Statement Of Key Issues On The Volume, Quality, And Timing Of Delta Outflows Necessary For The Delta Ecosystem to Protect Public Trust Resources With Particular Reference To Fall-Run Chinook Salmon In The San Joaquin River Basin

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The viability of the fall-run Chinook salmon populations in the San Joaquin River are dependent on four aspects of flow management: (1) pulse flows in late October to provide the cue required for upstream migration of adult salmon to their natal river; (2) pulse flows to inundate tributary floodplain habitat in winter to augment food resources for salmon fry; (3) adequate flow releases to maintain water temperatures near 59°F (15°C) to the mouth of each tributary during the spring to accelerate smolt outmigration and maximize smolt health; and (4) Delta flows at Vernalis that increase from 3,000 cfs in late March to 10,000 cfs from May 15 to June 15, minimal entrainment within the Old River, 2,000 cfs outflow from the Old and Middle rivers, and a non-physical barrier (e.g., bubble barrier) to shunt the smolts into the Old River from March 15 to June 15 to improve smolt survival.

<u>Late October Attraction Flows</u>: Providing 1,200 cfs fall attraction flows for 10 days in late October in each of the tributaries should increase escapements by an average of 10%. Up to 58% of the adult Merced River Hatchery fall-run Chinook salmon with coded-wire-tags (CWTs) that were recovered in Central Valley rivers during the fall-run Chinook salmon escapement surveys from 1979 to 2007 strayed to the Sacramento River Basin when the 10-day mean flow in the San Joaquin River at Vernalis in late October was less than 3,500 cfs; in contrast, stray rates were less than 6% when flows were at least 3,500 cfs (Figure 6 in Mesick 2009). If 1,200 cfs is provided from each of the three San Joaquin River tributaries (total of 3,600 cfs at Vernalis), for at least a 10-day period in late October, the stray rates should decrease from the mean stray rate of 14.6% from 1996 to 2006 to a mean of about 5%, and thereby increase escapements by an average of 10% (Mesick 2009). It may be possible to reduce the October pulse flows if the combined Delta exports were reduced to less than 200% of Vernalis flows for a 10 day period in late October. However, there is insufficient empirical evidence to determine the magnitude of the pulse flows needed to minimize the adult salmon straying rates, if Delta exports were reduced.

<u>February-March Floodplain Inundating Flows</u>: Providing winter flows of at least 3,000 cfs to inundate floodplains for at least 2 days in the upper tributary reaches, augments the food supply for juvenile salmon, improves their survival as they migrate through the lower tributaries, and causes about 40% of the smolts to begin migrating in late March and early April compared to 8% migrating under base flows. Early smolt migration is important because it is possible to use flow management to maintain optimum water temperatures throughout the tributaries to the confluence with the San Joaquin River prior to May 15, which helps produce healthy smolts that have a relatively good chance of survival as they migrate through the Delta. Prolonged winter flow releases of 8,000 cfs provide maximum floodplain inundation that provides an even greater increase in food resources, refuge from predators, as well as optimum water temperatures.

My recommendations are based on rotary screw trap catch data for the Tuolumne River (pages 20 to 23 in Mesick 2009) that show that a 2- to 3-day pulse flow of at least 3,000 cfs in February or March at least doubled the number of smolt outmigrants and substantially accelerated the rate of smolt outmigration from the Tuolumne River compared to winter base flow releases. It is likely that the primary benefit of brief floodplain inundation is that invertebrates and organic matter are flushed into the river, which increases the long-term availability of food resources for salmon fry and smolts (page 20 in Mesick 2009). Flow releases of 3,000 cfs inundate about 500 acres of floodplain habitat in the Tuolumne River between La Grange Dam (rivermile 52) and the Santa Fe Bridge (rivermile 21; USFWS 2008).

The relation between flow releases and floodplain inundation on the Stanislaus and Merced rivers has not been quantified. However, prolonged winter pulse flows of at least 3,000 cfs in the Stanislaus River increased fry survival in the lower river from 14% to 67% and increased the number of smolt outmigrants by 26% based on rotary screw trap studies (pages 23 and 24 in Mesick 2009). It is likely that 3,000 cfs flow releases would have a similar effect on the Merced River based on the presence of functional floodplains in the 20-mile long section immediately downstream of Crocker Huffman Dam.

The rotary screw trap catch data for the Tuolumne River (Mesick 2009) indicate that the number of smolt outmigrants increased 25- to 35-fold when flood control releases were a mean of 4,000 and 5,000 cfs from February 1 to June 15 in 2005 and 1998, respectively, compared to the base flow releases during dry and normal water years.

The duration and magnitude of floodplain inundation should be increased as water availability increases from dry to wet years as recommended in Table 1. When possible, the floodplain inundation flow releases should begin in mid February to maximize food resources for fry. To quantify these benefits, juvenile salmon survival should be monitored with well calibrated rotary screw trap studies near the downstream boundary of the spawning reach and near the river's mouth for at least 10 years.

Creating wildlife refuges in the upper San Joaquin River tributary reaches would help restore the benefits of floodplain inundation during the dry years when water availability is low, if they were operated like those in the Sutter Bypass on Butte Creek. The Sutter Bypass has about 6,250 acres of wetlands converted from rice fields that are managed for waterfowl. Presumably most Chinook salmon fry migrate from the East and West Borrow Canals onto the wetlands during brief rain storms when flows exceed about 1,000 cfs for several days. While on the inundated wetlands, the fry rapidly grow to a smolt size when the fields are drained in March (pages 3-7 and 3-8 in FMWG 2009). The Department of Water Resources operates small pumps that keep these areas inundated through early summer. The refuges would have to be created in the upper reaches of the San Joaquin River tributaries that are accessible to fry during the low-flow, dry years. The Anadromous Fish Restoration Program has recently funded the planning phases of floodplain restoration projects on all three San Joaquin River tributaries.

Flow Management to Maintain Suitable Water Temperatures in the Tributaries in Spring: Salmon smolt survival can be improved by maintaining water temperatures near 59°F from March 15 to May 15 and as low as practical from May 16 to June 15. I base my recommendation on the temperature criteria recommended by the U.S. Environmental Protection Agency's Region 10 (EPA) to protect salmon and trout (EPA 2003) and my analyses of rotary screw trap catch data and adult recruitment (number of salmon that survive to Age 2 and are large enough to be caught in the ocean fishery) in the Tuolumne River (Mesick 2009). Water temperatures greater than 59°F impair smoltification and increase the risk of disease (Table 1 in EPA 2003). Impaired smoltification delays the migration of smolts from the tributaries until late spring when many succumb to the combined effects of high water temperatures, disease, unsuitable water quality (pesticides, ammonia, selenium, low dissolved oxygen, etc.), and high predation rates in the Delta (Section 4.2 in FMWG 2009). The EPA temperature criteria apply to the San Joaquin River Basin salmon populations because smolt outmigration rates and adult recruitment were highest when water temperatures were at or below 59^{o}F when smolts were migrating in the lower Tuolumne River (Mesick 2009).

To maintain mean water temperatures near 59^{o}F and maximum temperatures below 65^{o}F from March 15 to May 15 in the tributaries downstream to the confluence with the San Joaquin River, it will be necessary to gradually increase flow releases in response to seasonal increases in air temperature. I used the flow and water temperature estimates produced by the San Joaquin River Basin-Wide Water Temperature Model based on the HEC-5Q computer simulation model (AD Consultants and others 2009) for the period between 1984 and 2004 to make my recommendations in Table 1 (Mesick 2010a).

Tributary flow requirements should also include (1) base flows of 275 cfs to provide spawning and rearing habitat for Central Valley steelhead and fall-run Chinook salmon; (2) up-ramping rates of no more than 2,000 cfs per day and down-ramping rates of no more than 500 cfs during winter and spring, except at the cessation of spring pulse flows during Above Normal and Wet years, when down-ramping rates should be 100 cfs per day to promote riparian tree seedling survival (USFWS 2005).

Table 1. Recommended flow releases for the Stanislaus, Tuolumne, and Merced rivers during dry, normal, and wet water year types to provide attraction cues for migrating adult salmon in October, floodplain inundating flows beginning between February 15 and March 15, and maintain mean water temperatures near 59^{o}F and maximum temperatures below 65^{o}F to the confluence with the San Joaquin River from March 15 to June 15 (Mesick 2010 c).

	Critical and Dry	Below Normal	Above Normal	Wet Water Year
Oct 20-29	1,200 cfs	1,200 cfs	1,200 cfs	1,200 cfs
Beginning Feb 15 to Mar 15	3,000 cfs, 2 days	3,000 cfs, 16 days 6,000 cfs, 2 days	3,000 cfs, 13 days 6,000 cfs, 5 days	3,000 cfs, 17 days 6,000 cfs, 5 days
March 15-31	1,000 cfs	1,000 cfs	1,000 cfs	3,000 cfs
April 1-15	1,500 cfs	1,500 cfs	1,500 cfs	3,000 cfs
April 16-20	2,000 cfs	2,000 cfs	2,000 cfs	3,000 cfs
April 21-30	275 cfs	2,000 cfs	2,000 cfs	3,000 cfs
May 1-15	275 cfs	2,500 cfs	2,500 cfs	3,000 cfs
May 16 – June 15	275 cfs	275 cfs	275 cfs	≥ 3,000 cfs[1] ≥ 4,000 cfs[2]

[1]Stanislaus and Merced River Releases
[2]Tuolumne River Releases

Implementing the recommended flow schedules in Table 1 will require increasing the fishery flow volumes for the Stanislaus River during Above Normal water years and rescheduling flow releases during the other water year types (Mesick 2010c). For the Tuolumne River, it will be necessary to augment fishery flow volumes during Critical, Dry, and Below Normal water years and reschedule flow releases during Above Normal and Wet years to the extent possible (Mesick 2010 c). For the Merced River, it will be necessary to augment fishery flow volumes during all but Wet water years (Mesick 2010c). Implementation of the recommendation flows could also reduce upstream reservoir storage to a level that would cause unsuitably warm surface waters to be released if water diversions are not reduced. To prevent the release of warm flows, minimum cold water pool volumes will have to be set to constrain diversions, particularly during dry and critical years. It may be possible to install temperature control devices at the dams to increase the volume of the usable cold water pools and thereby decrease potential restrictions on water deliveries. The San Joaquin River Basin-Wide Water Temperature Model (AD Consultants and others 2009) could be used to determine the minimum cold water pools for the reservoirs that would protect the fish populations.

<u>Flow Management in the Deepwater Ship Channel and the Old River:</u> The survival of migrating smolts in the Delta has been low regardless of whether they migrate in the Deepwater Ship Channel or the Old River. In the Deepwater Ship Channel, smolt survival is low due to the unsuitable water quality which is worsened by the abnormal hydraulics of the dredged channel. In the Old River, smolt survival is low due to the high entrainment rates at the Federal and State water pumping stations.

The VAMP studies based on CWT smolt releases at Dos Reis and Jersey Point prior to 2003 when the physical Head of the Old River Barrier (HORB) was installed indicate that there is a positive association between Delta flow and smolt survival (Newman 2008). The VAMP studies also indicate that the HORB minimized the number of smolts that entered the Old River, where they were subject to entrainment, and increased the flows in the Deepwater Ship Channel (Newman 2008).

My analyses of the number of salmon with CWTs that were released as juveniles near Mossdale or Dos Reis and recovered as adults in the ocean harvest and inland escapement, suggest that managing Delta flows that exceed 1,350 cfs and exports that exceed 1,740 cfs have little effect on salmon smolt survival when no physical HORB is installed (Mesick 2010b). It is likely that without the HORB, flow cannot substantially reduce the impacts of the poor water quality in the Deepwater Ship Channel. In the Old River, export levels that exceed 1,740 cfs result in high rates of entrainment and indirect mortality associated with exports (e.g., predation near the intakes). In addition, flows have little if any effect on spring water temperatures in the Delta (AD Consultants and others 2009, Mesick 2010a).

A method to improve smolt survival rates in the Delta would be to shunt the migrating smolts into the Old River, minimize entrainment at the SWP and CVP pumping facilities including Clifton Court Forebay, and maintain a positive outflow of at least 2,000 cfs during the smolt outmigration period. The 2007 VAMP studies suggest that 69% of the smolts released in the Old River on May 4 survived to the export facilities or downstream (Highway 4) when flows were 350 cfs in the Old River; whereas only 14% of the smolts released at Dos Reis on May 10 survived to a site below Turner Cut (R16) when flows were 2,970 cfs in the San Joaquin River at Mossdale (SJRGA 2008). Therefore, the Old River might be a viable smolt migratory corridor if the impacts of Delta exports were eliminated.

<u>Population Viability</u>: Maintaining viable Chinook salmon populations requires that escapements do not decline below about 833 adult salmon (a total of 2,500 salmon in 3 years), fluctuations in escapement between wet and dry years are reduced by increasing dry year escapements, and the percentages of hatchery fish are reduced to no more than 10% (Lindley and others 2007, pages 29 and 30 in Mesick 2009). Currently, the Tuolumne River population is at a high risk of extinction (Mesick 2009); final analyses have not been conducted for the Stanislaus and Merced rivers, but it is likely that both populations would be considered to be at a high risk of extinction due to high percentages of hatchery fish. Restoring these populations to viable levels will require implementing the recommended flows in Table 1. The Dry year recommendations are needed to keep escapements above the minimum level of 833 adults per year. The Normal and Wet year recommendations are needed to reduce the percentage of hatchery fish in the population to about 10%.

The Table 1 flow recommendations would be expected to increase the total Basin escapements by about 90% compared to the escapements observed from 1967 to 1991 using the population model described by USFWS (2005) and assuming that short duration floodplain inundation would provide 50% of the benefits provided by long-term inundation. Implementing measures to restore the Old River as the primary smolt migration corridor should provide a substantial additional increase in escapements, so that the combined benefits of the Table 1 releases and the Delta measures should be sufficient to achieve the doubling objective. The 2005 recommendation to double the total Chinook salmon production for the Basin (Table 2 in USFWS 2005) should also achieve the doubling objective but may not be sufficient to sustain population viability (minimum escapements of 833 adult salmon) in the Stanislaus and Merced rivers due to inadequate winter and spring flows during the Critical and Dry years.

VAMP Protective Measures: The VAMP protective measures implemented since 1995 failed to increase salmon escapements in the Stanislaus and Tuolumne Rivers. In the Tuolumne River, the recruitment of naturally produced adult salmon declined by 50% after the 1987 to 1992 drought (Mesick 2009). In the Stanislaus River, the mean recruitment of natural and hatchery adults declined from 15,718 fish per year from 1984 to 1996 to 12,752 fish per year from 1997 to 2004 (Mesick and others 2009). In the Merced River, the mean recruitment of natural and hatchery adults increased from 8,536 fish per year from 1984 to 1996 to 12,642 fish per year from 1997 to 2004 (Mesick and others 2009). It is unlikely that the population declines in the Stanislaus and Tuolumne rivers were related to ocean conditions because the mean Coastal Upwelling Index, which is highly correlated with salmon food resources in the ocean, was higher from 1996 to 2004 than from 1980 to 1995 (Mesick 2009). The low escapements in 2007 and 2008, which resulted from poor ocean conditions in 2005 and 2006, were abnormal considering that the wet year conditions in 1983 and 1998 produced high escapements when ocean conditions were worse than in 2005 and 2006 (Mesick 2009).

It is likely that the VAMP protective measures failed to increase escapements in the Tuolumne and Merced rivers for three reasons. First, the pulse flows were implemented too late to improve fry survival or protect the early migrating smolts in the tributaries (Mesick 2009). Second, the survival of fry and smolts is primarily dependent on flows in the tributaries rather than the Delta (Mesick 2009) and so flow standards are needed for each tributary. Finally, the HORB provided only minimal improvements in the Deepwater Ship Channel. The Merced River escapements probably increased during VAMP, because there were no spring pulse flow releases in the Merced River during Dry and Normal water years prior to VAMP, and so the VAMP pulse flows would have improved the survival of hatchery smolts that were released in the Merced River during the pulse flows.

Scientific Uncertainty: Future Delta smolt survival studies need to focus on environmental factors that affect survival in both the Deepwater Ship Channel and the Old River when no physical HORB is installed. These should include (a) on-site bioassay labs that evaluate the potential lethal and sublethal impacts of water quality, contaminated food, water temperature, and disease; (b) studies that quantify predation rates on smolt survival in the Old River and mainstem; (c) studies of direct and indirect impacts of exports on smolt survival in the Old River; and (d) evaluations of non-physical barriers to direct fish into the Old River or the Deepwater Ship Channel. Flow protective measures should be used to protect the natural migrants beginning in mid-March and should not be delayed for the purposes of studies.

Supporting Exhibits

AD Consultants, Resource Management Associates, Inc., and Watercourse Engineering, Inc. 2009. San Joaquin River Basin water temperature modeling and analysis. Prepared for CALFED, ERP-06D-S20. Moraga, California. October 2009.

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[FMWG] Fisheries Management Work Group. 2009. Conceptual models of stressors and limiting factors for San Joaquin River Chinook salmon. San Joaquin River Restoration Program Technical Memorandum. 178 pages. June 2009. Available at: http://www.restoresjr.net/program_library/03-Tech_Memoranda/index.html

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Mesick, C.F. 2009. The High Risk of Extinction for the Natural Fall-Run Chinook Salmon Population in the Lower Tuolumne River due to Insufficient Instream Flow Releases. Report prepared for the U.S. Fish and Wildlife Service, Sacramento, CA. Manuscript submitted to the *California Fish and Game* journal in October 2009.

Mesick, C.F., D. Marston, and T. Heyne. 2009. Estimating recruitment for fall-run Chinook salmon populations in the Stanislaus, Tuolumne, and Merced rivers. Report prepared for the U.S. Fish and Wildlife Service, Sacramento, CA. Manuscript to be submitted to a peer reviewed journal by October 2009.

Mesick, C.F. 2010a. Relationships between flow and water temperature in the Stanislaus, Tuolumne, and Merced rivers near their confluences with the San Joaquin River and in the San Joaquin River near Mossdale from March 15 to May 15. Report produced on behalf of the California Sportfishing Protection Alliance.

Mesick, C.F. 2010b. Relationships between flow, water temperature, and exports in the San Joaquin River Delta and the rate that adult Merced River Hatchery fall-run Chinook salmon with coded-wire-tags were recovered in the Central Valley escapement and the ocean fisheries. Report produced on behalf of the California Sportfishing Protection Alliance.

Mesick, C.F. 2010c. Instream flow recommendations for the Stanislaus, Tuolumne, and Merced rivers to maintain the viability of the fall-run Chinook salmon populations. Report produced on behalf of the California Sportfishing Protection Alliance.

Newman, K.B. 2008. An evaluation of four Sacramento-San Joaquin River Delta juvenile salmon survival studies. Report prepared for the CalFed Science Program, Project number SCI-06-G06-299.

San Joaquin River Group Authority. 2008. 2007 Annual Technical Report - On implementation and monitoring the San Joaquin River Agreement and the Vernalis Adaptive Management Plan. Prepared by the San Joaquin River Group Authority for the California Water Resource Control Board.

[USFWS] U.S. Fish and Wildlife Service. 2005. Recommended Streamflow Schedules to meet the AFRP Doubling Goal in the San Joaquin River Basin. 27 September 2005. Prepared by the Anadromous Fish Restoration Program, USFWS, 4001 N. Wilson Way, Stockton.

[USFWS] U.S. Fish and Wildlife Service. 2008. Flow-overbank inundation relationship for potential fall-run Chinook salmon and steelhead/rainbow trout juvenile outmigration habitat in the Tuolumne river. Prepared by staff of The Energy Planning and Instream Flow Branch, Sacramento. 15 pp.