THE VERNALIS ADAPTIVE MANAGEMENT PROGRAM (VAMP):

REPORT OF THE 2010 REVIEW PANEL

Panel Members:

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- David Hankin (Chair), Ph.D., Humboldt State University
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Prepared for the Delta Science Program

PART I. INTRODUCTION

Panel members were asked by the Delta Science Program to carry out an independent review of a 12-year VAMP (Vernalis Adaptive Management Plan) experimental program designed to develop water management measures that would provide protection to juvenile Chinook salmon migrating through the San Joaquin River system and associated Sacramento-San Joaquin River Delta (Delta) waterways. The Charge to the Panel was expressed as a series of three questions that the Panel was obligated to address:

1) Do the results to date from the VAMP study provide useful scientific information about the relationship between salmon survival and each of the following factors?

- Flows,
- Exports, and
- Barrier installation at the head of Old River?

2) How can the results from the VAMP to date be used to inform the State Water Resources Control Board's (SWRCB) current efforts to review and potentially revise the San Joaquin River flow objectives and their implementation?

3) How can the experiences to date from the VAMP study be used in a scientific manner to inform future monitoring and study efforts related to determining appropriate flow, operational, and water quality requirements to protect San Joaquin River fisheries (specifically Chinook salmon and steelhead)?

The review process began with all panel members reviewing a set of pertinent reports and documents (see Appendix A). Review of these written documents was followed by a two-day workshop (2-3 March 2010; see Appendix B for Agenda) in Sacramento at which invited presentations on objectives, history and findings from VAMP-sponsored studies were made on the first day. In the morning of the second day of the workshop, Review Panel members met to consider their preliminary findings and observations which were presented to those attending the workshop during the afternoon of the second day. Panel members were able to provide preliminary responses to the first and third questions listed above, but were unable to determine how most appropriately to respond to the second question. For that reason, the Panel requested additional materials concerning the SWRCB water quality and water management planning as it relates to the VAMP program. These additional materials were received, via email, on 11 March 2010, and are included as Appendix D.

Following the workshop, the Panel Chair distributed a preliminary outline for a draft Review Panel Report and individual Panel members were identified to take lead responsibility for developing draft sections of the report as appropriate given their areas of expertise. Panel members circulated comments and suggested revisions via email, and used conference calls to develop a consensus regarding structure, format, and content of the report. This draft version of the report was submitted to Sam Harader, Delta Science Program, for distribution to solicit comments prior to preparation of the final report. This Final Report reflects our response to these comments.

Of the documents provided to the review panel prior to the workshop, we wish to take special note of the value of the 2008 VAMP Summary report (SJRTC 2008). This report provided panel members with an excellent overview of the VAMP program to that time and provided context within which to place the other materials that the panel reviewed. We also wish to extend our thanks to all presenters at the workshop that was held as part of the review panel process. The presentations were well done and provided us with valuable information to conduct our review. We also thank Sam Harader of the Delta Science program who was very helpful in assisting with all the logistics of the review, from contracts to conference calls.

We have structured our report in a fashion which, we hope, will allow all readers to quickly develop a notion of our essential findings, concerns, and recommendations, but which will also allow interested readers to understand the logic that supports these conclusions. Following this Introduction, we provide an Executive Summary that consists of brief responses to each of the three questions that the review panel was obligated to address. Immediately thereafter, we provide supporting documentation or arguments for the responses that are provided in the Executive Summary. As we proceeded in our review, we felt that our review would not be complete unless we also noted certain concerns that we have regarding the VAMP program itself and related activities, and developed certain recommendations that we feel might improve the future performance of the VAMP program or might enhance survival of juvenile Chinook salmon in their freshwater migration to the ocean. Although such expressions of concerns and statements of recommendations were not explicitly requested in the Charge to the Panel, we hope that these additional thoughts will contribute to the VAMP review process. Remaining materials consist of References and several Appendixes, including brief biographical sketches for review panel members.

Although the charge to the panel was focused on identifying San Joaquin flows that best support survival of outmigrating Chinook salmon smolts, we found that this task was exceptionally difficult. Panel members are in agreement that simply meeting certain flow objectives at Vernalis is unlikely to achieve consistent rates of smolt survival through the Delta over time. The complexities of Delta hydraulics in a strongly tidal environment, and high and likely highly variable impacts of predation, appear to affect survival rates more than the river flow, by itself, and greatly complicate the assessment of effects of flow on survival rates of smolts. And overlaying these complexities is an apparent strong trend toward reduced survival rates at all flows over the past ten years in the Delta. Nevertheless, the evidence supports a conclusion that increased flows generally have a positive effect on survival and that it is desirable, to the extent feasible, to reduce or eliminate downstream passage through the Old River channel. The panel understands, of course, that flow, exports, and the placement of barriers in the Delta are the variables affecting survival that are most easily managed.

This review report is intended mostly for the Delta Science Program lead scientist, SWRCB, the VAMP Technical Committee, workshop attendees, and others that are familiar with the Delta and Central Valley salmon. Further information on the VAMP history, goals, objectives, and experimental design can be found in the VAMP summary report (SJRTC, 2008) and the many references listed at the end of this report.

PART II. EXECUTIVE SUMMARY

In this section we provide brief responses to the three specific questions which the review panel was asked to answer

1) Do the results to date from the VAMP study provide useful scientific information about the relationships between salmon survival and each of the following factors?

Flows

We provide a qualified "yes" response to this question.

Survival rates of juvenile Chinook salmon have been estimated from recoveries of coded-wire tagged (CWT) fish released (as pairs or sets of three distinct codes) from 1989 through 2006. Two distinct statistical analyses provide evidence in support of a positive relationship between flow and survival of downstream-migrating Chinook salmon:

- Over a restricted set of flows (about 2,500 – 6,500 cfs measured at Vernalis) using seven years of data (1994, 1997, 2000-2004) when the Head of Old River Barrier (HORB) was in place, SJRTC (2008) estimated survivals between Mossdale or Durham Ferry and Jersey Point on the mainstem San Joaquin River. A strong positive relation between estimated survival rates and Vernalis flow was evident. A considerably weaker positive relation between estimated survival rates from Dos Reis (immediately below Old River) and Jersey Point, over a much broader range of flows, and for years with the HORB in place or not, is evident in Figure 16 of SJRTC (2008).

- In a broader and more sophisticated hierarchical Bayesian analysis of all relevant sets (many VAMP-generated) of San Joaquin CWT releases from 1989 through 2006, Newman (2008) found a positive influence of San Joaquin River flow below Old River on survival rates. Newman's analyses cover the full range of flows that were encountered over this time period. However, migratory pathways when the HORB was not in place were unknown.

- In addition, the panel's own summaries of CWT-based estimates of survival rates from Mossdale (when the HORB has been in place) or Dos Reis to Jersey Point (see the following section) are consistent with a general increase of mean survival rates with increasing flows measured at Dos Reis.

Although the two statistical analyses and the panel's own summaries of CWT-based survival rates provide support for a contention that greater Vernalis flows have been associated, on average, with higher survival rates for juvenile Chinook salmon migrating through the San Joaquin River, the review panel's "yes" response to this question is qualified in four very important respects:

- Conditions for successful migration through the San Joaquin River and the Delta probably depend on a very complicated set of interacting hydraulic features (including export pumping, flows in Sacramento River tributaries and in the main Sacramento Channel, tidal influences, others), of which Vernalis flow is only a single feature, and also on biological factors (such as predation) which may vary interannually, independent of Vernalis flow.

- Apparent downstream migration survival of juvenile Chinook salmon was very poor during 2005 and 2006 even though Vernalis flows were unusually high (10,390 cfs and 26,020 cfs, respectively). These recent data serve as an important indicator that high Vernalis flow, *by itself*, cannot guarantee strong downstream migrant survival. We recognize that estimated survival estimates for 2005 and 2006 releases have greater uncertainty due to closure of nearly all ocean salmon fisheries south of Cape Falcon in 2008 and 2009.

- There is no statistically significant relation between estimated CWT survival rates and Vernalis flow for Mossdale/Durham Ferry releases made when the HORB has not been in place (SJRTC (2008). However, statistical identification of a flow-dependence for these survival rates is strongly affected by the recent low survival rate calculated during the highest VAMP flow year of 2006. As noted above, however, the uncertainty of this estimate is higher than prior years as ocean fisheries were essentially closed in 2008 and 2009, eliminating ocean coded wire tag recoveries at age 3 and 4 for 2006 releases. The result may also reflect variable but unknown rates of diversion into the Old River system as compared to the mainstem San Joaquin River.

- We are concerned that there has been an apparent substantial decline in downstream migrant survival rates over the past ten years, at very low flows, low VAMP flows, medium VAMP flows, and at high (exceeding VAMP) flows (see Figure 13 in SJRTC 2008 and following section). Although the statistical basis for this decline is not yet compelling, all review panel members were struck by the coincident decline across independent CWT release groups at four different flow groupings. It seems likely that this apparent decline in survival rates is real. If this apparent time-dependent decline is real, and presumably due to recent changes in the Delta ecosystem or other factors, then Figure 14 from SJRTC (2008) would predict higher survival rates than would be achieved given flows *under current circumstances.*

Exports

We believe the information obtained from VAMP studies regarding export effects on juvenile salmon survival has been useful, but inconclusive. Both standard regression analyses (summarized in SRJTC, 2008) and Bayesian hierarchical modeling (BHM) analyses (Newman, 2008) were unable to detect any statistical associations between exports and smolt survival through the Delta using the VAMP CWT study data. For a number of reasons, however, we do not believe these findings should be interpreted as meaning that exports, especially at high levels, have no effect on survival rates. CWT study data were not collected over an adequate range of export levels to achieve enough statistical power to identify an export effect. More recent acoustic-tagging studies done under the VAMP have not yet generated enough data to conclude much about export effects and these studies have also been carried out under tightly restricted levels of exports. Below we provide a summary of our thoughts concerning the effects of export flows.

- One of the arguments for asserting that export flows affect salmon survival in the Delta is the relationship found between adult salmon escapement for the San Joaquin River and the ratio of Vernalis flow/export flow between April 15 and June 15 from 2 ½ years earlier (SJRGA, 2007). The escapement relationship using the flow/export ratio as independent variable was found to better predict the data for 1951-2003 than a relationship using flow alone (SJRGA, 2007). The mechanism hypothesized for the relationship is the effects of both flow and exports on survival in the smolt life stage. As noted by the SJRTC (2008, p. 27), however, there is uncertainty and noise in this relationship "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 escapement estimates themselves." Thus, this relationship alone is not an adequate basis for assuming an export effect. Indeed, part of the reason for VAMP was to further investigate the role of exports on smolt survival through the Delta as hypothesized from the escapement relationship.

- The VAMP experimental design limits exports to between 1,500 and 3,000 cfs depending on the target for San Joaquin River flow. This range was required to achieve the two objectives of protecting naturally spawned juvenile salmon and meeting the terms of the delta smelt biological opinion in effect at the time the VAMP was formulated. The five years (2000-2004) of actual VAMP CWT studies done with a HORB in place investigated a range of exports only between 1,450 and 2,250 cfs. We believe this is much too narrow a range in exports to allow detection of a statistically significant export-survival relationship for the San Joaquin River. Additional CWT studies conducted without a HORB in place, and including all pre-VAMP years since 1994, investigated only a slightly larger range of exports (between about 1,400 and 3,700 cfs) with the one exception being 2006 when an experiment in mid-May of that year was done with exports at 6,000 cfs. Because the 2006 experiment with high exports was done during very high flow conditions (Vernalis flow = ~25,000 cfs) and with the Paradise Cut flood bypass in use, it is not helpful for comparing with earlier years at much lower flows.

Several of the earliest pre-VAMP studies conducted in the years 1985-1991 investigated spring export levels much higher than 3,000 cfs, although without a HORB in place. Most of these studies compared paired smolt releases on the mainstem San Joaquin River at Dos Reis and on upper Old River. Studies in 1989 and 1990 targeted both high (~10,000 cfs) and low (~2,000 cfs) export levels. Exports for studies between 1985 and 1987 and in 1991, ranged between 4,000 and 7,000 cfs (SJRTC, 2008, p. 34). The inclusion of results from these early, high-export experiments in the BHM analyses by Newman (2008) did not produce evidence of any statistical associations between export levels and survival probabilities that were more than weak or negligible. In fact, one of the models developed by Newman (2008) indicated the surprising result that survival improved with increasing exports in both the mainstem San Joaquin River and Old River. Unfortunately, comparing data from these early experiments with more recent data might not be useful if other conditions, such as predatory/prey balance and resulting predation rates on juvenile salmon, have changed over time in the Delta. There are reasons to suspect conditions have changed. For example, survival estimates calculated from the experiments with high (~10,000 cfs) exports and very low (near zero) San Joaquin River flows at Dos Reis in 1989 and 1990 (for releases at Dos Reis) were found to be much higher than survival estimates from experiments with low (~1,500 cfs) exports and higher

(~3,000 cfs) San Joaquin River flows at Dos Reis in the years 2003 and 2004 (for releases at Mossdale with a HORB in place).

- Data from the early (1985-1991) pre-VAMP studies with high exports indicated that, on average, survival estimates for smolts released on upper Old River appear to be about half those for smolts released on the mainstem San Joaquin River just below the Head of Old River at Dos Reis (Brandes and McLain, 2001). Newman (2008) confirmed statistically that the survival probability for fish traveling through Old River is generally lower than the survival probability for fish traveling down the mainstem San Joaquin River. We believe that any "Export" effect must be masked by this "Old River" effect, and that the lower survival observed for the Old River route is at least partially attributable to export effects, both direct and indirect. One reason we believe this is that while predation might naturally be higher along Old River, the export facilities themselves seem to attract additional predators to the south Delta. A second reason is that the data show that the numbers of CWT study smolts detected in the salvage at the fish facilities are always higher for releases on upper Old River versus Dos Reis. Thus there are clear differences in direct entrainment losses between the two routes. Finally, if a fish traveling the Old River route does successfully navigate past the fish facilities during periods of high exports, it is then subjected to the reverse net flows, caused by exports, in the reaches of Old and Middle Rivers north of the facilities. It is difficult to imagine that migrating salmon smolts, cueing mostly on flow direction, will not have greater difficulty navigating to the north through these reaches to San Francisco Bay in a direction that might appear as "upstream" to their senses. Losses of smolts due to altered hydrodynamic conditions or migration cues in the Delta related to exports are referred to as "indirect" losses or mortality. Indirect mortality due to exports is discussed in more detail later in this report.

- The panel believes that additional acoustic-tagging experiments hold promise for better quantifying direct export losses and survival through collection, handling, transport, and release (CHTR) of tagged fish moving into the fish facilities, and for quantifying reach-specific indirect mortality as affected by exports, assuming that an adequate range of exports can be investigated.

Barrier installation at the Head of Old River?

We believe that both empirical evidence and logical inference support a conclusion that installation of a barrier at the Head of Old River improves survival of downstream migrating juvenile Chinook salmon. These lines of evidence include the following:

- Newman's (2008) thorough analyses of CWT releases showed that survival from the Durham Ferry or Mossdale to Jersey Point reach has consistently exceeded apparent survival of fish that were released in or that presumably entered Old River and, presumably, were salvaged, trucked and released back into the San Joaquin or Sacramento rivers;

- Early paired CWT releases made in Old River and at Dos Reis, in addition to Jersey Point, support this same conclusion: recovery rates at Chipps Island were greater for fish released in the mainstem San Joaquin;

- Recent acoustic tagging experiments at low flows have generated additional persuasive evidence that survival rates for fish migrating through Old River are less than those for fish released at Dos Reis, and have also suggested that essentially no fish successfully navigate through the Delta on their own once they entered the Old River Channel. Survivors via the Old River route appear to have consisted exclusively of fish that were salvaged, trucked and released. We recognize, however, that reduced tag life due to premature tag failure in 2007 and 2008 may have prevented detection of some fish that successfully navigated the Old River channel;

- The hydraulic flow patterns that emerge in the Delta when export pumping is proceeding, especially when San Joaquin flows are relatively low, means that fish entering Old River would be naturally drawn to the pumps (they would to that point be following the natural downstream flow of Old River). Thereafter, if they successfully avoided the pumps or entered other Delta channels, they would typically be faced by reverse net flows. We find it biologically untenable to imagine that downstream-migrating salmon can easily navigate to the mainstem Sacramento River by migrating in a direction that would appear, based on the net flow direction, as "upstream" to them. That kind of behavior would be an unsuccessful one in any natural system.

2) How can the results from the VAMP to date be used to inform the SWRCB's current efforts to review and potentially revise the San Joaquin River flow objectives and their implementation?

In setting flow objectives, there are many issues the Board must consider in balancing water needs for all beneficial uses in California. Many of these issues are well beyond the scope of our science panel to consider. We therefore limit our discussions here to San Joaquin salmon science issues only.

- In our answer to question 1, we attempted to summarize the scientific information obtained from the VAMP studies related to salmon survival through the Delta and the three factors of flow, exports, and the HORB. For several reasons, it is not straightforward to use that information to inform the Board’s current efforts to review and revise San Joaquin River flow objectives. Because our review focused on the survival and passage of salmon smolts through the Delta, we did not evaluate other factors that may be limiting future salmon production. In setting flow objectives, we believe the Board should consider the role of Delta survival for the smolt life stage in the larger context of the entire life cycle of the fall-run Chinook, including survival in the upper watershed, the Bay and the ocean and fry rearing in the Delta (SJRTC 2008). Although some positive statistical associations between San Joaquin River flow and salmon survival have been identified, there is also very large variation in the estimated survival rates at specific flow levels and there is a disturbing temporal trend to reduced survival rates at all flows. This large variability and associated temporal decline in survival rates strongly supports a conclusion that survival is a function of a complex set of factors, of which San Joaquin River flow at Vernalis is just one. It does not seem possible to choose a precise flow target that will reliably achieve a certain survival result.

- Given these caveats, we do believe the Board needs to consider that survival of San Joaquin River smolts through the Delta is low and appears to have gotten lower (for unknown reasons) in the past 10 years. San Joaquin River mainstem survival estimates from Mossdale or Dos Reis to Jersey Point were just slightly greater than 1 percent in 2003 and 2004 and the estimate was only about 12 percent in the very high flow year of 2006. This compares to survival estimates that ranged between about 30 and 80 percent in the years 1995 and 1997-2000. The recent survival estimates are significantly lower than the long-term average survival estimate of about 20 percent, which itself is considered low when compared to the Sacramento River and other estuaries like the Columbia River. The very low recent survival rates seem unlikely to be high enough to support a viable salmon population, even with favorable conditions for ocean survival and upstream migration and spawning success for adults.

- Regarding the HORB, we believe that installing the physical barrier is valuable for improving survival through the Delta because it keeps fish in the mainstem San Joaquin River channel and increases the flow past the City of Stockton. We understand, however, that there are issues related to delta smelt that may prevent the installing of the physical barrier in the future. We briefly comment on the issue of delta smelt and the HORB later in our report.

- Regarding export objectives, our feeling is that it makes sense during VAMP to continue limiting exports to some fraction of San Joaquin River flow at Vernalis so that the entire flow of the San Joaquin River is not diverted and so that reverse flows, if they occur, are not large. We cannot, however, offer any guidance as to what the Vernalis flow/export ratio should be. With through-Delta survival estimates presently so low and no physical HORB in place, it seems worthwhile to continue investigations to understand and improve the efficiency of the fish facilities and the overall CHTR process so as to boost the survival for smolts that are entrained at the facilities and are then trucked and released. However, we do not believe that migration through Old River and subsequent salvage trucking and release is a desirable route for downstream migrating smolts. To the maximum extent possible, migration through the mainstem San Joaquin channel should be encouraged.

- In establishing flow objectives for any future VAMP experimental design for adaptive management investigations, it makes sense to deliberately include more frequent flows at the higher target levels (5,000-7,000 cfs with HORB in place, or 6,000 - 10,000 cfs with no HORB in place) whenever possible. VAMP flows generally have been too restricted in range and have included more low flows than high flow. From an experimental or adaptive management perspective, it is impossible to learn much about effects of higher flows without having a chance to observe survival (and carry out acoustic tagging experiments) at such higher flows.

3) How can the experiences to date from the VAMP study be used in a scientific manner to inform future monitoring and study efforts related to determining appropriate flow, operational, and water quality requirements to protect San Joaquin River fisheries (specifically Chinook salmon and steelhead)?

The review panel was not provided with any review materials or presentations specifically pertinent to water quality requirements for San Joaquin River fisheries (with the minor exception of occasional reference to temperature data), so we do not feel qualified to comment on that topic. Also, our panel was provided with no review materials that focused on survival of outmigrating juvenile San Joaquin River steelhead. Our response to this question as it concerns steelhead fisheries is therefore very limited in scope.

We believe that the experiences to date from the VAMP suggest that some modifications to program activities should be made. In many cases, these modifications have already been made as part of the adaptive VAMP process.

- A shift in emphasis from CWT releases to use of acoustic tagging technologies appears well justified. Past CWT tagging was informative, but capture efficiencies in trawl surveys were extremely low and this procedure only allows single point capture. Acoustic tagging is a promising new technique that should allow accurate estimation of survival rates along known migration routes, and allows application of well-developed statistical procedures (Cormack-Jolly-Seber type) for working with re-sighting data. More years of acoustic tagging data will be needed to develop relations between estimated survival rates, San Joaquin flows and exports, and improvements in tag longevity seem needed to confidently establish use of certain migratory paths, but the approach seems clearly excellent. Nevertheless, we believe that it is important to continue some CWT releases so as to establish interannual variation in ocean survival rates based on ocean recoveries and freshwater adult escapement of San Joaquin origin Chinook salmon.

- It would be desirable for VAMP to explore a greater range in mainstem flows than seem currently possible or projected. Especially informative would be flows in the range of 5,000-7,000 cfs (assuming HORB in place) or 6,000 - 10,000 cfs (with no HORB in place) at Vernalis. The importance of exploring survival under such higher flows is in part based on the fact that contemporary San Joaquin flow patterns bear little resemblance to the unimpaired flow regimes to which Chinook salmon must have adapted in the San Joaquin system.

- Although lack of an ability to detect an "Export effect" on survival rates can be in large part attributed to lack of variation in recent export flows, we are reluctant to recommend substantial increases in export flows so as to improve the ability to detect an export effect. Among other things, the potential negative consequences of increased exports during downstream migration of juvenile Chinook salmon (and also on survival of juvenile delta smelt) probably outweigh any possible increase in knowledge.

- Recent acoustic tagging has presented dramatic evidence that predation can be a very substantial cause of downstream migrant mortality. However, these very high predation rates have coincided with extremely low flow conditions and also with years during which an experimental "Bubble Curtain" rather than a physical barrier has been used to divert fish away from the Old River channel. Both low flows (2008 and 2009) and the Bubble Curtain (2009 only) may have contributed to high predation in 2008 and 2009. Although it is too soon to conclude that observed predation rates in these two years are "typical" rates of predation, it seems clear that identification and management of predation must be a future focus of studies and management activities. It is conceivable that predation impacts on juvenile Chinook has increased due to the recent decline in other pelagic organisms that previously served as alternative prey for predators.

- Life history differences between Chinook salmon and steelhead are striking, and we therefore do not believe that performance of acoustic tagged juvenile Chinook salmon provides a reliable basis for inference concerning the potential relations between San Joaquin flow and downstream migration survival of steelhead. Instead, we believe that acoustic tagging of steelhead will be required. As a source for these tagged steelhead, we recommend use of steelhead from whatever Central Valley hatchery would be characterized as rearing fish that are genetically most closely related to steelhead from San Joaquin tributaries. We surmise that Mokelumne River hatchery might be a reasonable source for acoustic tagging of steelhead.

- Although a physical HORB appears to improve survival rates of downstream migrating Chinook salmon smolts, the bubble curtain installed in 2009 had limited effectiveness due to predation and probably also because it did not change local hydraulics - a factor known to direct smolt movement. While predation will continue to be an issue at any type of structure, hydraulics should be incorporated into any barrier design, especially if a bubble curtain is again used instead of a physical barrier.

- Operational issues of smolt entrainment, predation, transportation and release effectiveness should continue to be worked on at the SWP/CVP facilities (objective being to increase smolt survival) with the assumption that a proportion of smolts will continue to encounter these export facilities at some point in their downstream migration period if a physical barrier is not installed at the Head of Old River.

PART III. Support for Answers to Questions Provided in Executive Summary.

In this section, we provide justification for many of the statements that we made in our Executive Summary. We begin this section with an overview of our understanding of the hydraulic dynamics of the Delta as it relates to conditions faced by downstream migrating Chinook salmon. We believe that this overview is essential to justifying several of our answers.

A. Overview of Delta Hydraulics

A1 — San Joaquin River flows during VAMP versus "unimpaired flows"

Because higher experimental flows would be desirable for VAMP studies of salmon smolt survival, it is natural to ask how springtime “unimpaired flows” compare to the target flows for the San Joaquin River at Vernalis that were achieved during VAMP. Unimpaired flow is an approximate substitute for natural flow that represents the runoff from a basin that would occur without upstream controls, regulation or diversions, but with the channel network in the existing configuration. The California Department of Water Resources (DWR) has estimated the monthly unimpaired flows for sub-basins in the Central Valley of California and for the Delta for the period 1921-2003 (California DWR, 2007). The panel used the DWR unimpaired flow data to prepare Figure 1, which shows the average unimpaired flows for the San Joaquin Valley between April 15 and May 15 and the VAMP target flows for the years of 2000-2003. Because snowmelt from the upper elevations of the San Joaquin River watershed typically is high in April/May, the unimpaired flows normally are highest during those months and the alterations to flows caused by upstream water development are the greatest (Fleenor and others, 2010). On average the San Joaquin River target flows at Vernalis during April-May of the first four VAMP years were 22 percent of the unimpaired flows.

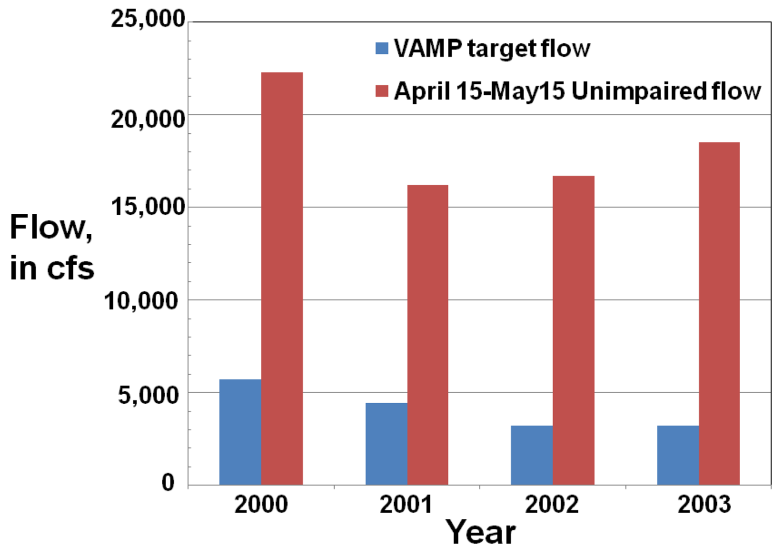

Figure 1 -- VAMP target flows and average April-May unimpaired flows for the San Joaquin River during 2000-03.

A2 — Migration of San Joaquin River smolts through the tidal Delta

When Chinook salmon smolts enter the Delta on the San Joaquin River they encounter a much different physical habitat than the upper river. The channels increase in width and depth, but the most significant change is that the flow oscillates, twice daily, due to tidal effects. The range in magnitude of these oscillations along the mainstem San Joaquin River increases significantly in the down-estuary direction and becomes very large in the lower reaches of the river near Jersey Point (Figure 2). During periods of relatively low San Joaquin River inflows (< ~ 3,000 cfs), migrants first encounter tidally oscillating flows in the reach between Vernalis and Mossdale and encounter fully bi-directional (flood and ebb) flows beginning near the Head of Old River. Near Jersey Point, flood and ebb tidal currents can exceed 1 m/s and daily tidal excursions of water parcels can exceed 10 kilometers. At high flows (> ~ 20,000 cfs) on the San Joaquin River, flows can remain unidirectional until beyond Stockton, but a migrating fish will in almost all circumstances encounter bi-directional flows beyond that point.

Superimposed upon the oscillating tidal flows in the Delta, migrating fish also are subjected to more slowly varying “net” or “tidally averaged” flows. As an example, graphs showing time series of both the tidal and tidally averaged flows on the San Joaquin River just upstream from the City of Stockton during calendar year 2004 are shown in Figure 3. The tidally averaged (net) flows depend mostly on the river inflows at Vernalis, but fluctuations also occur due to tidal-flow interactions with the bathymetry, meteorological effects, and other factors. The net flows further down-estuary on the San Joaquin River are increased by flows leaving the Sacramento River near Walnut Grove that travel south through Georgiana Slough and through the Delta Cross Channel (if the gates are open) and then join with flows originating from the Mokelumne and Cosumnes Rivers before entering the San Joaquin River. Near Jersey Point the net flows typically become a small fraction of the maximum ebb and flood tidal flows.

Migrating smolts that enter the Delta estuary at Vernalis must find their way to the San Francisco Bay (and ultimately the ocean) through the large oscillating tidal flows, while avoiding a host of predators and finding new sources of food. Not a great deal is known about the fine-scale migratory behavior of salmon smolts in estuaries and about how those movements are affected by large tidal flows. In contrast to the home-stream migration of adult salmon through estuaries, it is felt that the olfactory sense is not essential for outmigrating smolts navigating to the sea. And while salinity would seem like an obvious cue for migration, there is little evidence of that (Williams, 2006). The fish are thought to cue on downstream flow direction, although they may use the position of the sun or cues from the Earth’s magnetic field to navigate if flow cues cannot be detected, for example in turbid water (Williams, 2006). In the Delta, because of the large differences between tidal and net current speeds and the frequent occurrence of reverse flows, it seems likely that successful navigation must depend to some degree on factors other than the direction of the net current alone. Despite the dramatic differences between river and estuarine systems, coho salmon smolts have been documented to behave similarly in both systems (Moser et al. 1991). Observed migratory progress was saltatory, characterized by movement in the direction of the current and extended periods of holding in areas of low current velocity. Consequently, coho salmon smolts were displaced rapidly downstream by swift, unidirectional river currents but were retained in the estuary by relatively low-velocity, reversing tidal currents (Moser et al.

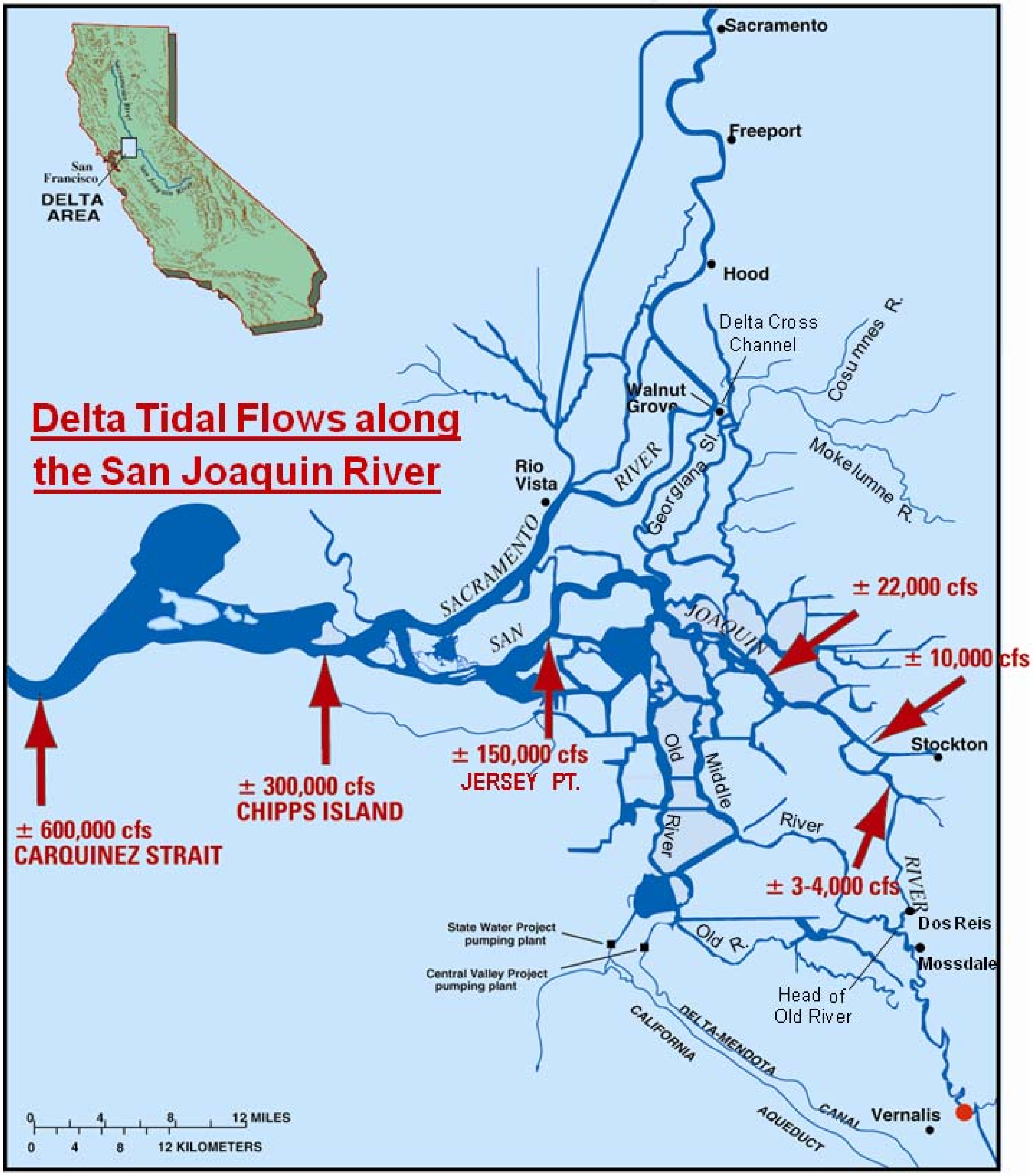

Figure 2 -- Typical ranges of measured tidal flows at various locations along the San Joaquin River during conditions of low inflow at Vernalis.

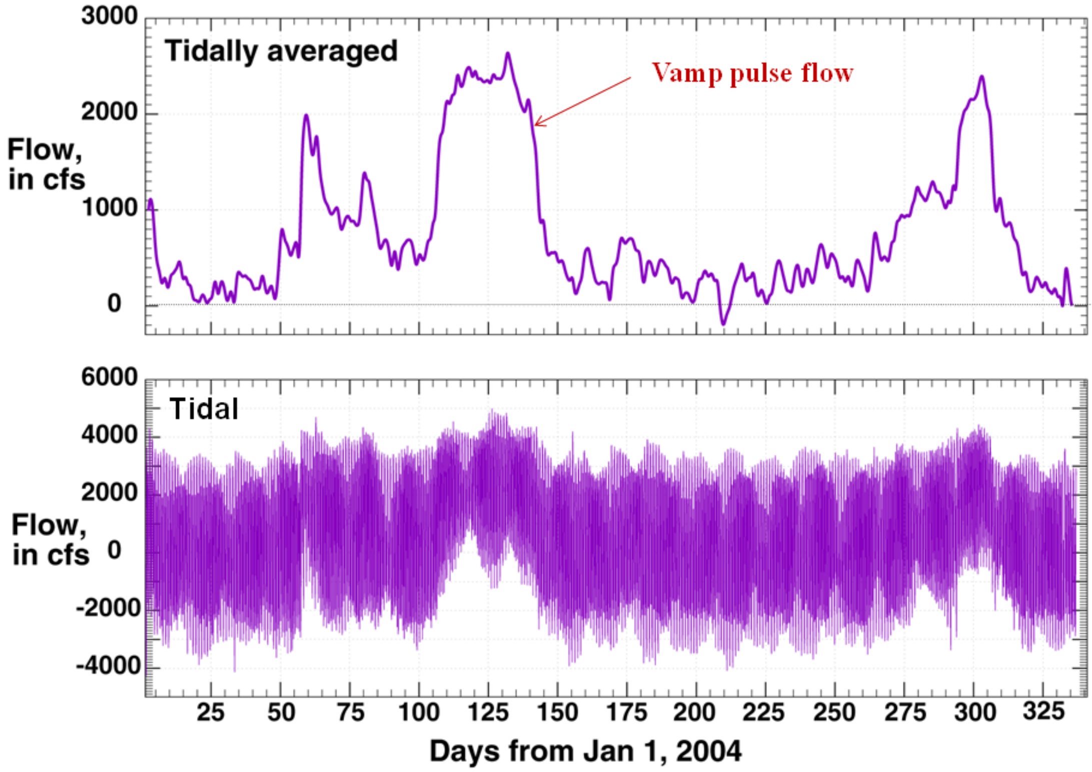

Figure 3 -- Measured tidal and tidally averaged flows on the San Joaquin River above Stockton during 2004.

1991). It is unknown, but conceivable, that tidal current phasing could influence Chinook salmon smolt progress down-estuary if, for example, a diel pattern of smolt holding and movement corresponds with maximum ebb flows during times of smolt movement and maximum flood flows during times of holding or vice-versa. Diel patterns of holding and movement by acoustic-tagged hatchery smolts have been reported in preliminary findings from north Delta juvenile salmon outmigration studies (Burau et al. 2007). Moser et al. (1991) did not find coho salmon smolts modifying behavior to make use of tidal currents to move seaward, so any speedup or slow-down on Chinook salmon smolt transit times due to tidal effects could occur simply by happenstance relating to the synchrony of the tidal cycle with normal migration behavior. Clearly more research is needed to better understand any role tidal flows might play in affecting downstream migration.

The VAMP study results support the widely held notion that increased inflows to estuaries and increased down-estuary net current velocities decrease juvenile salmon travel times through the system and increase survival. It is crucial, however, to understand what quantities of flow releases are needed to increase smolt survival.

A3 — The Stockton DWSC

We suspect that one variable that may have particular relevance to survival of salmon smolts down the mainstem San Joaquin River is the net flow through the Stockton Deep Water Ship Channel (DWSC). During VAMP acoustic tagging studies in 2008 and 2009, receivers were placed at both ends of this reach, so particular attention is already being paid to this reach by VAMP investigators, which seems justified. As illustrated in Figure 4, the cross-sectional area of the San Joaquin River increases significantly (5 or 6 times) in the reach downstream of Channel Point. This increase in area causes a large increase in the water transit time through the reach of river between Channel Point and Turner Cut.

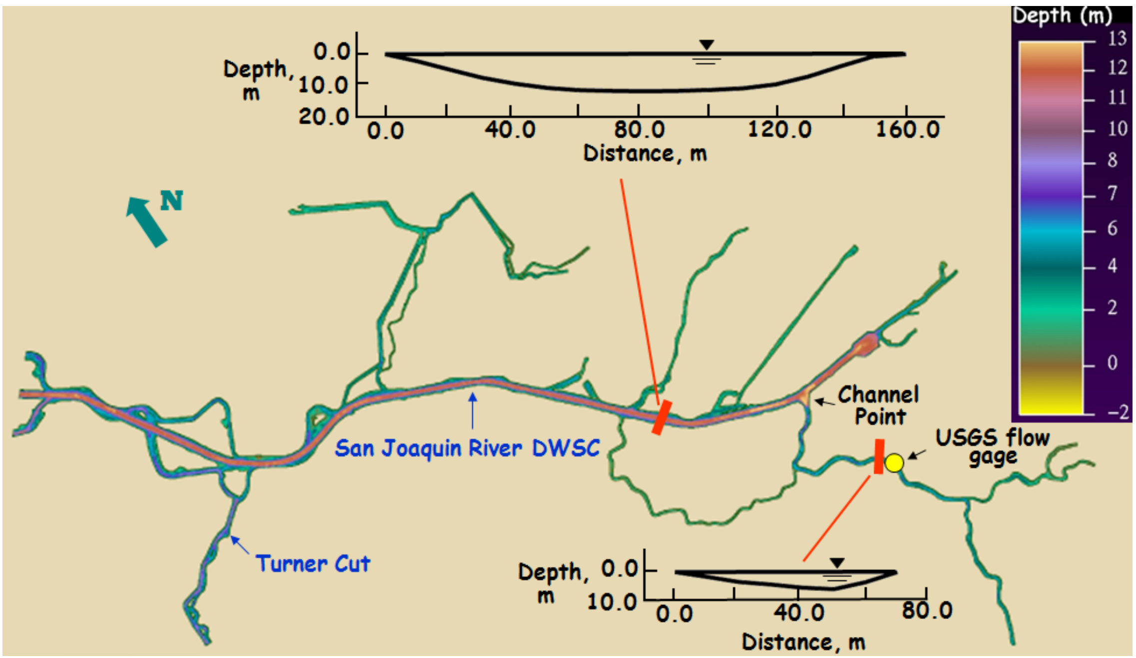

Figure 4 -- Comparison of San Joaquin River cross-sections from the Deep Water Ship Channel and the reach upstream of Channel Point.

Figure 5 shows two relationships developed using particle-tracking models to calculate the transit time through the DWSC for various net (tidally averaged) flows. The transit times are computed between Channel Point and a location just downstream of Turner Cut (but upstream of Columbia Cut). The curves were computed using slightly different assumptions and with two different sets of hydrodynamic and particle-tracking models, one three-dimensional and the other one-dimensional, so there are differences between the two curves. Both curves, however, indicate a rapid increase in mean particle transit time that occurs through the reach when flows fall below approximately 2,000 cfs, and especially below 1,000 cfs. The extensions of the curves have not been calculated for flows lower than 800 cfs. During low flows, when salmon smolts experience long water transit times combined with the large, back-and-forth movement of the tidal flows that occur in this reach, it is likely that their downstream movement might stall, increasing the likelihood of their becoming prey to larger fishes.

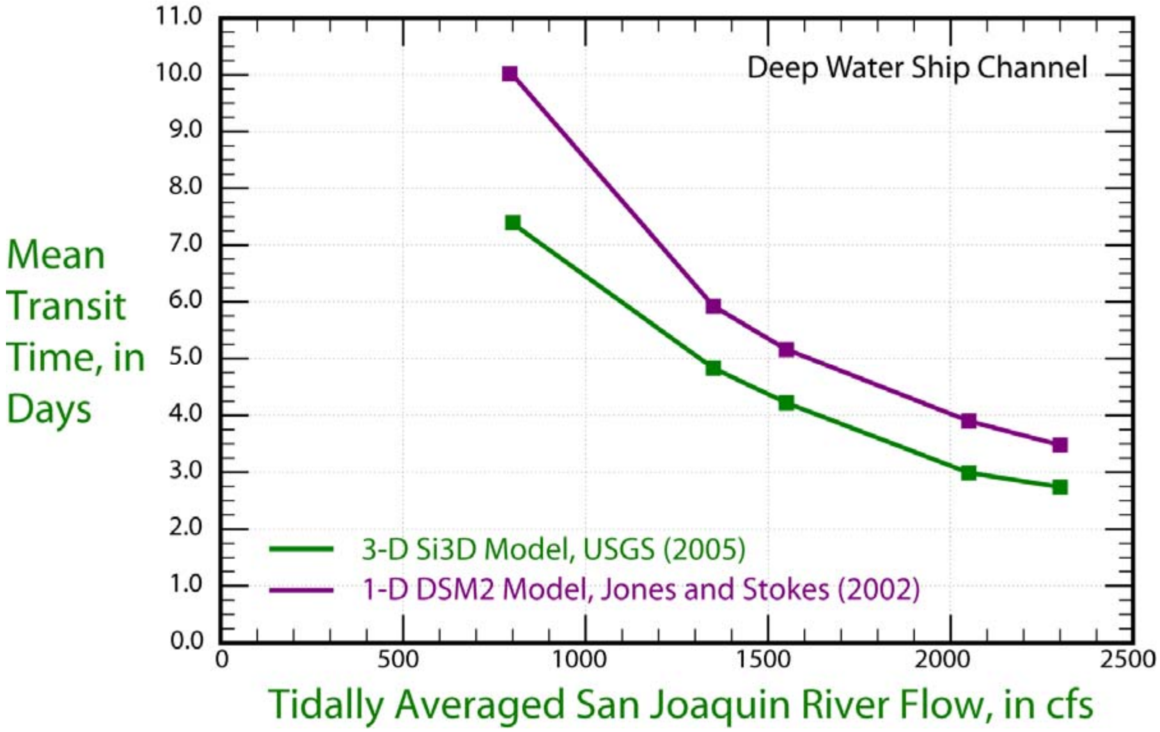

Figure 5 -- Curves of mean water transit time through the Stockton Deep Water Ship Channel as a function of flow calculated from two different particle-tracking models.

Figure 6 is a graph of the net flows at the USGS Garwood Bridge gaging station near Stockton measured during the period April 1-May 31 for 2008 and 2009. The magnitudes of flows during the 2009 VAMP fish releases were very low compared to all other years of VAMP and pre-VAMP studies since 1991; flows ranged between approximately 250 and 600 cfs. During 2008 the flows were higher, ranging between approximately 1,000 and 1,400 cfs. The smolt survival measured through this reach in the acoustic-tagging experiments of 2009 was only 12 percent, which was reported as “surprisingly low” by the investigator (Vogel, 2010). In 2008 the average survival estimate (fish-tag survival probability) was 49 percent and 56 percent for weeks 1 and 2, respectively (Holbrook et al. 2009). Although there were several important differences between the tagged fish (different hatchery origin and size) and data-processing procedures (auto-tracking versus manual) used in the 2008 and 2009 experiments, the large difference in survivals between the two years could, at least in part, be due to the lower flows in 2009. In both years, survival through the upstream reach of the San Joaquin River (between Old River and Stockton) was much higher (69% to 85% survival) than through the DWSC, despite being approximately equal length migration distances. Understanding the relationship between flow and survival through the DWSC of the San Joaquin River warrants further investigation to clarify whether it might serve as a “bottleneck” for survival, especially at flows under approximately 1,000 cfs.

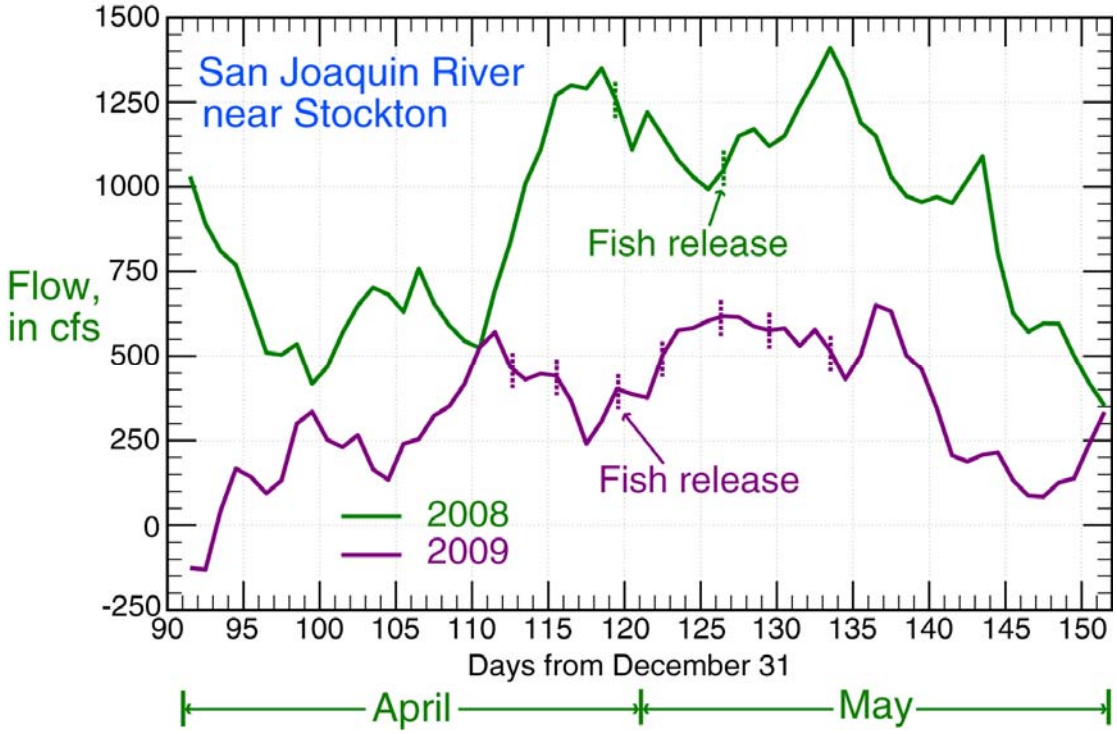

Figure 6 -- Measured net flows for the San Joaquin River upstream of Stockton for April and May of 2008 and 2009.

A4 — "Indirect" effects of south Delta exports on smolt mortality

In our answer to question 1b (Effects of Exports), we defined "indirect" export losses or mortality as losses of smolts due to altered hydrodynamic conditions or migration cues in the Delta that are caused by exports. The south Delta exports, especially when they are larger than San Joaquin River flows at Vernalis, can have a rather profound effect on the net flows in south and central Delta channels as illustrated in Figure 7, reproduced from Arthur et al. (1996). The flows in Old and Middle Rivers are affected most by exports and it is common for the flows in those channels to be in the reverse direction (i.e., "negative" flows) from their natural flow, which is positive to the north. It seems biologically reasonable to suspect that migrating salmon smolts, cueing on flow direction, would have great difficulty navigating to the north through these reaches to San Francisco Bay, in a direction that might appear as "upstream" to their senses. Because net flows are reversed, hydrodynamic transport of smolts to the north by the action of the net currents themselves cannot happen. Fish that remain in this portion of the Delta for a period of days and somehow avoid being entrained at the export facilities are most likely lost to predation, which is thought to be high near the entrances to both the state and federal facilities. These losses would be considered as indirect mortalities resulting from exports. Although during VAMP reverse flows are typically small because of low exports and San Joaquin River pulse flows, reversed flows have still occurred in all but the high-flow VAMP years. It is because of these reverse flows, and the possibility of indirect losses they can cause, that it seems wise to keep smolts out of Old River, whether by a physical or non-physical barrier at the Head of Old River (HOR).

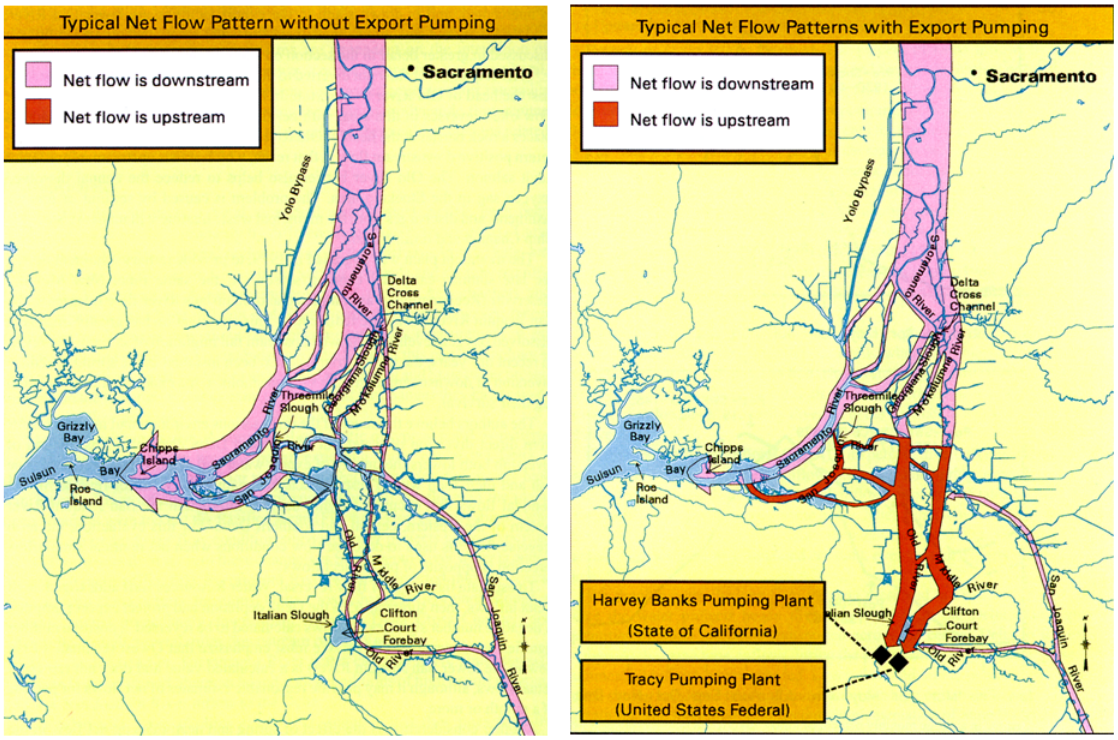

Figure 7 -- Effects of high exports on net flow patterns in the Delta (modified from Arthur et al, 1996).

Indirect mortality due to exports can conceivably occur with smolts traveling down the mainstem San Joaquin River as well as Old River if exports are sufficiently high to cause reverse or significantly reduced flows on the San Joaquin River mainstem as illustrated in Figure 7. When the magnitude of export flow exceeded Vernalis flow (which occurred only during many of the early, pre-VAMP studies, prior to 1993), it was common for reverse flows to occur on the reach of the San Joaquin River down-estuary from Turner Cut. Without a HORB in place, high exports can also incrementally reduce flows on the mainstem San Joaquin River leading to Stockton by drawing more water through the HOR than would otherwise occur.

B. Coded Wire Tag Recoveries

Sets (typically pairs) of releases of Chinook salmon smolts given adipose fin clips and distinct coded wire tag numbers have been used to assess survival rates of juvenile Chinook salmon through various reaches of the San Joaquin River system, in particular for the reach from Mossdale/ Durham Ferry or Dos Reis to Jersey Point, just upstream of the confluence of the San Joaquin and Sacramento rivers. The experimental strategy has been to release a group of CWT fish at Mossdale/Durham Ferry or Dos Reis on the mainstem San Joaquin and to release a group at Jersey Point at approximately the same time. Trawl surveys at Antioch and Chipps Island, below Jersey Point, generated recoveries of fish from these releases. For meaningful analysis of these release and recovery data, two key assumptions must be met: (a) there is no substantial initial "release mortality", and (b) the recovery rates of fish from all CWT groups in a particular set are identical in the Antioch or Chipps Island trawls. The first assumption might be violated if, for example, temperatures in the mainstem San Joaquin were sufficiently high to induce thermal shock which resulted in substantial immediate mortality following release at that location. The second assumption might be violated if fish from paired groups were not vulnerable to the Antioch and Chipps Island trawls over the same period of time and trawl capture efficiency had substantial temporal variation (as a result of flows, tidal cycles, or other factors).

If the two assumptions above are met, then the ratio of recovery rates (Antioch plus Chipps Islands recoveries divided by release group size) from a CWT group released at Durham Ferry/Mossdale or Dos Reis as compared to a group released at Jersey Point should provide an estimate of survival between Durham Ferry/Mossdale or Dos Reis and Jersey Point. Although this approach has substantial conceptual merit when the assumptions are met, it also has three important limitations. First, the recovery rates in the Antioch and Chipps Island trawls have historically been exceptionally low (say 0.1% of CWT release group size for fish released at Jersey Point, SJRTC 2008, Table 14), leading to poor precision of estimates. Second, when the Old River channel is available for entrance (i.e., HORB is not in place), some unknown portion of downstream migrating juveniles may move through the Old River channel to the delta salvage operations where they may be collected, transported and released at one of four locations: just above Antioch Bridge in the San Joaquin River below Jersey Point; two locations near the confluence of Horseshoe Bend and the main Sacramento River channel; and at an unspecified location on the north bank of the San Joaquin River off Sherman Island. Although all of these release locations would appear to make fish vulnerable to capture in the Chipps Island trawl, availability to the Antioch trawl seems certain only for those fish released above the Antioch Bridge. Third, the above kind of analysis ignores a data source of substantial value in analysis of CWT recovery data: ocean catch sampling. Ocean fisheries are sampled in a rigorous fashion, with a target 20 percent sampling fraction in commercial and recreational fisheries, thus allowing unbiased estimation of the number of fish from particular CWT groups that are landed in ocean fisheries.

The analysis limitations identified in the above paragraph have been addressed in two very different manners. First, both Newman (2008) and SJRTC (2008) have advocated use of a "combined differential recovery rate" to estimate survival from Durham Ferry or Mossdale to Jersey City. This calculation is similar to the ratio of recovery rates of paired groups at the Antioch and Chipps Island trawls, except that estimated ocean catches over the lifespan of the release groups are included in the group-specific recovery rates. Addition of these ocean recovery data helps address concerns regarding low recovery rates in the Antioch and Chipps Island trawls and should greatly improve the precision of estimation. The other issue (unknown migratory pathways) has been addressed in two quite different manners.

Conventional Analyses Reported in SJRTC (2008).

Several provocative and informative figures were included in the useful 2008 Summary of the VAMP Program (SJRTC 2008). First, to address the confounding issue that migratory path of downstream migrants is unknown for many releases (see below), SJRTC (2008) plotted calculated combined differential recovery rate estimates of survival as a function of Vernalis flows for paired releases *for which the HORB was installed* (Figure 14 from SJRTC 2008). Assuming that the HORB indeed prevented downstream migrants from passing through the Old River system to the pumps, these data should display survival rates for fish known to have migrated through the mainstem San Joaquin channel. Although the ranges of flows displayed on this figure is limited to about 2,500 - 6,500 cfs under which the HORB may be installed, plotted data do suggest a strong positive association of survival with Vernalis flow. Also, the range of survival rates (from near 0% to near 50%) is very substantial. The clear suggestion from this plot is that, over this range of flows, increased flow has had a very strong positive influence on survival rates through the Durham Ferry or Mossdale to Jersey Point reach with the HORB installed.

A second provocative figure from SJRTC (2008) consisted of estimated survival rates of fish released at Durham Ferry or Mossdale plotted against Vernalis flow for release periods when the HORB was not in place (Figure 15). No dependence of survival rate on flow is evident from this plot. Our panel finds it difficult to interpret these data, however, as the migration paths taken by fish are unknown for all of these releases.

Our Panel was also struck by an apparent striking trend toward reduced estimated survival rates from Durham Ferry/Mossdale over the period 1997 through 2006 (Figure 13 in SJRTC 2008). We explored this issue in further detail by plotting in Figure 8 the estimated survival rates against year for Dos Reis to Jersey Point (all available years) and Mossdale to Jersey Point (only years when the HORB was installed). (All of these release groups would have been expected to take the mainstem San Joaquin migration route,[1] though distances of migration to Jersey Point differ by about 5 miles.) When these survival rates were grouped by four different flow intervals (very low, low, moderate, high), a trend of decreasing survival rates seemed evident for all flow groupings. Nevertheless, mean survival rates remain positively associated with flows (Figure 8).

[1] The panel is aware that some fish released at Dos Reis could enter the upper Old River, especially if released during a strong flood tide, but we are assuming this does not happen to a significant number of fish.

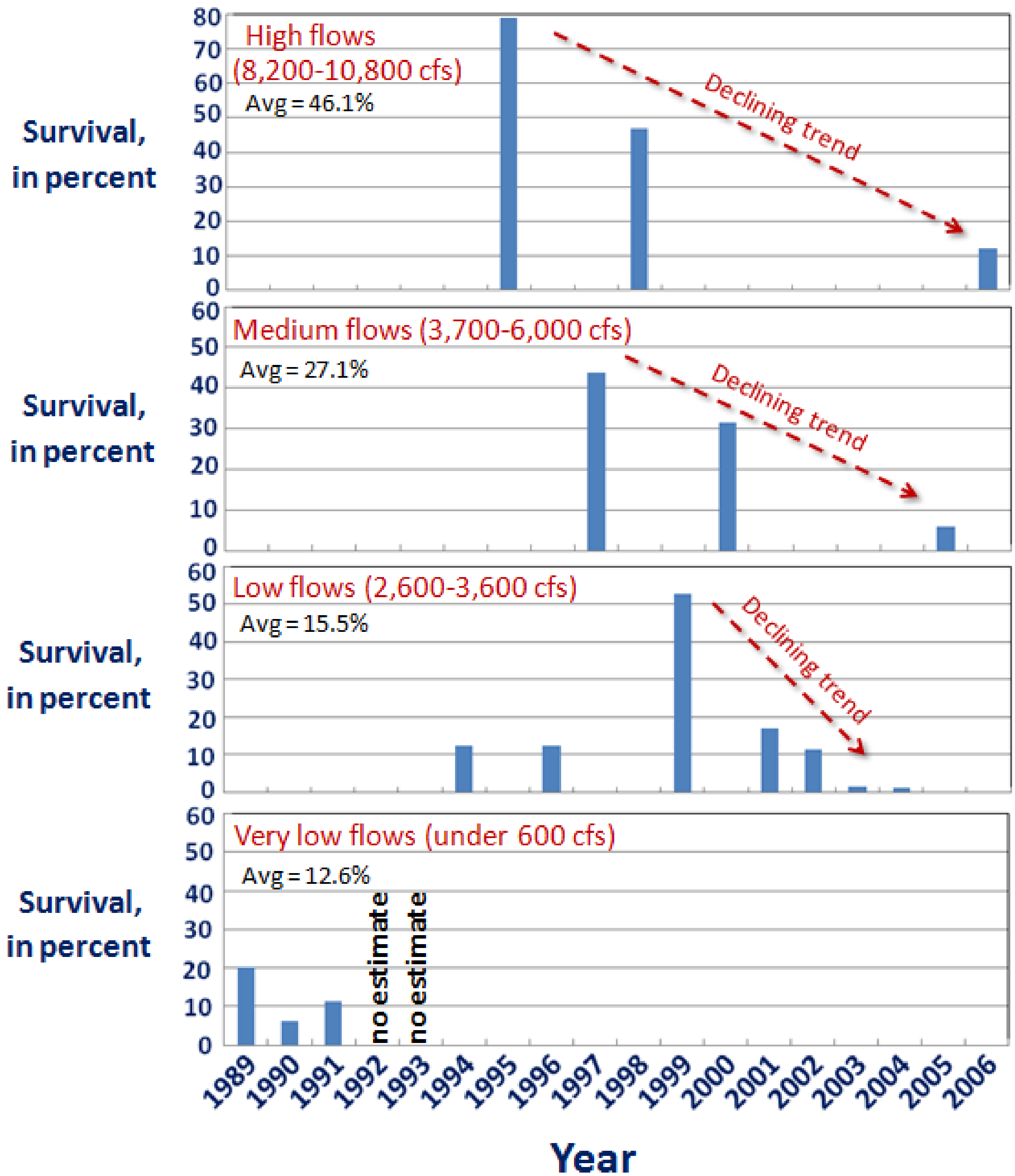

Figure 8 -- CWT smolt survival estimates along the mainstem San Joaquin River to Jersey Point for various ranges of flow at Dos Reis. Data are for all releases at Mossdale (with HORB in place) and Dos Reis. For years with multiple releases, the survival estimates were averaged to obtain a single estimate. Data are based on Table 5 from Newman (2008). The analysis assumes that because Mossdale and Dos Reis are only about 5 miles apart, survival from the two locations should be similar when no flow is being diverted into upper Old River.

Newman's (2008) Bayesian Hierarchical Modeling Analysis Results

Newman's (2008) analyses of San Joaquin VAMP-related CWT recovery data relied upon a considerably more sophisticated statistical analysis approach. Review panel members were not well qualified to fully assess the mathematical or statistical merits of this approach, so we comment instead on the important findings that emerge from Newman's work and also on some analysis issues which we find problematic.

Using Bayesian Hierarchical Modeling (BHM), Newman characterizes the nature of VAMP CWT recovery data at three hierarchical levels. At "Level 1", recoveries of fish released at various locations (Durham Ferry, Mossdale, Dos Reis, Old River, Jersey Point) are assumed to be multinomially distributed with multinomial parameters expressed in terms of the survival rates that are of ultimate interest (e.g., survival from Mossdale to Jersey Point) and unknown recovery parameters that are assumed the same for different groups (e.g., recovery rate between Jersey Point and Antioch given that a fish has survived to Jersey Point). At "Level 2", the logits of these survival and recovery rates are modeled as linear functions of covariates such as Vernalis Flow and export flows. Finally, at "Level 3", the model parameters from Level 2 are assumed to follow normal distributions or inverse gamma distributions (variances only). The Level 3 specifications are for *prior* probability distributions of the unknown model parameters that theoretically are driving relationships of interest.

Also unlike the analyses carried out in SJRTC (2008), Newman does not separate his analyses according to whether or not the HORB is in place. Instead, he introduces a model parameter which accounts for the proportion of downstream migrants which use the Old River channel as their migratory route. The recovery rate of a group of fish released above Old River can then be expressed as the sum of recoveries from those fish that enter the Old River channel and those that remain in the main channel. This unknown "diversion" parameter and survival from Old River to the Jersey Point "reach" then become additional parameters subject to estimation. The BHM approach allows comparison of alternative models relating survival and recovery rates to flows (via comparison of Deviance Information Criterion values), and generates "posterior" distributions of parameters (e.g., survival rates from Dos Reis to Jersey Point) that are consistent with the data that have been collected in VAMP experiments. Chief among the conclusions arrived at by Newman include the following:

1. Posterior mean survival probabilities for 35 different "release sets" provide consistent evidence that survival rates from Dos Reis to Jersey Point exceed those for fish that migrate via Old River and successfully navigate through the Delta to the mainstem San Joaquin and/or Sacramento rivers or are salvaged, trucked and transported back to the mainstem San Joaquin and/or Sacramento rivers (his Figure 27). Thus, if the HORB effectively keeps fish out of Old River, survival of downstream migrants should be improved.

2. There was a positive association between expected mainstem San Joaquin flow at Dos Reis and survival from Dos Reis to Jersey Point (Newman 2008, p. 75, and Newman workshop presentation, slide 19). In contrast to the SJRTC (2008), this finding

applied to the full spectrum of flows that have been encountered at Dos Reis (i.e., was not restricted to relatively low flow periods when the HORB was in place).

3. There was no clear association between survival probabilities and export flows.

As noted above, when fish are salvaged at the Delta pumps and are thereafter trucked and released, their release locations have been variable and have not always been in the mainstem San Joaquin River near Jersey Point. Instead, substantial numbers of salvaged fish have been released near Horseshoe Bend on the mainstem Sacramento River. It seems unlikely for any of these latter releases to be captured at Antioch and it may or may not be reasonable to expect them to have the same recovery rates at Chipps Island as those released near Jersey Point. For that reason, we express some misgivings concerning the merits of the differential mean posterior survival rates found by Newman (point number 1, above). In his Level 1 models, his formula (40) assumes that fish passing through Old River experience the same recovery probability between Jersey Point and Chips Island as for fish released at Jersey Point or fish passing through the mainstem San Joaquin River channel. Given the variable release locations for salvaged fish and the recent acoustic tagging information suggesting that at low flows few fish may survive from Old River to Chipps Island unless they are salvaged, trucked and released, we suspect that this assumed equality of recovery probabilities may be in substantial error. We recognize, of course, that because CWT recovery data allow just a single recovery location to be known for any individual fish, it is therefore impossible to know the actual migratory paths taken by individual fish.

Conclusions

Based on CWT recovery data from the VAMP and earlier programs, the panel believes that San Joaquin flow does affect survival of San Joaquin River salmon smolts, but given the extremely low recapture rates and high standard errors associated with CWT mark-recapture studies, these studies have provided an imprecise approach for estimating the effects of flow on survival in an estuarine system as complex as the Delta. The large amount of environmental “noise” associated with measuring survival in the Delta under conditions of high predation rates, large tidal variations in flow, and large variations in water quality make the detection of associations between survival and the three primary covariates (San Joaquin River flow, exports, and HORB placement) difficult using any approach. There is no guarantee that continued sets of CWT studies, if repeated for additional years, would substantially improve our understanding of the importance of flow for downstream migrant survival.

We believe that the recent introduction of acoustic tagging technologies (beginning first in 2006 and with substantial success in 2008 and 2009) for estimation of short-term survivals of juvenile Chinook through various alternative migratory routes provides a much improved basis for future understanding of the role of San Joaquin River flows on survival of downstream migrating Chinook.

C. Acoustic Tagging.

The VAMP program began using acoustic telemetry in 2006 with an objective to obtain improved information on the movement histories and survival of juvenile fall Chinook salmon migrating through the lower San Joaquin River and the Delta. Studies were conducted over the next 3 years to assess the relative impacts of changes in

Vernalis flow and SWP and CVP export rates on the survival of smolts passing through various reaches of the delta. Challenges to meeting specific study objectives included equipment failure, high rates of predation and a narrow range of flow/export conditions. What the acoustic telemetry studies did show, however, was that survival rates of smolts through the delta were quite low. These new low estimates of survival rates were consistent with recent estimates based on coded-wire tags.

Despite challenges associated with the application of new technology, the panel believes that the VAMP technical team has pursued a worthwhile shift away from coded-wire tag to acoustic-tagging studies. Acoustic telemetry requires fewer test fish, yields much higher precision in estimating short-term survival probabilities, and allows identification of route-selection and reach-specific survival information for juvenile salmon. While shortcomings in acoustic tagging do exist (such as tedious data processing, acoustic background noise, and difficulties in identifying a live acoustic-tagged salmon from a dead acoustic-tagged salmon inside a predatory fish), it seems likely that over the next few years improved technology and software processing will largely overcome these shortcomings.

Because acoustic tagging (AT) technology allows unambiguous identification of migration routes for individual fish, it answers a nagging uncertainty that has plagued many VAMP studies since their inception: estimating the proportion of juvenile salmon that migrate into the head of Old River as compared to the proportion that stay in the mainstem San Joaquin River. Acoustic tagging studies also can be used to estimate how many salmon survive through the entire entrainment, salvage, transportation and release process for the south Delta fish facilities and how that survival compares to estimates of through-Delta survival. Comparing these survivals is important to fully understand the effect of exports on overall survival from the San Joaquin River and to assess certain management actions that might be taken.

The VAMP study team has done an admirable job of learning how to apply AT technology in a complex environment. Although useful experience and scientific information has already been gained from experiments conducted for VAMP since 2006, additional study is needed to determine if consistent relationships exists between flows, exports and smolt survival. Technology problems with failed receivers and poor battery life plagued AT studies in 2007 and 2008. In addition, the 2009 study was unable to monitor fish survival to the downstream locations of Jersey Point and Chipps Island. Other issues include low survival estimates in 2009, especially in the Stockton Deep Water Ship Channel (DWSC), which we believe deserves further study.

Despite challenges, our Panel believes that if smolt survival studies are adequately funded and successfully implemented, the next few years should reveal whether definitive relationships exist between salmon survival and flow. For example, the planned use of supplemental releases to increase sample size in 2010 is a good approach. The panel supports implementation of the 2010 study design with the caveat that it needs to be repeated under a different set of flow conditions. Efforts directed at monitoring at Jersey Point should be added in future years.

Our brief review of the technical program suggested several areas of opportunity for future AT studies as outlined below:

- The high cost of the system and tags has affected the overall study design and sample size required to obtain precise estimates of survival versus flow conditions. One advantage of the current AT system is that much of the monitoring equipment is largely paid for. However, the system consists of complex underwater receivers with long cables and is subject to difficult operation, maintenance, retrieval, and cabling logistics. The VAMP needs to continue to work closely with the AT vendor to improve issues related to tag failure, tag life, tag size/weight, and to reduce cost for all parts of the system.

- The release strategy for AT studies did not appear consistent relative to environmental conditions that influence fish behavior, specifically whether tagged smolts were released in the day versus night and at what tidal stage. Consistency is important to achieve greater precision among replicate releases. For example, diel differences in smolt behavior are well documented for freshwater migration that includes periods of feeding as well as active downstream movement (reviewed in Dauble et al 1989). In addition, previous studies in the Columbia River estuary (Carter et al 2009) indicated that subyearling Chinook salmon exhibited greater movement seaward under conditions of ebb tide. Other experimental goals should include having test fish representative of the naturally-produced fall Chinook salmon population in terms of source, condition and size at release.

- Apparent loss (up to 20 percent within the first 48 hrs following release) of smolts has compromised the experimental design. These results suggest the need to better identify what is sometimes called “tagging effect” or latent mortality of smolts due to tag implantation/handing and how to improve tagging/release procedures or to incorporate this effect (if present) into the release strategy.

- Researchers discussed potential issues with “noise” and signal processing across the range of stations. It is not clear that these issues have been resolved as they relate to maximizing measures of detection probability and ultimately estimates of survival (Vogel 2010).

- In future, it would be useful for researchers to more broadly interact with scientists currently working with a range of acoustic tagging systems, (e.g., HTI, Vemco, JSATS, Lotek, Sonotronics). There are lessons that could be shared in terms of tagging/surgery methods, deployment options for receiving systems, and improvements in data management/processing. A recent review by McMichael et al (2010) sheds some light on some of these issues.

Part IV. Issues of Concern or Importance that Merit Additional Attention.

A. Predation

Loss of juvenile Chinook salmon due to predation in the Delta is not a new issue. For example, as part of the CALFED Science Program, a workshop was held in 2005 to examine predation at the SWP/CVPP intake facilities. Although striped bass appeared to be the principal culprit, Sacramento pike minnow, largemouth bass, and white catfish also prey on juvenile salmon. What appears to be missing from studies conducted to-date is an ecological context. For example, how do predator populations vary in time and space? What is the potential for “cascading trophic interaction” or large-scale shift in the food chain to occur as a result of changes in population size of other prey species such as delta smelt? Additionally, it would be useful to know how predator populations respond to changing hydrodynamic and water quality conditions in the Delta. Finally, studies conducted to-date may lack information on Delta-wide predation in relation to water project operations (Kimmerer and Brown, 2006).

More recent limited scope studies were conducted on striped bass movement near the Tracy Fish Facilities in relation to juvenile salmon migration behavior (Vogel 2010). These studies were part of ongoing efforts to characterize acoustic “tracks’ of juvenile salmon and predators for assessing distinct signatures that would verify loss of smolts due to a predation event. Although this approach could provide useful information for estimating impacts due to predation, it does not address the larger issue of Delta-wide predation. Particularly disturbing is the affect of high rates of predation on the ability to estimate survival. For example, the 2009 studies showed that using tag detection data alone to estimate smolt survival (and apparent movement relative to hydrodynamics) was confounded by predation events and subsequent predator behavior. Additionally, data-processing time required to separate the tracks of actively-migrating smolts from those presumably consumed by a predator is considerably longer than for traditional auto-tracking methods.

It seems clear that meeting smolt survival objectives will be difficult at best without better understanding and some resolution of the predation problem.

B. Installation of a Physical Barrier at Head of Old River (HORB)

As noted in the previous section, survival rates of Chinook salmon smolts through the Old River/Middle River system are considerably less than survival rates through the mainstem San Joaquin channel. At the head of Old River, the San Joaquin channel divides and upwards of 50 percent or more of the San Joaquin River exits the main channel via Old River. Diversion into Old River presumably is influenced by tides, channel hydraulics, mainstem flows, and export flows that draw water into Old River. Because smolts generally follow downstream bulk flow, it is reasonable to assume that the percent of smolts diverted into Old River will be highly correlated with the percent of mainstem discharge that is diverted into Old River.

Recent acoustic tagging data generated with no physical barrier in place showed that 60 percent of migrants entered Old River without barriers in place; 35 percent continued down the San Joaquin River, and 5 percent were lost to Turner Cut (Skalski and Buchanan, personal communication). These new data provide additional confirmation of the value of a physical barrier (HORB). Due mostly to issues related to delta smelt, installation of a physical barrier was recently abandoned. Given the demonstrated benefits of the HORB to survival of downstream migrating Chinook salmon smolts, we believe that more thought needs to be given to weighing the benefits of HORB installation against possible impacts to other species.

A physical HORB installation should provide the following two benefits: (1) prevent migration through the Old River Channel where survival rates are reduced, and (2) ensure that essentially all San Joaquin flow proceeds down the main channel, thereby presumably enhancing smolt survival via a mainstem flow effect.

Implementation of an operable barrier to Old River such as an Obermeyer Gate (Obermeyer 2010) could control flows into Old River for multiple purposes including (a) improving Chinook salmon smolt survival; (b) managing flows in the San Joaquin River to eliminate low dissolved oxygen problems near Stockton; (c) flood control; (d) increasing exports during periods when controls exist on Old and Middle River (OMR) flows; and (e) possibly managing negative OMR flows to minimize entrainment of delta smelt at the pumps.

If an Obermeyer Gate is considered, it should be located near the edge of the hydraulic flow line of the main channel of the San Joaquin River. Data support that in-river structures such as a fill dam, but also bridge abutments, scour holes, piers and pump stations, provide habitat for predators in this reach of the river (Dave Vogel, personal communication). The position of the original HORB was set back into the entrance of the channel leading into Old River. This site was chosen most likely for ease and cost to construct and remove. Unfortunately, it also set up hydraulic conditions ideally suited for predators: slack water and cover. If a future HORB is constructed, alignment along the San Joaquin embankment would create a higher sweeping velocity down the main channel, would move smolts more swiftly past this location, and should reduce predator habitat.

An Obermeyer Gate could be opened and closed any time during the year and on short duration cycles. By studying salmon smolt behaviors, such a gate at this site (and possibly other locations where downstream migrants might be diverted to off-channel routes) would enable appropriately timed closure to minimize ingress into channels where survival is known to be low. Although such gates are not without disadvantages, they are the closest engineered solution to having a natural channel configuration when not closed. They also offer experimental flexibility impossible with a fill structure and they offer potential to balance competing interests for water among different uses by designing scheduled operations that balance competing demands.

C. HORB vs Delta Smelt

In this report we have discussed the ample evidence that suggests a physical HORB has benefits for improving survival of outmigrating San Joaquin River juvenile Chinook salmon through the Delta. Not only is the physical barrier nearly 100 percent effective at preventing salmon from entering Old River where survival is known to be very low, but it also approximately doubles the flow of water down the mainstem San Joaquin River to Stockton which may significantly improve survival through that route, especially during periods of low flow. Even if a non-physical barrier were fully effective at deterring salmon entry into Old River, it would not provide the added benefit of redirecting greater flows down the mainstem of the San Joaquin River.

Since 2008, a physical barrier during spring has not been installed at the Head of Old River because of concerns regarding delta smelt. The management decision on whether or not to install the barrier has often been described as a tradeoff between choosing protections for delta smelt or salmon. The panel does not believe this is the real tradeoff, and we would simply like to make that point. The Reasonable and Prudent Alternative to protect juvenile delta smelt under the 2008 USFWS Biological Opinion requires only that Old and Middle River (OMR) flows during March to June be maintained somewhere in the range of -1,250 cfs and -5,000 cfs (with the actual value determined based on recommendations from the Smelt Working Group). As long as an OMR standard is no more restrictive than -1,250 cfs, the standard can usually[2] be met either with or without a physical HORB in place without requiring exports to be any lower than the required minimum of about 1,500 cfs. Without a physical HORB in place, the difference is that a specific OMR standard can be met while allowing a higher export flow. The tradeoff then, is not one between delta smelt and salmon, but one between species protection (mostly salmon[3]) and water supply. Given the current demands for water from the Delta, the latter tradeoff may create an even more difficult choice than one between species. The panel has no recommendations regarding that tradeoff. It is a difficult one. We support, however, the placement of an operable gate at the HOR, so that it would allow more options for managing the system.

D. Importance of Full Life Cycle Perspective

To date, three types of tags have been employed in the VAMP to assess juvenile behavior and survival: coded wire tags (CWT), radio tags (RT), and acoustic tags (AT). Both RT and AT allow for mobile tracking with similar tag burden and both have limitations with respect to battery life that preclude estimation of long-term survival. In contrast, CWTs are less obtrusive with the advantage of lasting through the entire life cycle.

The current VAMP program favors the use of acoustic tags because they provide more precise estimates of route-specific survival with fewer fish. For example, recent AT experiments involved ~1,000 fish while CWT releases averaged close to 50,000 fish in some years. A missing element of the current AT approach is a measure of how in-river conditions affect ocean survival and adult return. Thus, the program has no life cycle perspective. For example, the AT approach, while appropriate for examining smolt survival in the Delta, does not provide a means to assess relationships between smolt versus adult population size, (i.e., the ratio between smolt numbers and adult returns). In the absence of a coded-wire tag program, how will the goal of increasing adult production two-fold be measured? For example, little seems to be known about the adult return rate of various “treatment groups” of migrants. Examples of key questions that should be considered in future tagging investigations include whether salvaged juvenile migrants are less successful than main channel juvenile migrants in returning to the mainstem San Joaquin channel as mature adults; if Old River migrants return more (or fewer) adults than main channel migrants; and if years experiencing high flow conditions return more adults than low flow years.

In order for the overall recovery program to be successful, juvenile survival studies need to be integrated with studies of ocean survival, in addition to measures of wild and hatchery adult escapement. Additionally, adult production goals are not likely to be achieved unless tagging and recovery studies accommodate questions broader than the question of juvenile survival as affected by flow modifications and export pumping operations. Therefore, we caution against exclusive use of acoustic tags and elimination

[2] Assumes open culverts are installed under the HORB and that the sum of Contra Costa Water District diversions from Old River and south Delta channel depletions are not greater than a few hundred cfs.
[3] The panel does believe that for a given OMR flow standard, the placement of a physical HORB should provide some additional benefits to delta smelt as well as salmon because of the boost in flow down the San Joaquin River it creates.

of CWT releases. Instead, we believe that limited releases of CWT fish will be critically important in the future.

Part V. Recommendations for Future Studies

1. Hydrodynamic modeling and additional hydrodynamic measurements

Hydrodynamic and particle-tracking models could be used to estimate reach-specific transit times of neutrally buoyant particles to compare with fish movements. Behavior could be assigned to particles to simulate fish movement and to assist in understanding fish behavior. It might be worthwhile to do detailed 3-D hydrodynamic modeling in the HOR junction to more fully understand water movement there and how they might affect movements of Chinook salmon smolts. Additional measurements of the velocity field in the HOR junction could be made with HF Radar systems (CODAR) or by flow mapping using downward-looking acoustic Doppler current profilers mounted on remote-controlled robotic boats available to DWR and USGS.

2. Need for more information on fine-scale movements of fish in the mainstem SJ channel below Dos Reis.

If new management actions are to be successful (such as installation of an Obermeyer Gate at the Head of Old River) more information will be needed on fine-scale movements of smolts as they are affected by various factors that may influence migratory behavior. Wilder and Ingram (2006) have already found valuable evidence suggesting that salmon smolts are primarily diurnal during spring and nocturnal during fall, and more active at crepuscular periods. Using mobile telemetry of acoustic-tagged smolts offers a promising new way to observe fish behavior *in situ* and to expand upon information learned previously by trawl sampling continuously for 24 hours at a single location as was done by Wilder and Ingram (2006). Examples of questions that might be addressed include: How do smolts respond to tidal flows? Are smolt movements typically diurnal, moving by day and holding by night (or vice-versa)? Do most fish enter Old River and Turner Cut on the flood tide? How do daily variations in the magnitude and phasing of the maximum ebb and flood tidal flows affect the rate of smolt progress through the estuary? Do diel activity patterns in juvenile salmon change in response to environmental conditions? Either radio tags or acoustic tags could be used for such studies.

3. Possible uses of PIT Tags in the San Joaquin River system.

The panel believes that consideration should be given to the use of Passive Integrated Transponder (PIT) tags for selective studies of smolt behavior and survival. PIT tags have an advantage over acoustic and radio tags due to their smaller size/weight and less obtrusive tagging methodology. Thus, PIT tags are less likely to affect the relative fitness or survival of test fish. In addition, PIT tags have a passive rather than active signal that allows for interrogation over the full lifespan of San Joaquin Chinook salmon. An advantage over coded wire tags is that PIT tags can be detected at many different locations and times without the need to sacrifice fish to decode tags.

A serious limitation of PIT tag technology, however, is that fish must pass within a meter or so of a tag reader in order for a tag to be detected. Thus, options for applying this technology to the VAMP study are restricted to locations where fish can be collected and handled. Promising application contexts might include monitoring releases of test fish moving from the head of Old River to recovery at Clifton Court and Tracy Fish Salvage operations. Depending on availability of test fish (i.e., sample sizes requirements for desired level of accuracy/precision), PIT-tagged fish from these and other release scenarios could be recovered by trawl in the lower river and estuary, perhaps Chipps Island.

NOAA Fisheries has used a surface pair-trawl effectively in the lower Columbia River to obtain precise survival estimates for smolts migrating past Bonneville Dam. Fish entering the trawl body exit after passing by a detection antenna in the open cod end. There is no handling of target species and no retained by-catch of other species. This approach generated detections of nearly 2% of PIT tags previously detected at a point 159 km upstream of the study area (Ledgerwood et al. 2004). Higher capture efficiencies of smolts might be possible in the Delta area due to smaller water volume. PIT tags could also be detected on spawning grounds.

4. Installation of Physical HORB

We believe that existing information provides a compelling basis to conclude that survival rates of Chinook salmon smolts moving through the Old River system are considerably less than for those moving through the mainstem San Joaquin River. For that reason, we believe that anything that can be done to increase directed movement of smolts downstream in the mainstem River and out of the south Delta "confusion zone" would be expected to benefit smolt survival if for no other reason than to speed entry to the estuary and subsequently reducing the encounter rate of predators. The bubble curtain, as currently implemented, does not include local hydraulics in its design, and thus does not consider a key factor influencing smolt behavior. Therefore, we consider that installation of a physical HORB is highly desirable. We believe that an Obermeyer Gate should be located near the edge of the hydraulic flow line of the main channel of the San Joaquin River and that it should be closed during the period of downstream migration of San Joaquin Chinook salmon smolts.

5. Predation Studies.

We recommend studies to more broadly characterize predator seasonal distribution, abundance and feeding habits in order to better determine the extent of predation, including identification of “hot spots” or locations where predator abundance leads to especially high mortality of Chinook salmon smolts. For example, presence of engineered structures and/or water export operation may increase the encounter rate of predators and smolts over that which would occur in a more natural system (Vogel, 2010). Immediate action should be taken to quantify, monitor and mitigate these effects. One area of research might focus on improving the “fish-friendliness” and hydraulic “efficiency” of capturing (Gingras 1997, Ott 2005, Clark et. al. 2009, Kimmerer and Brown, 2006), handling and releasing juveniles (including smelt) and isolating them from predators during these procedures. Additionally, the panel believes that current release strategies for smolts captured at export facilities could be improved to minimize predation at the point of release. We do not, however, endorse a predator control program at this point given competing objectives of resource management agencies and general lack of information on predator populations in the Delta. However, against the backdrop of such high rates of predation, occurring during the critical estuary-entry stage of the fall Chinook salmon life cycle, assessing relationships between flow, export volume and smolt survival will be difficult at best.

6. Continued Improvements in CHTR

Panel members were unanimous in their belief that it is advantageous to promote downstream migration through the mainstem San Joaquin channel and to minimize migration through the Old River route. Nevertheless, we were all unanimous in supporting continued efforts to improve CHTR, in particular to reduce pre-screening mortality and predation in the Clifton Forebay (Gingras 1997, Ott 2005, Clark et. al. 2009) and to improve release practices so as to enhance survival of trucked smolts.

7. More Frequent VAMP Program Reviews.

Given the rapid changes in tagging technologies and recent evidence of extremely low survival rates of Chinook salmon smolts migrating through the San Joaquin River/Delta system, we believe that it will be important to review VAMP program findings on a more regular basis. We recommend that such reviews be made every three years.

8. Adequate VAMP Funding.

Funding should ensure that experimental designs of studies make good sense and that small shortfalls do not result in substantial loss of information that results from a relatively modest shortfall in anticipated funding. For example, due to budget shortfalls, the 2010 acoustic tagging program does not include recovery arrays at Jersey Point, thereby diminishing the information content of this year's studies as compared to previous years and also contributing to interannual variation in the adopted experimental design.

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Appendix A. Documents that the Independent Review Panel was asked to review
Each independent review panelist was given access to the following electronic documents to review prior to attending the two-day public meeting: These reports can be found on the San Joaquin River Group Authority website at: http://www.sjrg.org/peerreview/.

a) Newman, KB. 2008. An evaluation of four Sacramento-San Joaquin River Delta juvenile salmon survival studies. Report for CALFED Science Program Project # Sci-06-G06-299 and peer reviewer's comments on a previous version of the report and model. (This report contains the analysis of four release and capture studies one of which is the VAMP. Portions of the report are specific to the VAMP while other portions discuss the analytical methods common to all of the studies. The panel was only asked to review those sections specific to VAMP.)

b) Holbrook, C. M., Perry, R., Adams, N., 2009. Distribution and Joint Fish-tag Survival of Juvenile Chinook Salmon Migrating through the Sacramento-San Joaquin River Delta, 2008.

c) Bowen, D. M., Hieber, S., Hueth, C., Maisonneuve, V., 2009. Technical Memorandum 86-68290-11: 2009 Effectiveness of a Non-Physical barrier at the Divergence of the Old and San Joaquin River (CA).

d) Brandes, P., Adams, N., Holbrook, C., Burau, J., Vogel, D., Foott S., Nichols, K., Hanson, C., and W. Stringfellow. 2009 VAMP Study Plan Proposal - Survival and distribution of migrating juvenile Chinook salmon in the San Joaquin River and Delta. April 16, 2008.

e) San Joaquin River Authority. 2007. 2006 Technical Annual Report On Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan

f) San Joaquin River Authority. 2009. 2008 Technical Annual Report On Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan

Additional reports for the purpose of historical context:

a) Brandes, P., et. al., 2008. Summary Report for the Vernalis Adaptive Management Program (VAMP) for the experimental determination of juvenile Chinook salmon survival within the lower San Joaquin River in response to river flow and State Water Project (SWP) and Central Valley Project (CVP) exports, 2000-2008.

Appendix B.   Agenda from March 2-3, 2010 VAMP Review

<u>Agenda</u>

March 2, 2010

0900 Welcome – Cliff Dahm, PhD, DSP Lead Scientist

Introduction of the panel

0915 Dennis Dauble, PhD, Washington State University
0920 David Hankin, PhD, Humboldt State University
0925 John J. Pizzimenti, PhD, GEI Consultants Inc.
0930 Pete Smith, PhD, USGS retired

Presentation by VAMP investigators

0935 Purpose of Review, Background, Diane Riddle (SWRCB)
0950 Study Design and Implementation, Bruce Herbold (USEPA)

1020 Break

1040 Hydrology, Mike Archer (MBK Engineering)
1110 Coded Wire Tag Study Results, Ken Newman (USFWS)

1145 Lunch

1300 2008 Acoustic Telemetry Studies, Chris Holbrook (USGS)
1330 2009 Evaluation of Non-Physical Barrier, Mark Bowen (USBR)
1400 2009 VAMP Study Design, ?????
1430 2010 Study Design, Pat Brandes (USFWS)
1445 Agency and Public Comments

1500 Break

1520 Facilitated discussion – Cliff Dahm, PhD – DSP Lead Scientist
1630 Recap - Cliff Dahm, PhD - DSP Lead Scientist
1645 Adjourn

March 3, 2010

0900 to 1200 – Panel will deliberate in private

0930 Continued facilitated discussions and invited presentations

1145 Lunch

1300 Presentation by Independent Review Panel – Initial Assessment and Impressions
1400 Facilitated discussion - Cliff Dahm, PhD - DSP Lead Scientist
1500 Adjourn

Appendix C. Brief Biographical Sketches for Review Panel Members.

Dr. Dennis D. Dauble

Dr. Dauble received his B.S. and Ph.D. from Oregon State and his M.S. from Washington State. He has been an Adjunct Professor at the WSU-Tri Cities branch campus since 1990. During this time he has taught graduate-level coursework in Biology and Management of Fishes and Fish Ecology. Dr. Dauble achieved Fellow status in 1998 in the American Institute of Fishery Research Biologists. He received a Laboratory Directors Fitzner-Eberhardt Award in 1999 for outstanding contribution to science and engineering education. Recent consulting activities since retirement have included working with Northwest Anthropology LLC on issues relating to traditional fishing practices of American Indians in the mid-Columbia region.
Dr. Dauble worked at Pacific Northwest National Laboratory from 1973 until 2009 when he retired. He oversaw business development activities for the U.S. Army Corps of Engineers while serving as Director of the Natural Resources Division from January 2000 to October 2007. Previously, he was Technical Group Manager for the Ecology Group and, prior to that, a Senior Staff Scientist. His technical background includes Endangered Species issues, Columbia River fish passage and behavior, ecological risk assessment and ecological monitoring. He has authored more than 60 peer-reviewed journal and symposium articles, 50 client reports, and made over 120 presentations at scientific symposia, educational workshops and public forums.

Dr. David Gregory Hankin

Dr. Hankin received his B.S. from Reed College and his Ph.D. from Cornell University. He is currently the Interim Associate Dean of Marine Sciences and Professor for Fisheries Biology at Humboldt State University. He serves as one of two U.S. members of the Pacific Salmon Commission's Committee for Scientific Cooperation and recently chaired a PSC Expert Panel on the Future of the Coded Wire Tag Recovery Program for Pacific Salmon.

Dr. Hankin has been a leader in development of survey designs for estimation of abundance of fish (especially juvenile salmon and trout) in small streams. His stream survey design methods have been adopted throughout the Pacific Northwest. His mathematical models of the impact of exploitation on Chinook salmon have formed the basis for harvest rate management of Chinook salmon off Northern California and Southern Oregon and for sharing of allowable catches between commercial, recreational and tribal fishers. His publications on hatchery marking practices to allow statistical separation of returns of hatchery and wild Chinook salmon form the essential basis for "constant fractional marking" programs that have recently been adopted throughout California's Sacramento River system and in the Klamath River system. He is a recognized expert on life history and fishery management of Dungeness crab with special expertise concerning female Dungeness crabs which remain a protected sex.

Dr. John Pizzimenti

Dr. Pizzimenti earned his B.A. at California State University, Northridge, and a Ph.D. from the University of Kansas. From 1974-1977 he conducted National Science

Foundation-sponsored research at the Field Museum and University of Chicago; and then served on the faculty of the University of Illinois-Chicago until 1981. Dr. Pizzimenti subsequently began consulting on impact assessment of water resource projects. His experience ranges across the Americas from Alaska to Argentina. Since 1989, his focus has been mostly on anadromous fish and Pacific Northwest environments. He has assembled teams of scientists and engineers who have developed new approaches to problem-solving for federal, state, municipal, tribal governments and the private sector. He is particularly interested in assessing biological efficacy and impacts of engineered structures and has consulted on more than 100 projects involving fisheries, fish passage, fish tracking, dams, reservoirs and regulated rivers. He has served the Northwest Power and Conservation Council's Independent Science Review Panel to review research and mitigation plans for the Federal Columbia River Power System and to make recommendations on Federal Columbia River Power System Operations to improve salmon survival.

Dr. Peter E. Smith

Dr. Smith received his B.S from Villanova University, his M.S from Colorado State University, and his Ph.D. from the University of California, Davis. Dr. Smith is a retired research hydrologist from the U. S. Geological Survey, where he worked for over 31 years. Since retiring from the USGS California Water Science Center in January 2008, he has remained active in environmental consulting and has served on a number of CALFED and Federal agency-sponsored review panels and teams. He is a specialist in estuarine hydrodynamics and modeling with an emphasis on ecological applications. He has particular expertise in the hydrodynamics of the San Francisco Bay-Delta estuary where he has conducted research and studies for 27 years. He served for nine years as the USGS representative to the Management Team for the Interagency Ecological Program of the San Francisco Bay-Delta Estuary, which oversees monitoring and studies programs in the estuary for nine federal and state agencies. He has also served for the past 12 years as a member of the Computational Hydraulics Committee for the Environmental and Water Resources Institute of the American Society of Civil Engineers (ASCE) and for the past 20 years on the advisory committee for ASCE's biannual Estuarine and Coastal Modeling Conferences.

APPENDIX D.

Summary of State Water Resources Control Board Water Quality Control Planning and Water Rights Information Relevant to the March 2010 VAMP Review

Purpose of This Document: On March 2 and 3, 2010, the Delta Science Program hosted a workshop for an independent panel review of the Vernalis Adaptive Management Plan (VAMP). As part of that review, State Water Resources Control Board (State Water Board) staff provided a presentation concerning the history behind the San Joaquin River flow objectives and the VAMP and the State Water Board's current efforts to review the San Joaquin River flow objectives. The review panel requested additional information concerning this history and the State Water Board's current process. This document is a final version of the draft summary information provided to the panel. The sources of the information are cited for reference.

Purpose and Applicability of Water Quality Control Plans

See: 2006 Water Quality Control Plan pg. 3 at:
http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/wq_control_plans/2006wqcp/docs/2006_plan_final.pdf

A Water Quality Control Plan establishes water quality objectives for which implementation can be fully accomplished only if the State Water Board assigns some measure of responsibility to water right holders and water users to mitigate for the effects on the designated beneficial uses of their diversions and use of water. A water quality control plan consists of: (1) beneficial uses to be protected; (2) water quality objectives for the reasonable protection of beneficial uses; and (3) a program of implementation for achieving the water quality objectives. Together, the beneficial uses and the water quality objectives established to reasonably protect the beneficial uses are called water quality standards under the terminology of the federal Clean Water Act.

The Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay Delta Plan; or The Plan) provides reasonable protection for the Estuary's beneficial uses that require control of salinity (caused by saltwater intrusion, municipal discharges, and agricultural drainage) and water project operations (flows and diversions). The Bay Delta Plan supersedes the regional water quality control plans to the extent of any conflict between this plan and the regional water quality control plans. The other plans and policies establish water quality objectives and requirements for parameters such as toxic chemicals, bacterial contamination, and other parameters which have the potential to impair beneficial uses or cause nuisance.

Most of the objectives in the Bay Delta Plan are being implemented by assigning responsibilities to water right holders because the parameters to be controlled are primarily impacted by flows and diversions. A Water Quality Control Plan, however, is not to be construed as establishing the responsibilities of water right holders. Nor is a Water Quality Control Plan to be construed as establishing the quantities of water that any particular water right holder or group of water right holders may be required to release or forego to meet the objectives in the Water Quality Control Plan. Subsequent to establishment of a Water Quality Control Plan the nature and extent of water right holders' responsibilities to meet the objectives will be determined in a water rights proceeding. If necessary after a water rights proceeding, the Water Quality Control Plan will be amended to reflect any changes that may be needed to ensure consistency between the plan and the water right decision.

Periodic and Triennial Review of Water Quality Control Plans

State law requires that state policy for water quality control and water quality control plans be reviewed periodically [CWC §13143, §13240]. Federal law [CWA §303(c)(1)] requires that a state's water quality standards be reviewed every three years, i.e., triennially. These reviews are formal State or regional board actions requiring a resolution adopting the triennial review.

Triennial reviews are comprehensive and include a public hearing to identify issues to be addressed including, but not limited to, the appropriateness of the water quality standards. The review identifies standards that need to be revised, and affirms those standards that are appropriate and require no revision. Information on continuing or new water quality problems, impairment of beneficial uses, or violation of water quality objectives may come from monitoring data, compliance inspections, discharger reports, and public suggestions. Changes in State or federal laws and regulations may also dictate the need for a Plan amendment. The State or regional board evaluates all available information and determines whether revisions to water quality standards or implementation plans are needed and the nature of any necessary revisions. The record and adopting resolution of basin plan triennial review are transmitted by the Regional Board to the State Board, which makes the triennial review available to US EPA.

1995 Water Quality Control Plan

See: 1995 Water Quality Control Plan pg. 19; Decision 1641 pg. 184 at: http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/wq_control_plans/1995wqcp/docs/1995wqcpb.pdf

The 1995 Plan was the first Plan in which the State Water Board established flow objectives for the San Joaquin River to protect fish and wildlife beneficial uses including delta smelt and Chinook salmon. These flow objectives were based on the Principles for Agreement on Bay-Delta Standards between the State of California and the Federal Government (http://www.calwater.ca.gov/content/Documents/library/SFBayDeltaAgreement.pdf) and information submitted to the State Water Board during the plan amendment process.

1995 Plan flow objectives were adopted for three different time periods: a fall flow objective during October; spring flow objectives from February through June excluding April 15-May 15, and spring pulse flow objectives from April 15-May 15. The timing of the spring pulse flow period may be varied based on real-time monitoring to coincide with fish migration in the San Joaquin River.

Below is an extracted section from Table 3 of the Bay Delta Plan (page 19) identifying the San Joaquin River at Airport Way Bridge near Vernalis flow objectives.

COMPLIANCE LOCATIONS	INTERAGENCY STATION NUMBER (RKI [4])	PARAMETER	DESCRIPTION (UNIT) [5]	WATER YEAR TYPE [6]	TIME PERIOD	VALUE
RIVER FLOWS						
San Joaquin River at Airport Way Bridge, Vernalis	C-10 (RSAN112)	Flow rate	Minimum monthly average [7] flow rate (cfs) [8]	W,AN BN,D C	Feb-Apr 14 and May 16-Jun	2,130 or 3,420 1,420 or 2,280 710 or 1,140
				W AN BN D C	Apr 15-May 15 [9]	7,330 or 8,620 5,730 or 7,020 4,620 or 5,480 4,020 or 4,880 3,110 or 3,540
				All	Oct	1,000 [10]

The fall flow objective is intended to provide attraction flows for Chinook salmon returning to the San Joaquin River watershed to spawn. The spring flows are intended to provide minimum net downstream freshwater flows to address habitat concerns from reduced flows and water quality degradation. The spring pulse flows were principally developed to aid in cuing Chinook salmon smolt outmigration from the San Joaquin River. The spring flow and spring pulse flow objectives vary based on water year type and the required location of the 2 parts per thousand isohaline, which is a component of the Delta outflow objectives (see Table 3 of the 1995 or 2006 Bay-Delta Plan). The water year types are based on hydrologic conditions in the San Joaquin River watershed and the required location of the 2 parts per thousand isohaline is based on hydrologic conditions in both the Sacramento and San Joaquin River watersheds.

Water Right Decision 1641

See: Decision 1641 pg. 12-17 at:
http://www.waterboards.ca.gov/waterrights/board_decisions/adopted_orders/decisions/d1600_d1649/wrd1641_1999dec29.pdf

Water right Decision 1641 (Decision 1641) implements portions of the 1995 Plan, including establishing responsibility for meeting the San Joaquin River flow objectives. It recognizes the San Joaquin River Agreement and accepts commitments by the San Joaquin River Group Authority (SJRGA) members, Bureau of Reclamation (Bureau), and Department of Water Resources to assume various responsibilities for the San Joaquin River portions of the 1995 Bay-

4 River Kilometer Index station number

5 Determination of compliance with an objective expressed as a running average begins on the last day of the averaging period. The averaging period commences with the first day of the time period of the applicable objective. If the objective is not met on the last day of the averaging period, all days in the averaging period are considered out of compliance.

6 The Sacramento Valley 40-30-30 Index applies unless otherwise specified.

7 Partial months are averaged for that period. For example, the flow rate for April 1-14 would be averaged over 14 days. The 7-day running average shall not be less than 20% below the flow rate objective, with the exception of the April 15 –May15 pulse flow period when this restriction does not apply.

8 The water year classification will be established using the best available estimate of the 60-20-20 San Joaquin Valley Water Year Hydrologic Classification at the 75 % exceedence level. The higher flow objective applies when the 2-ppt isohaline (measured as 2.64 mmhos/cm surface salinity) is required to be at or west of Chipps Island.

9 This time period may be varied based on real time monitoring. One pulse, or two separate pulses of combined duration equal to the single pulse, should be scheduled to coincide with fish migration in San Joaquin River tributaries and the Delta. The USBR will schedule the time period of the pulse or pulsed in consultation with the USFWS, NOAA Fisheries, and the DFG. Consultation with the CALFED Operations Group established under the Framework Agreement will satisfy the consultation requirement. The schedule is subject to the approval of the Executive Director of the State Water Board.

10 Plus up to an additional 28 TAF pulse/attraction flow during all water year types. The amount of additional water will be limited to that amount necessary to provide a monthly average flow of 2,000 cfs. The additional 28 TAF is not required in a critical year following a critical year. The pulse flow will be scheduled by the DWR and USBR in consultation with the USFWS, the NOAA Fisheries and the DFG. Consultation with the CALFED Operations Group established under the Framework Agreement will salsify the consultation agreement

Delta Plan. Decision 1641 authorizes a staged implementation of the Vernalis pulse flow objectives by allowing the SJRGA parties to meet the VAMP target flows for a period of 12 years in lieu of assigning responsibility for meeting the spring pulse objectives adopted in the 1995 Bay-Delta Plan in order to obtain additional scientific information on which to base long-term objectives. Decision 1641 does not, however, implement the export restrictions specified in the VAMP (see Table 3, page 184 of Decision 1641). Decision 1641 requires the Bureau to meet the spring flow (February through June with the exception of the spring pulse flow/VAMP period) and fall flow objectives (October).

Review of 1995 Water Quality Control Plan

> **See: Plan Amendment Report, Appendix 1 to the 2006 Water Quality Control Plan pg. 50-64 at:**
> **http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/wq_control_plans/2006wqcp/docs/2006_app1_final.pdf**

During review of the 1995 Bay-Delta Plan, several concerns regarding the San Joaquin River flow objectives were raised. Concerns were raised by the Department of Fish and Game and others regarding the adequacy of VAMP flows, including the magnitude, duration, and frequency, in protecting salmon, steelhead and pelagic fishes.

Concerns were also raised regarding the scientific validity of the VAMP. Conditions related to the pelagic organism decline, fish availability for study purposes, hydrology, the inability to operate the Head of Old River Barrier, and other issues have complicated conduct of the VAMP and required major modifications to the study design that may affect the utility of the study data. This has resulted in concerns regarding the ability of the VAMP to provide information on which to base long-term pulse flow objectives for the San Joaquin River. Furthermore, the VAMP has yet to yield conclusive results regarding needed changes to the spring pulse flow objectives.

In addition, the Bureau raised concerns about its responsibility to meet the spring flow objectives. The Bureau has not met the objectives during several years and argues that it is unable to consistently meet the objectives due to competing demands.

Another issue raised during review of the 1995 Bay-Delta Plan was that the spring flow objectives are based on an agreement rather than science and are not based on hydrological conditions in the San Joaquin River watershed. Although the water year type for the spring flow objectives is determined entirely by conditions in the San Joaquin River watershed, conditions within the Sacramento River watershed often dictate whether the higher or lower flows for each year type apply. The Sacramento River and its tributaries contribute the majority of the flow comprising the Eight River index and as a result largely determine the required Delta outflow. Because the San Joaquin River watershed experiences snow-melt dominated runoff and the Sacramento River experiences both rain-fall and snowmelt runoff, and since the watersheds are situated in different geographical regions, the two watersheds may produce different hydrological conditions. As a result, the higher spring flow objectives may be triggered by wetter conditions in the Sacramento River watershed even when conditions in the San Joaquin River watershed are much drier, and vice versa.

2006 Water Quality Control Plan

> **See: 2006 Water Quality Control Plan pg. 6, 7, and 25; Decision 1641 pg. 20 at:**
> **http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/wq_control_plans/2006wqcp/docs/2006_plan_final.pdf**

While data submitted by fisheries agencies suggested that various fish species within the Delta and San Joaquin River basin have shown significant signs of decline since adoption of the San Joaquin River flow objectives in the 1995 Bay-Delta Plan and the implementation of the objectives in Decision 1641, the State Water Board did not revise the San Joaquin River flow objectives in the 2006 Bay-Delta Plan due to a lack of scientific information on which to base any changes. The State Water Board determined that additional data and scientific analyses were needed to either support or modify the current objectives. As a result, the State Water Board identified San Joaquin River flows as an emerging issue requiring further consideration along with the effects of San Joaquin River flows on pelagic organisms and requested that the fisheries agencies develop additional information on which to base changes to the objectives. In addition, the State Water Board requested that the SJRGA parties conduct a review of the VAMP.

In the 2006 Plan, the State Water Board did make changes to the program of implementation for the spring pulse flow objectives in order to allow for staged implementation of the objectives, with the first stage consisting of conduct of the VAMP and the second stage consisting of the Board either implementing or revising the objectives.

The interim spring pulse flows (a.k.a. VAMP) may be implemented on the San Joaquin River at Vernalis during the 31-day April and May pulse period in order to obtain additional scientific information concerning flow needs on the San Joaquin River during the pulse flow period, and are identified below (2006 Plan, page 25). The target flows for the pulse period should be based on the existing flow which is defined as the forecasted flows in the San Joaquin River at Vernalis during the pulse flow period that would exist absent the San Joaquin River Agreement or water acquisitions.

Existing Flow[1] (cfs)	Target Flow (cfs)
0-1999	2,000
2,000-3,199	3,200
3,200-4,449	4,450
4,450-5,699	5,700
5,700-6,999	7,000
7,000 or greater	Existing Flow

During years when the sum of the current year's 60-20-20 numeric indicator (shown below; 2006 Plan, page 25) and the previous year's 60-20-20 numeric indicator is seven (7) or greater, target flows should be one step higher than those required in the above table. The licensee is not required to meet the target flow during years when the sum of the numeric indicators for the current year and the previous two years is four (4) or less.

SJR Basin 60-20-20 Classification	60-20-20 Indicator
Wet	5
Above Normal	4
Below Normal	3
Dry	2
Critical	1

Review of the 2006 Water Quality Control Plan

See: Second Revised Notice for April 22, 2009 Workshop - Consideration of Potential Amendments to the Water Quality Control Plan for the San Francisco Bay/ Sacramento-San Joaquin Delta Estuary Relating to Southern Delta Salinity and San Joaquin River Flow Objectives at:
http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/bay_delta_plan/water_quality_control_planning/docs/notice2ndrev.pdf

and Powerpoint presentation from meeting (not posted)

The State Water Board is currently in the process of considering potential changes to the San Joaquin River flow objectives and their implementation included in the 2006 Bay-Delta Plan. Following any update of the objectives or their implementation in the 2006 Bay-Delta Plan, the State Water Board will undertake any needed water right proceeding to assign responsibility to water rights holders for meeting the objectives.

The State Water Board is considering alternative flows for the San Joaquin River that are based on modeling using percentages of unimpaired flow (UF). This type of flow would modify the current hydrologic regime to more closely mimic the natural flow regime to which salmonids and other native fishes are adapted. In order to develop reasonable alternatives for San Joaquin River flow objectives, the State Water Board is modeling three alternatives based on a set percentage of unimpaired flows consisting of a high, medium, and low flow alternative. Alternative percentages of UF may be considered for the February through June period (spring period) and may vary by water year type.

For illustrative purposes only, staff prepared a graph depicting flows in the San Joaquin River. The graph is shown below and includes: 1) unimpaired flows in 2003 (a below normal water year), 2) actual conditions which include conduct of the VAMP, 3) the Bay-Delta Plan required flows, and 4) an example of 50% unimpaired flows. The 50% UF example was not chosen for any purpose other than to illustrate the proposed alternatives modeling concept. In general, the graphic shows that the natural hydrograph has been substantially flattened under existing regulations (other years generally show similar flattening effects, though to different degrees).