal of Fisheries and Aquatic Sciences 59:1385-1393.

San Joaquin River Group Authority. 2001. 2000 Annual Technical Report: On implementation and monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan. January 2001. 84 pages.

San Joaquin River Group Authority. 2002. 2001 Annual Technical Report: On implementation and monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan. January 2002. 125 pages.

San Joaquin River Group Authority. 2003. 2002 Annual Technical Report: On implementation and monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan. January 2003. 120 pages.

San Joaquin River Group Authority. 2004. 2003 Annual Technical Report: On implementation and monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan. January 2004. 124 pages.

San Joaquin River Group Authority. 2005. 2004 Annual Technical Report: On implementation and monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan. January 2005. 132 pages.

San Joaquin River Group Authority. 2006. 2005 Annual Technical Report: On implementation and monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan. January 2006. 129 pages.

San Joaquin River Group Authority. 2007. 2006 Annual Technical Report: On implementation and monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan. January 2007. 137 pages.

San Joaquin River Group Authority. 2008. 2007 Annual Technical Report: On implementation and monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan. January 2008. 127 pages.

Seber, G.A.F. 1965. A note on the multiple recapture census. Biometrika 52:249-259.

TID. 2005. Coded-wire tag evaluation. *In* Annual Report to FERC, 2005.

USFWS. 1992. Abundance and Survival of Juvenile Chinook Salmon in the Sacramento-San Joaquin Estuary. 1992 Annual Progress Report. Sacramento-San Joaquin Estuary Fisheries Resources Office, U.S. Fish and Wildlife Office, Stockton, California. 59 pgs.

USFWS. 1993. Abundance and Survival of Juvenile Chinook Salmon in the Sacramento-San Joaquin Estuary. 1993 Annual Progress Report. Sacramento-San Joaquin Estuary Fisheries Resources Office, U.S. Fish and Wildlife Office, Stockton, California. 81 pgs.

USFWS. 1994. Abundance and Survival of Juvenile Chinook Salmon in the Sacramento-San Joaquin Estuary. 1994 Annual Progress Report. Sacramento-San Joaquin Estuary Fisheries Resources Office, U.S. Fish and Wildlife Office, Stockton, California. 58 pgs.

USFWS. 1998. Abundance and Survival of Juvenile Chinook Salmon in the Sacramento-San Joaquin Estuary. 1995 Annual Progress Report. Sacramento-San Joaquin Estuary Fisheries Resources Office, U.S. Fish and Wildlife Office, Stockton, California. 93 pgs.