EXHIBIT NO. DFG-17

DRAFT

Limiting Factor Analyses & Recommended Studies for

Fall-run Chinook Salmon

and

Rainbow Trout

in the Tuolumne River

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by

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Executive Summary

Historically, annual Tuolumne River adult fall-run Chinook salmon spawning escapement has ranged from pre-New Don Pedro Federal Energy Regulatory Project No. 2299 levels of more than 40,000 fish to less than one hundred fish during the six year drought in the late 1980's and early 1990's. This large fluctuation in escapement led Tuolumne River resource managers to initiate large scale restoration actions in the mid-1990's that included improving spawning habitat and restoring captured mine pits to reduce predation of juvenile salmon. In 1996, minimum instream flows for the Tuolumne River were increased to improve the quantity and quality of spawning and rearing habitat and pulse flows were implemented to improve adult and juvenile migratory conditions in the river and the Delta. At the same time, protective actions were initiated in the Delta by the State Water Resources Control Board that curtailed exports to reduce juvenile entrainment mortality and installed of a Head of the Old River barrier that improved smolt survival when San Joaquin River flows were less than 7,000 cfs. However, spawning escapements in the Tuolumne River returned to levels below 1,000 fish in fall 2005 and 2006. Resource managers had hoped restoration and smolt protection efforts would prevent the large scale escapement fluctuation and especially the "bottoming-out" of the salmon population. During the same period, Central Valley steelhead were listed as a protected species under the Endangered Species Act and determining their status in the Tuolumne River as well as the status of resident rainbow trout has become another high priority.

To help guide the recovery of the Chinook salmon and rainbow trout populations in the Tuolumne River, we developed a Tuolumne River Management Conceptual Model (Model) that includes a limiting factor analysis of the Tuolumne River populations, unanswered management questions and related testable hypotheses, and recommended studies and experimental instream flow schedules needed to test the hypotheses.

The limiting factor analyses suggest that Chinook salmon recruitment, which is the total number of adults in the escapement and harvested in the sport and commercial fisheries in the ocean, is highly correlated with the production of smolt outmigrants in the Tuolumne River and that winter and spring flows are highly correlated with the number of smolts produced. Other evidence from rotary screw trap studies indicate that many more fry are produced in the Tuolumne River than can be supported with the existing minimum instream flow schedules, and so, producing more fry by restoring spawning habitat is unlikely to increase adult recruitment. Stock-recruitment relationships based on the long-term escapement and harvest data suggest that the rearing habitat is saturated with juvenile fish when at least 500 adults return to spawn. Low spawner abundances (< 500 fish) have occurred as a result of extended periods of drought when juvenile survival is reduced as a result of low winter and spring flows and not as a result of high rates of ocean harvest. And other factors, such as cyclic changes in ocean productivity, Delta export rates, and Microcystis blooms do not explain the trends in the Tuolumne River population. Based on these results, the Model for Chinook salmon focuses on winter and spring flows in the Tuolumne River as key factors controlling the production of adult

Chinook salmon. The Model for Central Valley steelhead also includes winter and spring flows in addition to summer flows and water temperatures as key controlling factors.

A series of management questions and testable hypotheses were developed from these Models that are critical for the effective management of the salmon and trout populations in the Tuolumne River. The most important question for Chinook salmon is to determine the timing, duration, and magnitude of winter and spring flows that will most effectively increase smolt production and adult recruitment. Alternative questions were also posed to compare the importance of fry rearing in the Delta, fall pulse flows to facilitate the upstream migration of adult salmon through the Delta, fall base flows to protect spawning adults and their developing eggs, spawning habitat restoration versus floodplain restoration, ocean conditions, and ocean harvest with the importance of winter and spring flows on the production of salmon smolts and adult salmon recruitment.

To test these hypotheses, several overall recommendations were made. First, the hypotheses should be simultaneously tested with three different metrics: (1) adult recruitment; (2) juvenile production; and (3) the response of individual juveniles. Together, these three metrics should be able to demonstrate both the response of the population to various management and restoration actions and the underlying cause-and-effect mechanisms. We also suggest that an experimental flow schedule will be needed to help distinguish between the effects of natural flooding and controlled reservoir releases.

Another recommendation is that a source of hatchery reared juvenile salmon may be needed to calibrate rotary screw traps and for other studies that must tag many juveniles to evaluate the importance of fry production (spawning) versus the abundance of smolts outmigrants (rearing) and river rearing versus Delta rearing. Many of the past studies in the Tuolumne River and throughout the San Joaquin Basin have been hampered by the lack of study fish. We also suggest that the Tuolumne River stock should be used to produce the study fish so that potential genetic impacts to the natural population are minimized.

Finally, monitoring studies are described that would help determine (1) the status of the rainbow trout and Central Valley steelhead populations in the Tuolumne River; and (2) how summer flows affect the quantity and quality of rearing habitat, juvenile survival, and the trends in population abundance over time.

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Introduction

Purpose

This paper describes a Tuolumne River Salmonid Management Conceptual Model (Model) that provides a plausible explanation of how environmental factors, including streamflow and habitat restoration, affect the abundance of fall-run Chinook salmon (*Oncorhynchus tshawytscha),* rainbow trout (*O. mykiss*), and Central Valley steelhead (*O. mykiss*) in the Tuolumne River. The Models for these species are based on limiting factor analyses that are summarized in this report. The main function of the Models is to help identify the gaps in our knowledge that are critical for effective management of the salmonid populations in the Tuolumne River. We developed testable hypotheses for each knowledge gap and recommended monitoring studies and experimental flow schedules that would address those hypotheses.

This paper is intended to be a living document that, in the spirit of adaptive resource management, will be updated as new information regarding management action effectiveness becomes clear. We intend that others will provide information to update this conceptual model over time and will participate in its development and implementation. As a result, we will always consider this paper to be a draft in progress.

Background

The Tuolumne River is located in California's southern Central Valley (Figure 1). The Tuolumne is the largest of the three primary San Joaquin River (SJR) salmonid bearing streams, having a watershed area of 1,540 square miles and an unimpaired mean monthly flow of 1,456 cubic feet per second (cfs). The combined reservoir storage volume for Tuolumne River dams is 2,777,000 acre-feet (AF) [i].

Salmon

There is a self-sustaining, native population of fall-run Chinook salmon (salmon) in the Tuolumne River. Although the Tuolumne River population is thought to primarily consist of naturally produced fish, some of the returning adults are known to be juveniles that were reared in the Merced River Hatchery and released in the Tuolumne, Stanislaus, Merced, and San Joaquin rivers for studies. The population also includes hatchery fish from the Mokelumne, American, and Feather rivers as well as the Coleman fish hatchery on Battle Creek that were released as juveniles outside of the San Joaquin Basin but returned (strayed) to the Tuolumne River as adults. For now, our population trend analyses do not distinguish between the naturally produced and hatchery reared fish. In the future, we hope to segregate these two groups of fish based on the recoveries of some of the adult hatchery fish that were fin clipped and coded-wire tagged as juveniles at the hatcheries.

The abundance of naturally produced and hatchery reared salmon in the Tuolumne River has declined in recent history. The average adult salmon production[ii], which includes both the salmon that returned to spawn and those that were harvested in the ocean, declined from a mean of 18,996 from 1967 to 1991 to a mean of 10,324 from 1992 to 2004 (approximately a 46% decline). To help reverse this decline, many actions were identified and implemented in the Tuolumne River and Delta. These include (a) increasing minimum instream flows in the Tuolumne River, (b) restoring spawning and rearing habitats in the Tuolumne River, (c) reducing south Delta Exports, and (d) reducing ocean harvest. To date, approximately $22,250,000 has been invested in physical habitat restoration alone in the Tuolumne River. Despite these management actions, the Tuolumne River salmon population continues to decline. Therefore, it is timely to update the foundational framework guiding Tuolumne River flow management and habitat restoration.

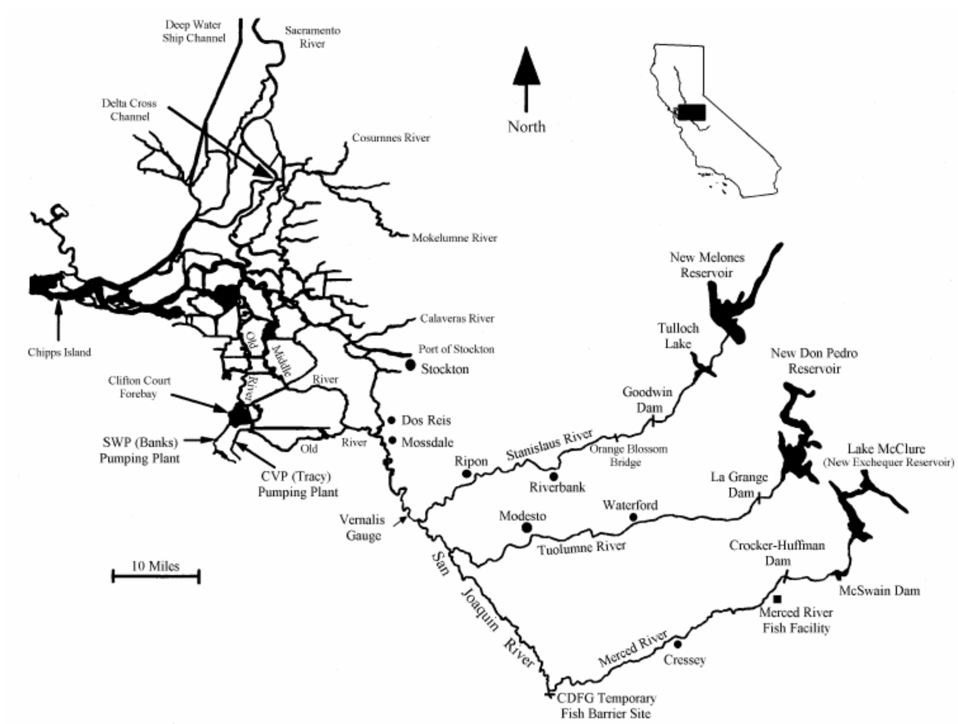

Figure 1. Map of the Stanislaus, Tuolumne, Merced and San Joaquin rivers and the Sacramento-San Joaquin Delta.

Trout

The Tuolumne River provides habitat for and sustains populations of rainbow trout (trout) and presumably Central Valley steelhead as well. Steelhead, which is the migratory form of rainbow trout, is thought to occur in the Tuolumne River. Both adult and juvenile steelhead have been documented in neighboring SJR tributaries to the north and south (e.g. Stanislaus and Merced Rivers respectively). In the Tuolumne River, juvenile trout have been captured with rotary screw traps and beach seines and adult trout that have typical steelhead characteristics have been caught and photographed by anglers primarily in the area between La Grange Dam and Roberts Ferry Bridge. However, microchemical analyses of 12 otoliths taken from trout captured in the Tuolumne River indicate that none had migrated to the ocean, which is the defining characteristic for steelhead. Considering the difficulties in sampling the relatively rare steelhead, the National Marine Fisheries Service (NMFS) considers steelhead to be present in a river if the river has both a resident rainbow trout population and has continuity with the ocean. The Tuolumne River meets both of these requirements.

The low productivity of Central Valley steelhead resulting from the loss of a vast majority of historic spawning areas in the Central Valley and a lack of sufficient knowledge about steelhead are areas of concern to the Agencies. NMFS listed the Central Valley steelhead Distinct Population Segment (DPS) as threatened on January 5, 2006. The listing includes all naturally-produced Central Valley steelhead in the Sacramento and San Joaquin basins. Central Valley steelhead are widely distributed throughout their range but are low in abundance, particularly in the San Joaquin Basin, and their abundance continues to decline (National Marine Fisheries Service 2003). The Agencies regard the anadromous life-history form as a critical component of the diversity of the *O. mykiss* population and are very concerned by the reduced expression of the anadromous life-history form as a result of the many impassable dams. Impassable dams also reduce population abundance and prevent the exchange of migrants among resident populations.

Effective management of the Central Valley steelhead population in the lower Tuolumne River has been hampered by a lack of basic population data. For example, there are little or no data on the percentages of steelhead and rainbow trout in the population, their abundance and distribution in the river, or the effects of flow on their populations. Therefore, the Agencies recommend that basic population studies should be conducted for migratory and resident rainbow trout in the lower Tuolumne River.

Limiting Factor Analyses

The Agencies are developing conceptual models for the salmon and trout populations in the Tuolumne River by first evaluating trends in the salmon population relative to flow and other habitat conditions in the river, Delta, and ocean. The result of these trend analyses provides a likely explanation of how ecosystem processes, including flow management and restoration, affect the production of adult Chinook salmon and adult Central Valley steelhead in the Tuolumne River. However, the trend analyses alone do not provide proof of cause-and-effect mechanisms and there are numerous data gaps, and therefore, they primarily help develop key hypotheses regarding ecosystem effects on salmonid populations. The Agencies refer to this set of hypotheses as their conceptual model. The Agencies envision that their conceptual model and corresponding sets of hypotheses would be tested with a two level approach: (1) monitor the response of the salmonid populations to manipulations of flow and physical habitat; and (2) monitor the response of individual fish to show the cause-and-effect mechanism(s) that drive the observed response of the population to the habitat manipulations.

Fall-run Chinook Salmon

The historical abundance of Tuolumne River salmon, as indicated by annual adult salmon escapement abundance estimates (Figure 2), has fluctuated greatly over time. Fishery managers frequently use correlation analyses to help identify environmental factors that may cause population fluctuations. In the San Joaquin Basin, it has long been recognized that the most critical stage for the San Joaquin Basin salmon populations occurs when the juvenile fish rear and then migrate toward the ocean in the spring. Therefore, correlation analyses typically use an index of juvenile production as the dependent variable to be compared against various environmental factors, such as flow, spawner abundance, Delta export rates, ocean harvest rates, etc., as the independent variables. The most commonly used index of juvenile production is adult recruitment, which is the abundance of same aged fish that survived in the ocean to maturity.

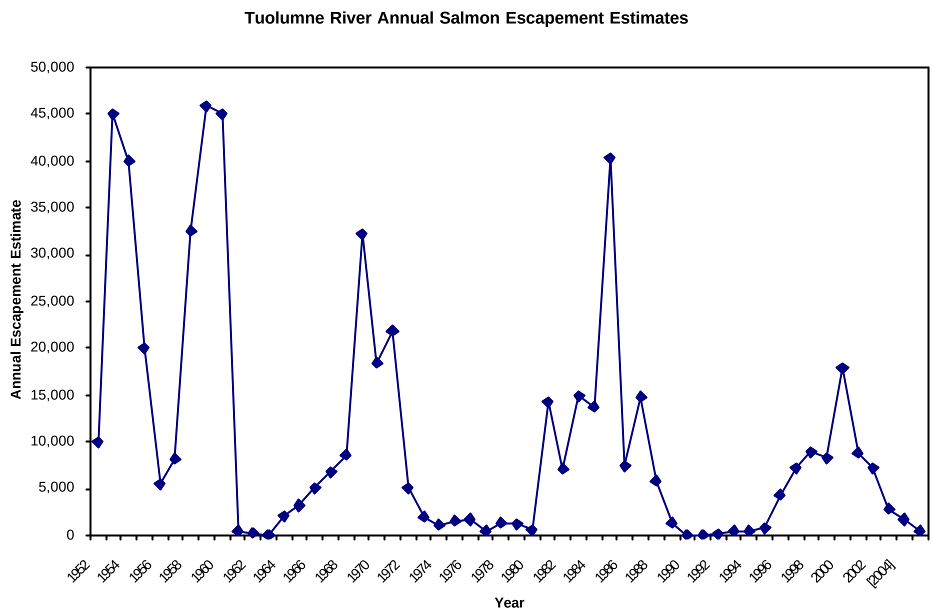

Figure 2. Tuolumne Fall-run Chinook Salmon Annual Escapement Estimates.

The estimates of adult recruitment reported here were computed by first estimating the number of naturally produced salmon in the Tuolumne River escapements. This was done by first expanding the number coded-wire-tagged (CWT) hatchery adults that returned to the Tuolumne River. The total number of CWT fish was computed as the number of CWT salmon recovered during the escapement surveys, multiplied by the total escapement estimates, and divided by the number of salmon examined for tags during each escapement survey. The CWT fish were identified during the escapement surveys by the presence of an adipose fin clip. The numbers of fish examined for tags during each year, which usually included only the fresh and decayed but not skeleton carcasses, were provided by Steve Khirihara, a Turlock Irrigation District biologist who participated in many of the surveys.

The second step in computing recruitment estimates was to estimate the number of unmarked hatchery fish in the Tuolumne River escapement. The number of unmarked fish released from each hatchery was obtained from the CDFG annual reports for the Feather, Nimbus, Mokelumne, and Merced hatcheries. The estimated numbers of unmarked returns to the Tuolumne River are based on the assumption that the unmarked hatchery fish would have returned to the Tuolumne River at the same rates that the marked hatchery fish returned to the Tuolumne River. The CWT recoveries indicate that almost all of the adult hatchery fish in the Tuolumne River originated from Bay releases from the Nimbus and Feather River hatcheries, Delta and Bay releases from the Mokelumne Hatchery, and Tuolumne and Merced river releases from the Merced River Hatchery. Correlation analyses indicated that there were no statistically significant relationships between water year type or ocean conditions and the rate that juvenile hatchery fish returned to the Tuolumne River. Therefore, CWT return estimates for the Tuolumne River were used to estimate the number of unmarked returns for those same years; whereas the mean rates of CWT returns to the Tuolumne River were used to estimate the number of unmarked returns for all the other years in the study period (Table 1). The number of unmarked juveniles from each hatchery was multiplied by the corresponding CWT recovery rate and then the number of returns was segregated into cohorts based on the mean percentage of each age class in the Tuolumne River escapement based on scale analysis described in Mesick et. al. 2007: 31.2% for Age 2, 50.7% for Age 3, and 17.2% for Age 4. The estimates of natural and hatchery reared Chinook salmon in the Tuolumne River are presented in Table 2. They are preliminary because the estimates estimated CWT return rate for Merced River Hatchery releases to the Tuolumne River do not include all CWT releases for which there were no adult returns. As a result, it is likely that the estimates of unmarked Merced River Hatchery fish that returned to the Tuolumne River are overestimated to a small degree. Future analyses will include all CWT releases from the Merced River.

Table 1. The years with estimates of the number of adult hatchery Chinook salmon with Coded-Wire-Tags (CWT) that returned to the Tuolumne River, the release location of the juvenile hatchery fish, and the mean CWT return rate for the Feather, Nimbus, Mokelumne River, and Merced River hatcheries.

Hatchery	Release Location	Years with CWT Return Estimates	Mean CWT Return Rate
Feather River	Bay	1978 - 2004	0.00373%
Nimbus	Bay	1983, 1984, 1986 to 1990, 2001, and 2002	0.000853%
Mokelumne River	Bay	1987, 1989, and 1995 to 2000	0.02331%
Mokelumne River	Delta	1992, 1994, and 1998 to 2002	0.01179%
Merced River	Merced River	1995 and 1998 to 2004	0.0197%

Table 2. The Department of Fish and Game estimated escapement of fall-run Chinook Salmon in the Tuolumne River (GrandTab), the estimated total number of marked (coded-wire tag and adipose clipped) hatchery adults that returned to the Tuolumne River, the preliminary estimates of the number of unmarked hatchery adults from the Mokelumne, Nimbus, Feather, and Merced river hatcheries that returned to the Tuolumne River, the preliminary estimates of escapement of naturally produced adults, the preliminary estimates of escapement of hatchery produced adults, and the percent hatchery fish in the escapement from 1981 to 2005. The estimates of unmarked adults are based on bay releases from the Nimbus and Feather River hatchery, Delta and Bay releases from the Mokelumne Hatchery, and Merced River releases from the Merced River Hatchery. The estimates of natural escapement were truncated at zero.

			Unmarked Hatchery Adults						
	Total Escapement	Marked Hatchery Adults	Mokelumne Hatchery	Nimbus Hatchery	Feather River Hatchery	Merced River Hatchery	Estimated Natural Escapement	Estimated Hatchery Escapement	Percent Hatchery
1981	14,253	0	48	1	2	10	14,192	61	0.4%
1982	7,126	30	87	17	697	0	6,295	831	11.7%
1983	14,836	433	91	35	1,107	0	13,170	1,666	11.2%
1984	13,689	31	80	24	375	0	13,180	509	3.7%
1985	40,322	208	62	5	0	5	40,042	280	0.7%
1986	7,404	153	34	12	0	7	7,198	206	2.8%
1987	14,751	1,619	31	51	0	41	13,009	1,742	11.8%
1988	5,779	277	33	56	0	78	5,336	443	7.7%
1989	1,275	175	38	17	0	47	998	277	21.7%
1990	96	98	34	32	0	20	0	184	100.0%
1991	77	20	30	51	0	18	0	119	100.0%
1992	132	23	47	26	0	13	23	109	82.7%
1993	471	115	60	26	0	10	260	211	44.8%
1994	506	107	72	30	0	4	293	213	42.2%
1995	827	142	79	29	35	0	542	285	34.5%

	Total Escapement	Marked Hatchery Adults	Unmarked Hatchery Adults: Mokelumne Hatchery	Nimbus Hatchery	Feather River Hatchery	Merced River Hatchery	Estimated Natural Escapement	Estimated Hatchery Escapement	Percent Hatchery
1996	4,362	1,046	58	35	56	390	2,777	1,585	36.3%
1997	7,146	1,321	15	37	19	622	5,133	2,013	28.2%
1998	8,910	1,413	0	35	0	211	7,251	1,659	18.6%
1999	8,232	1,043	61	34	0	97	6,996	1,236	15.0%
2000	17,873	1,053	115	36	0	159	16,510	1,363	7.6%
2001	8,782	1,561	190	37	0	64	6,930	1,852	21.1%
2002	7,173	2,650	241	24	55	14	4,189	2,984	41.6%
2003	2,163	497	159	19	97	9	1,382	781	36.1%
2004	1,984	473	109	32	52	4	1,314	670	33.7%
2005	500	55	211	38	17	3	177	323	64.6%

We deconvolved the escapement estimates into estimates of single cohorts using a combination of age analyses of scale samples from 1981 to 2002 and length-frequency data from 1981 to 2005 from adult fish collected in the Tuolumne River (Mesick et al. 2007). We then computed the estimates of adult recruitment by expanding the escapement cohort estimates to include the number of Central Valley fish harvested in the commercial troll and sport fisheries as reported annually by the Pacific Fishery Management Council, Oregon (Mesick et al. 2007). These estimates form the basis of our correlation analyses between adult recruitment and the flow, habitat, and stock variables discussed below.

Salmon Abundance and Flow

The intent of the 1996 FERC Settlement Agreement[iii] (FSA) and subsequent modified FERC License No. 2299 (License) Articles 37 and 58 was to improve minimum flow levels from the New Don Pedro Project, implement an adaptive management research program, and restore critical habitat to help recover the fall-run Chinook salmon population in the Tuolumne River. However, the number of adult Tuolumne River fall-run Chinook salmon produced at a given spring flow has significantly declined by about 50% since the FSA was implemented (Figure 3). The statistical test of significance was based on a permutation test conducted by Dr. Allan Hubbard[1] to avoid violations of assumptions for correlation tests resulting from potential autocorrelations in population trend analyses. His analysis indicates that the intercepts of the regressions between the two data sets shown in Figure 3 are significantly different ($P = 0.01$).

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[1] Dr. Allan Hubbard, Assistant Professor of Biostatistics (Division of Biostatistics, School of Public Health, University of California, 101 Haviland Hall, MC 7358, Berkeley, CA 94720

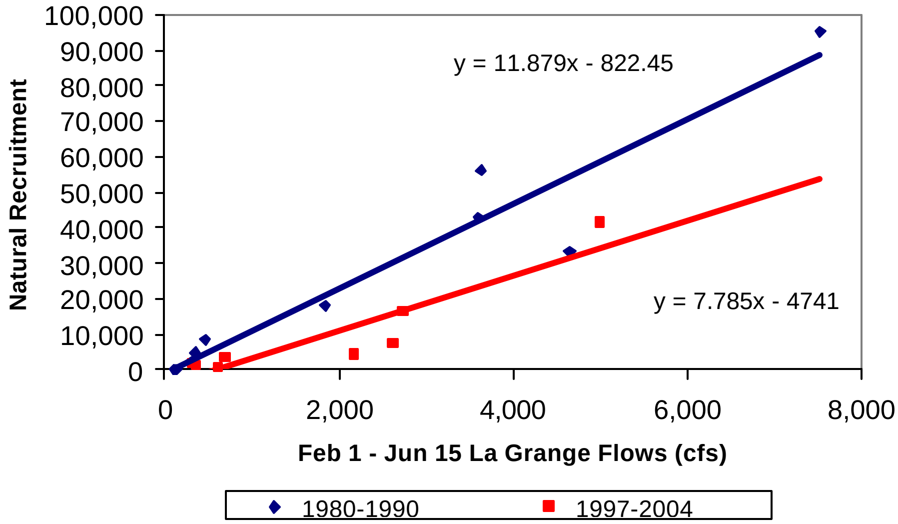

Figure 3. Tuolumne River natural fall-run Chinook salmon recruitment plotted with mean flow in the San Joaquin River at Vernalis during February 1 through June 15 during two periods: 1980 to 1990 (pre-FSA) and from 1997 to 2004 (post-FSA). Recruitment is the number of adults in the escapement and ocean harvest (including shaker mortality) that belong to individual cohorts of same-aged fish (Mesick et al. 2007). Estimates were excluded for which spawner abundance was less than 650 Age 3 equivalent fish to minimize the effect of spawner abundance on the relationship between flow and recruitment.

Prior trend analysis suggests that the number of naturally produced and hatchery adult salmon that return to the lower Tuolumne River is strongly correlated with spring time flow (e.g. April and May) when the fish migrated to the ocean as juveniles (as summarized in Mesick and Marston 2007). The most recent evaluation by Mesick and Marston (2007) indicates that the mean spring flow in the San Joaquin River near Vernalis between March 1 and June 15 explains about 92% of the variation (adjusted R-squared) in total (natural and hatchery) adult recruitment to the Tuolumne River between 1980 and 2003 (Figure 4). Instream flow releases in the Tuolumne River as gauged at La Grange are almost as important as they explain about 82% of the variation in Tuolumne River recruitment. Adding stock abundance and a categorical variable to account for the population change that occurred sometime between 1987 and 1994, increases the amount of variation explained by the Vernalis flow model to about 95%. Other factors, such as *Microcystis* blooms, pyrethroid insecticides, water quality in the Stockton Deep-Water Ship Channel, CVP and SWP Delta export rates, Delta Cross Channel Gate operations, and ocean productivity (e.g., upwelling and Pacific Interdecadal Oscillation) explain relatively little variation in adult recruitment to the Tuolumne, Stanislaus, and Merced rivers (Mesick and Marston 2007).

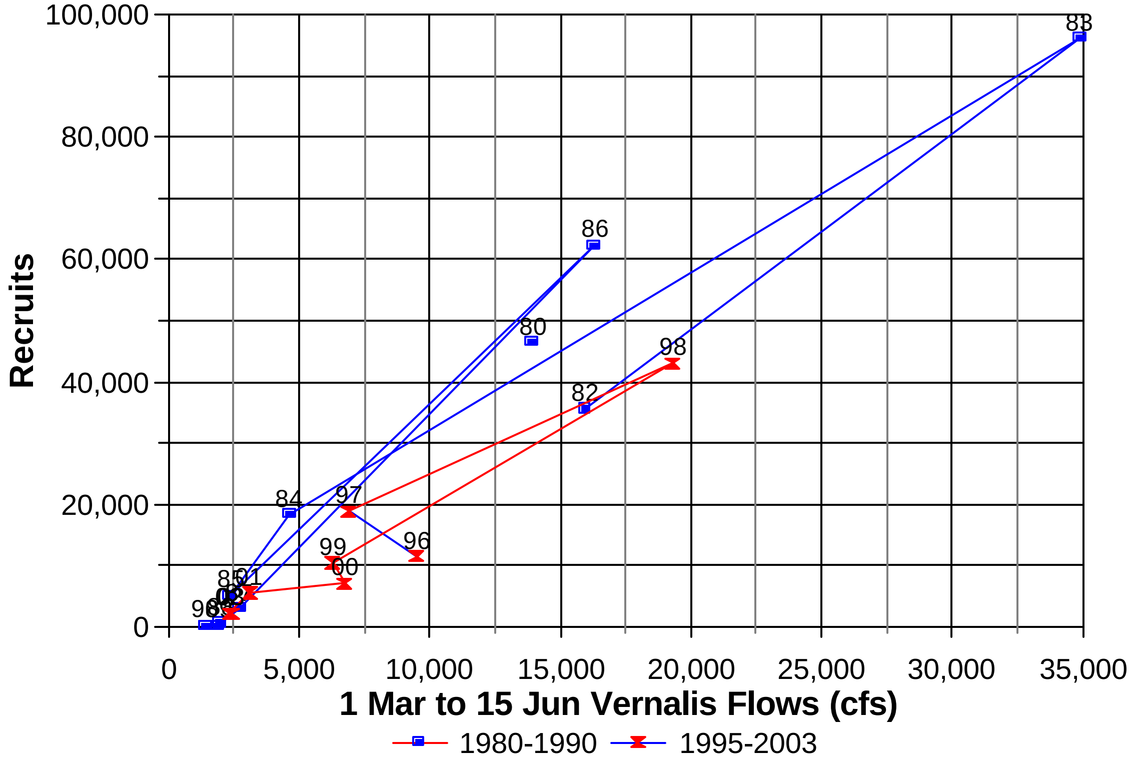

Figure 4. Number of fall-run Chinook salmon recruits to the Tuolumne River plotted with flows in the San Joaquin River at Vernalis from March 1 to June 15 from 1980 to 2003. This analysis excludes recruitment estimates that were affected by a low number of spawners (< 500 Age 3 equivalent fish) to better illustrate the relationship with flow. The recruitment estimates are labeled according to the year when the fish outmigrated as smolts.

Spring flow affects juvenile survival in the Tuolumne River as well as the Delta based on rotary screw trap surveys in the Tuolumne and Stanislaus rivers and coded-wire-tag smolt survival studies in the Tuolumne River and Delta[iv]. Preliminary analyses of rotary screw trap data from the Tuolumne River near Grayson (RM 5.2) suggest that spring flow releases at La Grange from March 1 to June 15 are highly correlated (adj-R^2 = 0.82, P = 0.0005) with the number of Tuolumne River smolt outmigrants passing the Grayson traps at rivermile 5 (Figure 5)[v] and the number of Tuolumne River smolt outmigrants is highly correlated (adj-R^2 = 0.96, P = 0.0004) with the number of Tuolumne River adult recruits (Figure 6).

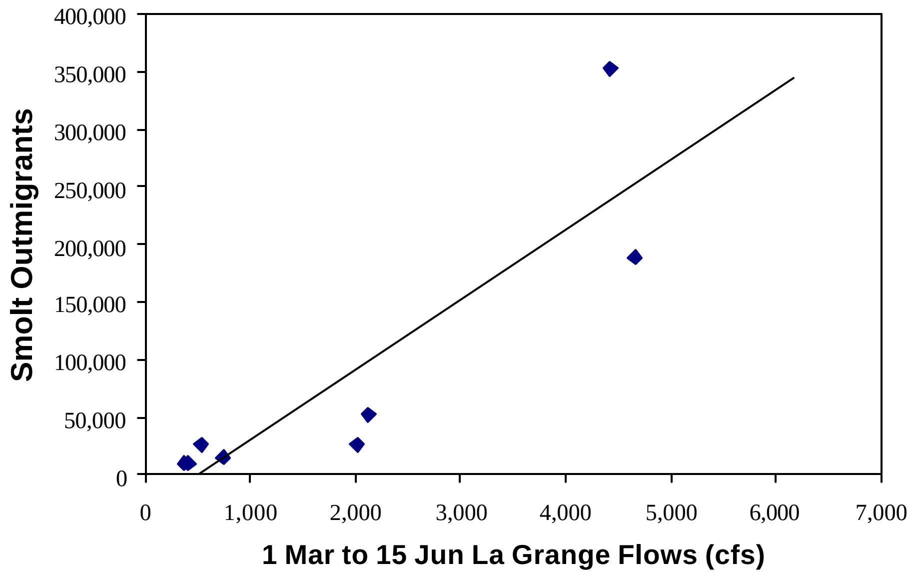

Figure 5. The Number of smolt-sized Chinook salmon outmigrants (FL > 70 mm) passing the Grayson rotary screw trap site (RM 5) plotted with flows at La Grange between March 1 and June 15 in the Tuolumne River from 1998 to 2005. The regression model has an adj-R2 of 0.73 and a probability level of 0.0004.

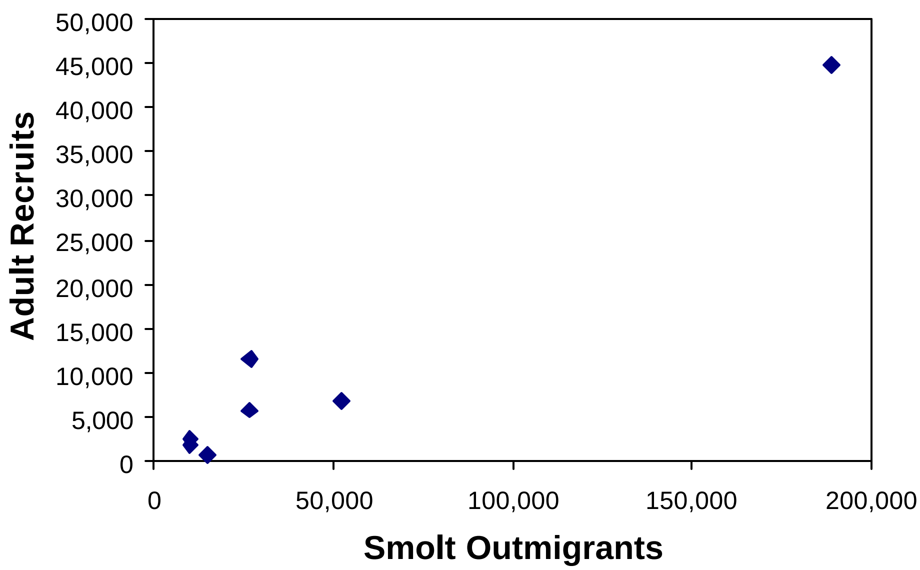

Figure 6. The number of smolt-sized Chinook salmon outmigrants (FL $\geq$ 70 mm) measured at the Grayson rotary screw trap site (RM 5) regressed with the number of adult recruits in the Tuolumne River from 1998 to 2003. The regression model has an adj-R^2 of 0.95 and a probability level of 0.0001.

Critical Flow Periods

Most biologists assume that the survival of salmon smolts through the lower Tuolumne River and the Delta between early April and mid June is the most critical life history stage affecting adult recruitment. However, we present evidence here that there are two critical flow periods affecting adult recruitment: (1) winter flow affects the number of fry that survive to a smolt size in the Tuolumne River and (2) spring flow affects the number of smolts that survive their migration through the Tuolumne River and the Delta. Evidence showing the importance of winter flows for fry rearing and spring flows for smolt outmigration are discussed separately below.

Winter Flows For Fry Rearing

Preliminary evidence that winter flows during February and March may be an important factor controlling the production of smolt-sized juveniles in the Tuolumne River is primarily provided by long-term rotary screw trap studies of juvenile abundance relative to flow patterns, and to a lesser degree, an analysis of the trends in adult recruitment. The rotary screw trap studies provide estimates of the abundance of naturally produced juvenile salmon near the downstream end of the spawning grounds and near the terminal end of the river. Survival indices are computed by dividing the estimated number of fish caught at the terminal end of the river by the estimated number that were captured at the downstream end of the spawning grounds. We consider these estimates to be preliminary, because the traps are not very effective at capturing smolt-sized fish, particularly at high flows, and there is a high degree of variability in the results of the trap efficiency tests that cannot be explained by fish size or flow (Appendix B). We expect that the trap efficiency models will improve as we collect more trap efficiency data. In the meantime, we use these results to help refine our hypotheses.

Ideally monitoring results directly from the Tuolumne River would be used to guide restoration actions on the Tuolumne River. However, in the absence of long term monitoring data from the Tuolumne River at the lower end of the spawning grounds, we also include data from the Stanislaus River, which also has fall-run Chinook salmon and a similar highly confined and degraded channel morphology in the lower river.

In the Stanislaus River during 1998, 1999, and 2000 when flows were high between February and June, the number of juveniles that survived to a smolt size (fork length $\geq$ 70 mm) as they migrated through the lower river averaged 84% (range 74% to 95%). In addition, there were more smolt-sized fish near the terminal end of the river (Caswell State Park at RM 5) than near the lower end of the spawning grounds (Oakdale at RM 40) in April and early May, which suggests that juveniles were successfully rearing in the lower river. The spring 2000 data are shown in Figure 7. However, during 2001 to 2003 when flows were pulsed primarily between mid-April and mid-May, juvenile survival averaged 10% (range 7% to 11%) and there was no evidence of successful rearing in the lower river. The spring 2001 data are shown in Figure 8. These data suggest that flow during February and March might be an important determinant of the number of smolts that migrated from the Stanislaus River.

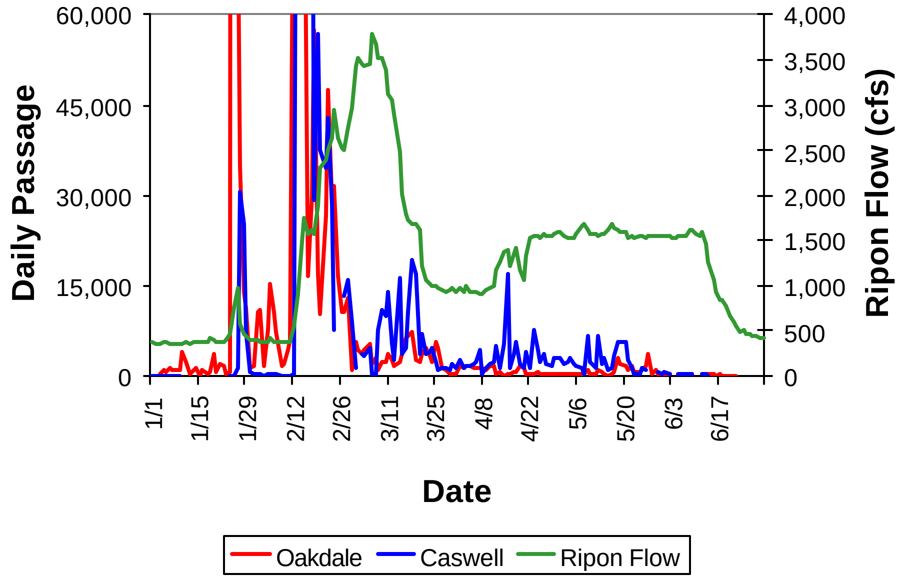

Figure 7. The estimated daily passage at the Oakdale and Caswell Park screw traps plotted with the mean daily flow at Ripon in the Stanislaus River during spring 2000, an Above Normal year. Overall juvenile survival between the Oakdale and Caswell traps was 74% in 2000.

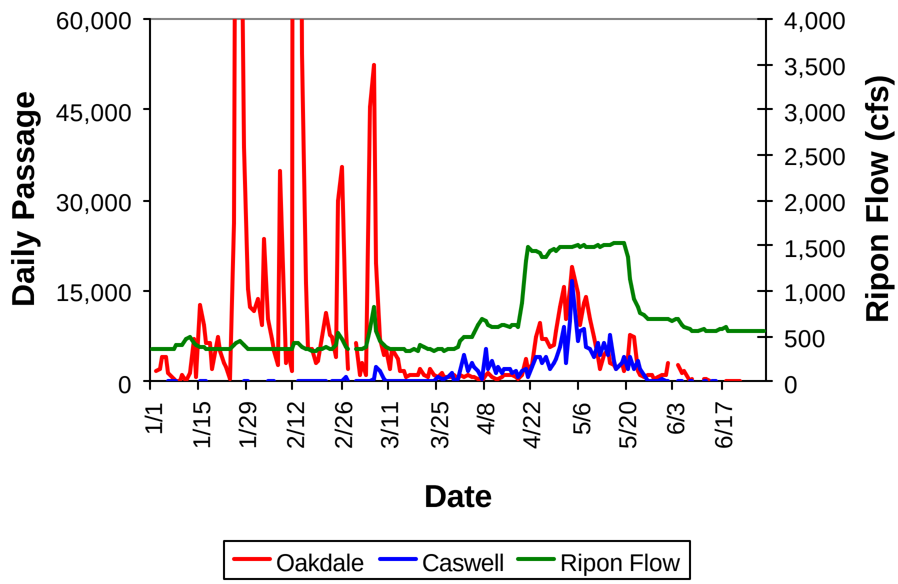

Figure 8. The estimated daily passage at the Oakdale and Caswell Park screw traps plotted with the mean daily flow at Ripon in the Stanislaus River during spring 2001, a Dry year. Overall juvenile survival between the Oakdale and Caswell traps was 11% in 2001.

Rotary screw trapping studies on the Tuolumne River from 1995 to 2005 were primarily focused on determining the number of smolt outmigrants passing from the river as surveyed at the Shiloh (RM 3.4) and Grayson sites (RM 5.2) and so it is not possible to compare the relationship between February and March flows on the relative passage between an upper and lower screw traps as was done with the Stanislaus River data. Screw trap surveys that were conducted between January and late May at Grayson between 1998 and 2006 show the same pattern observed at the Caswell State Park trap site in the Stanislaus River: fry, parr, and smolt passage was high during wet years such as 2000 when there were extended periods of high flows in February and March (Figure 9), moderate during dry years such as 2001 when there moderate periods of high flows in February and March (Figure 10), and low during dry years such as 2002 when only base flows were released between February and early April (Figure 11).

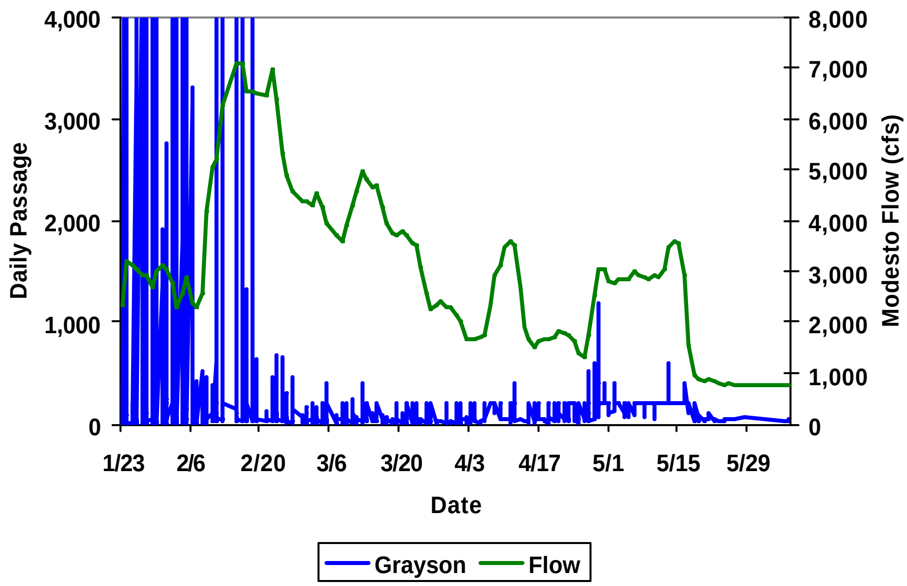

Figure 9. The estimated daily passage (truncated at 6,000 fish/day) at the Grayson screw trap plotted with the mean daily flow at Modesto in the Tuolumne River during spring 1999, an Above Normal year. The total number of all sizes of juvenile out-migrants and smolt-sized (> 70 mm Fork Length) out-migrants was 455,079 and 62,168, respectively.

To further assess the importance of winter flows for fry rearing, we also tested correlations between winter flows, spring flows and adult recruitment for the Tuolumne River. Alone, these analyses cannot fully distinguish between the effects of winter (February and March) and spring (April through mid June) flow due to the problem of multicollinearity between the spring and winter flow variables: when spring flows were high, winter flows were typically high as well. As a result, there is almost no difference in the amount of variation explained by the regression models of adult recruitment that include stock abundance, a categorical variable to account for the population change that occurred sometime between 1987 and 1994, and the mean Vernalis flow estimates for the winter period (February and March) or the spring period (April through mid-June). The

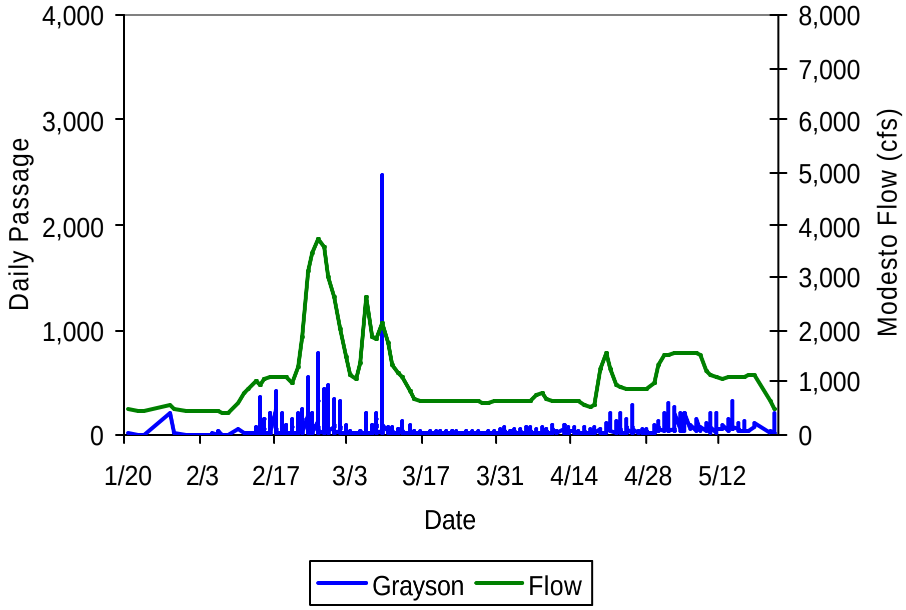

Figure 10. The estimated daily passage at the Grayson screw trap plotted with the mean daily flow at Modesto in the Tuolumne River during spring 2001, a Dry year. The total number of all sizes of juvenile out-migrants and smolt-sized (> 70 mm Fork Length) out-migrants was 111,254 and 34,824, respectively.

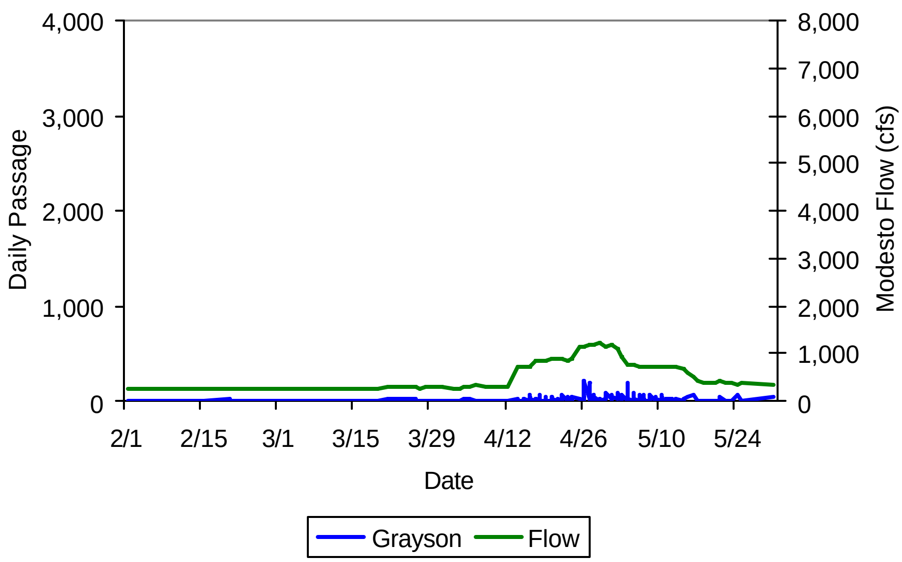

Figure 11. The estimated daily passage at the Grayson screw trap plotted with the mean daily flow at Modesto in the Tuolumne River during spring 2002, a Dry year. The total number of all sizes of juvenile out-migrants and smolt-sized (> 70 mm Fork Length) out-migrants was 13,442 and 13,076, respectively.

model with winter flows has an adjusted R-squared of 0.88 and significance level (*P*) of 0.000; whereas the model with spring flows has an adjusted R-squared of 0.87 and significance level (*P*) of 0.000. When both the winter and spring periods are included in the same regression model, the adjusted R-squared increases to 0.97 and both the winter and spring variables are significant ($P = 0.000$). The coefficients for the flow variables are slightly higher for the spring period (1.51) than the winter period (1.31).

Focusing this analysis on individual annual hydrographs and corresponding adult recruitment also supports our hypothesis that both winter and spring flows are important. When low winter flow occurred with elevated spring flow during 1993 (Figure 12), 3,339 adult recruits were produced (approximately 66% exceedence level). When moderately elevated winter flow occurred with low spring flow during 1984 (Figure 13), 18,369 adult recruits were produced (approximately 22% exceedence level). And when both high winter and spring flows occurred during 1998 (Figure 14), 43,119 adult recruits were produced (approximately 9% exceedence level).

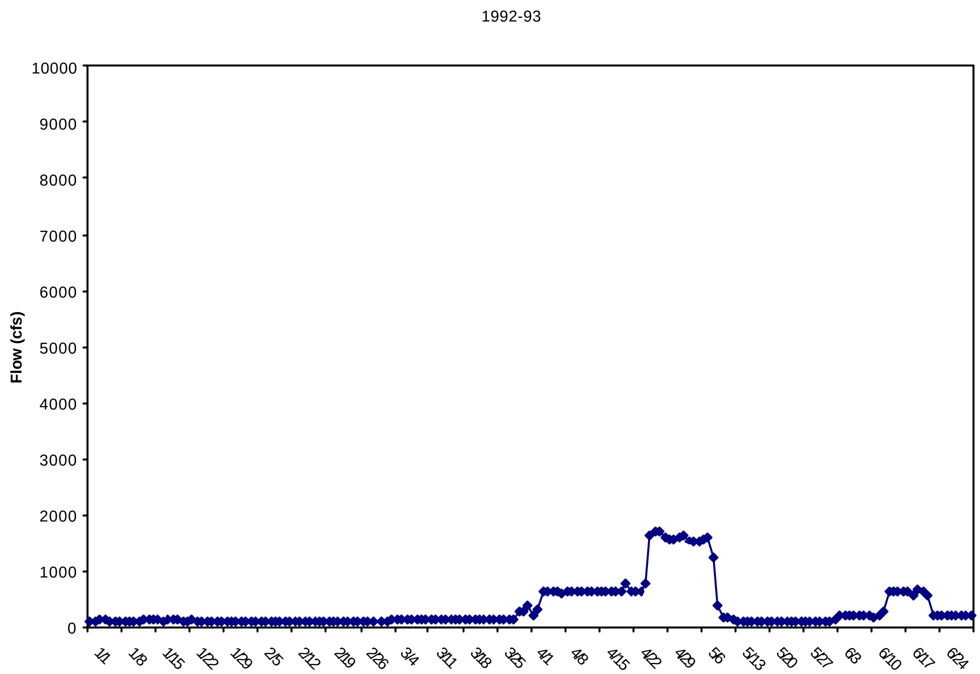

Figure 12. Water Year 1992-93 Winter and Spring Hydrograph (La Grange Flow) when 3,339 adult recruits were produced.

Delta Flow

The Vernalis Adaptive Management Plan[vi] (VAMP) coded-wire-tag (CWT) studies conducted with fish reared at the Merced River Hatchery suggest that the survival of smolts migrating in the San Joaquin Delta between Mossdale and Jersey Point increases from an average of 7% when San Joaquin River flows at Vernalis are about 2,500 cfs to an average survival of 14.5% when Vernalis flows are increased to 5,000 cfs (SJRGA 2005)[vii]. The CWT studies also indicate that smolt survival is more strongly correlated with San Joaquin River flows at Vernalis, which ranged between 2,500 cfs and 6,500 cfs, than with Delta exports, which ranged between 1,450 and 2,350 cfs during the VAMP study period (SJRGA 2005).

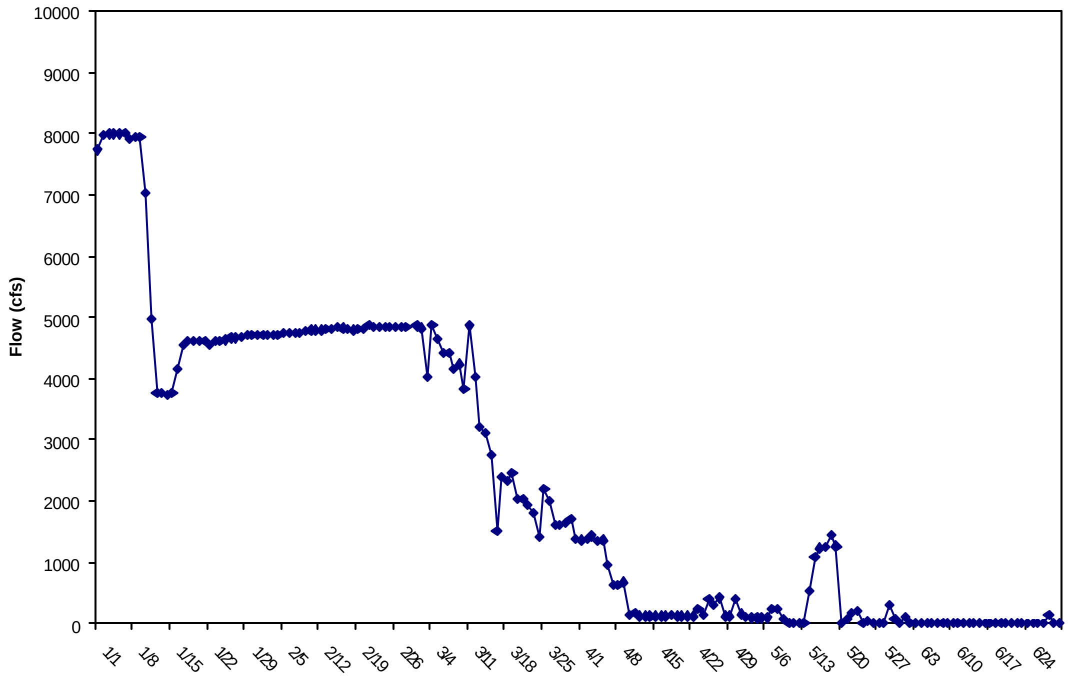

Figure 13. Year 1983-84 Winter and Spring Hydrograph (La Grange Flow) when 18,369 adult recruits were produced.

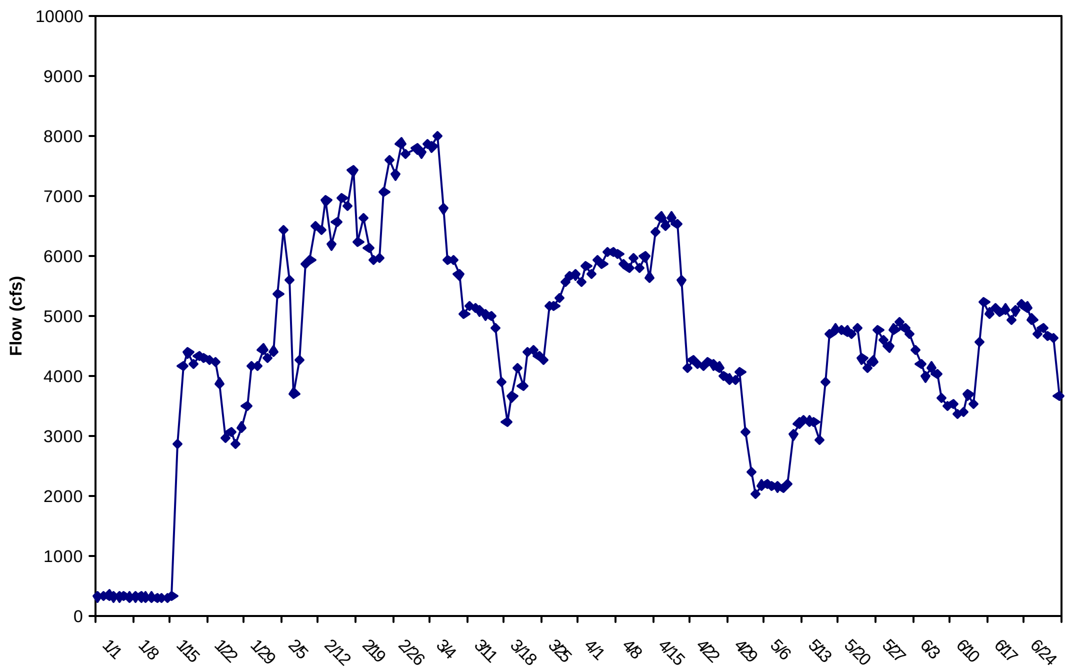

Figure 14. Water Year 1997-98 Winter and Spring Hydrograph (La Grange Flow) when 43,119 adult recruits were produced.

Water Temperature

Water temperature is thought to be a population limiting factor for both salmon and rainbow trout in the Tuolumne River. However, it is unknown how, or if, water temperature is limiting salmonid production in the Tuolumne River. Recently a comprehensive water temperature computer modeling simulation exercise was conducted for the Stanislaus River to evaluate how water operations on the Stanislaus influenced water temperatures in the Stanislaus. As part of this assessment, a literature review was conducted, and CALFED peer reviewed (Deas et.al. 2004), to identify water temperature criteria for both salmon and steelhead to evaluate how water temperature response might influence salmon and steelhead by life history stage. The Stanislaus River Water Temperature Peer Review Panel adopted the Environmental Protection Agency water temperature for fall-run Chinook salmon and steelhead (Table 1) finding no variation in temperature exposure tolerance between northern and southern Chinook salmon stocks.

Table 3. Temperature criteria/goal for identified species and lifestages in the Stanislaus River (after EPA, 2003 as presented in Deas et. al. 2004).

Stanislaus R. Terminology	EPA-based Recommended Temperature Criteria/Goals to Protect Salmon and Trout (Criteria are based on the 7-day average of the daily maximum values)
Adult migration	<64°F (<18°C) for salmon and trout migration <68°F (<20°C) for salmon and trout migration - generally in the lower part of river basins that likely reach this temperature naturally, <u>if</u> there are cold-water refugia available [but no evidence of such refugia are available for the Stanislaus River]
Incubation	<55°F (<13°C) for salmon and trout spawning, egg incubation, and fry emergence
Juvenile rearing (early year)	<61°F (<16°C) for salmon "core" juvenile rearing - generally in the mid- to upper part of river basins
Smoltification	<59°F (<15°C) for salmon smoltification <57°F (<14°C) for steelhead smoltification (for composite criteria steelhead conditions are applied)
Juvenile rearing (late year)	<64°F (<18°C) for salmon and steelhead migration plus non-Core Juvenile Rearing - generally in the lower part of river basins

Modeling results from the Stanislaus River indicate that water temperatures can exceed threshold values for salmonids, in some years, during the spring, summer and fall time periods. The degree of water temperature violation (extent of threshold exceedence) is dependent upon ambient air temperature, reservoir storage, reservoir release location and release volume (unpublished data). The water temperature model prepared for the Stanislaus is being applied to the Tuolumne, but no results have been produced to date. For Tuolumne River salmon, from information provided above, the smolt life history stage is critically important to adult recruitment abundance. Preliminary assessment of water temperatures during this time period suggests that flow volume (Figure 15) is important to conveying a suitable out-migration temperature for Tuolumne River salmon smolts.

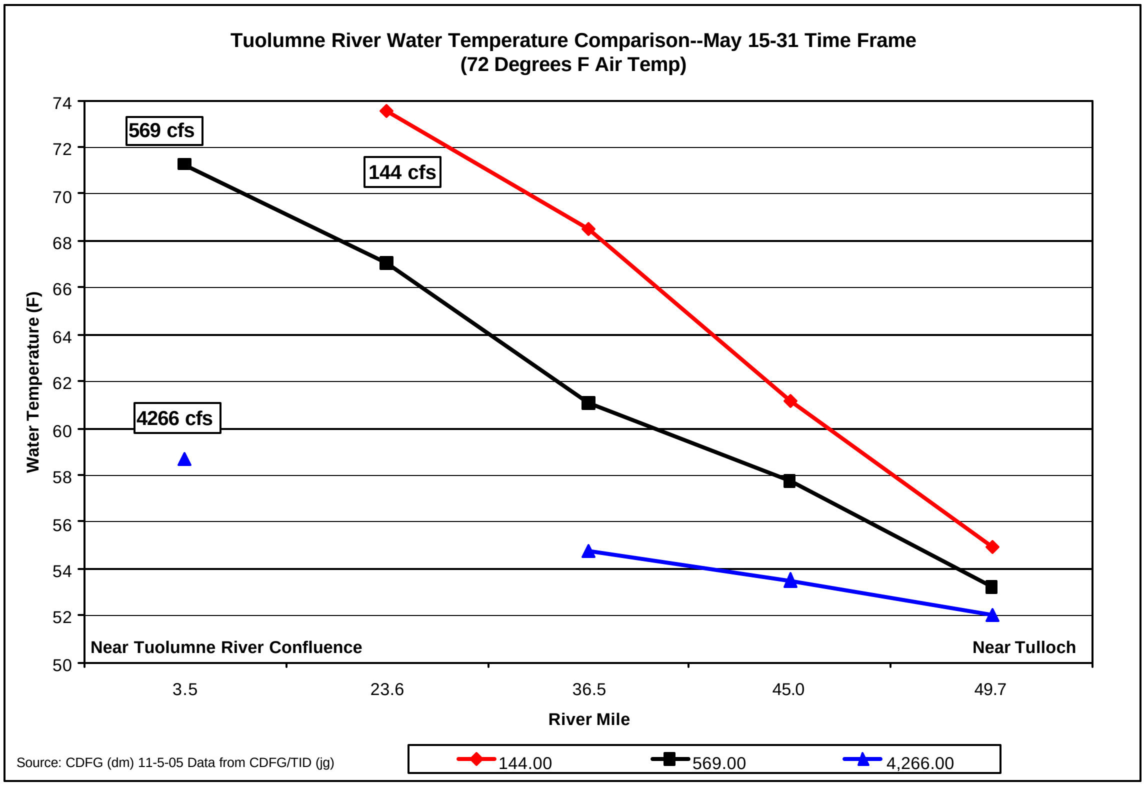

Figure 15. Tuolumne River Late Spring Flow and Water Temperature.

Fall Flows

Fall attraction flows have been thought be critically important for the production of both salmon and steelhead in terms of the potential loss of adults that stray to the Sacramento Basin, reduced gamete viability, and increased egg mortality due to redd superimposition. Adult migration of salmon through the South Delta and into the Tuolumne River begins during the early fall when Delta conditions are their worst in terms of water quality and flow. In the early fall, the rate of Delta Pumping is typically ten times greater than the total San Joaquin River flow, which makes it difficult for adult Tuolumne River salmon to detect their natal waters, and migrate through, the South Delta (Mesick 2001). When pumping rates have exceeded about 350% of the San Joaquin River flow, up to 20% of the San Joaquin River adults tagged with coded-wire-tags strayed to the Sacramento Basin (Mesick 2001).

Hallock and others (1970) have shown that during the early fall, flow-related conditions in the deep-water ship channel, which include low dissolved oxygen concentrations (< 5 ppm) and high water temperatures (> 70^{o} F) in the Deep Water Ship Channel, can block adult migration. Mann and Peery (2005) reported that when adult Chinook salmon migrate in water that is at least 68^{o} F, the viability of their eggs can be reduced. Egg viability tends to be lower for the early arriving fish at the Merced River Hatchery, particularly when flows were low and water temperatures were high in the late 1980s and early 1990s prior to the release of October pulse flows (CDFG unpublished data). We assume that the same may have been true for Tuolumne River fish. It is also possible that high water temperatures could result in high levels of pre-spawning mortality. Pre-spawning mortality data are not currently collected as part of annual Tuolumne River adult salmon escapement surveys. However, surveys conducted in the Stanislaus River in 2005 and 2006 found no female carcasses with large numbers of unspawned eggs. In addition, there has been no evidence of pre-mature adult mortality at the Merced River hatchery.

Another concern is that the distribution of early arriving adult spawners has been gradually shifting toward the upstream areas below La Grange Dam, particularly over the last 15 years. We suspect that low flows, unsuitably warm temperatures, and poor water quality in the lower reaches have caused the upstream shift in spawner distribution. As a result of the crowding, we suspect that redd superimposition rates are increasing which may result egg mortality for the early arriving fish. The rate of superimposition of artificial redds in the Stanislaus River that were constructed early in the spawning season was about 71% in fall 2000 when escapement was relatively high (Carl Mesick Consultants 2002). High rates of redd superimposition were also observed in the Tuolumne River during the late 1980s when fall base flows were unusually low during the drought (Turlock Irrigation District and Modesto Irrigation District 1992a). However, the relationships between flows and habitat restoration, redd superimposition rates, and egg mortality rates have not been studied in the Tuolumne River.

The combined effect of delaying migrations in the Delta, straying, and crowding spawners may reduce the survival of the progeny of the early arriving fish. We assume that the progeny of early arriving fish are important for the production of adult recruits, because it is likely that the early fish begin their downstream migration early in the spring when conditions in the Delta are most suitable for their survival. However, fall attraction flows and increased fall base flows were implemented during the mid-1990s when the Tuolumne River population declined and so our assumptions described above about the early arriving fish are wrong or there are other offsetting problems for early arriving spawners that have not yet been identified. We recommend that this issue should be studied further.

Spawning Habitat Restoration

Preliminary analyses suggests that although the degraded condition of the spawning habitat in the Tuolumne River limits the production of fry, more fry are currently being produced than can be supported by the rearing habitat. If true, then gravel augmentation and restoring sediment transport will not substantially increase adult recruitment.

The preliminary analysis is based on rotary screw trap captures in the Tuolumne River. At least 7,300,000 and 3,500,000 juveniles were produced in the Tuolumne River in 1999 and 2000, respectively. The estimates are based on rotary screw trap catches at the 7/11 site (RM 38.6), which is downstream of the majority of the spawning habitat in the

Tuolumne River (Turlock Irrigation District and Modesto Irrigation District 2005); only a portion of the migratory period was sampled during both years and so the true estimates are probably higher. It is likely that these numbers far exceeded the capacity of the rearing habitat, because only 0.4% of these fish in 1999 and 1.4% of these fish in 2000 survived to a smolt-size at the downstream Tuolumne River trap at Grayson (RM 5.2).

Smolt production also appears to be controlled by the quality of the rearing habitat and not the production of fry in the Stanislaus River. After implementing a spawning habitat restoration project in the Stanislaus River that added spawning-sized gravel to 18 sites between Goodwin Dam and Oakdale in summer 1999 (Carl Mesick Consultants 2002), juvenile production, which was measured with a rotary screw trap at Oakdale (RM 40), increased by 32% in spring 2000 compared to spring 1999 (Figure 16). However, there was no increase in the number of smolt-sized fish that migrated from the river in spring 2000 compared to spring 1999 (Figure 16) as measured with rotary screw traps at Caswell Park (RM 5) even though the mean flow from March 1 to June 15 at Goodwin Dam was nearly identical (1,497 cfs) in 1999 and 2000.

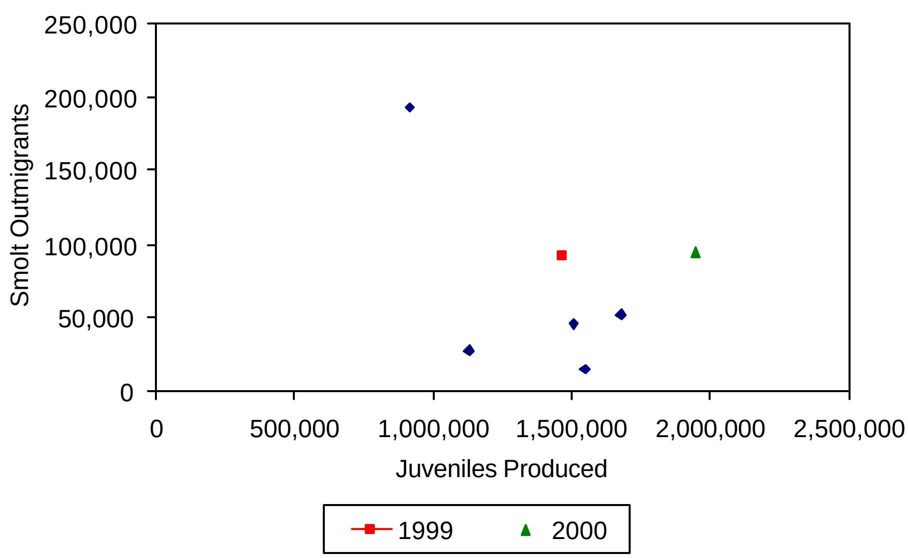

Figure 16. The estimated abundance of all sizes of juveniles that passed the Oakdale screw trap (RM 40) plotted with the estimated abundance of smolt out-migrants (≥ 70 mm Fork Length) at the Caswell State Park screw traps (RM 5) in the Stanislaus River from 1998 to 2004. The Knights Ferry Gravel Replenishment Project (KFGRP) constructed 18 spawning beds in the Stanislaus River in summer 1999. A comparison of the 1999 and 2000 estimates provides the best evaluation of the effects of gravel augmentation on juvenile and smolt production, because they occurred immediately before and after the KFGRP and they were both affected by similar spring flows between February 1 and June 15 (7,394 cfs and 6,940 cfs, respectively) and similar numbers of spawners (2,600 and 3,200 Age 3 equivalent fish, respectively).

Fish Predators

It is likely that high winter and spring flows reduce predation by largemouth bass (*Micropterus salmoides*), smallmouth bass (*M. dolomieu*), Sacramento pikeminnow

(*Ptychocheilus grandis*), and striped bass (*Morone saxatilis*) on juvenile salmon in the Tuolumne River and that predation rates are abnormally high where predator habitat was enhanced by in-river gravel extractions. Although the initial studies indicated that predation by largemouth and smallmouth bass in the large captured mine pits is a major source of mortality in the Tuolumne River (Turlock Irrigation District and Modesto Irrigation District 1992b), there is uncertainty about the importance of predation relative to other rearing habitat limitations and there is uncertainty about the importance of other predator species, such as Sacramento pikeminnow and striped bass. The initial studies conducted by EA indicated that very few bass contained juvenile salmon in their stomachs except during May 1990 when 93,653 hatchery reared salmon smolts were released at Old La Grange Bridge for survival studies (Table 2). Furthermore, predation by black bass should have been unusually high during the drought conditions of 1989 and 1990 when EA conducted their studies, and so typical predation rates by black bass should be much lower than those shown in Table 2. And there is no evidence that restoring the large pond at Special Run Pool 9 and isolating the pond at Special Run Pool 10 reduced predation rates or improved the survival of juvenile salmon in the Tuolumne River (Turlock Irrigation District and Modesto Irrigation District 2005).

Table 4. EA Engineering, Science, and Technology predation studies in the lower Tuolumne River in 1989 and 1990.

Sampling Dates	La Grange Flows (cfs)	% Largemouth Bass with juvenile salmon in their stomachs	% Smallmouth Bass with juvenile salmon in their stomachs	Origin of Juvenile Salmon
4/19 to 5/17, 1989	40 – 121	3.6% (2/56)	8.6% (5/58)	Naturally Produced
1/29 to 3/27, 1990	142 – 174	2.1% (2/97)	3.1% (1/32)	Naturally Produced
4/25 to 4/28, 1990	187 – 207	2.6% (2/76)	6.3% (1/16)	Naturally Produced
5/2 to 5/4, 1990	299 -572	26% (40/152)	33.3% (6/18)	CWT Hatchery

We also suspect that the electrofishing methods used by EA (Turlock Irrigation District and Modesto Irrigation District 1992b) were selective for largemouth and smallmouth bass, which utilize cover, compared to striped bass and Sacramento pikeminnow, which tend to utilize open water.

Radio tracking studies conducted by S.P. Cramer & Associates in 1998 and 1999 in the Stanislaus River (Demko and others 1998, SPCA unpublished data) suggest that the survival of large naturally produced and hatchery juveniles, 105 to 150 mm fork length, with gastrically implanted transmitters and 12-inch external whip antennas, was less than 10% during May and June (Demko and others 1998). Three striped bass collected had radio tagged juvenile Chinook salmon in their stomachs and striped bass were observed near the locations where many of the tagged juveniles ceased their migration. However, there is uncertainty as to whether the tagging procedure affected the fish's vulnerability to predators. Gastric implantation is stressful to juvenile salmonids and the whip antenna impairs their swimming ability (Vogel, personal communication, see "Notes"). During the 1998 SPCA studies, only 73% of the fish survived the tagging procedure and no observations were made to verify that tagging did not affect the fish's behavior (Demko and others 1998).

Another potential predator of juvenile salmon in the Tuolumne River is the adult Sacramento pikeminnow, which forms large schools in 3-8 foot deep ditch-like channels called Special Run-Pools. Sport anglers report that large adults frequently have numerous salmon fry in their stomachs particularly during January and February.

Delta Exports

South Delta exports have long been identified as a limiting factor for Tuolumne River salmon recruitment. Federal pumping at Tracy began in the mid-1950s while State Pumping at the Harvey O. Banks facilities began in the late-1960s. However, preliminary correlation analyses suggest that the combined State and Federal export rates during the smolt outmigration period (April 1 to June 15) have relatively little effect on the production of adult recruits in Tuolumne River compared to the effect of winter and spring flows. Furthermore, reducing export rates from an average of 264% of Vernalis flows between 1980 and 1995 to an average of 43% of Vernalis flows and installing the Head of the Old River Barrier between 1996 and 2002 during the mid-April to mid-May VAMP period did not result in an increase in Tuolumne River adult recruitment (Figures 3 and 17).

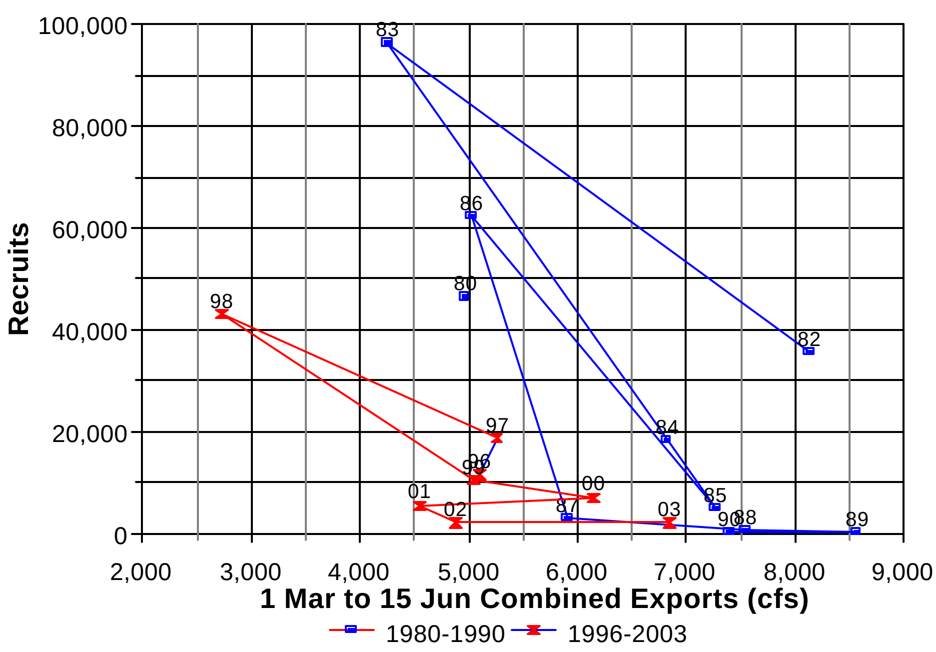

Figure 17. The mean combined export rates at the Federal and State water projects from March 1 to June 15 relative to the Tuolumne River adult salmon recruitment from 1980 to 2003. During the 1996-2003 period, export rates were primarily reduced between mid April and

mid May whereas there was relatively little change in the export rate between March 1 and April 15 from 1980 to 2003.

Fry Contribution

Millions of fry out-migrate from the Tuolumne River in February and March, particularly during wet years, according to rotary screw trap studies and it is possible that these fry rear in the South Delta and substantially contribute to adult recruitment. Wet year flood control releases on the Tuolumne River typically last throughout the spring and therefore presumably result in favorable conditions for fry to survive to a smolt-size in the Delta. However, the total number of juveniles out-migrating from the Stanislaus River based on rotary screw trap studies is poorly correlated with adult recruitment (Figure 18a) compared to the regressions between smolt-sized fish and adult recruits (Figure 18b). Although these preliminary results suggest that few fry survive in the Delta, further studies are needed.

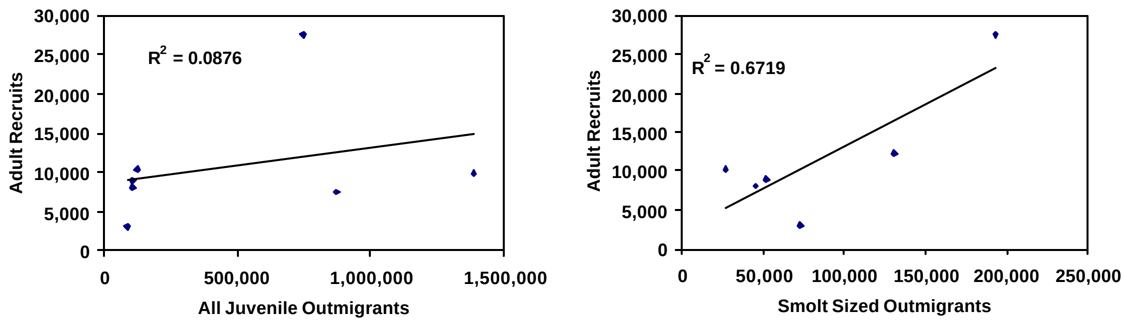

Figure 18a & b. The number of adult recruits relative to the number of juvenile outmigrants and smolt-sized outmigrants (≥70 mm FL) at Caswell State Park (RM 5) in the Stanislaus River from 1996 to 2003.

Ocean Productivity

Two indices of ocean productivity conditions, which include the mean November to March values of the Pacific Interdecadal Oscillation (PDO) and the mean of the May to July values of the Pacific Fisheries Environmental Laboratory coastal upwelling index (PFEL Upwelling Index) for the San Francisco area (interpolated values to a latitude of 37.5 degrees North) were used in this analysis. The mean November to March values of the Pacific interdecadal Oscillation (PDO) is defined by Steven Hare as the leading principal component of North Pacific monthly sea surface temperature variability (poleward of 20N since 1900). The PFEL Upwelling Index is a measure of the intensity of large-scale, wind-induced coastal upwelling along the West Coast and is based on estimates of offshore Ekman transport driven by geostrophic wind stress (PFEL 2001). A mean index value for the May through July period because MacFarlane and Norton (2002) reported that this was when juvenile Chinook salmon entered the Gulf of the Farallones in 1997.

The PDO is highly correlated with sea surface temperatures and the ocean harvest of pacific salmon off the Alaska coast and the West coast (Mantua and others 1997). When sea surface temperatures are warm off the entire northeastern Pacific rim, PDO tends to be positive, Alaska landings of sockeye and pink salmon are relatively high, and West Coast landings of spring-run Chinook and coho salmon are low (Mantua and others 1997). Long-term records indicate that there are 15- to 25-year cycles of warm and cool periods that are strongly correlated with marine ecosystem productivity (Mantua and others 1997; Hollowed and others 2001). Cool productive cycles prevailed from 1947-1976 and a new cycle began in 1998, whereas warm unproductive cycles dominated from 1925-1946 and from 1977-1997 (Mantua and others 1997; Mantua and Hare 2002). The coastal warming that occurred in the mid-1970s is believed to have caused increased stratification in the California Current, a sharper thermocline with less vertical displacement of nutrient rich water due to coastal upwelling, a reduction in the duration of upwelling, conditions, and a reduction in nutrients and/or zooplankton abundance carried by the California Current (Francis and others 1998). In addition, the abundance of coastal euphausiids (*Thysanoessa spinifera*) declined whereas oceanic euphausiids (*T. pacifica*) increased (Francis and others 1998). Such changes are thought to affect salmon early in the marine life history (Hare and Francis 1995) and coastal invertebrate species are important prey for ocean-type juveniles, such as Central Valley fall-run Chinook salmon.

However, the PDO productivity cycles are not highly correlated with fall-run Chinook salmon production in the Central Valley. The USFWS ChinookProd estimates[viii], which sums the escapement and ocean harvest estimates, for the entire Central Valley were compared between the productive and unproductive ocean periods. The mean in-river Central Valley wide Chinook production during the productive cool cycles was 31.1% and 139.3% higher for the 1952 to 1976 period and the 2000 to 2004 period, respectively, than during the unproductive warm cycle between 1979 and 1997 (Table 3). However, the higher production estimates during the 1952 to 1976 period may not be meaningful since a majority of the estimates (pre-1973) are not based on currently utilized mark-recapture techniques and so it is possible that the 31.1% increase is an artifact of different escapement survey methods. In addition, the higher production estimates during the 2000 to 2004 period are based on unusually large increases in several tributaries to the Sacramento Basin, including Battle Creek (592%), Clear Creek (198%), Butte Creek (438%), Feather River (150%), and American River (273%), that may be due to extensive habitat restoration, improved flow releases, and/or hatchery production. The increase in the San Joaquin Basin during the 2000 to 2004 period was only 19%, which may be a result of improved base flows, habitat restoration, and hatchery production in the Mokelumne and Merced rivers. Moreover, the PDO and PFEL upwelling indices explained almost no variation in Tuolumne River recruitment. The spawner-recruit model with the PDO index had an adj-R^2 of 0.005 and a P value of 0.409. The spawner-recruit model with the PFEL upwelling index had an adj-R^2 of -0.015 and a P value of 0.457.

Ocean Harvest

Another factor thought to limit Tuolumne River adult salmon recruitment is ocean harvest by reducing the number of spawners such that the rearing habitat would not be saturated with juveniles. The Central Valley Index (CVI) of ocean harvest is estimated each year by the Pacific Fishery Management Council (PFMC 2006) by dividing total harvest south of Point Arena by the total hatchery and natural escapement to all Central Valley rivers. It is assumed that Tuolumne River adult salmon are exposed to the same fishing pressure as other Central Valley salmon and therefore have the same chance of being caught. The CVI is poorly correlated with Tuolumne River annual escapements from 1967 through 2004 (Figure 19) and so it is unlikely that ocean harvest is an important factor controlling Tuolumne River adult salmon escapement. Moreover, 500 spawners should be enough to saturate the rearing habitat with juveniles (Mesick and Marston 2007) and low spawner abundance tends to result from low spring flows during extended droughts rather than from high ocean harvest rates.

Table 5. Fall-run Chinook salmon production, Sacramento Basin Water Year Index (WYI), San Joaquin Basin Water Year Index (WYI) for the unproductive ocean cycle between 1979 and 1997 and the productive cool ocean cycles between 1952 and 1976 and between 2000 and 2004.

	Central Valley Production	Sacramento Basin WYI	San Joaquin Basin WYI	Percent Change in Central Valley Production between Warm and Cool Period	Percent Change in Sacramento WYI between Warm and Cool Period	Percent Change in San Joaquin WYI between Warm and Cool Period
Warm Unproductive (1979-1997)	204,266	8.09	3.40	--	--	--
Cool Productive (1952-1976)	267,980	8.77	3.23	+31%	+8%	-5%
Cool Productive (2000-2004)	488,984	7.35	2.59	+139%	-9%	-24%

Riparian Vegetation

Another area of management concern is the health of riparian vegetation along the entire Tuolumne River corridor. A mature riparian canopy is important to juvenile salmon production by (a) providing detritus to the river as a food source for primary production food source for aquatic insects that juvenile salmonids prey upon, (b) providing a terrestrial insect food source, (c) providing shade to aid in providing cooler, and therefore, more suitable water temperatures for salmon migration, spawning, and rearing, and (d) providing large woody debris that provides and maintains in-river habitat complexity. The primary concern is that many of the riparian forests on the Tuolumne River primarily consist of mature trees that are not being replaced with new growth.

Establishing new riparian plant growth is dependent upon the rate and timing that flows are ramped down in late spring to support riparian seedling establishment. Research on a variety of cottonwood and willow species suggests that 1 to 1.5 inches/day is the maximum rate of water table decline for seedling survival (McBride et al. 1989; Segelquist et al. 1993; Mahoney and Rood 1993, 1998; Amlin and Rood 2002). However, a recent manipulation experiment of Fremont cottonwood, black willow, and narrow leaf willow seedlings found that water table declines of one inch or more resulted in 80% mortality within 60 days, even when the water table was maintained near the soil surface for several weeks before drawdown (Stillwater Sciences, unpublished data). Ramping rates of 100 to 300 cfs/day in the San Joaquin Basin are thought to prevent seedling desiccation under the assumed 1 inch/day maximum root growth rate. Recruitment flows may also have to occur from mid-April to late-May to improve cottonwood recruitment and from mid-May to late June to benefit black willow.

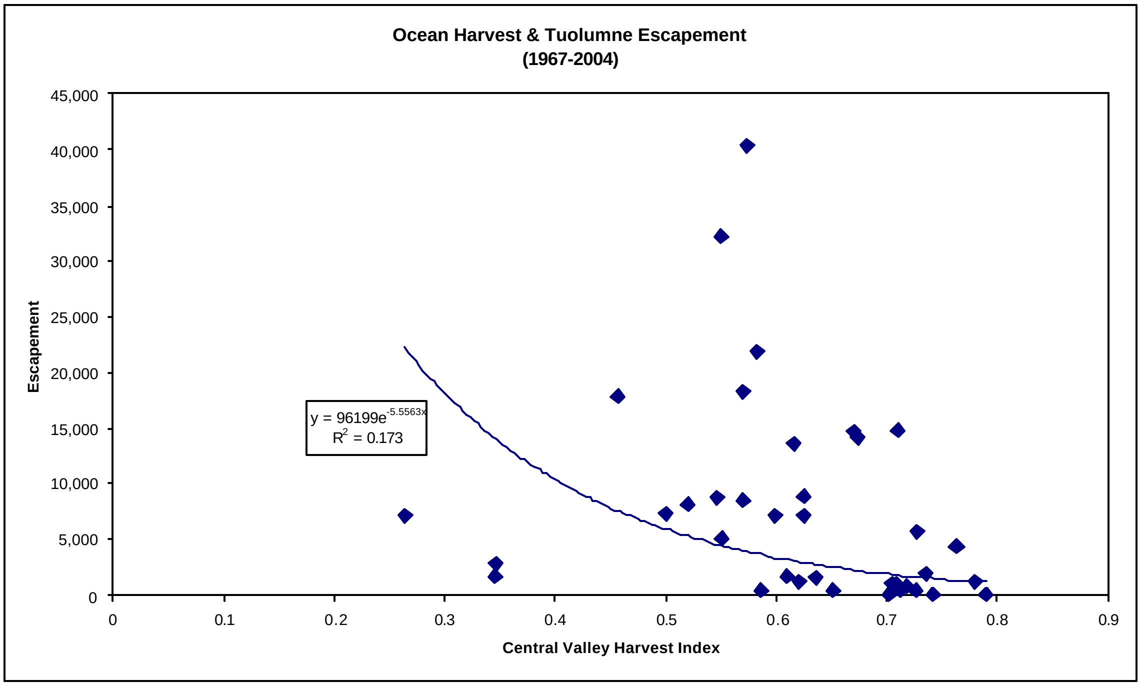

Figure 19. Central Valley Harvest Index Plotted relative to Tuolumne River Adult Salmon Escapement.

Rainbow Trout

Life History

The life history patterns of rainbow trout are highly variable and flexible, consisting of two basic patterns; anadromous and resident. Both these types of life-history stages exists in the same population, but dominance of one or the other commonly defines the population (Moyle 2002). Reports of migratory rainbow trout making extensive freshwater migrations are unfounded and extensive river migrations have not been demonstrated except in unusuall circumsantces such as in large lakes or reservoirs (Good et al. 2005). Although the anadromous and resident forms have long been taxonomically classified within the same species, in any given areas the exact relationship between the forms is not well understood (Good et al. 2005), and NMFS now distinquishes the two forms as separate distinct population segements (see FR 834, January 5, 2006). Recent studies have confirmed that genetic capability of anadromy is retained in rainbow trout for numerous generations (Thomas R. Payne & Associates and S.P. Cramer & Associates, 2005). Thus the protection of both life history patterns of rainbow trout is important to maintain the viability of the species.

Life history requirements and habitat needs of rainbow trout have been extensively studied and are not reviewed thoroughly here. Regardless of the life history form, for the first year or two, rainbow trout are found in cool, clear, fast-flowing permanent streams and rivers (Moyle 2002). As the agencies are primarily concerned with the anadromous form of rainbow trout, the following information primarily addresses life history traits, population levels, habitat needs, and limiting factors of the anadromous form in the Tuolumne River and San Joaquin basin.

Steelhead can be divided into two life history types, based on their state of sexual maturity at the time of river entry and the duration of their spawning migration, stream-maturing and ocean-maturing. Stream-maturing steelhead enter freshwater in a sexually immature condition and require several months to mature and spawn, whereas ocean-maturing steelhead enter freshwater with well-developed gonads and spawn shortly after river entry. These two life history types are more commonly referred to by their season of freshwater entry (*i.e.*, summer (stream-maturing) and winter (ocean-maturing) steelhead). Only winter steelhead currently are found in Central Valley rivers and streams (McEwan and Jackson 1996), although there are indications that summer steelhead were present in the Sacramento river system prior to the commencement of large-scale dam construction in the 1940s (Interagency Ecological Program (IEP) Steelhead Project Work Team 1999). At present, summer steelhead are found only in North Coast drainages, mostly in tributaries of the Eel, Klamath, and Trinity River systems (McEwan and Jackson 1996).

Central Valley steelhead generally leave the ocean from August through April (Busby *et al.* 1996), and spawn from December through April with peaks from January though March in small streams and tributaries where cool, well oxygenated water is available year-round (McEwan and Jackson 1996; Hallock *et al.* 1961)(Table 4). Timing of upstream migration is correlated with higher flow events, such as freshets or sand bar breaches, and associated lower water temperatures. Unlike Pacific salmon, steelhead are iteroparous, or capable of spawning more than once before death (Busby *et al.* 1996). However, it is rare for steelhead to spawn more than twice before dying; most that do so are females (Busby *et al.* 1996). Iteroparity is more common among southern steelhead populations than northern populations (Busby *et al.* 1996). Although one-time spawners are the great majority, Shapolov and Taft (1954) reported that repeat spawners are relatively numerous (17.2 percent) in California streams.

Table 6. The temporal occurrence of adult (a) and juvenile (b) CV steelhead in the Central Valley. Darker shades indicate months of greatest relative abundance.

(a) Adult

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
[1,3]Sac. River												
[2,3]Sac R at Red Bluff												
[4]Mill, Deer Creeks												
[6]Sac R. at Fremont Weir												
[6]Sac R. at Fremont Weir												
[7]San Joaquin River												

(b) Juvenile

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
[1,2]Sacramento River												
[2,8]Sac. R at Knights Land												
[9]Sac. River @ KL												
[10]Chipps Island (wild)												
[8]Mossdale												
[11]Woodbridge Dam												
[12]Stan R. at Caswell												
[13]Sac R. at Hood												

Source: [1]Hallock 1961; [2]McEwan 2001; [3]USFWS unpublished data; [4]CDFG 1995; [5]Hallock *et a*l. 1957; [6]Bailey 1954; [7]CDFG Steelhead Report Card Data; [8]CDFG unpublished data; [9]Snider and Titus 2000; [10]Nobriga and Cadrett 2001; [11]Jones & Stokes 2002; [12]S.P. Cramer and Associates, Inc. 2000 and 2001; [13]Schaffter 1980

Relative Abundance: = High = Medium = Low

The female selects a site where there is good intergravel flow, then digs a redd and deposits eggs while an attendant male fertilizes them. The eggs are then covered with gravel when the female begins excavation of another redd just upstream. The length of time it takes for eggs to hatch depends mostly on water temperature. Hatching of steelhead eggs in hatcheries takes about 30 days at 51 °F. Fry emerge from the gravel usually about four to six weeks after hatching, but factors such as redd depth, gravel size, siltation, and temperature can speed or retard this time (Shapovalov and Taft 1954). The newly emerged fry move to the shallow, protected areas associated with the stream margin (McEwan and Jackson 1996) and they soon move to other areas of the stream and establish feeding locations, which they defend (Shapovalov and Taft 1954).

Steelhead rearing during the summer takes place primarily in higher velocity areas in pools, although young-of-the-year also are abundant in glides and riffles. Productive steelhead habitat is characterized by complexity, primarily in the form of large and small woody debris. Cover is an important habitat component for juvenile steelhead both as velocity refugia and as a means of avoiding predation (Meehan and Bjornn 1991).

Juvenile steelhead emigrate episodically from natal streams during fall, winter, and spring high flows. Emigrating CV steelhead use the lower reaches of the Sacramento River and the Delta for rearing and as a migration corridor to the ocean. Juvenile Central Valley steelhead feed mostly on drifting aquatic organisms and terrestrial insects and will also take active bottom invertebrates (Moyle 2002).

Some may utilize tidal marsh areas, non-tidal freshwater marshes, and other shallow water areas in the Delta as rearing areas for short periods prior to their final emigration to the sea. Hallock *et al.* (1961) found that juvenile steelhead in the Sacramento River basin migrate downstream during most months of the year, but the peak period of emigration occurred in the spring, with a much smaller peak in the fall. Nobriga and Cadrett (2000) also have verified these temporal findings based on analysis of captures at Chipps Island, Susuin Bay.

CV steelhead historically were well-distributed throughout the Sacramento and San Joaquin Rivers (Busby *et al.* 1996) and were found from the upper Sacramento and Pit River systems (now inaccessable due to Shasta and Keswick Dams) south to the Kings and possibly the Kern River systems (now inaccessible due to extensive alterations from numerous water diversion projects) and in both east- and west-side Sacramento River tributaries (Yoshiyama *et al.* 1996). The present distribution has been greatly reduced (McEwan and Jackson 1996). Historic CV steelhead run sizes are difficult to estimate given the paucity of data, but may have approached 1 to 2 million adults annually (McEwan 2001). By the early 1960s the steelhead run size had declined to about 40,000 adults (McEwan 2001). Over the past 30 years, the naturally-spawned steelhead populations in the upper Sacramento River have declined substantially. Hallock *et al.* (1961) estimated an average of 20,540 adult steelhead through the 1960s in the Sacramento River, upstream of the Feather River. Steelhead counts at the RBDD declined from an average of 11,187 for the period of 1967 to 1977, to an average of approximately 2,000 through the early 1990s, with an estimated total annual run size for the entire Sacramento-San Joaquin system, based on RBDD counts, to be no more than 10,000 adults (McEwan and Jackson 1996, McEwan 2001). Steelhead escapement surveys at RBDD ended in 1993 due to changes in dam operations.

Recent estimates from trawling data in the Delta indicate that approximately 100,000 to 300,000 smolts emigrate to the ocean per year representing approximately 3,600 female Central Valley steelhead spawners in the Central Valley basin (Good *et al*. 2005). This can be compared with McEwan's (2001) estimate of one million to two million spawners before 1850, and 40,000 spawners in the 1960s."

Existing wild steelhead stocks in the Central Valley are mostly confined to the upper Sacramento River and its tributaries, including Antelope, Deer, and Mill Creeks and the Yuba River. Populations may exist in Big Chico and Butte Creeks and a few wild steelhead are produced in the American and Feather Rivers (McEwan and Jackson 1996). Recent snorkel surveys (1999 to 2002) indicate that steelhead are present in Clear Creek (J. Newton, USFWS, pers. comm. 2002, as reported in Good *et al*. 2005). Because of the large resident *O. mykiss* population in Clear Creek, steelhead spawner abundance has not been estimated.

Recent monitoring has detected small self-sustaining populations of steelhead in the Stanislaus, Mokelumne, Calaveras, and other streams previously thought to be devoid of steelhead (McEwan 2001). On the Stanislaus River, steelhead smolts have been captured in rotary screw traps at Caswell State Park near the mouth of the river and Oakdale each year since 1995 (S.P. Crammer and Associates Inc. 2000, 2001). It is possible that naturally-spawning populations exist in many other streams but are undetected due to lack of monitoring programs (IEP Steelhead Project Work Team 1999). Incidental catches and observations of steelhead juveniles also have occurred on the Tuolumne and Merced Rivers during fall-run Chinook salmon monitoring activities, indicating that steelhead are widespread, throughout accessible streams and rivers in the Central Valley (Good *et al*. 2005). CDFG staff have prepared juvenile migrant Central Valley steelhead catch summaries on the San Joaquin River near Mossdale representing migrants from the Stanislaus, Tuolumne, and Merced Rivers. Based on trawl recoveries at Mossdale between 1988 and 2002, as well as rotary screw trap efforts in all three tributaries, CDFG staff stated that it is "clear from this data that rainbow trout do occur in all the tributaries as migrants and that the vast majority of them occur on the Stanislaus River" (Letter from Dean Marston, CDFG, to Madelyn Martinez, NMFS, January 9, 2003). The documented returns on the order of single fish in these tributaries suggest that existing populations of Central Valley steelhead on the Tuolumne, Merced, and lower San Joaquin Rivers are severely depressed.

Limiting Factors

A number of documents have addressed the history of human activities, present environmental conditions, and factors contributing to the decline Central Valley steelhead. For example, NMFS prepared range-wide status reviews for west coast steelhead (Busby *et al*. 1996). NMFS also assessed the factors for steelhead decline in supplemental documents (NMFS 1996). Information also is available in Federal Register notices announcing ESA listing proposals and determinations for some of these species and their critical habitat (e.g., 58 FR 33212; 59 FR 440; 62 FR 24588; 62 FR 43937; 63 FR 13347; 64 FR 24049; 64 FR 50394; 65 FR 7764). The following general description is based on a summarization of these documents.

Hydropower, flood control, and water supply dams, and other municipal and private entities have permanently blocked or hindered salmonid access to historical spawning and rearing grounds resulting in the complete loss of substantial portions of spawning, rearing, and migration habitat. Yoshiyama *et al*. (1996) surmised that steelhead habitat loss was even greater than salmon loss, as steelhead migrated farther into drainages. The California Advisory Committee on Salmon and Steelhead Trout (1988) estimated that there has been a 95 percent reduction of Central Valley anadromous fish spawning habitat.

In general, large dams on every major tributary to the Sacramento River, San Joaquin River, and the Delta block steelhead access to the upper portions of their respective watersheds. Friant Dam construction in the mid 1940s has been associated with the elimination of anadromous salmonid runs in the San Joaquin River upstream of the Merced River. On the Stanislaus River, construction of Goodwin Dam (1912), Tulloch Dam (1957), and New Melones Dam (1979) blocked both spring- and fall-run Chinook salmon as well as CV steelhead. Similarly, La Grange Dam (1893) and New Don Pedro Dam (1971) blocked salmon and steelhead from upstream spawning areas on the Tuolumne River. Upstream migration on the Merced River was blocked in 1910 by the construction of Merced Falls and Crocker-Huffman Dams and later New Exchequer Dam (1967) and McSwain Dam (1967). The loss of substantial habitat above dams also has resulted in decreased juvenile and adult steelhead survival during migration, and in many cases, had resulted in the dewatering and loss of important spawning and rearing habitats.

Changes in the thermal profiles and hydrographs of the Central Valley rivers have presumably subjected salmonids to strong selective forces (Slater 1963). The degree to which current life history traits reflect predevelopment characteristics is largely unknown, especially since most of the habitat degradation occurred before salmonid studies were undertaken late in the nineteenth century. Increased temperatures as a result of reservoir operations during winter and fall can affect emergence rates of salmoninds; thereby, significantly altering the life history of a species (California Bay-Delta Authority 2005). Shifts in life history have the potential to seriously affect survival (California Bay-Delta Authority 2005). In addition, Brown and May (2000) found stream regulation to be associated with declines in benthic macroinvertebrate communities in Central Valley rivers. Macroinvertebrates are key prey species for salmonids.

Water diversions for irrigated agriculture, municipal and industrial use, and managed wetlands are found throughout the Central Valley. Hundreds of small and medium-size water diversions exist along the Sacramento River, San Joaquin River, and their tributaries. Although efforts have been made in recent years to screen some of these diversions, many remain unscreened. Depending on the size, location, and season of operation, these unscreened diversions entrain and kill many life stages of aquatic species, including juvenile salmonids. For example, as of 1997, 98.5 percent of the 3,356 diversions included in a Central Valley database were either unscreened or screened insufficiently to prevent fish entrainment (Herren and Kawasaki 2001).

Increased sedimentation resulting from agricultural and urban practices within the Central Valley is a primary cause of salmonid habitat degradation (NMFS 1996). Sedimentation can adversely affect salmonids during all freshwater life stages by: clogging or abrading gill surfaces, adhering to eggs, hampering fry emergence (Phillips and Campbell 1961), burying eggs or alevins, scouring and filling in pools and riffles, reducing primary productivity and photosynthesis activity, and affecting inter-gravel permeability and dissolved oxygen levels. Excessive sedimentation over time can cause substrates to become embedded, which reduces successful salmonid spawning and egg and fry survival.

Land use activities such as agricultural conversion, and industrial and urban development continue to have large impacts on salmonid habitat in Central Valley watersheds, affecting spawning habitat, freshwater rearing habitat, freshwater migration corridors, estuarine areas, and nearshore marine areas. While historical uses of riparian areas (e.g., wood cutting, clearing for agricultural uses) have substantially decreased, urbanization still poses a serious threat to remaining riparian areas. Riversides are desirable places to locate homes, businesses, and industry. Further, development within the flood plain results in vegetation removal, stream channelization, habitat instability, and point and non-point source pollution (NMFS 1996). In addition, the armoring, revetment, and narrowing of stream banks tends to reduce the amount of habitat per unit channel length (Sweeney *et al*. 2004). As a result of river narrowing, benthic habitat decreases and the number of macroinvertebrates, such as stoneflies and mayflies, per unit channel length decreases affecting salmonid food supply.

Point source (PS) and non-point source pollution (NPS) occurs at almost every point that urbanization activity influences the watershed. Impervious surfaces (*i.e*. concrete) reduce water infiltration and increase runoff, thus creating greater flood hazard (NMFS 1996). Flood control and land drainage schemes may increase the flood risk downstream by concentrating runoff. A flashy discharge pattern results in increased bank erosion with subsequent loss of riparian vegetation, undercut banks and stream channel widening. Runoff from residential and industrial areas also contributes to water quality degradation (California Regional Water Quality Control Board-Central Valley Region 1998). Urban stormwater runoff contains pesticides, oil, grease, heavy metals, polynuclear aromatic hydrocarbons, other organics and nutrients (California Regional Water Quality Control Board-Central Valley Region 1998) that contaminate drainage waters and destroy aquatic life necessary for salmonid survival (NMFS 1996). In addition, juvenile salmonids are exposed to increased water temperatures as a result of thermal inputs from municipal, industrial, and agricultural discharges.

Past mining activities routinely resulted in the removal of spawning gravels from streams, channelization of streams from dredging activities, and leaching of toxic effluents into streams. Many of the effects of past mining operations still impact steelhead habitat today. While some of this mining habitat has been repaired on the Tuolumne and Merced rivers, a substantial portion of the habitat is still degraded as a result of past activities.

The world is about 1.3 °F warmer today than a century ago and the latest computer models predict that, without drastic cutbacks in emissions of carbon dioxide and other gases released by the burning of fossil fuels, the average global surface temperature may raise by two or more degrees in the 21st century (IPCC, 2001). Much of that increase will likely occur in the oceans, and evidence suggests that the most dramatic changes in ocean temperature are now occurring in the Pacific (Noakes 1998). Using objectively analyzed data Huang and Liu (2000) estimated a warming of about 0.9 °F per century in the Northern Pacific Ocean.

Sea levels are expected to rise by 0.5 to 1.0 meters in the northeastern Pacific coasts in the next century, mainly due to warmer ocean temperatures, which lead to thermal expansion much the same way that hot air expands. This will cause increased sedimentation, erosion, coastal flooding and permanent inundation of low-lying natural ecosystems (*e.g*., salt marsh, riverine, mud flats) affecting salmonid PCEs. Increased winter precipitation, decreased snow pack, permafrost degradation and glacier retreat due to warmer temperatures will cause landslides in unstable mountainous regions, and destroy fish and wildlife habitat, including salmon-spawning streams. Glacier reduction could affect the flow and temperature of rivers and streams that depend on glacier water, with negative impacts on fish populations and the habitat that supports them.

Summer droughts along the south coast and in the interior of the northwest Pacific coastlines will mean decreased stream flow in those areas, decreasing salmonid survival and reducing water supplies in the dry summer season when irrigation and domestic water use are greatest. Global warming may also change the chemical composition of the water that fish inhabit: the amount of oxygen in the water may decline, while pollution, acidity, and salinity levels may increase. This will allow for more invasive species to over take native fish species and impact predator-prey relationships (Stachowicz *et al.*, 2002 and Peterson and Kitchell, 2001).

An alarming prediction is the fact that Sierra snow packs are expected to decrease with global warming and that the majority of runoff in California will be from rainfall in the winter rather than from melting snow pack in the mountains. This will alter river runoff patterns and transform the tributaries that feed the Central Valley from a spring/summer snowmelt dominated system to a winter rain dominated system. It can be hypothesized that summer temperatures and flow levels will become unsuitable for salmonid survival. The cold snowmelt that furnishes the late spring and early summer runoff will be replaced by warmer precipitation runoff. This should truncate the period of time that suitable cold-water conditions exist below existing reservoirs and dams due to the warmer inflow temperatures to the reservoir from rain runoff. Without the necessary cold water pool developed from melting snow pack filling reservoirs in the spring and early summer, late summer and fall temperatures below reservoirs, such as Lake Shasta, could potentially rise above thermal tolerances for juvenile and adult salmonids (*i.e.* Sacramento River winter-run Chinook salmon and CV steelhead) that must hold below the dam over the summer and fall periods.

During flood events, land disturbances resulting from logging, road construction, mining, urbanization, livestock grazing, agriculture, fire, and other uses may contribute sediment directly to streams or exacerbate sedimentation from natural erosive processes (California Advisory Committee on Salmon and Steelhead Trout 1988, NMFS 1996). Sedimentation of stream beds has been implicated as a principle cause of declining salmonid populations through-out their range. In addition to problems associated with sedimentation, flooding can cause scour and redeposition of spawning gravels in typically inaccessible areas. As streams and pools fill in with sediment, flood flow capacity is reduced. Such changes cause decreased stream stability and increased bank erosion, and subsequently exacerbate existing sedimentation problems (NMFS 1996). All of these sources contribute to the sedimentation of spawning gravels and filling of pools and estuaries used by all anadromous salmonids. Channel widening and loss of pool-riffle sequence due to aggradation has damaged spawning and rearing habitat of all salmonids.

Unusual drought conditions may warrant additional consideration in California. Flows in 2001 were among the lowest flow conditions on record in the Central Valley. The available water in the Sacramento watershed and San Joaquin watershed was 70 percent and 66 percent of normal, according to the Sacramento River Index and the San Joaquin River Index, respectively. Back-to-back drought years could be catastrophic to small populations of steelhead that are dependent upon reservoir releases for their success. Therefore, reservoir carryover storage (usually referred to as end-of-September storage) is a key element in providing adequate reserves to protect salmon and steelhead during extended drought periods. In order to buffer the effect of drought conditions and over allocation of resources, NMFS in the past has recommended that minimum carryover storage be maintained in Shasta and other reservoirs to help alleviate critical flow and temperature conditions in the fall.

The extensive introduction of non-native invasive species (NIS) has dramatically altered the biological relationships between and among salmonids and the natural communities that share rivers (NMFS 1998). As currently seen in the San Francisco Estuary, NIS can alter the natural food webs that existed prior to their introduction. Perhaps the most significant example is illustrated by the Asiatic freshwater clams *Corbicula fluminea* and *Potamocorbula amurensis*. The arrival of these clams in the estuary disrupted the normal benthic community structure and depressed phytoplankton levels in the estuary due to the highly efficient filter feeding of the introduced clams (Cohen and Moyle 2004). The decline in the levels of phytoplankton reduces the population levels of zooplankton that feed upon them, and hence reduces the forage base available to salmonids transiting the Delta and San Francisco Estuary which feed either upon the zooplankton directly or their mature forms. This lack of forage base can adversely impact the health and physiological condition of these salmonids as they migrate through the Delta to the Pacific Ocean.

Attempts to control the NIS also can adversely impact the health and well being of salmonids within the affected water systems. For example, the control programs for the invasive water hyacinth and *Egeria densa* plants in the Delta must balance the toxicity of the herbicides applied to control the plants to the probability of exposure to listed salmonids during herbicide application. In addition, the control of the nuisance plants has certain physical parameters that must be accounted for in the treatment protocols, particularly the decrease in DO resulting from the decomposing vegetable matter left by plants that have died.

Water Temperature

Water temperature is thought to be a population limiting factor for both salmon and rainbow trout in the Tuolumne River (see Limiting Factor Analyses for Chinook salmon on page 20). One particular concern for rainbow trout is that the adults spawn in the San Joaquin tributaries between January and late-May and the water temperatures can be too high when eggs are incubating in late spring. The optimum temperature range for steelhead egg incubation is estimated to be 46ºF to 52ºF based on various studies (Reiser and Bjornn 1979, Bovee 1978, Bell 1986, Leidy and Li 1987). Egg mortality may begin at temperatures above 56ºF (McEwan and Jackson 1996). Adult straying and egg viability may be affected by flow if (a) water temperatures in the Delta affect egg viability and (b) flow and export rates in the Delta affect the number of San Joaquin adults that stray to the Sacramento Basin. If true, then managing flow and Delta export rates may be an important tool for maximizing the number of adult fish with viable eggs that return to the Tuolumne River each year.

Management Conceptual Models

Chinook Salmon Model

The Agencies' Salmon Model (Figure 20) is life history based and includes the following six components in order of highest to lowest priority: (1) smolt survival in the Tuolumne River and Delta is primarily affected by instream flow releases from April 1 to June 15; (2) fry survival to the smolt-stage in the Tuolumne River is primarily affected by instream flow releases between early-February and late-May; (3) fry survival in the Delta is relatively low compared to fry survival in the Tuolumne River ; (4) fall flows may have a small affect on adult recruitment by enhancing the production of early migrating juveniles that presumably survive at higher rates than late migrating juveniles; (5) the quality and quantity of spawning gravels does not substantially affect adult recruitment; and (6) factors that affect salmonid survival in the ocean are relatively unimportant.

To evaluate the mechanism(s) between flow and the survival of juvenile Chinook salmon, the Agencies provide hypotheses and recommended study elements for developing a long-term monitoring program.

Life History Components:

1. **Smolt Outmigration**: *High flows between early April and mid-June are a primary determinant of smolt survival and adult recruitment in the Tuolumne River.* The specific mechanism(s) by which flow affects smolt survival is unknown, and it is likely that there are several mortality factors that are ameliorated by increased spring flow. It is assumed that:
    a. Water quality (e.g., water temperature, contaminants, and dissolved oxygen) in the lower river and Delta improves which reduces mortality causal factors (e.g., disease, contaminants, and starvation);
    b. Smoltification and out-migration transit time are reduced through the lower Tuolumne River and Delta;
    c. Predation, by native Sacramento pikeminnow and introduced black bass and striped bass, is reduced as water temperature declines, water quality improves, water velocity increases, and flood-related turbidity increases; and
    d. Entrainment and impingement in the lower river and Delta is a minor mortality factor.

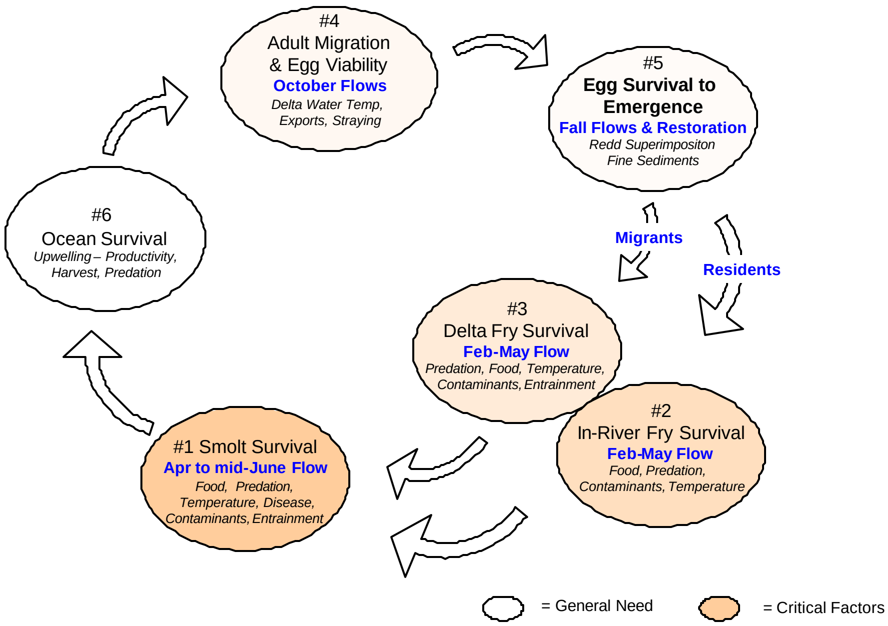

Figure 20. The Agencies' conceptual model explaining how flow, restoration, and other factors can best be managed to substantially increase the abundance of fall-run Chinook salmon in the lower Tuolumne River. The importance of the factors is shown numerically by assigning # 1 to the most critical factor and #6 to the least critical factor.

2. **In-River Rearing**: *High flows between early-February and late-May are a primary determinant of the number of juvenile salmon that survive to smolt size in the Tuolumne River and contribute to adult recruitment.* It is assumed that when high flows begin in February and extend into late-May, a higher percentage of juveniles survive as a result of
   a. increased rearing habitat quantity and quality as floodplain habitat increases;
   b. increased food availability from inundated floodplains,
   c. improved water quality (including water temperature, contaminants, and dissolved oxygen) improves which reduces mortality from other stressors (e.g., disease, contaminates, and starvation), and
   d. reduced predation by Sacramento pikeminnow, black bass and striped bass.
3. **Delta Rearing:** *The number of fry and parr that survive their migration through the Tuolumne River and then rear to a smolt size in the San Joaquin River and Delta provides a minor contribution to adult recruitment compared to the number of smolts produced in the Tuolumne River.* Although deltas and estuaries in their undisturbed states are thought to provide high quality habitats for juvenile Chinook salmon (Healey 1991, page 333), it is currently assumed there are too many stressors in the South Delta for any juvenile salmon to survive to the smolt stage.

4. **Fall flows:** *Fall flows improve egg viability, reduce egg mortality from redd superimposition, and minimize straying of early arriving adult salmon.* The protection of early arriving fish and their eggs would be expected to increase the production of juveniles that would migrate early in the spring when conditions are most favorable for their survival and thereby increase adult recruitment. However, there has been no detectable increase in adult recruitment in the Tuolumne, Stanislaus, or Merced rivers in response to the releases of fall attraction flows or increased fall base spawning flows since the mid 1990s. Therefore, it is likely that fall flows have a relatively minor effect on adult recruitment compared to the effects of winter and spring flows on juvenile rearing and migratory habitats.
5. **Habitat Restoration:** *Restoration of physical habitat and fluvial geomorphic processes intended to increase egg survival to emergence will not substantially increase adult recruitment. Conversely, physical habitat restoration that increases the availability of rearing habitat, improves food availability, and protects and increased mature riparian vegetation that provides shade and instream woody debris will help increase juvenile and adult salmon production if implemented in combination with sufficient spring flows that inundate floodplains and provide sufficient outmigration conditions*. Salmon need suitable physical habitat for spawning and rearing without stressors from exotic predators and entrainment into unscreened diversions to successfully complete their life cycle and meet adult escapement abundance goals. However, winter and spring flows are the primary factor that limit juvenile production and adult recruitment in the lower Tuolumne River, not degraded spawning habitat. The degraded spawning habitat in the lower Tuolumne River currently produces more juveniles than can survive to a smolt-size. Therefore, improving spawning habitat or restoring fluvial geomorphic processes to naturally improve the quality of spawning habitats will not substantially increase the production of smolts or adult recruitment. Moreover, projects implemented in the Tuolumne River since the late 1990s to restore fluvial geomorphic processes and spawning habitat quality were designed to (a) create sources of spawning gravel on floodplains by adding gravel and removing riparian vegetation; and (b) confine the flow to the active channel to mobilize spawning gravels. Instead, the opposite approach of enhancing riparian production on floodplains and increasing floodplain inundation may have done more to improve rearing habitats and the production of salmon smolts.
6. **Indices of ocean conditions:** *Indices of ocean conditions, such as the mean November to March values of Pacific interdecadal oscillation and the mean May to July values of the Pacific Fisheries Environmental Laboratory coastal upwelling index, are not correlated with adult recruitment in the Tuolumne River (Mesick and Marston 2007).* It is assumed that ocean mortality factors have a small effect on adult recruitment compared to the factors affecting juvenile survival in the Tuolumne River and Delta.
7. **Ocean Harvest:** *Ocean harvest does not materially influence adult escapement into the Tuolumne River*. It takes relatively few spawners to saturate the habitat with juvenile fish in the Tuolumne River and low spawner abundance is primarily

due to low winter and spring flows affecting juvenile survival rather than excessive harvest rates.

Rainbow Trout Model

The Agencies' migratory rainbow model separates the life history components into critical factors and general needs (Figure 21). There are two critical factor components in the model: (1) survival of downstream migrating smolts in the Tuolumne River and Delta is primarily affected by flow between early-January and mid-June; and (2) juveniles survival is dependent on adequate flow between February and November during the entire two- to three-year rearing period as it affects summer water temperatures, food, and predation. The model also includes two general need components, which must be managed to sustain the population: (1) egg survival to emergence is primarily affected by water temperatures during late spring and degraded spawning habitats and (2) adult straying and the viability of eggs in upmigrating adults are affected by low flows and high Delta exports primarily from December through May. The Agencies believe that factors that affect steelhead survival in the ocean are relatively unimportant for the same reason cited for Salmon.

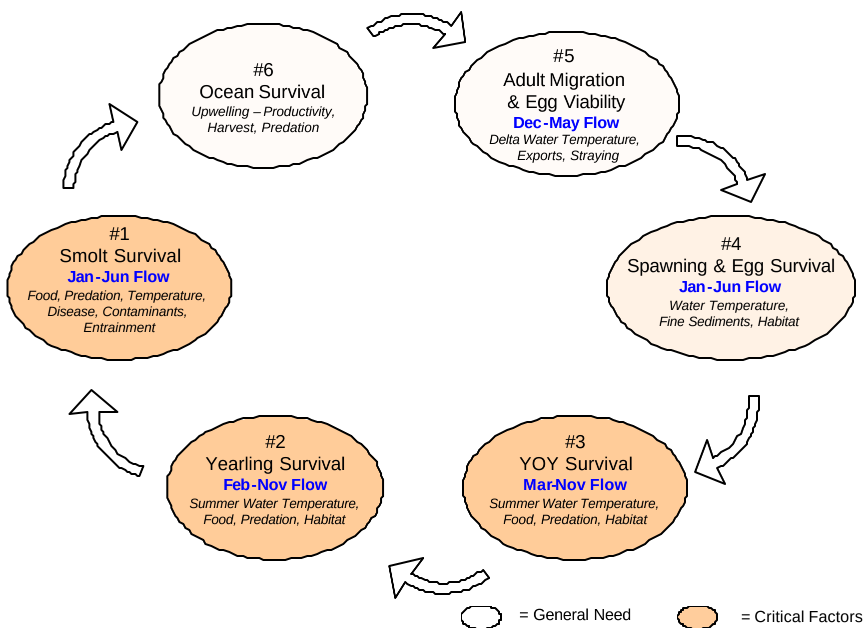

Figure 21. The Agencies' conceptual model explaining how flow, restoration, and other factors can best be managed to protect migratory rainbow trout in the lower Tuolumne River. The importance of the factors is shown numerically by assigning # 1 to the most critical factor and #6 to the least critical factor.

Life History Components

1. **Smolt Outmigration**: *High flows between January and mid-June are a primary determinant of smolt survival and adult recruitment in the Tuolumne River.* The mechanism(s) by which flow affects steelhead smolt survival is unknown. It is assumed that flow levels that increase salmon smolt production will also increase steelhead smolt production as the two species are closely related and adapted to the same circumstances in the Tuolumne River.

2. **Summer Juvenile Rearing:** *Summer water temperatures downstream to the Roberts Ferry Bridge are a primary determinant of the number of juveniles that survive to a smolt size in the Tuolumne River.* It is assumed that sustaining a steelhead population in the Tuolumne River requires that suitable water temperatures are provided at least to Roberts Ferry Bridge every year. It is assumed that most, if not all, steelhead smolts require two rearing summers before beginning their downstream migration. It is assumed that most of the habitat downstream of the Roberts Ferry Bridge is unsuitable for spawning and rearing juveniles because the channel gradient is too low to provide suitable physical habitat (i.e., few riffle habitats).

3. **Winter and Spring Juvenile Rearing**: *High flows between early-January and late-May affect juvenile survival.* It is assumed that high flows between early January and late-May affect steelhead smolt survival by:
    a. increasing rearing habitat quantity/quality as floodplain habitat increases;
    b. increasing food availability from inundated floodplains,
    c. improving water quality (including water temperature, contaminants, and dissolved oxygen) improves which reduces mortality from other stressors (e.g., disease, contaminates, and starvation), and
    d. possibly reducing predation by Sacramento pikeminnow, black bass and striped bass.

Information Gaps

The above limiting factor analyses for Tuolumne River salmon and trout has identified key information gaps in life history trends for both species. In summary these include:

Salmon

1. The specific mechanism(s) by which elevated winter and spring flows result in increased in-river smolt production is unknown;
2. The most efficient flow schedule that would conserve water supplies and provide an adequate magnitude, duration, and timing of winter and spring flows to accomplish targeted production goals is unknown;
3. Out-migrant fry contribution (Delta rearing) to escapement is unknown;
4. Water temperature impacts to juvenile production are unknown;

5. Non-flow habitat restoration that would substantially increase juvenile survival and in-river smolt production, is unknown; and
6. Whether fall pulse flows and base flows during spawning affect the survival of out-migrating smolts and thereby substantially affect the production of adult recruits is unknown.

Rainbow Trout

1. The population abundance of rainbow trout in the lower Tuolumne River.
2. The relative proportion of resident and migratory rainbow trout in the lower Tuolumne River.
3. The distribution of adult rainbow trout relative to habitat conditions in the lower Tuolumne River.
4. The effects of flow on the rainbow trout abundance and habitat availability.
5. Rainbow trout limiting factors analysis.

Recommended Study Elements

Our recommendations for a Tuolumne River Fishery Study Plan include five basic elements:

1. Appropriate management questions framed as testable hypotheses;
2. Metrics that can be measured at both the site-specific and populations levels;
3. Methods that provide relatively accurate measurements of the test metrics;
4. Experimental conditions that, to the extent possible, vary one habitat variable at a time. For example, an experimental flow schedule should evaluate the importance of flow duration while holding flow magnitude and timing relatively constant. In regard to experimental conditions for restoration, different restoration strategies, such as improving rearing habitat versus spawning habitat, should be implemented sequentially in similarly sized, nearby sites. Population models should be used to separate the effects of spawner abundance from flow and restoration effects on the production of juveniles and adults. Previously, flow studies occurred opportunistically depending on natural variations in water availability, baseline data at restoration projects were inadequate, and different restoration strategies were not compared; and
5. Statistical designs that provide assurances that a sufficient number of observations will be made and specifies how the data will be assessed to adequately test the hypotheses and reach statistically valid conclusions.

In the following section, we recommend important management questions and related testable hypotheses that pertain to the Tuolumne River. The study metrics are contained in the hypotheses. In the next section, we recommend study methods that will be needed to test each hypothesis. We also recommend an experimental flow schedule that will create the conditions needed to test the hypotheses. And we assume that a commitment will be made to collect a sufficient amount of data needed to adequately test all of the hypotheses.

Management Questions, Testable Hypotheses, and Metrics

Salmon Management Questions, Hypotheses, and Metrics

The following management questions are listed in order of priority of importance needed to reverse the long term declining Salmon population trend. Research should be designed to sufficiently evaluate the following management questions. It is also anticipated that an adaptive management strategy will have to be implemented assuming that the initial results may suggest revisions management questions and/or actions.

We focus on the development of testable hypotheses below. In statistical design, there are two conflicting (i.e., mutually exclusive) hypotheses called the null hypothesis and the alternative hypothesis for each management question. Nowadays, it is common practice not to associate any special meaning to the null or alternative hypotheses, but instead to have the null hypothesis be the one that contains an equal sign whereas the alternative hypothesis would contain a "not equal", "greater than", or "less than" sign (Harnett 1982). Although many of our hypotheses about population parameters do not contain equal signs, the likely population limiting factors discussed in our conceptual model indicate specific conditions (e.g., the critical period is April 1 to June 15) to be tested and so are designated as the null hypothesis, which is identified as H_o. We state the alternative hypotheses, H_a (e.g., the critical period is not April 1 to June 15), only when the conflicting statement is not obvious.

We recommend study methodologies to test each of the following hypotheses in the following section.

Management Question #1: *Are continuously high flows between early-April and mid-June the primary determinant of the survival of smolt outmigrants and adult recruitment in the Tuolumne River?* This question is our highest priority because the results will enable the development of instream flow schedules that should maximize the production of adult salmon given the limited flow volume that has been allocated for fish. The primary objective of the following hypotheses is to determine the timing and duration of the critical period that high flows are needed to maximize the production of smolt-sized outmigrants and thereby maximize the production of adult recruits. A secondary objective is to quantify the relative importance of flow magnitude and flow duration to the production of smolts. The null hypotheses for this question assumes that the survival of smolt-sized outmigrants is the key determinant of adult recruitment. The alternative hypotheses would test (1) whether other factors unrelated to flow are more strongly correlated with adult recruitment than spring flows and (2) whether the critical flow period for adult recruitment is either substantially longer than or shorter than the April 1 to June 15 period.

H_o: The estimated number of smolt-sized outmigrants ($\geq$ 70 mm FL) that pass the Grayson River Ranch Site is most strongly correlated with the mean flow from La Grange Dam between 1 April and 15 June.

H_o: The survival of smolt-sized outmigrants ($\geq$ 70 mm FL) in the San Joaquin River between Mossdale and Jersey Point between 1 April and 15 June is most strongly correlated with the mean flow in the San Joaquin River near Vernalis.

H_o: The number of adult recruits is most strongly correlated with the mean flow from La Grange Dam and in the San Joaquin River near Vernalis between 1 April and 15 June during the year when the fish migrated toward the ocean.

H_a: The number of adult recruits is most strongly correlated with non flow factors, such as egg mortality from an insufficient quantity and quality of spawning habitat in the Tuolumne River, poaching of adult spawners, insufficient spawner abundance due to excessive rates of ocean and sport harvest, Delta export rates, contaminants, predation in the Stockton deep-water ship channel, and ocean conditions.

H_o: The number of smolt-sized outmigrants ($\geq$ 70 mm FL) estimated to be passing the Grayson River Ranch Site is strongly correlated with the corresponding number of adult recruits.

Management Question #2: *Do continuously high flows between early-April and mid-June affect survival of smolt outmigrants in the Tuolumne River by ameliorating a combination of stressors, including increasing the amount of available high quality habitat, increasing food availability, reducing disease, reducing predation, accelerating smoltification, reducing contaminants, reducing entrainment, and by improving the suitability of water temperatures?* This question is also a high priority because the results will help determine whether our efforts to achieve our goal of doubling fish will focus on flow management, habitat restoration, and/or other non-flow management actions. The primary objective of the following hypotheses is to determine whether a combination of stressors affects smolt survival that can only be improved by managing streamflow. The alternative hypotheses would test whether the primary stressors affecting smolt survival are only partially related to flow, such as predation by black bass and Sacramento pikeminnow in captured mine pits or dredged special run pools, contaminants in agricultural runoff, and entrainment at unscreened pumps, and therefore could be managed through habitat restoration and by installing fish screens.

H_o: The number of naturally produced smolt-sized outmigrants ($\geq$ 70 mm FL) with surgically implanted sonic tags that survive their migration between La Grange and the Grayson River Ranch is positively correlated with the mean flow in the Tuolumne River between 1 April and 15 June.

H_o: The percentage of naturally produced outmigrants that survive their migration between the rotary screw trap sites near the downstream boundary of the spawning reach (between the 7/11 site and Waterford) and the Grayson River Ranch site is most strongly correlated with the mean flow in the Tuolumne River between 1 April and 15 June.

H_o: The sources of mortality of smolt-sized outmigrants ($\geq$ 70 mm FL) with surgically implanted sonic tags that migrate between La Grange and the Grayson

River Ranch, those held in live wells, and those captured in rotary screw traps between 1 April and 15 June primarily include a combination of stressors, such as a lack of inundated floodplain habitat, insufficient food resources, disease, delayed smoltification, unsuitably high water temperatures, and predation by striped bass and rainbow trout, that must be primarily managed with flow releases.

H_a: The sources of mortality of smolt-sized outmigrants ($\geq$ 70 mm FL) with surgically implanted sonic tags that migrate between La Grange and the Grayson River Ranch, those held in live wells, and those captured in rotary screw traps between 1 April and 15 June primarily includes stressors, such as predation by black bass or Sacramento pikeminnow in habitats degraded by gravel mining, contaminants from agricultural runoff, entrainment at unscreened diversions, and other stressors that can be managed with habitat restoration, fish screens, and other non-flow management actions.

<u>Management Question #3:</u> *Do elevated floodplain inundation level flows between early-February and late-March concurrent with elevated spring time flow levels increase the number of salmon fry that survive to a smolt size and adult recruitment in the Tuolumne River?* This question is another high priority issue because the results will help us focus habitat restoration and flow management on either fry rearing in the river or smolt outmigration through the lower river and Delta. The primary objective of the following hypotheses is to determine whether flows that inundate floodplains and thereby affect fry rearing during February and/or March are critical to the production of smolt-sized outmigrants from the Tuolumne River. Floodplain inundation between La Grange and the Ruddy Gravel Mine primarily occurs between flows of 1,100 cfs and 3,100 cfs (Turlock Irrigation District and Modesto Irrigation District 2001) and so tests of these hypotheses should compare base flows and flows of at least 2,000 cfs. The following hypotheses need to be tested at the population level (i.e., not with tagged survival studies) to address this management question:

H_o: The estimated number of smolt-sized outmigrants ($\geq$ 70 mm FL) that pass the Grayson River Ranch Site is most strongly correlated with the mean flow from La Grange Dam between 1 February and 15 June.

H_a: The estimated number of smolt-sized outmigrants ($\geq$ 70 mm FL) that pass the Grayson River Ranch Site is most strongly correlated with the mean flow from La Grange Dam between 1 April and 15 June.

<u>Management Question #4:</u> *Do elevated floodplain inundation level flows between early-February and late-March concurrent with elevated spring time flow levels in the Tuolumne River affect the number of salmon fry that survive to a smolt size by ameliorating a combination of stressors, including increasing the amount of available high quality habitat, increasing food availability, reducing disease, reducing predation, accelerating smoltification, reducing contaminants, reducing entrainment, and by improving the suitability of water temperatures?* This question is also a high priority because the results will help focus our efforts on flow management, habitat restoration,

and/or other non-flow management actions. The primary objective of the following hypotheses is to determine whether a combination of stressors affects the survival of fry to a smolt size that can only be improved by managing streamflow. The alternative hypotheses would test whether the primary stressors affecting fry survival are only partially related to flow, such as predation by black bass and Sacramento pikeminnow in captured mine pits or dredged special run pools, contaminants in agricultural runoff, and entrainment at unscreened pumps, and therefore could be managed through habitat restoration and by installing fish screens.

> H_o: The percentage of naturally produced outmigrants that survive their migration between the rotary screw trap sites at the downstream boundary of the spawning reach and the Grayson River Ranch site is most strongly correlated with the mean flow in the Tuolumne River between 1 February and 15 June.

> H_o: The sources of mortality of juvenile salmon < 70 mm FL rearing in the Tuolumne River between 1 February and 31 March primarily include a combination of stressors, such as a lack of inundated floodplain habitat, insufficient food resources, disease, delayed smoltification, unsuitably high water temperatures, and predation by striped bass and rainbow trout, that must be primarily managed with flow releases.

> H_a: The sources of mortality of juvenile salmon < 70 mm FL rearing in the Tuolumne River between 1 February and 31 March primarily includes stressors, such as predation by black bass or Sacramento pikeminnow in habitats degraded by gravel mining, contaminants from agricultural runoff, entrainment at unscreened diversions, and other stressors that can be managed with habitat restoration, fish screens, and other non-flow management actions.

<u>Management Question #5:</u> *Do fry outmigrating from the Tuolumne River materially contribute to adult recruitment?* This question is a moderately high priority because of the need to determine whether Tuolumne River adult recruitment is mostly affected by conditions in the river or the Delta. The primary objective of the following hypotheses is to determine whether fry survive in the Delta, and if so, whether flow substantially affects their survival. Attempts to conduct similar studies in Butte Creek and the Mokelumne River by differentially tagging naturally produced fry and smolt sized fish have so far failed to recover a sufficient number of adult fish with tags to assess this question. Since rotary screw traps catch a high percentage of fry and relatively few smolts, the low rate of tag recoveries in escapement surveys suggests that most adults were juveniles that remained in the rivers until they reached the smolt stage. To better address this question, we recommend using otolith microchemical or microstructural analysis to determine fry contribution rates because of the likelihood that there are substantial differences in water chemistry and water temperature between the Tuolumne River and the Delta that will be evident in the otoliths. We also recommend that the analysis should begin with a cohort of adults that reared during wet conditions when outmigrating fry would be expected to contribute to adult recruitment.

H_o: At least 25% of the otoliths from adult salmon that outmigrated as juveniles to the ocean during years when flows averaged at least 2,000 cfs from early-February through mid-June will indicate that the fish primarily reared in the Delta. The percentage of fish successfully rearing in the Delta is expected to be less than 10% in years with either a shorter duration or magnitude of spring flows.

H_a: At least 75% of the otoliths from adult salmon that outmigrated as juveniles to the ocean during years when flows were high from early-February through mid-June will indicate that the fish primarily reared in the Tuolumne River before they reached the smolt stage (> 70 mm FL). The percentage of adults that reared in the Tuolumne River before smolting is expected to be at least 90% in years with either a shorter duration or magnitude of spring flows.

<u>Management Question #6:</u> *Do elevated fall pulse flows improve egg viability and minimize straying of early arriving adult salmon?* This question is a moderate priority because the results would help determine the best allocation of a relatively small volume of water between the spring outmigration period and the fall spawning period. The primary objective of the following hypotheses is to determine whether fall pulse flows help improve the production of smolt outmigrants and adult recruitment.

H_o: Straying rates of coded-wire-tagged smolts released in the Tuolumne River are minimized (<5%) by releases of fall pulse flows in October when Delta export rates do not exceed 350% of Vernalis flows.

H_o: Egg viability rates at the Merced River hatchery are significantly higher during years when fall pulse flows occur and Delta water temperatures do not exceed 70^{o}F in October than during years when no fall pulse flows were released and water temperatures exceeded 70 ^{o}F.

H_o: Pre-spawn mortality of adults is less than 5% when fall pulse flows occur in October and fall base flows exceed 200 cfs.

H_o: Spawner densities less than 500 fish reduce adult recruitment.

<u>Management Question #7:</u> *Do flow and water temperature levels in the fall affect the distribution of spawners and redd superimposition rates?* This question is also a moderate priority for the same reason as the previous question. The primary objective of the following hypotheses is to determine whether base flows for spawning between late-October and late-December and restoration of spawning habitat affect the production of early migrating smolts, which may substantially affect adult recruitment.

H_o: As spawner abundances exceed 1,000 fish, the production of juveniles from early arriving females decreases due to redd superimposition.

H_o: Juveniles produced from early arriving females migrate at an earlier age and therefore have a greater chance of survival to adulthood than would juveniles produced from late arriving females.

H_o: Increasing fall base flows between late-October and mid-November to increase the river miles of habitat with water temperatures less than 53°F by 25% will increase the distribution of spawners in the Tuolumne River and thereby reduce redd superimposition rates by at least 10%.

H_o: Doubling the availability of spawning habitat in the 6-mile reach below La Grange Dam will reduce redd superimposition rates by at least 25%.

H_o: Reducing the superimposition of early redds by 25% will result in at least a 25% increase in adult recruitment.

Management Questions #8: *Do physical habitat restoration projects that focus on improving floodplain habitat quantity and quality improve smolt production, and survival, in combination with elevated winter and spring time flows?* This is another important question because it will provide evidence as to whether restoration in the Tuolumne River should focus on rearing conditions or spawning conditions. The primary objective of the following hypotheses is to determine whether (a) restoring floodplains to become inundated annually and to develop productive riparian forests or (b) restoring fluvial geomorphic processes by adding gravel and confining the active channel provides the greatest increase in the production of smolts and adult recruits.

H_o: The estimated number of smolt-sized fish (< 70 mm FL) at Grayson River Ranch is more highly correlated with the amount of inundated floodplain habitat and the duration of inundation than with an index of the number of fry produced based on the estimated number of all juveniles that pass a rotary screw trap site near the downstream boundary of the spawning reach (7/11 or Waterford).

H_o: The estimated number of smolt-sized fish (< 70 mm FL) at Grayson River Ranch will increase to a greater degree after restoring a substantial amount of floodplain habitat with productive riparian forests that is inundated annually than from restoring a substantial amount of spawning habitat in the 6-mile reach below the La Grange Dam.

Management Question #9: *Do late spring ramping rates affect riparian vegetation establishment?* If Management Questions #2 and #4 indicate that smolt production in the Tuolumne River is substantially dependant upon terrestrial food resources, then we will need to know how to manage flow ramping rates in late spring and early summer to promote riparian vegetation establishment.

H_o: Smolt production in the Tuolumne River is substantially dependant on terrestrial food resources compared to autochthonous sources, upstream reservoir produced resources, and decomposing adult salmon.

H_o: Riparian vegetation establishment requires flood flows to be ramped down at rates that cause the water table to decline no faster than 0.75 inches per day (approximately 100 cfs/day) from mid-April to late-May to improve cottonwood recruitment and from mid-May to late June to benefit black willow.

Rainbow Trout Management Questions

The following management questions are listed in order of priority of importance needed to assess the impacts of the Don Pedro FERC License and Settlement Agreement on rainbow trout. These questions focus on obtaining basic population data and so no hypotheses are recommended.

Management Question #1: What is the trend abundance of adult rainbow trout in the Tuolumne River? Management Action: Determine abundance of adult rainbow trout in the Tuolumne River.

Management Question #2: What is the abundance trend of juvenile rainbow trout in the Tuolumne River? Management Action: Determine abundance of adult rainbow trout in the Tuolumne River.
Management Question #3: What is the migratory behavior of adult *O. mykiss* in the Tuolumne River? Management action: Determine migratory behavior of adult *O. mykiss* in the Tuolumne River.

Management Question #4: What is the migratory behavior of juvenile *O. mykiss* in the Tuolumne River? Management action: Determine migratory behavior of juvenile *O. mykiss* in the Tuolumne River.

Management Question #5: What is the distribution and habitat condition in the Tuolumne River for adult O. mykiss? Management action: Determine distribution and habitat condition in the Tuolumne River for adult *O. mykiss*.

Management Question #6: What is the distribution and habitat condition in the Tuolumne River for juvenile O. mykiss? Management action: Determine distribution and habitat condition in the Tuolumne River for juvenile *O. mykiss*.

Management Question 7: What are the effects of the Tuolumne River instream flow schedule on both adult, and juvenile, rainbow trout and steelhead habitat? Management action: Determine effects of instream flow schedule upon both adult and juvenile rainbow trout, and steelhead, habitat in the Tuolumne River.

Management Question #8: What are the factors limiting both resident, and anadromous, *O. mykiss* populations in the Tuolumne River? Management action: Determine limiting factors for resident, and migratory, *O. mykiss* populations in the Tuolumne River.

Recommended Methods (Studies)

The following describes the study methods needed to test the key management questions described above. Conditions in the Tuolumne River cannot be sufficiently controlled to produce the experimental conditions needed to implement the most robust statistical designs. There will always be several different environmental variables that vary each year and it will be nearly impossible to adhere to strict flow regimes, particularly during the unpredictable winter and spring runoff period. In addition, we cannot implement habitat restoration and then return the site to a natural condition as would be required for a Factorial Experiment (Snedecor and Cochran 1989). As a result, it will be necessary to rely on correlation analyses of population level metrics and cause-and-effect analyses based on the response of individual fish to experimental flow and restoration treatments to fully test our recommended hypotheses.

Adult and juvenile population metrics should be monitored in relation to all the important habitat features, such as streamflow, water temperature, changes in the suitability of the physical habitat, predation, etc. The hypotheses would be tested by determining the habitat feature(s) that are most strongly correlated with the population metrics. Adult metrics should be used for three reasons: (1) escapement estimates are relatively accurate compared to rotary screw trap estimates of juvenile abundance, (2) there is a long-term escapement database that provides a benchmark for future management actions, and (3) escapement provides a direct measure of our goal to recover the adult population. Juvenile metrics should also be used because they directly reflect the conditions in the Tuolumne River; whereas the adults are also affected by conditions in the Delta and ocean. It should also be possible to improve the rotary screw trap estimates of juvenile abundance, by improving the studies used to calibrate the efficiency of the traps.

To verify that cause-and-effect mechanisms drive the observed correlations between the population metrics and the habitat in the Tuolumne River, it will be necessary to also monitor the response of individual fish to the changes in their habitat. For example, high winter and spring flows are directly correlated with the number of smolt-sized fish produced as well as adult recruitment. Studies of individual fish should be able to determine whether energy reserves, health, predation, and/or smoltification timing improve throughout the high flow period and thereby explain the population response. It will also be necessary to show the link between habitat conditions in the Tuolumne River and the production of Tuolumne River adult fish.

It is also important to try to falsify the null hypothesis by fully describing and then testing the alternative hypotheses. For example, if the survival of fry to a smolt size in the Tuolumne River is highly correlated with adult recruitment (i.e., rearing conditions in the Tuolumne River), then it is important to evaluate whether the relationships between adult recruitment and the number of fry produced in the Tuolumne River (i.e., spawning habitat limitations) and the contribution of fry that rear in the Delta (i.e., rearing conditions in the Delta) are relatively unimportant.

We also suggest that an experimental flow schedule is needed to test flow related hypotheses and to help recover the Tuolumne River salmon and rainbow trout populations. The current population correlation analyses were conducted by evaluating the salmon's response to the natural variation in water availability. They show that adult recruitment and juvenile production increase when flooding occurs throughout the watershed. The greater the magnitude and duration of the flooding, the more fish are produced. However, there is uncertainty as to whether the salmon will respond in a similar manner to controlled reservoir releases. Natural floods may provide benefits, such as increased turbidity that reduces predation and large amounts of organic matter and food flushed into the river from the entire watershed, that are not provided by controlled reservoir releases. Therefore, alternative instream flow schedules must be tested by implementing them on an interim basis.

It is anticipated that at least 10 years of study will be needed to collect a sufficient number of observations over a wide range of habitat conditions to rigorously test these management questions. Another recommendation is to develop an adaptive management plan that would implement new studies and management actions as new management questions are raised throughout the course of this study program. The estimated costs to implement these studies are summarized in Appendix A.

Salmon Management Studies

The nine overall management questions and associated hypotheses are repeated below along with our recommended management actions needed to assess the hypotheses.

Management Question #1: *Are continuously high flows between early-April and mid-June the primary determinant of the survival of smolt outmigrants and adult recruitment in the Tuolumne River?* Four null hypotheses and one alternative hypothesis were developed for this question:

H_o: The estimated number of smolt-sized outmigrants ($\geq$ 70 mm FL) that pass the Grayson River Ranch Site is most strongly correlated with the mean flow from La Grange Dam between 1 April and 15 June.

H_o: The survival of smolt-sized outmigrants ($\geq$ 70 mm FL) in the San Joaquin River between Mossdale and Jersey Point between 1 April and 15 June is most strongly correlated with the mean flow in the San Joaquin River near Vernalis.

H_o: The number of adult recruits is most strongly correlated with the mean flow from La Grange Dam and in the San Joaquin River near Vernalis between 1 April and 15 June during the year when the fish migrated toward the ocean.

H_a: The number of adult recruits is most strongly correlated with non flow factors, such as egg mortality from an insufficient quantity and quality of spawning habitat in the Tuolumne River, ongoing degradation of in-river rearing habitat in the Tuolumne River, poaching of adult spawners, insufficient spawner abundance due to excessive rates of ocean and sport harvest, Delta export rates, water quality and predation in the Stockton deep-water ship channel, and ocean conditions.

H_o: The number of smolt-sized outmigrants ($\geq$ 70 mm FL) estimated to be passing the Grayson River Ranch Site is strongly correlated with the corresponding number of adult recruits.

There are three Management Actions required to test the above hypotheses:

Management Action #1: implement an experimental flow schedule designed to test the relative importance of the magnitude, duration, and timing of springtime pulse flows as described in the following section.

Management Action #2: annually monitor the abundance out of juvenile salmonids with rotary screw trapping near the Grayson River Ranch at a minimum from March 15 to June 15 and preferably from January 1 to June 15. Fish species, body length, weight, and smolt appearance should be recorded for up to 50 fry per day and for all parr and smolt sized fish collected. Calibration tests should be conducted every 7 to 14 days depending on the availability of naturally produced or hatchery reared juveniles. Ideally, at least 500 fry, 1,000 parr, or 2,000 smolt-sized fish (> 70 mm FL) would be marked and released for each test. A protocol should be developed to standardize the efficiency tests relative to the minimum number of marked fish used for each test, determining the survival of the marked fish, the time of day that the fish are released, the rate that fish are released, and whether the test fish are released across the channel or from a single location. Due to past difficulties in obtaining a sufficient number of Merced River hatchery fish and naturally produced Tuolumne River fish for calibration studies, we recommend considering the need to construct and operate an experimental hatchery facility that would produce the necessary Tuolumne River study fish (100,000 fish annually for these tests). The estimated study costs are up to $175,000 annually, which do not include the costs to produce study fish.

Management Action #3: monitor the abundance of adult salmon (escapement) by continuing the CDFG carcass surveys. Estimated cost: approximately $75,000 annually. To improve the method of segregating escapement into cohorts, continue the age analyses with the scale and otolith samples collected since the 1980s. The estimated cost to complete the analysis for the remaining Tuolumne River samples is about $30,000 and $10,000 a year thereafter to analyze newly collected samples.

The following hypothesis is being tested under the Vernalis Adaptive Management Program (VAMP). It has been refined to separately test different flow and export levels with and without the springtime Head of the Old River Barrier (HORB) being installed. We acknowledge the importance of VAMP and recommend that the above survival studies should be coordinated with the VAMP studies.

H_o: The survival of smolt-sized outmigrants ($\geq$ 70 mm FL) in the San Joaquin River between Mossdale and Jersey Point between 1 April and 15 June is most strongly correlated with the mean flow in the San Joaquin River near Vernalis.

Management Question #2: *Do continuously high flows between early-April and mid-June affect survival of smolt outmigrants in the Tuolumne River by ameliorating a combination of stressors, including increasing the amount of available high quality habitat, increasing food availability, reducing disease, reducing predation, accelerating smoltification, reducing contaminants, reducing entrainment, and by improving the suitability of water temperatures?* Three null hypotheses and one alternative hypothesis were developed for this question:

H_o: The number of naturally produced smolt-sized outmigrants ($\geq$ 70 mm FL) with surgically implanted sonic tags that survive their migration between La Grange and the Grayson River Ranch is positively correlated with the mean flow in the Tuolumne River between 1 April and 15 June.

H_o: The percentage of naturally produced outmigrants that survive their migration between the rotary screw trap sites near the downstream boundary of the spawning reach (between the 7/11 site and Waterford) and the Grayson River Ranch site is most strongly correlated with the mean flow in the Tuolumne River between 1 April and 15 June.

H_o: The sources of mortality of smolt-sized outmigrants ($\geq$ 70 mm FL) with surgically implanted sonic tags that migrate between La Grange and the Grayson River Ranch, those held in live wells, and those captured in rotary screw traps between 1 April and 15 June primarily include a combination of stressors, such as a lack of inundated floodplain habitat, insufficient food resources, disease, delayed smoltification, unsuitably high water temperatures, and predation by striped bass and rainbow trout, that must be primarily managed with flow releases.

H_a: The sources of mortality of smolt-sized outmigrants ($\geq$ 70 mm FL) with surgically implanted sonic tags that migrate between La Grange and the Grayson River Ranch, those held in live wells, and those captured in rotary screw traps between 1 April and 15 June primarily includes stressors, such as predation by black bass or Sacramento pikeminnow in habitats degraded by gravel mining, contaminants from agricultural runoff, entrainment at unscreened diversions, and other stressors that can be managed with habitat restoration, fish screens, and other non-flow management actions.

Management Actions are divided into Phase I tests, which would be completed before starting Phase II tests, which would be completed before starting Phase III tests. There are four Management Actions recommended for the Phase I tests:

Phase I Actions

Management Action #1: estimate smolt survival by surgically implanting sonic tags into at least 100 naturally produced smolt-sized outmigrants (80-110 mm FL) captured with rotary screw traps. After the fish have thoroughly recovered from the surgery, they should be released at dusk near La Grange. Stationary receivers should be installed throughout the river, particularly above and below large captured mine pits, and other likely sources of substantial mortality. Mobile receivers should be used to detect fish use of floodplain habitats and restoration sites and sources of mortality related to predation and entrainment.

Management Action #2: annually monitor the abundance of juvenile salmonids with rotary screw trapping near the downstream boundary of the spawning reach (between the 7/11 project and Waterford) from January 1 to June 15 to provide an index of the number of juveniles produced. The same sampling site should be used every year if possible. All data, including fish length, weight, and smolt appearance, should be collected in compliance with standards established in the Central Valley Project Improvement Act Comprehensive Assessment and Monitoring Program (CAMP) protocol. Calibration tests should be conducted every 7 to 14 days depending on the availability of naturally produced or hatchery reared juveniles. Ideally, at least 500 fry, 1,000 parr, or 2,000 smolt-sized fish (> 70 mm FL) would be marked and released for each test. A protocol should be developed to standardize the efficiency tests relative to the minimum number of marked fish used for each test, the time of day that the fish are released, the rate that fish are released, and whether the test fish are released across the channel or from a single location. Due to past difficulties in obtaining a sufficient number of Merced River hatchery fish and naturally produced Tuolumne River fish for calibration studies, we recommend considering the need to construct and operate an experimental hatchery facility that would produce the necessary Tuolumne River study fish. The estimated study costs are up to $175,000 annually, which do not include the costs to produce study fish.

Management Action #3: evaluate the importance of food availability, contaminants, smoltification timing, and disease as potential mechanisms of smolt mortality, by collecting a total of 360 juvenile salmon on a weekly basis from March 1 through June 15 over the next ten years with rotary screw traps and seines for physiological, histological, and disease analyses. The US Fish and Wildlife Service, California - Nevada Fish Health Center has proposed to conduct the following four tasks for an annual cost of about $60,000; this estimate assumes that other researchers will collect, preserve, and ship the samples to their lab in Anderson, California.

- Task 1: determine the incidence and severity of infection for external and internal parasites, including Tetracapsuloides bryosalmonae (detected in 2001 and causes Proliferative Kidney Disease), systemic viral and bacterial infections (including R. salmoninarum that causes Bacterial kidney disease in salmonids) in juvenile Chinook salmon (50 - > 80 mm FL, March – June).
- Task 2: determine the energy reserves of juvenile Chinook salmon (50 - > 80 mm FL, March – June). Specific measurements to include whole body content of protein, triglyceride, and percent lipid.

- Task 3: monitor gill Na-K- Adenosine Triphosphatase activity to track smoltification timing;
- Task 4: examine sections of liver and kidney for abnormalities associated with toxic insult.

Management Action #4: develop a water temperature model and a juvenile salmon production simulation model to estimate juvenile production under a variety of water temperature conditions. The Calfed Bay Delta Authority has funded the water temperature model; whereas additional funded is needed to develop a juvenile salmon production simulation model. It will also be necessary to continue monitoring water temperatures with multiple thermographs located throughout the lower Tuolumne River for the duration of these studies.

Management Action #5: conduct coded-wire-tag (CWT) survival studies using paired releases of hatchery salmon in the Tuolumne River at flows of 4,000 cfs or greater in April or early May. Releases of study fish should be made near La Grange and the mouth of the river to compute the survival of smolt-sized fish migrating through the river as has been done since 1987. The data would be compared to the "validated survival estimates" that were primarily conducted at flows less than 4,000 cfs (Turlock Irrigation District and Modesto Irrigation District 2005).

Phase II and III Actions

The following studies would only be implemented if the Phase I studies identify potentially important factors limiting the production of adult recruits that would require verification before corrective measures are taken.

If Phase I histological studies show signs of toxic insult (i.e., adverse impacts from pesticides or other contaminants), then a bioassay lab should be established on the Tuolumne River. Dr. Don Weston, UC Berkeley, recommends that a stream-side bioassay system could be used to create three treatment levels: unfiltered water, sediment-free water, and dissolved organic free water, in which juvenile salmon would be reared. This design would determine if the causative agent of the developmental defects is in the water, and if so, if it is particle-bound or dissolved. It may also be important to include prey organisms of the juvenile salmon, thus getting information on toxicity to prey and indirect food limitation impacts. The study metrics would include estimates of direct mortality as well as sublethal effects determined by histology studies. Dr. Weston estimated that the cost to conduct the bioassay tests would be about $160,000 annually, the costs for the histological studies would be about $25,000 annually, and the cost to construct a stream-side lab would be about $50,000.

If Phase I lipid content analysis indicates that food availability for juvenile fish may be a limiting factor, studies should be conducted to evaluate whether food resources are primarily aquatic or terrestrial and to compare allochthonous production, autochthonous production, and production from within New Don Pedro reservoir (planktonic). Food resources should be evaluated by examining the gut contents of at least 100 juveniles each month from January 1 through June 1. At a minimum, the studies would be conducted during dry years (base flows only during rearing) and wet years (immediately following floodplain inundation between February 1 and April 15) to compare allochthonous production with autochthonous production. Allochthonous production (e.g., invertebrates and organic matter) would be measured directly using drift-type nets placed at the downstream end of floodplains and in small tributaries. Autochthonous production should evaluate the importance of salmon carcasses using isotope analyses. The results of these studies will be important considerations in (1) restoration planning, particularly regarding floodplain features, (2) management of instream flows and reservoir operations, and (3) the disposition of salmon carcasses. The costs for these studies have not been estimated.

If Phase I sonic tag survival studies indicate that entrainment is a substantial source of mortality, then entrainment into unscreened diversion canals should be monitored with small fyke nets during peak diversion periods of the rearing and smolt out-migration periods. This task depends on obtaining landowner permission to conduct these studies. Such permission is typically granted only when the agencies guarantee the landowner that funds will be provided to fully screen the diversion if observed entrainment rates require screening. The implementation and costs of this task have not been determined.

If Phase I sonic tag survival studies indicate that predation is a substantial source of mortality, then Phase II predation studies consisting of a combination of electrofishing, gill netting, and angling (lures that simulate the appropriately sized juvenile salmonids) should be utilized to determine the fish species that prey on juvenile salmonids, when predation is occurring, and in what habitats predation is occurring. It is likely that electrofishing would be most effective for collecting black bass, driving fish into gill nets with electrofishing gear would be most effective for striped bass and Sacramento pikeminnow, and angling would be effective for all species of predators, but primarily effective at low to moderate flows. The Phase II studies would be conducted over a variety of flows associated with Critical, Dry, Below-Normal, Above-Normal, and Wet water year types. Estimated costs: $120,000 annually for Phase II studies, which should be conducted for at least four years.

If the results of the Phase II predation studies suggest that predation is a substantial source of mortality for juvenile salmonids, then Phase III studies should be implemented that would estimate the proportion of the juvenile population consumed by specific predators utilizing specific habitats. This would include estimates of the total number of predators (electrofishing in early summer to minimize impacts to salmon and trout), predation rates for fry, parr, and smolts by evaluating predator stomach contents, and the percentage of juveniles consumed (percentage determined by dividing numbers consumed by the calibrated screw trap estimates of total juvenile abundance) should be considered before restoring habitat to primarily reduce predation. Estimated Phase III costs would range from $250,000 to $500,000 annually for a minimum of three years.

Management Question #3: *Do elevated floodplain inundation level flows between early-February and late-March concurrent with elevated spring time flow levels increase the number of salmon fry that survive to a smolt size and adult recruitment in the Tuolumne River?* One null hypothesis and one alternative hypothesis were developed for this question:

> H_o: The estimated number of smolt-sized outmigrants ($\geq$ 70 mm FL) that pass the Grayson River Ranch Site is most strongly correlated with the mean flow from La Grange Dam between 1 February and 15 June.
>
> H_a: The estimated number of smolt-sized outmigrants ($\geq$ 70 mm FL) that pass the Grayson River Ranch Site is most strongly correlated with the mean flow from La Grange Dam between 1 April and 15 June.

There are three Management Actions required to test the above hypotheses that are essentially the same as those for Management Question #1. The primary difference is that the experimental flow schedule will include a comparison of base flows with 2,000 cfs or greater constant high flows during February and March.

> *Management Action #1*: implement an experimental flow schedule designed to test the relative importance of the magnitude and duration of February and March pulse flows in combination with elevated spring pulse flows as described in the following section.
>
> *Management Action #2*: annually monitor the abundance of smolt outmigrants with rotary screw trapping at Grayson River Ranch at a minimum from March 15 to June 15 and preferably from January 1 to June 15. Calibration tests should be conducted every 7 to 14 days depending on the availability of naturally produced juveniles or hatchery reared juveniles. There are no additional costs for this study element beyond those for Management Question #1.
>
> *Management Action #3*: monitor the abundance of adult salmon (escapement) by continuing the CDFG carcass surveys. There are no additional costs for this study element beyond those for Management Question #1.

Management Question #4: *Do elevated floodplain inundation level flows between early-February and late-March concurrent with elevated spring time flow levels in the Tuolumne River affect the number of salmon fry that survive to a smolt size by ameliorating a combination of stressors, including increasing the amount of available high quality habitat, increasing food availability, reducing disease, reducing predation, accelerating smoltification, reducing contaminants, reducing entrainment, and by improving the suitability of water temperatures?* Three null hypotheses and one alternative hypothesis were developed for this question:

> H_o: The percentage of naturally produced outmigrants that survive their migration between the rotary screw trap sites at the downstream boundary of the spawning

reach and the Grayson River Ranch site is most strongly correlated with the mean flow in the Tuolumne River between 1 February and 15 June.

H_o: The sources of mortality of juvenile salmon < 70 mm FL rearing in the Tuolumne River between 1 February and 31 March primarily include a combination of stressors, such as a lack of inundated floodplain habitat, insufficient food resources, disease, delayed smoltification, unsuitably high water temperatures, and predation by striped bass and rainbow trout, that must be primarily managed with flow releases.

H_a: The sources of mortality of juvenile salmon < 70 mm FL rearing in the Tuolumne River between 1 February and 31 March primarily includes a combination of stressors, such as predation by black bass or Sacramento pikeminnow in habitats degraded by gravel mining, contaminants from agricultural runoff, entrainment at unscreened diversions, and other stressors that can be most effectively managed with habitat restoration, fish screens, and other non-flow management actions.

The Management Actions required for testing the above hypotheses are similar to those that were recommended for Management Question #2. The primary difference is that the tests are conducted with fry and parr sized fish in February and March. Another difference is that water temperatures are not assumed to be important for the survival of fry and parr during February and March. There are four Management Actions recommended for the Phase I tests:

Phase I Actions

Management Action #1: annually monitor the abundance juvenile salmonids with rotary screw trapping near the downstream boundary of the spawning reach (between the 7/11 site and Waterford) from January 1 to June 15. Calibration tests should be conducted every 7 to 14 days depending on the availability of naturally produced juveniles or hatchery reared juveniles. There are no additional costs for this study element beyond those for Management Question #2.

Management Action #2: annually monitor the abundance smolt outmigrants with rotary screw trapping at Grayson River Ranch at a minimum from March 15 to June 15 and preferably from January 1 to June 15. Calibration tests should be conducted every 7 to 14 days depending on the availability of naturally produced juveniles or hatchery reared juveniles. There are no additional costs for this study element beyond those for Management Question #1.

Management Action #3: To estimate the importance of predation on fry and parr, a combination of electrofishing, gill netting, and angling (lures that simulate the appropriately sized juvenile salmonids) should be utilized to determine (a) the fish species that prey on juvenile salmonids by examining their stomach contents and (b) the habitats where predation is occurring during February and March over a range of Critical, Dry, Below-Normal, Above-Normal, and Wet water year types. Estimated costs: $120,000 annually for Phase II studies, which should be conducted for at least four years.

Management Action #4: Fry and Parr will be evaluated as part of the US Fish and Wildlife Service, California - Nevada Fish Health Center's proposal to evaluate the importance of food availability, contaminants, and disease in the Tuolumne River for Management Question #2. The costs for this study element are included with those for the Management Question #2 studies.

Phase II Actions

The Phase II studies are identical to those for Management Question #2 except that they would be conducted with fry and parr during February and March. Please refer to Management Question #2 for study details.

If Phase I histological studies show signs of toxic insult (i.e., adverse impacts from pesticides or other contaminants), then a bioassay lab should be established on the Tuolumne River. Costs for this study element are included in those for the Management Question #2 studies presented previously.

If Phase I lipid content analysis indicates that food availability for juvenile fish may be a limiting factor, studies should be conducted to evaluate whether food resources are primarily aquatic or terrestrial and to compare allochthonous production, autochthonous production, and production from within New Don Pedro reservoir (planktonic). The costs for these studies have not been estimated.

If Phase I studies indicate that predation is a substantial source of mortality, then Phase II studies that would estimate the proportion of the juvenile population consumed by specific predators utilizing specific habitats. This would include estimates of the total number of predators (using angling, snorkeling, and gill netting to minimize impacts to salmon and trout), predation rates for fry, parr, and smolts by using angling surveys and gill nets to collect predator stomach contents, and the percentage of juveniles consumed (percentage determined by dividing numbers consumed by the calibrated screw trap estimates of total juvenile abundance) should be considered before restoring habitat to specifically reduce predation. Estimated costs range from $250,000 to $500,000 annually for a minimum of three years.

<u>Management Question #5:</u> *Do fry outmigrating from the Tuolumne River materially contribute to adult recruitment?* One null hypothesis and one alternative hypothesis were developed for this question:

H_o: At least 25% of the otoliths from adult salmon that outmigrated as juveniles to the ocean during years when flows averaged at least 2,000 cfs from early-February through mid-June will indicate that the fish primarily reared in the Delta. The percentage of fish successfully rearing in the Delta is expected to be less than 10% in years with either a shorter duration or magnitude of spring flows.

H_a: At least 75% of the otoliths from adult salmon that outmigrated as juveniles to the ocean during years when flows were high from early-February through mid-June will indicate that the fish primarily reared in the Tuolumne River before they reached the smolt stage (> 70 mm FL). The percentage of adults that reared in the Tuolumne River before smolting is expected to be at least 90% in years with either a shorter duration or magnitude of spring flows.

Management Action: Determine fry contribution rates to adult recruitment either by otolith microchemical or microstructural analysis. Studies would be conducted in a phased approach. The initial pilot studies will evaluate whether microchemical or microstructural analysis of adult otoliths can distinguish between juveniles that reared in the Tuolumne River and those that reared in the Delta. The estimated cost to conduct the pilot microchemical and microstructural analyses would be about $100,000 for 100 otolith samples.

<u>Management Question #6:</u> *Do elevated fall pulse flows improve egg viability and minimize straying of early arriving adult salmon?* Four null hypotheses were developed for this question:

H_o: Straying rates of coded-wire-tagged smolts released in the Tuolumne River are minimized (<5%) by releases of fall pulse flows in October when Delta export rates do not exceed 350% of Vernalis flows.

H_o: Egg viability rates at the Merced River hatchery are significantly higher during years when fall pulse flows occur and Delta water temperatures do not exceed 70^{o}F in October than during years when no fall pulse flows were released and water temperatures exceeded $70\,^{o}$F.

H_o: Pre-spawn mortality of adults is less than 5% when fall pulse flows occur in October and fall base flows exceed 200 cfs.

H_o: Spawner densities less than 500 fish reduce adult recruitment.

There are three recommended management actions to test the above hypotheses.

Management Action #1: Evaluate straying rates of coded-wire-tagged smolts that were released in the Tuolumne River and recovered in Central Valley adult escapement surveys relative to pulse flow releases, Delta water quality, and fall export rates. The

AFRP has funded Stillwater Sciences to conduct this analysis with the existing CWT recovery data through fall 2005.

Management Action #2: Evaluate egg viability at the Merced River hatchery relative to tributary and Delta water temperatures. This analysis could be done with existing data for an estimated cost of $10,000 to $30,000.

Management Action #3: Evaluate pre-spawn mortality surveys in the Tuolumne River relative to pulse flow releases. This task would require the CDFG carcass survey crews to collect the eggs from a sample of at least 100 adult female carcasses and then count the eggs following the surveys. Relationships would be evaluated between the timing and occurrence of fall pulse flows and the number of eggs retained per female. Estimated cost: $10,000 to $20,000 annually.

Management Action #4: Continue to evaluate relationships of stock-recruitment and stock-juvenile production as conducted by Mesick and Marston (2007). These studies would utilize the escapement and rotary screw trap studies described previously.

<u>Management Question #7:</u> *Do flow and water temperature levels in the fall affect the distribution of spawners and redd superimposition rates?* Five null hypotheses were developed for this question:

H_o: As spawner abundances exceed 1,000 fish, the production of juveniles from early arriving females decreases due to redd superimposition.

H_o: Juveniles produced from early arriving females migrate at an earlier age and therefore have a greater chance of survival to adulthood than would juveniles produced from late arriving females.

H_o: Increasing fall base flows between late-October and mid-November to increase the river miles of habitat with water temperatures less than 53^{o}F by 25% will increase the distribution of spawners in the Tuolumne River and thereby reduce redd superimposition rates by at least 10%.

H_o: Doubling the availability of spawning habitat in the 6-mile reach below La Grange Dam will reduce redd superimposition rates by at least 25%.

H_o: Reducing the superimposition of early redds by 25% will result in at least a 25% increase in adult recruitment.

There are four management actions to evaluate the above hypotheses.

Management Action #1: conduct two intensive redd counts with foot surveys of all spawning habitats between La Grange and Waterford during November for at least three years. Estimates of the total number of redds and total number of superimposed redds would be produced. Excavate 20 superimposed and 20 non superimposed redds after emergence has occurred to compare the number of entombed alevins and dead eggs between the two types of redds. The estimated cost for the intensive redd counts and redd excavations would range between $50,000 and $75,000 annually.

Management Action #2: conduct rotary screw trap surveys at the downstream boundary of the spawning reach (between 7/11 and Waterford) and Grayson River Ranch and evaluate smoltification indices of collected juveniles as recommended for Management Questions #1 and #2.

Management Action #3: continue monitoring water temperatures between La Grange and Waterford with thermographs as recommended for Management Question #2.

Management Action #4: evaluate past CWT smolt survival studies that differentially marked early migrating smolts and late migrating smolts during the same year, released the marked fish in the Tuolumne River, and recovered the juveniles in the Delta west of Jersey Point or adults in the ocean fishery and escapement. Estimated cost is $25,000 to $50,000.

Management Questions #8: *Do physical habitat restoration projects that focus on improving floodplain habitat quantity and quality improve smolt production, and survival, in combination with elevated winter and spring time flows?* Two null hypotheses were developed for this question:

H_o: The estimated number of smolt-sized fish (< 70 mm FL) at Grayson River Ranch is more highly correlated with the amount of inundated floodplain habitat and the duration of inundation than with an index of the number of fry produced based on the estimated number of all juveniles that pass a rotary screw trap site near the downstream boundary of the spawning reach (7/11 or Waterford).

H_o: The estimated number of smolt-sized fish (< 70 mm FL) at Grayson River Ranch will increase to a greater degree after restoring a substantial amount of floodplain habitat that is inundated annually than from restoring a substantial amount of spawning habitat in the 6-mile reach below the La Grange Dam.

There are three Management Actions needed to address the above two hypotheses.

Management Action #1: model the relationship between flow and the amount of inundated floodplain habitat between La Grange and Waterford. The estimated cost for has not been estimated.

Management Action #2: conduct rotary screw trap surveys at the downstream boundary of the spawning reach (between 7/11 and Waterford) and Grayson River Ranch and evaluate smoltification indices of collected juveniles as recommended for Management Questions #1 and #2.

Management Action #3: compare the effectiveness of restoration designs that inundate floodplains annually and promote and preserve riparian vegetation versus restoration designs that inundate floodplains primarily during wet years and promote the transport of spawning sized gravels using two metrics. One metric would compare juvenile fish use at the restoration sites and the other would compare changes in the abundance of smolt outmigrants measured with rotary screw traps relative to the implementation of various restoration projects. Evaluations of projects designed to provide or enhance spawning habitat should also measure the survival of newly fertilized eggs in incubation chambers rather than rely on indirect measures of egg survival, such as dissolved oxygen and gravel permeability. Egg survival studies should be conducted over three years to account for variation in turbid storm runoff, egg viability in hatchery fish, and flood control releases. The estimated cost of egg survival studies, which would only measure egg survival without monitoring environmental parameters, would be about $50,000 annually. The rotary screw traps surveys are described for Management Questions #1 and #2.

<u>Management Question #9</u>: *Do late spring ramping rates affect riparian vegetation establishment?* The primary objective of the following hypothesis is to determine flow ramping rates in late spring and early summer that promote riparian vegetation establishment, if Management Questions #2 and #4 indicate that smolt production in the Tuolumne River is substantially dependant upon terrestrial food resources. Two null hypotheses were developed for this question:

H_o: Smolt production in the Tuolumne River is substantially dependant on terrestrial food resources compared to autochthonous sources, upstream reservoir produced resources, and decomposing adult salmon.

H_o: Riparian vegetation establishment requires flood flows to be ramped down at rates that cause the water table to decline no faster than 0.75 inches per day (approximately 100 cfs/day) from mid-April to late-May to improve cottonwood recruitment and from mid-May to late June to benefit black willow.

There are two Management Actions for these hypotheses.

Management Action #1: As recommended under Phase II studies for Management Question #3, evaluate whether food resources are primarily aquatic or terrestrial and to compare allochthonous production, autochthonous production, and production from within New Don Pedro reservoir (planktonic). The costs for these studies have not been estimated.

Management Action #2: Evaluate riparian plant establishment in relation to variable flow ramping schedules. This action would be implemented under existing studies to monitor restoration projects. Specific methods or costs have not been estimated for this action.

Rainbow Trout Management Studies

Management Question #1: What is the trend abundance of adult rainbow trout in the Tuolumne River?

Pipal (2005) identified 6 Central Valley sampling programs specifically designed for estimating the population size of the anadromous component of *Oncorhynchus mykiss* (*O. mykiss*). These sampling programs were located in the upper Sacramento River and in Battle, Mill, and Deer Creeks and consisted of obtaining passage estimates at weirs and dams and in addition utilized fyke nets, and miscellaneous traps. Two widely used methods for estimating stream fish abundance are seining and electrofishing. These methods have commonly been used across North America, including the Tuolumne River in effort to estimate abundance (Hankin and Reeves 1988, Reynolds, J.B. 1996, Thompson 2003). In addition, electrofishing has been used to track the relative abundance of resident fishes in large bodies of water such as the Sacramento-San Joaquin Delta (Michniuk and Silver 2002, Michniuk 2003). Redd surveys also are another potential method used to estimate populations of *O. mykiss*; however, these methods have proven difficult in the Tuolumne River as spawning often occurs in deep turbulent water, making visual observation difficult. Hook and line fishing completed on the Tuolumne River in conjunction with professional fishing guides in recent years has yielded samples for anadromous *O. mykiss* analysis. Note this method is dependent on scarce fishing expertise.

Management Action: Electrofishing, snorkeling, and other recapture methods such as hook and line are recommended to estimate the abundance of *O. mykiss* on the lower Tuolumne for several reasons: they both target anadromous and resident *O. mykiss*, they take advantage of existing efforts and resources keeping costs down, are widely accepted methods in the literature, and appear to have the most feasibility.

(1) Electrofishing – Intensive sampling for adult *O. mykiss* (excluding YOY) approximately every 5-10 days between February and April with a boat between river miles 30 and 52. A total of four, one mile segments with representative stream habitat types should be sampled. "Catch per unit effort by electrofishing is a useful, easily obtained index to the abundance of the populations of many species;" however, estimates of absolute abundance can be biased (Reynolds 1996). Catch per unit effort in a variety of habitat types should be calculated. Methods also should be developed to capture and tag adult *O. mykiss* for recapture purposes and for abundance estimation. Marking estimates visible during snorkeling are encouraged. Depending on the observed biases of using electrofishing for mark recapture purposes, and whether or not correction factors can be utilized, other measures may be needed for tagging and or recovery (such as hook and line). The use of photo mark recapture should also be evaluated.

Data Analysis/Reporting/Costs: Population estimates for the lower Tuolumne River should be calculated using recapture data from electrofishing, hook and line, or other methods as appropriate. A technical report should be produced, reviewed, and approved by fisheries agencies. Estimated cost for this assessment is $130,000 per year (based on 30 days of electrofishing at $2,000 per day, $30,000 for additional recovery efforts, and $40,00 for analysis and report writing).

(2) Snorkeling – Monthly at selected sites from La Grange Dam, downstream to RM 30. A total of three snorkelers should be utilized: one on each bank of the river, and one in the center. Snorkelers should float downstream noting adult and juvenile *O. mykiss* (for acceptable methods, see California Department of Water Resources (2003).

Data Analysis/Reporting/Costs: If adult *O. mykiss* are sufficiently marked, and can be identified using snorkeling methods, additional populations estimates should be possible. In addition, the population can be estimated using snorkeling techniques without the use of recapture methods. A technical report should be produced, reviewed, and approved by fisheries agencies. Estimated costs for this effort are estimated at $52,000 per year (12 days at $1,000 per day, and $40,000 per year for analysis and report writing).

Management Question #2: What is the abundance trend of juvenile rainbow trout in the Tuolumne River?

As Pipal (2005) indicates, most juvenile steelhead data on migration periods and relative abundance is collected from rotary screw traps in the Central Valley. For example, 7 separate steelhead recovery efforts are currently implemented with rotary screw traps in the Central Valley (Pipal 2005). Other sampling devices used to calculate relative abundance include seines, fyke nets, and trawls. Habitat in the lower Tuolumne River prohibits trawling, and rotary screw traps scarcely capture juvenile steelhead/rainbow trout. The best choices for monitoring the relative abundance of steelhead/rainbow trout is snorkeling. Past snorkeling in the Tuolumne River for Chinook salmon has reported *O. mykiss* observations and with some adjustment, this sampling program could significantly improve steelhead/resident rainbow trout abundance estimates.

Management Action: Snorkeling is recommended to estimate the abundance of *O. mykiss* on the Lower Tuolumne as it takes advantage of existing efforts and resources keeping costs down, is a widely accepted method in the literature, and appear to have the most feasibility. See adult snorkeling methods.

Management Question #3: What is the migratory behavior of adult *O. mykiss* in the Tuolumne River?

The Anadromous Fish Restoration Program (AFRP) funded the CDFG to determine the distribution and relationship of resident and anadromous Central Valley *O. mykiss* (AFRP identification code 2003-05). Otoliths of juvenile trout from many Central Valley watersheds have been and continue to be analyzed to determine parental life history strategy (anadromous or resident). The determination will be based on examination of the ratio of strontium to calcium within the otolith. Anadromy has been documented from the Calaveras, Merced and San Joaquin Rivers. A variety of methods have been reported in the literature to determine the presence of anadromy including microchemistry and microstructure analysis of otoliths and scales. Most prominent appears to be an analysis of the relationship of the strontium-to-calcium ratios and salinity, thus proof of anadromy.

Management Action: All adult *O. mykiss* encountered during authorized activities should have representative scale samples taken and archived for future anadromy determination. In addition, 10% of adult captures should be retained for otolith analysis (as well as all mortalities). Chain of custody and otolith and scale analysis should be completed by CDFG. For a review of methods see Zimmerman (2005).

Otolith microchemistry and scale microstructure analysis - Chemical tests of otoliths for anadromy should be completed using the strontium-to-calcium ratio. Scale microstructure analysis for anadromy should be completed and validated with otolith analysis.

Data Analysis/Reporting/Costs: A technical report should be produced, reviewed, and approved by fisheries agencies. Estimated costs are $55,000 per year (based on the processing of 10 otoliths at $1,000 each and 100 at $500 each, and $40,000 for analysis and technical report writing).

Management Question #4: What is the migratory behavior of juvenile *O. mykiss* in the Tuolumne River?

Pipal (2005) and the Interagency Ecological Program (IEP, 2005) reviewed the various juvenile salmonid sampling efforts in the Central Valley. Monitoring programs with the specific goal of determining the temporal patterns of steelhead smolts are dominated by the use of rotary screw traps; however, seining, snorkeling, electrofishing, enclosure nets, and trawling also are used. Based on the date of capture, size of the *O. mykiss*, and the physiological state of the fish, the anadromous presence can be established.

Management Action: To take advantage of existing and recommended to be expanded sampling for Chinook salmon, rotary screw traps are recommended. Though catchability of smolt *O. mykiss* is low in rotary screw traps, they nevertheless can be used to document the presence of smolts captured incidentally. Though electrofishing is most efficient at capturing adults, incidentally captured juvenile *O. mykiss* should be recorded. Lastly, seining and snorkeling will encounter juvenile *O. mykiss*. All dead *O. mykiss* encountered during authorized activities should be turned over to CDFG for otolith and scale analysis. In addition, to measure the parr-smolt transformation and increase in seawater tolerance, thus anadromoy, gill ATPase studies are recommended (evidence of smoltification is found with an increase in gill sodium-potassium-activated adenosine triphosphatase (Na+, K+,-ATPase). The measurement of gill Na+, K+,-ATPase activity has been utilized extensively to monitor smolt physiology.

(1) Rotary Screw Trap Sampling- Rotary screw trap sampling is recommended for Chinook salmon at two locations on the Tuolumne River; upstream and downstream, and studies and incidental captures of *O. mykiss* should recorded. Ten percent of the capture of *O. mykiss* should be sacrificed for gill ATPase studies.

Data Analysis/Reporting/Costs: Total catch of *O. mykiss*, fork length, date of capture, smolt level (1-5), and effort should be reported. Costs are covered under the Chinook salmon monitoring studies. Some additional costs may be needed for the analysis and summary. A technical report should be produced, reviewed, and approved by fisheries agencies.

(2) Electrofishing- Electrofishing is recommended to document the abundance of *O. mykiss* for a three-month period in the winter (February to April); however, additional sampling is needed monthly at a variety of sites between river mile 30 and 52.

Data Analysis/Reporting/Costs: Total catch of *O. mykiss*, fork length, date of capture, smolt level (1-5), and effort should be reported at all sample sites. Ten percent of the capture of *O. mykiss* should be sacrificed for gill ATPase studies. Costs are estimated at $78,000 per year (10 ATPase samples at $2,000 each, 9 electrofishing days at $2,000 per day, and $40,000 for analysis and report writing). A technical report should be produced, reviewed, and approved by fisheries agencies.

(3) Snorkeling- Snorkeling is recommended monthly between La Grange Dam and RM 30 (see above). Information on juvenile *O. mykiss* should be collected.

Data Analysis/Reporting/Costs: Total observations of *O. mykiss*, estimated fork length, date of observance, smolt level (1-5), and effort should be reported at snorkel sites. Costs are included above in snorkeling for abundance (#1). A technical report should be produced, reviewed, and approved by fisheries agencies.

<u>*Management Question #5:*</u> What is the distribution and habitat condition in the Tuolumne River for adult <u>O. mykiss</u>?

Management Action: The two most commonly used methods to determine the distribution of adult salmonids relative to habitat conditions in the Central Valley are electrofishing and snorkeling (Pipal 2005). These efforts have already been recommended above, and the results of surveys (#1, #2) in combination with habitat analysis can be used to distinguish the distribution of *O. mykiss* and their affinity for certain habitat types. In addition, redd surveys are needed.

(1) Electrofishing and Snorkeling- Utilizing recommended electrofishing and snorkeling elements above and collected habitat information, the affinity of adult *O. mykiss* for a variety of habitat types in the Tuolumne River should be established. This information could also be used to assess the potential impacts of restoration on *O. mykiss* habitat.

Data Analysis/Reporting/Costs: Additional costs are negligible, as they are primarily included in prior elements.

(2) Redd Surveys - The appropriate *O. mykiss* redd survey techniques should be developed on the Tuolumne River as done in other rivers of the Central Valley (American River, Battle Creek, Clear Creek, Calaveras River, *etc.*). Redd survey effort should be done weekly between December and April between Bobcat Flat and La Grange Dam.

Data Analysis/Reporting/Costs: Documented survey methods and results are required and this task must be operated adaptively. Costs are estimated $80,000 per year ($8,000 per week for 5 months, and $40,000 for analysis and report writing).

Management Question #6: What is the distribution and habitat condition in the Tuolumne River for juvenile O. mykiss?

Management action: Snorkeling is recommended in #1 and #2 above should be utilized in this respect to document specific habitat affinities of juvenile *O. mykiss*, including restored sites. Acceptable methods are found in California Department of Water Resources (2003).

(1) Snorkeling- Monthly at selected sites from La Grange Dam, downstream to RM 30. Special emphasis should be placed on restored sites. As the case for adults, the affinity of adult *O. mykiss* for a variety of habitat types in the Tuolumne River should be established.

Data Analysis/Reporting/Costs: A technical report should be produced, reviewed, and approved by fisheries agencies. Estimated costs for this effort are estimated at $40,000 per year for analysis and report writing (sampling costs covered above).

Management Question 7: What are the effects of the Tuolumne River instream flow schedule on both adult, and juvenile, rainbow trout and steelhead habitat?

Management action: The Instream Flow Incremental Methodology (IFIM) is a conceptual framework for presenting decision makers with a series of management options, and their expected consequences, in order that decisions can be made, or negotiations begun, from an informed position. Although physical habitat simulation is the most commonly applied component of PHABSIM, an IFIM study may also include water quality, temperature and legal / institutional analysis, time series analysis, effective habitat analysis and / or population modeling. Population studies, such as those above that relate flows to population levels and response, and validate the IFIM work also are important. Recent radio-telemetry work along the Pacific Coast offers a lot of promise and should be investigated.

(1) IFIM- IFIM modeling should be developed, incorporating flow and physical parameters such as temperature.

Data Analysis/Reporting/Costs: A rough cost estimate for the construction and calibration model is $750,000.

(2) Radio-telemetry- Radio-telemetry studies should be completed to evaluate and validate the IFIM recommendations. Radio tags should be inserted in adult and juvenile captured fish *O. mykiss* and monitored with vessel, car, or airplane. Specimen movement relative to flow changes, temperature conditions, and habitat features should be noted.

Data Analysis/Reporting/Costs: The results of the telemetry work should evaluate the IFIM work, and provide information on the impacts of flow and non-flow operations on *O. mykiss*. Costs for this effort are estimates at $100,000 per year for three years.

<u>Management Question #8: What are the factors limiting both resident, and anadromous, O. mykiss populations in the Tuolumne River?</u>

Management action. Conduct a limiting factors analysis. A synthesis of historic and new information (from above studies) should be utilized to evaluate the relative impacts of the following on *O. mykiss* in the lower Tuolumne River: contaminants, food limitation, disease, predation, parasites, temperatures, habitat quality, flows, recreational fishing, poaching, and other potential stressors.

Data Analysis/Reporting/Costs: Costs are estimated at $150,000 for this task.

Experimental Flow Schedules

To test the underlying hypotheses of the Agencies' Salmon Model and help recover the Tuolumne River salmonid populations, the Agencies recommend that a new experimental flow schedule should be implemented immediately. Using the multiple regression correlation between rearing flows and duration, and smolt flow and duration, a simple adult recruitment model was used to develop the following flow schedule (Table 5) which the model suggests would increase fall-run Chinook salmon in the Tuolumne River.

Table 7. Recommended experimental flow schedule intended to test the importance of the magnitude and duration of juvenile rearing flows (Rearing Q) during the February and March period and smolt out-migration flows (Smolt Q) during the April to mid-June period.

Proposed Flow Schedule					
Water Year Type	Rearing Q (cfs)	Rearing Duration (days)	Smolt Q (cfs)	Smolt Duration (days)	Expected Production Improvement (%)
Very Wet	4,000	60	5,000	60	TBD

Wet	3,000	60	4,000	60	TBD
Above Normal	3,000	30	3,000	45	TBD
Below Normal	2,000	30	3,000	45	TBD
Dry	2,000	15	2,000	30	TBD
Critical	500	15	1,000	30	TBD

For the experimental flow schedule, base flows are assumed to be of secondary importance. Therefore moderate levels are recommended to provide a minimal amount of habitat during most years for spawning, egg incubation, and summer rearing based on instream flow studies conducted by EA Engineering, Science, and Technology (Turlock Irrigation District and Modesto Irrigation District 1991, EA 1993). The recommended base flows are increased during Wet years to provide the means to evaluate the effects of base flows on Salmon and *O. mykiss* distribution. A spawning base flow of 200 cfs is recommended from October 1 through March 31 during all but Wet years; whereas spawning base flows of 300 cfs are recommended during wet years. A base flow of 400 cfs is recommended during April in Critical and Dry years. Summer base flows of 150 cfs are recommended during all but Wet years to provide a minimum of 8 miles of habitat with water temperatures below 65^{o} Fahrenheit for rearing *O. mykiss*; whereas, a summer base flow of 250 cfs is recommended during Wet years to provide a minimum of 13 miles of habitat. A 10-day, mid-October pulse flow of 1,500 cfs is recommended for all water year types to minimize the rate that Tuolumne River fish might stray to other watersheds (Mesick 2001). To help determine the optimum rate for ramping down spring flows to ensure the establishment of riparian seedlings, spring flow ramp down rates of 100 cfs/day, 200 cfs/day, and 300 cfs/day should be implemented in different years to permit seedling survival studies. The determination of the appropriate ramp down rate could be made by the Tuolumne River Technical Advisory Committee in each year depending on the availability of water and the need to conduct the study.

This approach assumes that a large increase in spring flow will be needed to detect a statistically significant change in adult recruitment. It also assumes that a large increase in fishery flows could be achieved by aggressively managing the storage in New Don Pedro Reservoir (NDP)[ix]. Since 1980, storage in NDP has been maximized (Figure 22) to primarily meet water supply and power generation demands, which results in flood control releases in January and February and low flows between April and mid-June during Below Normal and drier years that do not protect smolt out-migrants. By increasing the amount of water released during the smolt out-migration period, NDP storage would be reduced and more inflow could be captured to improve both flood control and fishery flows.

It is believed that sufficient storage (water assets) exists to accommodate the proposed flow schedule without impacting water supply reliability. The average total annual release[x] from La Grange Dam from 1970 through 2004 was 707 Thousand Acre-feet (TAF; Figure 23), much of which was released for flood control considering that the current average FERC minimum flow schedule annual amount is 185 TAF. The agencies assume that if fish flow releases were increased from a mean of 185 TAF required under the FSA to a mean annual total of about 600 TAF, the salmon population would increase and flood control would be improved without reducing the irrigation districts' water supply. To protect water supply for agricultural demand, hydropower generation, ad fish production, the Agencies expect that "triggers" (such as minimum NDP storage, and/or frequency of water year type—third consecutive critical dry year etc), in addition to water year type, would be identified and implemented in accordance with the proposed schedules that would create an adaptive management driven instream fish production schedule that differs from those presented below. It would be expected that the adaptive management schedules would be the exception, rather than the "norm." The Agencies recommend conducting a NDP operational study to identify an experimental instream

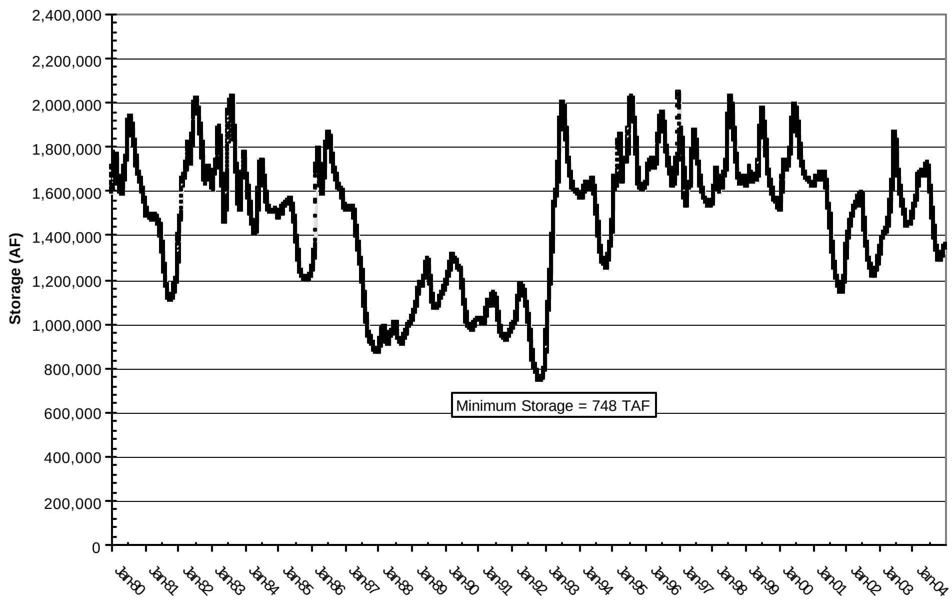

Figure 22. New Don Pedro Storage from 1980 to 2004.

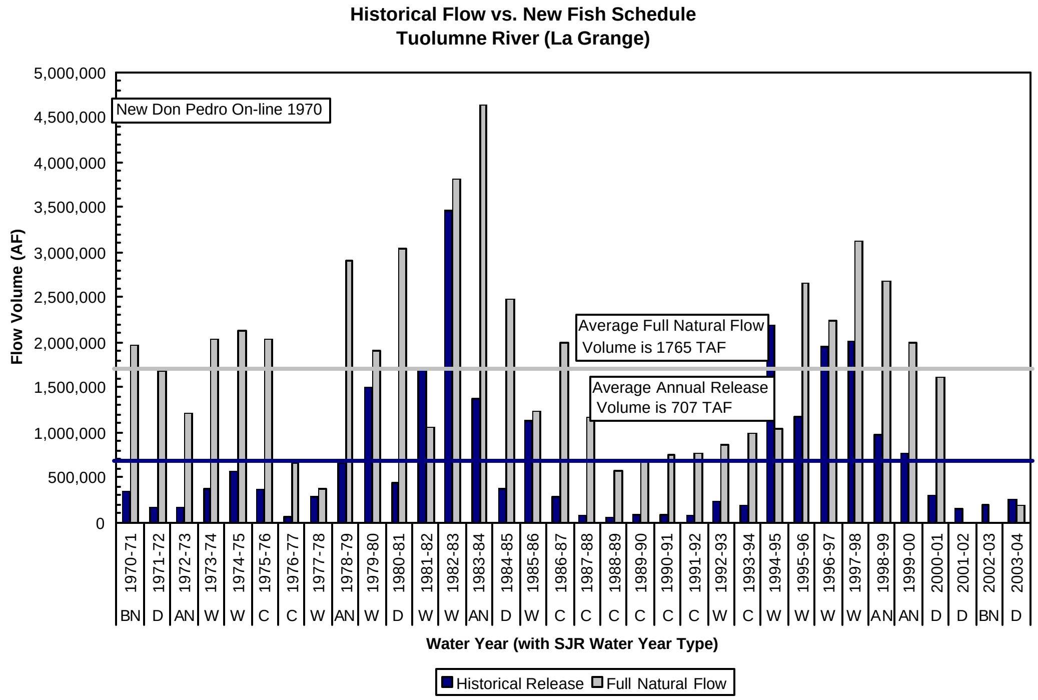

Figure 23. Tuolumne River Historical Annual Release Volume from 1980 to 2004.

flow schedule that would not reduce water supply reliability, minimize impacts to hydro-power generation, improve flood control operations, and provide the basis to test hypotheses regarding salmonid production. Preliminary revised minimum instream flow schedules are identified in Figures 24-29.

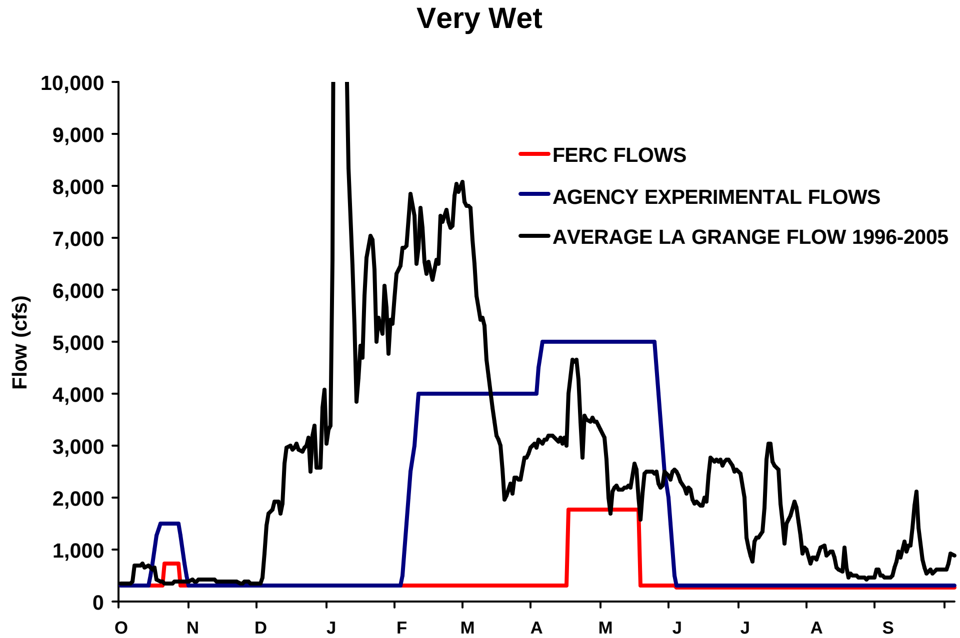

Figure 24. The Tuolumne River flow schedule presented in Table 5 for a Maximum Wet year as well as the current FERC minimum flow requirements and the mean estimated flow at La Grange between 1996 and 2005. Spring flows are ramped down 200 cfs/day. The total volume of the experimental flows and gauged La Grange flows are 1,174.016 and 1,979,743 AF, respectively.

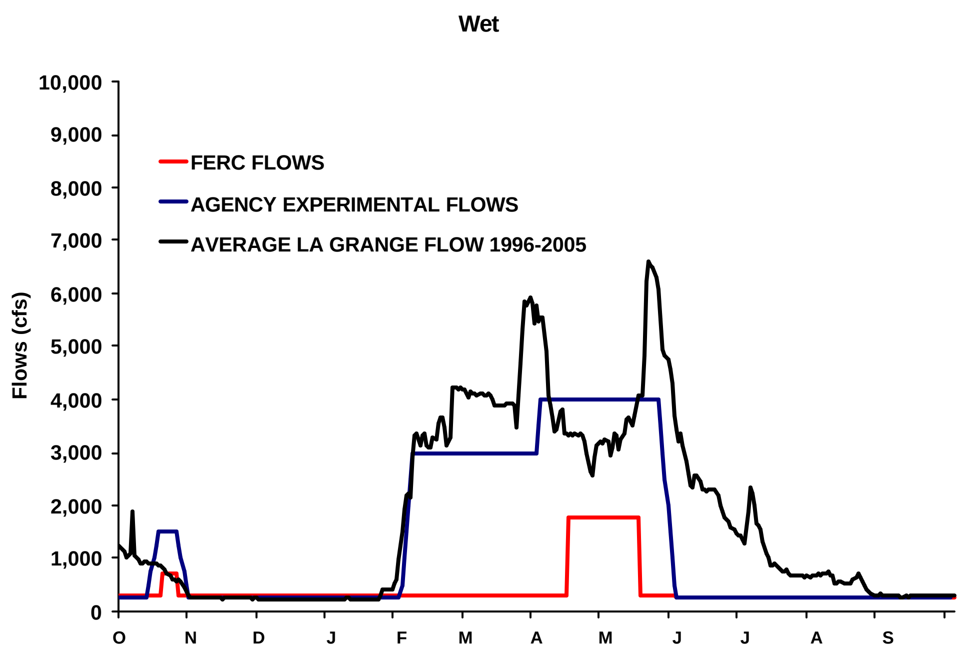

Figure 25. The Tuolumne River flow schedule presented in Table 5 for a Normal Wet year as well as the current FERC minimum flow requirements and the mean estimated flow at La Grange between 1996 and 2005. Spring flows are ramped down 200 cfs/day. The total volume of the experimental flows and gauged La Grange flows are 943,140 and 1,282,088 AF, respectively.

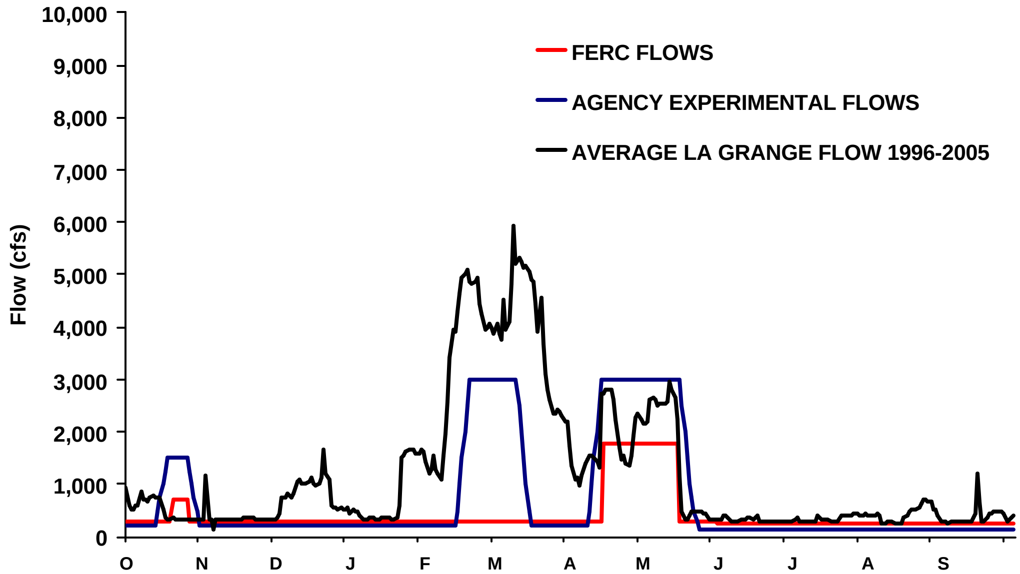

Figure 26. The Tuolumne River flow schedule presented in Table 5 for an Above Normal year as well as the current FERC minimum flow requirements and the mean estimated flow at La Grange between 1996 and 2005. The total volume of the experimental flows and gauged La Grange flows are 513,025 and 867,707 AF, respectively.

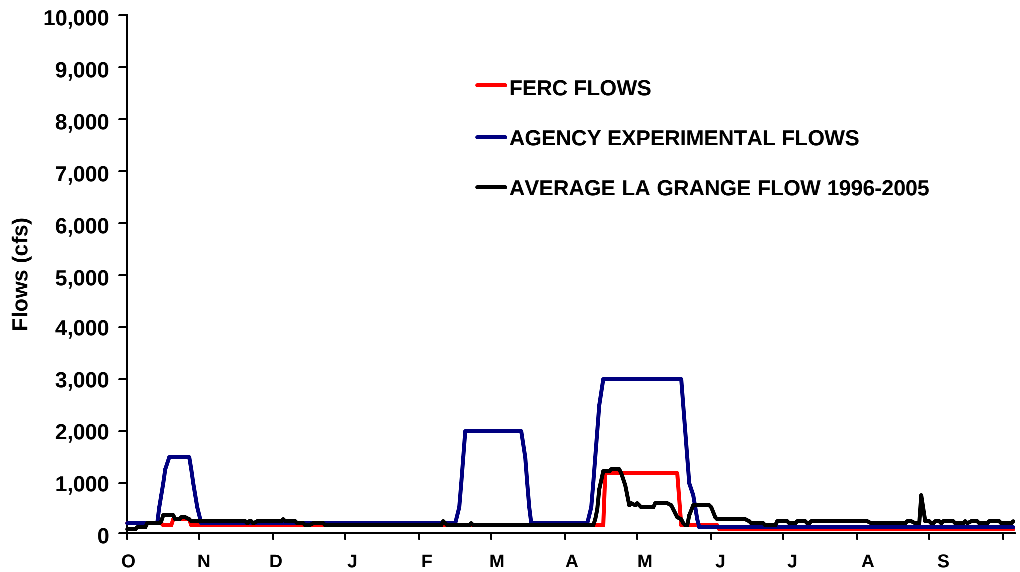

Figure 27. The Tuolumne River flow schedule presented in Table 5 for a Below Normal year as well as the current FERC minimum flow requirements and the mean estimated flow at La Grange between 1996 and 2005. The total volume of the experimental flows and gauged La Grange flows are 471,372 and 198,871 AF, respectively.

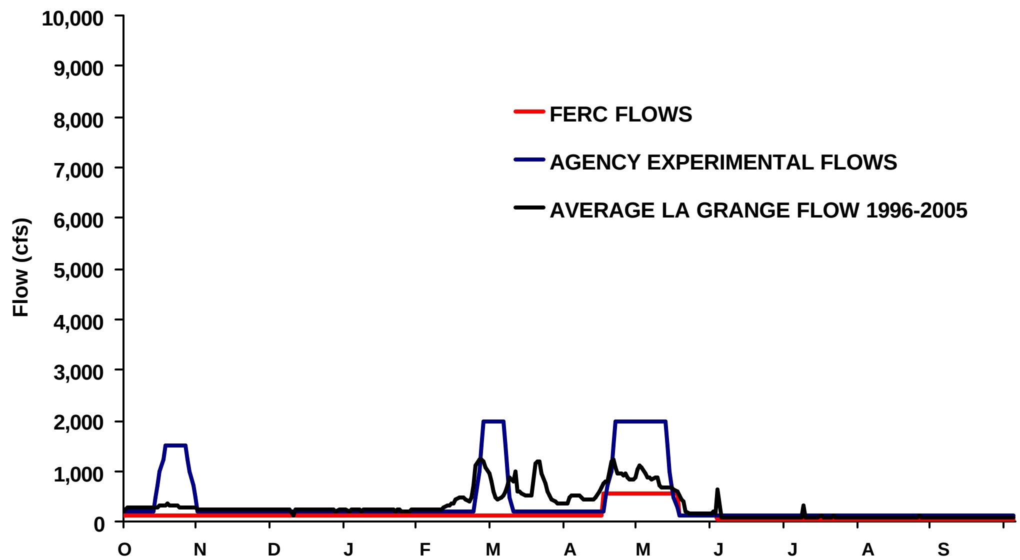

Figure 28. The Tuolumne River flow schedule presented in Table 5 for a Dry year as well as the current FERC minimum flow requirements and the mean estimated flow at La Grange between 1996 and 2005. The total volume of the experimental flows and gauged La Grange flows are 293,554 and 234,430 AF, respectively.

Critical Dry

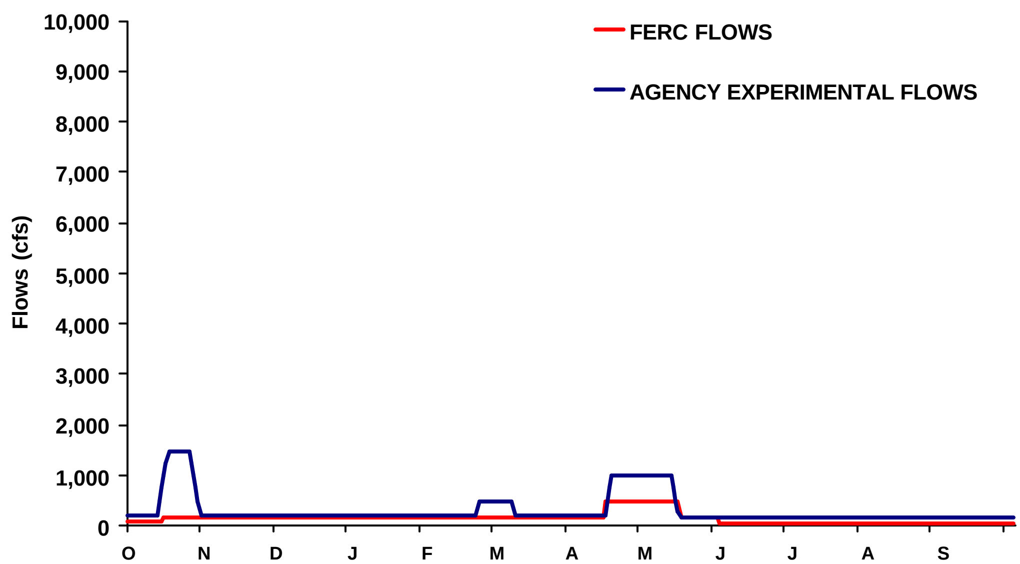

Figure 29. The Tuolumne River flow schedule presented in Table 5 for a Critical year as well as the current FERC minimum flow requirements. The total volume of the experimental flows is 217,139 AF. No Critical water years occurred from 1996 to 2006.

Discussion

A robust study plan will be needed to overcome the uncertainty that has hampered past management and restoration efforts in the Tuolumne River. We believe that adopting our recommendations on management questions, testable hypotheses, metrics, study methods, experimental conditions, and statistical designs will produce a robust plan for Chinook salmon, Central Valley steelhead, and rainbow trout in the Tuolumne River.

We also suggest that a source of hatchery reared juvenile salmon should be considered for calibrating rotary screw traps and the CWT smolt survival studies. Many of the past studies in the Tuolumne River and throughout the San Joaquin Basin have been hampered by the lack of study fish. We also suggest that Tuolumne River stock should be used to produce the study fish so that potential genetic impacts to the natural population are minimized.

Summary of Limiting Factor Analyses

Our limiting factor analysis has generated several preliminary results that although they require further investigation, they represent the best available information and should be considered when planning flow management and habitat restoration. Our preliminary results are listed below, but not in a prioritized order:

1. Conditions in the Tuolumne River may have caused the decline in salmon abundance. Adult salmon recruitment is highly correlated with the number of smolts that migrate from the Tuolumne River and the production of smolts in the Tuolumne River is highly correlated with the magnitude and duration of both winter and spring flows in the Tuolumne River.
2. Restoring spawning habitat through gravel augmentation and channel narrowing to increase sediment transport is unlikely to substantially increase adult recruitment, because the loss of eggs and fry from degraded habitats and redd superimposition has been inconsequential to the production of smolts in the Tuolumne River. This is because many more juveniles have been produced in spite of the degraded spawning habitat, than survived to a smolt-size under the FSA flows schedules.
3. Restoration of captured mine pits to reduce abundance of black bass is unlikely to substantially increase adult recruitment in the Stanislaus and Tuolumne Rivers, because there are many other predators that do not utilize the captured mine pits, black bass do not consume large numbers of naturally produced juveniles, and restoration of two mine pits has not reduced the abundance of black bass nor has it increased salmon recruitment in the Tuolumne River.
4. Reductions in Delta exports, increases in ocean productivity, and reductions in ocean harvest since the mid-1990s have had little effect on salmon recruitment in the Tuolumne River compared to the magnitude and duration of winter and spring streamflows.
5. Flow management and restoration should focus on enhancing the quality and

quantity of habitat for juveniles rearing in the Tuolumne River and for outmigrating smolts as the primary means of achieving adult salmon production targets.

6. As salmon smolts migrate through Tuolumne River and the South Delta, primarily from April 1 through mid-June, their survival is highly dependent on spring flow.
7. Winter flows in February and March may be important factors that affect the number of salmon fry that survive to a smolt-size ($\geq$ 70 mm FL) in the Tuolumne River.
8. One year of unsuitable summer water temperatures would impact two juvenile steelhead production cohorts and thereby constrain two more cohorts in the future by eliminating spawners.

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NOTES

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Appendix A

Summary Tables of Recommended Tuolumne River Fall-run Chinook Salmon and Rainbow Trout Studies

Tuolumne River Proposed Salmonid Studies (01-22-07)--Page 1
Phase I Chinook Salmon Studies

Fish Species	Task	Estimate Provided By	Current Funding Source	Year (Assumes 2007 Start Yea						
				1	2	3	4	5	6	
Fall-run Chinook Salmon	Chinook salmon escapement and redd surveys	CDFG	ERP	$75,000	$77,250	$79,568	$81,955	$84,413	$86,946	$
	Otolith and/or Scale Age analysis	"ball-park estimates"	ERP	$30,000	$10,000	$10,300	$10,609	$10,927	$11,255	$
	Rotary Screw Trap: Jan-Jun Upper and Lower Sites	FishBio	ERP	$350,000	$360,500	$371,315	$382,454	$393,928	$405,746	$4
	CWT smolt survival studies during non-low flows	CDFG	TBD	$50,000		$50,000		$50,000		$
	Smolt Tagging – Predation & other mortality factors	NRS - Dave Vogel	ERP	$225,000	$175,000	$175,000	$175,000		$175,000	
	Juvenile Fish Histology, Physiology, and Disease Study	USFWS	ERP	$75,000	$77,250	$79,568	$81,955	$84,413	$86,946	$
	Predator ID study Feb-Mar (fry)	"ball-park estimates"	ERP	$120,000	$123,600	$127,308	$131,127			
	Fall Pulse Flow on Egg Viability	"ball-park estimates"	TBD	$20,000						
	Pre-Spawn Mortality Study	"ball-park estimates"	TBD	$15,000	$15,000	$15,000	$15,000			
	Intensive Redd Use Surveys	"ball-park estimates"	TBD	$30,000		$30,900		$31,827		$

Estimated Costs by year for the Tuolumne River Salmonid Research Program over a 10 year period. Costs assume 3% annual inflation ra

Shaded years = years currently funded

Tuolumne River Proposed Salmonid Studies (01-22-07)--Page 2
Phase I Chinook Salmon Studies

Fish Species	Task	Estimate Provided By	Current Funding Source	Year (Assumes 2007 Start Y					
				1	2	3	4	5	6
Fall-run Chinook Salmon	Pilot Delta Fry Contribution Study using Microchemical and Microstructural Methods	Lawrence Livermore National Laboratory	TBD	$100,000					
	Water Temperature Monitoring	"ball-park estimates"	ERP/TID	$25,000	$25,750	$26,523	$27,318	$28,138	$28,982
	Early vs. Late Smolt Survival: Reanalysis of existing CWT data	"ball-park estimates"	TBD	$37,500					
	Model relationship between flow and floodplain area	"ball-park estimates"	TBD	?					

	inundated.								
	Fall Pulse Flow Straying Study	AFRP	Stillwater	Ongoing					
	Juvenile Use at Restoration Sites	"ball-park estimates"	ERP						
	Egg survival to emergence studies in restoration gravels	"ball-park estimates"	TBD	$50,000	$51,500	$53,045		$54,636	
	Water Temperature Modeling-Thermal Response (e.g. HEC5Q)	ERP	ERP	$250,000	$250,000				
	Water Temperature Modeling-Juvenile Production (e.g. SALMOD or ORCM)	"ball-park estimates"	TBD		$125,000	$125,000			

Estimated Costs by year for the Tuolumne River Salmonid Research Program over a 10 year period. Costs assume 3% annual inflation ra

Shaded years = years currently funded

Tuolumne River Proposed Salmonid Studies (01-22-07)--Page 3
Potential Phase II and III Chinook Salmon Studies

Fish Species	**Task**	**Estimate Provided By**	**Current Funding Source**	**Year (Assumes 2007 Star**					
				1	**2**	**3**	**4**	**5**	**6**
Fall-run Chinook Salmon	Predation stomach contents Apr-Jun—(Electrofishing, Angling, Gill Net Study)	"ball-park estimates"	ERP					$120,000	$123,600
	Water Quality Contaminant Bioassay Lab Study	UC Berkeley	TBD					$235,000	$185,000
	Juvenile food source study	TBD	TBD					TBD	TBD
	Entrainment studies at unscreened diversions	TBD	TBD					TBD	TBD
	Flow Ramping Rates and Riparian Vegetation Recruitment Surveys	"ball-park estimates"	TBD						
	Phase III Quantify Fry and Smolt Losses from Predation	"ball-park estimates"	TBD					$750,000	

Estimated Costs by year for the Tuolumne River Salmonid Research Program over a 10 year period. Costs assume 3% annual inflation ra

Shaded years = years currently funded

Tuolumne River Proposed Salmonid Studies (01-22-07)--Page 4

Fish Species	Task	Estimate Provided By	Current Funding Source	Year (Assumes 2007 Start Year 1	2	3	4	5	6	
Rainbow Trout	Otolith and Scale Study	CDFG	TBD	$55,000	$56,650	$58,350	$60,100	$61,903	$63,760	$
	Restored Site Snorkel of Videography Surveys	"ball-park estimates"	TBD	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$2
	Electro-fishing Adult Mark-Recapture Study	"ball-park estimates"	TBD	$130,000	$133,900	$137,917	$142,055	$146,316	$150,706	$1
	Adult Abundance--Snorkeling Survey	"ball-park estimates"	TBD	$52,000	$53,560	$55,167	$56,822	$58,526	$60,282	$
	Juvenile Abundance Snorkel Surveys	"ball-park estimates"	TBD	$40,000	$41,200	$42,436	$43,709	$45,020	$46,371	$
	Rotary Screw Trap Sampling	see Salmon	n/a	Covered Under Fall-run Chinook Sal						
	Juvenile Gill-ATPase Study	"ball-park estimates"	TBD	$78,000	$80,340	$82,750	$85,233	$87,790	$90,423	$
	IFIM Study	"ball-park estimates"	TBD			$250,000	$250,000	$250,000		

Estimated Costs by year for the Tuolumne River Salmonid Research Program over a 10 year period. Costs assume 3% annual inflation ra

Shaded years = years currently funded

Tuolumne River Proposed Salmonid Studies (01-22-07)--Page 5

Fish Species	Task	Estimate Provided By	Current Funding Source	Year (Assumes 2007 Start Yea 1	2	3	4	5	6
Rainbow Trout	Radio Telemetry/Sonic Tag Study	"ball-park estimates"	TBD				$225,000	$175,000	$175,000
	Creel/Poaching Survey	"ball-park estimates"	TBD	$50,000	$51,500	$53,045			
	Water Temperature Monitoring	"ball-park estimates"	ERP/TID	$25,000	$25,750	$26,523	$27,318	$28,138	$28,982
	Water Temperature Modeling-Thermal Response (e.g. HEC5Q)	ERP	ERP	$250,000	$250,000				
	Water Temperature Modeling-Juvenile	"ball-park estimates"	TBD		$125,000	$125,000			

	Production (e.g. SALMOD or ORCM)								
	Adult Redd Survey	"ball-park estimates"	TBD	$80,000	$82,400	$84,872	$87,418	$90,041	$92,742
	Limiting Factors Analysis	"ball-park estimates"	TBD				$75,000	$75,000	

Estimated Costs by year for the Tuolumne River Salmonid Research Program over a 10 year period. Costs assume 3% annual inflation ra

Shaded years = years currently funded

Appendix B

Calibration models used to expand the number of fish caught daily at the Shiloh and Grayson rotary screw trap sites in the Tuolumne River from 1998 to 2006

From February 15 to July 1 1998, one rotary screw trap was fished at Shiloh (RM 3.4) whereas two traps were fished at the Grayson site from 1999 to 2006. The trap efficiency test results used to generate the calibration models were obtained from the 2005 Lower Tuolumne River Annual Report, 2005-5: Rotary Screw Trap Summary Update (Turlock Irrigation District and Modesto Irrigation District 2006) and from the 2006 Data Report (Fishbio 2006). The results of the trap efficiency tests for spring 2002 were not used to generate the model of smolt-sized fish, because the efficiencies were abnormally low compared to all the other years.

A single calibration model was developed for all sizes of fish for the 1998 Shiloh trap data and two models were developed for fish < 65 mm fork length and fish $\geq$ 65 mm fork length for the combined 1998 to 2001, 2003, 2004, and 2006 Grayson trap data using multiple linear regressions. The percentage of marked fish recaptured was regressed against the natural log (Ln) of flow at Modesto and the mean fork length (FL) of the release group. The calibration models are as follows:

<u>1998 efficiency data at the Shiloh site</u>

% Juveniles Captured = -0.00106*LN (Modesto Flow cfs))-(0.00008773*FL) + 0.01733; low efficiency values were truncated at 0.0005. The adj-R^2 for this model is 0.04 and P = 0.409

<u>1999-2001, 2003, 2004, and 2006 efficiency data at the Grayson site</u>

% Juveniles < 65 mm FL Captured = -0.02851LN (Modesto Flow cfs)) - (0.00142*FL) + 0.35107; low efficiency values were truncated at 0.002. The adj-R^2 for this model is 0.51 and P = 0.000

% Juveniles $\geq$ 65 mm FL Captured = -0.02190*LN (Modesto Flow cfs)) - (0.0004120*FL) + 0.22453; low efficiency values were truncated at 0.002. The adj-R^2 for this model is 0.49 and P = 0.000

List of End Notes

[i] Information obtained from USFWS-AFRP website: http://www.delta.dfg.ca.gov/afrp/ws_stats.asp?code=TUOLR

[ii] Includes both ocean harvest and inland escapement

[iii] The FERC Settlement Agreement, or FSA as its commonly called, is not an official FERC Settlement Agreement but rather is an agreement between entered into in 1996 by the Modesto and Turlock Irrigation Districts, U.S. Fish and Wildlife Service, and the California Department of Fish and Game that proposed flow, and non-flows, actions to improve production of fall-run Chinook salmon in the Tuolumne River.

[iv] It is important to note that Tuolumne River flow level at Modesto is highly correlated with Delta flows at Vernalis (Marston 2005). Relationships between the survival of smolt-sized juveniles and flow are statistically significant at both locations. Therefore, elevated Tuolumne River out-flow improves juvenile salmon survival both in the Tuolumne River and in the South Delta.

[v] The estimates of the number of smolt outmigrants are preliminary because the trap efficiency models have not been peer-reviewed.

[vi]The Vernalis Adaptive Management Plan (e.g. VAMP) is a scientific study that evaluates the effects of Delta inflow, and outflow, upon fall-run Chinook salmon smolt survival.

[vii] The VAMP survival estimates are highly affected by whether the tagged fish are recovered as juveniles in the Delta or as adults in the ocean harvest. Ocean recoveries suggest that juvenile survival rates through the Delta are higher that those based on Delta recoveries. For example, ocean coded wire tag recoveries for juvenile salmon released as part of South Delta flow evaluations at 5,000 cfs show a 25% survival rate as compared to a 14.5% survival rate for Delta recoveries.

[viii] USFWS Chinook Prod Spreadsheet is available at http://www.delta.dfg.ca.gov/afrp/

[ix] Modified water year type based instream flow schedules would be met through re-operation of currently available water supply (i.e. re-operation of New Don Pedro to diminish frequency, magnitude, and duration of flood control releases without diminishing diversion supply).

[x] Annual = Water year type calendar beginning on October 1 and ending on September 30.