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MANAGING THE TUOLUMNE RIVER FOR SALMONIDS: ASSESSMENT OF THE 1995 SETTLEMENT AGREEMENT

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The Tuolumne River originates at elevations over 3,900 meters in Yosemite Valley, California along the Western Sierra and is the largest tributary to the San Joaquin River of the Central Valley, draining an area of approximately 2,500 km^2. The Tuolumne River was once home to a healthy population of spring and fall-run Chinook salmon, *Oncorhynchus tshawytscha*, the spring-run likely ascending upstream as high as the boundary of Yosemite National Park, at an elevation of nearly 760 meters. Although historical records of the presence of Central Valley steelhead, *Oncorhynchus mykiss* are poor, they were believed to be well distributed in the Tuolumne River and its smaller tributaries. A series of dams for water supply, hydroelectric generation, and flood control were constructed starting in the 1890s. These dams cut off access by native anadromous fish to as much as 90 % of their spawning habitat. In 1996 the Federal Energy Regulatory Commission issued an order amending a 1964 license, which included a 1995 Settlement Agreement. The 1995 Settlement Agreement designated a Technical Advisory Committee to oversee implementation of the agreement and its requirements. A review of the hydrographs of the Tuolumne River during the first 8 years under the Settlement Agreement revealed they were significantly different in timing and magnitude than recommended by resource agencies. This paper discusses management implications of the Settlement Agreement, and also offers recommendations for improvement.

Key Words: California, Chinook salmon, *Oncorhynchus mykiss*, *Oncorhynchus tshawytscha*, San Joaquin River, steelhead, Tuolumne River, Yosemite

INTRODUCTION

The Tuolumne River originates at elevations over 3,900 meters in Yosemite Valley along the Western Sierra and is the largest tributary to the San Joaquin River of the Central Valley, draining an area of approximately 2,500 km^2. The Tuolumne River flows west through the alluvial valley floor where it meets the San Joaquin River 16 kilometers west of the City of Modesto (Figure 1), its waters eventually entering the Sacramento-San Joaquin Delta to the northwest. The Tuolumne River became famous in the early 1900's as John Muir fought

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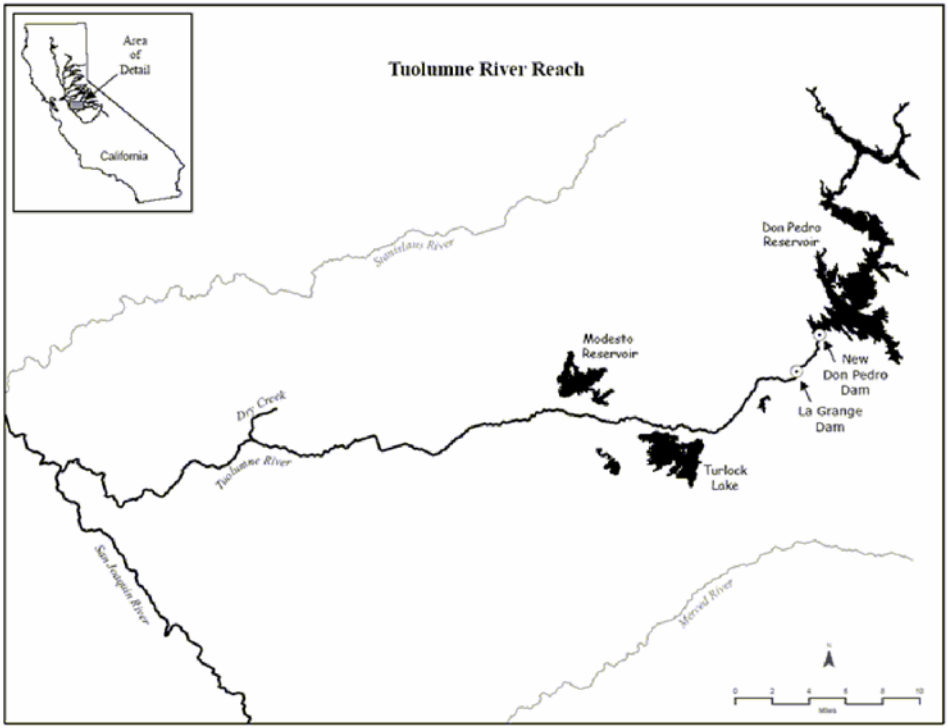

Figure 1. Map of Tuolumne River, California.

and lost the battle to stop the damming of the Hetch-Hetchy Valley, now used for drinking water and production of electricity for the city and county of San Francisco (Mount 1995).

A series of dams, starting on the Tuolumne River near the town of La Grange have been constructed for water supply, hydroelectric generation, and flood control (Figure 1). La Grange Dam is the first impassable barrier to upstream movement for anadromous fish and is located at river km 84 on the Tuolumne River. Built in 1893 by Turlock and Modesto Irrigation Districts (Districts), the 40-meter high diversion facility impounds approximately 500 acre-feet of water. Several kilometers upstream of La Grange stands the original Don Pedro Dam, built in 1923 and operated by Turlock Irrigation District. Storage at Don Pedro Dam was increased in 1971 with a new dam called New Don Pedro. New Don Pedro Dam is a 178-meter high earth and rock filled dam with a storage capacity of 2,030,000 acre-feet and is used for irrigation, flood control, and hydropower generation. Upstream of New Don Pedro Dam, the city and county of San Francisco manage two smaller reservoirs on Eleanor and Cherry creeks, and O'Shaughnessy Dam impounding Hetch-Hetchy Reservoir (Turlock and Modesto Irrigation Districts 2005).

The Tuolumne River was once home to a healthy population of spring and fall-run Chinook salmon, *Oncorhynchus tshawytscha*, the spring-run likely ascending upstream as high as the boundary of Yosemite National Park (Yoshiyama et al. 2001) at an elevation of nearly 760 meters. During the 1930s and 1940s, approximately 40 years after La Grange Dam blocked access to a considerable amount of spawning habitat for Chinook salmon, it was estimated that the population of fall-run salmon on the Tuolumne River was still larger than

any other stream in the Central Valley, except for the lower Sacramento River. Returns were estimated at 122,000 in 1940 and 130,000 in 1944 (California Department of Fish and Game [CDFG] 1946). There is now no discernable spring-run population left in the Tuolumne River, and fall-run Chinook salmon returns during the past four decades have averaged less than 10,000 (United States Fish and Wildlife Service [USFWS] 1995). Although historical records of the presence of steelhead, *Oncorhynchus mykiss* are poor, they were believed to be well distributed in the Tuolumne River and its smaller tributaries (McEwan 2001). Recent evidence confirms the low abundance of steelhead in the San Joaquin Basin tributaries and in the Tuolumne River (McEwan 2001, Zimmerman et al. 2009).

Ford and Brown (2001) captured 33 species of fish on the Tuolumne River between 1988 and 1994, 12 (36%) of which were native. In addition to weakened salmonid populations and declining habitat, the Tuolumne River is now home to many non-native species including striped bass and black bass (Ford and Brown 2001). Ford and Brown suggest the relatively high percentages of non-native fish in the Tuolumne River are due to the low-flow conditions during the summer.

The Federal Energy Regulatory Commission (FERC) issued a license to Turlock and Modesto Irrigation Districts in 1964, establishing minimum flow releases for the first 20 years of project operation (1971-1991), which were extended by FERC order in 1987 to last into 1998. The USFWS, CDFG, and the Districts ensued work under a 1971 study plan to further understand the impacts of the New Don Pedro Dam on Chinook salmon (McBain and Trush 2000). In 1996, FERC issued an order amending the license in response to an application to amend, which included the 1995 Settlement Agreement (SA). The Federal Energy Commission adopted two components of the SA into Articles 37 and 58, and these are what regulate project operations. Parties to the SA include Turlock and Modesto Irrigation Districts, CDFG, USFWS, city and county of San Francisco, San Francisco Bay Area Water Users Association, Friends of the Tuolumne, Tuolumne River Preservation Trust, Tuolumne River Expeditions, and the California Sportfishing Protection Alliance.

The SA designated a Tuolumne River Technical Advisory Committee (TRTAC) to oversee implementation of the SA and its requirements (Turlock and Modesto Irrigation Districts 1996). The SA requires various restoration projects, scientific studies, and minimum flows for the protection of Chinook salmon. Streamflow and restoration projects specific to Central Valley steelhead were not a part of the SA as they were not yet protected by the Endangered Species Act (ESA). Specific monitoring components of the SA include Chinook salmon spawning escapement, smolt survival, and smolt production, which are to be used to evaluate the success of the SA. In addition to the minimum flow requirements, the SA also gives the TRTAC the authority to make minor flow adjustments for the protection of Chinook salmon upon approval of the USFWS, the Districts, and CDFG (Turlock and Modesto Irrigation Districts 2005).

METHODS

Negotiation of a settlement agreement requires considerable agency effort. Recognizing that a settlement is a compromise among parties and includes many factors in addition to fisheries (e.g., dam safety, and municipal and agricultural water supplies) this paper reviews the function of the SA, its decision process, status of the fishery, and management implications during the most recent 8 years of implementation from a biologist's perspective. Recommendations for improvement are also provided.

RESULTS

Settlement Agreement Flow Schedule

The 1995 SA requires the Licensee maintain minimum streamflows in the Tuolumne River, measured downstream of La Grange Dam (at km 81.3) for the protection of fish, particularly fall-run Chinook salmon (Turlock and Modesto Irrigation Districts 1996). The flow schedule is separated into 10 water-year types built on the California State Water Resources Control Board's San Joaquin Basin 60-20-20 Water Supply Index, which is based on the California Department of Water Resources (CDWR) San Joaquin Valley unimpaired runoff forecast (Turlock and Modesto Irrigation Districts 1996). Each water year classification and corresponding San Joaquin Basin Index are associated with a frequency of occurrence readjusted as current runoff information becomes available (Turlock and Modesto Irrigation Districts 1996).

Table 1. Water Year Classification table used in the management of flow on the Tuolumne River based on 1995 FERC Settlement Agreement.

Water year classification	Cumulative occurrence (%)	Frequency	Index (1906-1995)
Critical Water Year and below	< 6.4	6.4	<1500 TAF
Median Critical Water Year	6.4 - < 14.4	8.0	1500
Intermediate C-D Water Year	14.4 - < 20.5	6.1	2000
Median Dry	20.5 - < 31.3	10.8	2200
Intermediate D-BN	31.3 - < 40.4	9.1	2400
Median Below Normal	40.4 - < 50.7	10.3	2700
Intermediate BN-AN	50.7 - < 66.2	15.5	3100
Median Above Normal	66.2 - < 71.3	5.1	3100
Intermediate AN-W	71.3 - < 86.7	15.4	3100
Median Wet/Maximum	86.7 - 100	13.3	3100

Specific water year types determined by Table 1 designate flow measured at La Grange for various fall-run Chinook salmon life history components (Table 2). In addition to base flows designated for each of 10 water year types, fall and spring pulse flows for upstream migration spawning cues and downstream juvenile migration are also allocated (Table 2). Figure 2 is a conceptual diagram of the flow management procedure used by the TRTAC. The procedure starts with a preliminary February 1 runoff forecast from CDWR. The forecast is used as a preliminary prediction to build the upcoming flow schedule. The March 1 CDWR runoff forecast starts the flow allocation process in which a San Joaquin Basin Index is produced. The San Joaquin Basin Index is referred to the far right column of Table 1, where a corresponding water year classification from the SA is designated. A designated amount of water is set aside for fall or spring pulse flows dependent on the water year classification.

The TRTAC makes a preliminary determination on the pulse flow duration and calendar. This preliminary pulse flow usage will vary depending on existing river temperatures, forecasted conditions, Chinook salmon return rates, etc. The preliminary

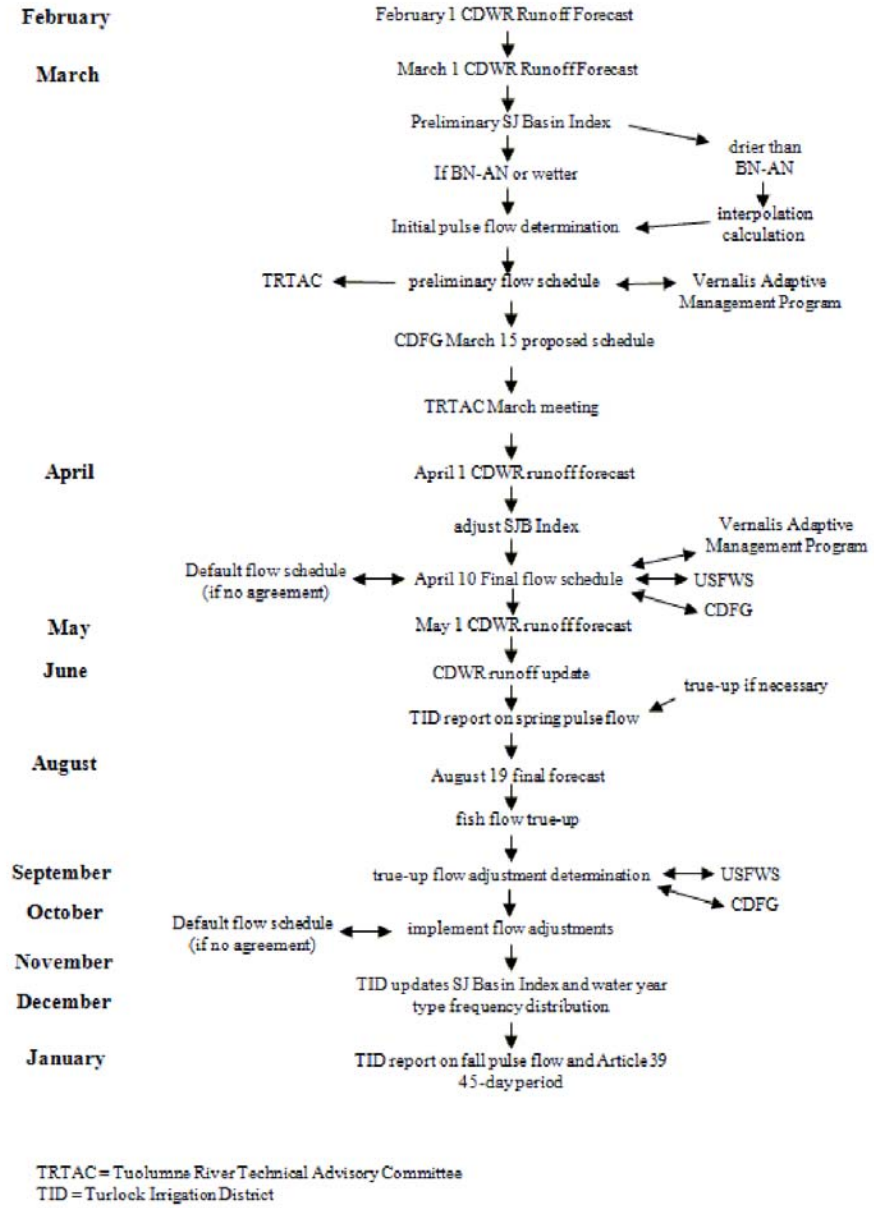

Figure 2. Flow management procedure diagram illustration dictated by the 1995 SA of the New Don Pedro FERC license on the Tuolumne River, California.

Table 2. 1995 SA Flow schedule based on 1906-1995 frequency of occurrence.

Occurrence /Schedule	6.4% Critical & below	8.0% Median Critical	6.1% Intermediate C-D	10.8% Median Dry	9.1% Intermediate D-BN	10.3% Median Below Normal	15.5% Intermediate BN-AN	5.1% Median AN	15.4% Intermediate AN-W	13.3% Median Wet/ Maximum
October 1 - October 15	100 cfs 2,975 ac-ft	100 cfs 2,975 ac-ft	150 cfs 4,463 ac-ft	150 cfs 4,463 ac-ft	180 cfs 5,355 ac-ft	200 cfs 5,950 ac-ft	300 cfs 8,926 ac-ft	300 cfs 8,926 ac-ft	300 cfs 8,926 ac-ft	300 cfs 8,926 ac-ft
Attraction Pulse Flow	None	None	None	None	1,676 ac-ft	1,736 ac-ft	5,950 ac-ft	5,950 ac-ft	5,950 ac-ft	5,950 ac-ft
October 16 - May 31	150 cfs 67,835 ac-ft	150 cfs 67,835 ac-ft	150 cfs 67,835 ac-ft	150 cfs 67,835 ac-ft	180 cfs 81,402 ac-ft	175 cfs 79,140 ac-ft	300 cfs 135,669 ac-ft	300 cfs 135,669 ac-ft	300 cfs 135,669 ac-ft	300 cfs 135,669 ac-ft
Outmigration Pulse Flow	11,091 ac-ft	20,091 ac-ft	32,619 ac-ft	37,060 ac-ft	35,920 ac-ft	60,027 ac-ft	89,882 ac-ft	89,882 ac-ft	89,882 ac-ft	89,882 ac-ft
June 1 - September 30	50 cfs 12,099 ac-ft	50 cfs 12,099 ac-ft	50 cfs 12,099 ac-ft	75 cfs 18,149 ac-ft	75 cfs 18,149 ac-ft	75 cfs 18,149 ac-ft	250 cfs 60,496 ac-ft	250 cfs 60,496 ac-ft	250 cfs 60,496 ac-ft	250 cfs 60,496 ac-ft
Volume (ac-ft)	94,000	103,000	117,016	127,507	142,502	165,002	300,923	300,923	300,923	300,923

ac-ft = acre-feet

flow schedule is distributed to members of the TRTAC for review, and in addition, is discussed in detail at a March TRTAC meeting. A new CDWR runoff forecast on April 1 results in a revised San Joaquin Basin Index and a final revision of the flow schedule on April 10. Because the final flow schedule is determined in mid-April, the May 1 forecast update is used to compare the predicted runoff forecast with actual runoff information. If additional water is available, or the water supply forecast drops to a lower water year classification and resultant lower water allocations, the Licensees, USFWS, and CDFG apply the extra water or remove the water at their discretion (true-up process). Subsequent CDWR runoff forecasts in June and July make it necessary to continue the true-up process. The final San Joaquin Basin Index occurs in mid-August and one final fish flow true-up is completed in October. With the final San Joaquin Basin Index for the year at hand, the Licensee updates the basin index and water year type frequency distribution to maintain the same frequency of water year types.

Resource Agency Guidelines on Tuolumne River Fish Flows

The CDFG Central Valley restoration plan of action (CDFG 1993) identified a need for additional instream flow on the Tuolumne River and recommended an interim flow schedule for five water year types (Table 3). High flow fluctuation rates disrupting adult passage and spawning as well as affecting fry emergence by stranding and downstream displacement were primary stressors identified during the winter period. High water temperatures, decreasing egg survival in the fall and juvenile survival during the spring were also identified as issues of concern. Additional concerns identified were: low summer flows for salmon and steelhead, predatory fish, and spawning and rearing habitat degradation. The restoration plan of action was completed prior to the SA and contains flow recommendations similar to those found in the SA, with the exception of wet year releases. For wet year agreements, CDFG recommended a total of 374,491 acre-feet of water to be released, whereas the SA mandates a total of 300,923 acre-feet.

Table 3. Interim flow schedule recommendations during key salmon life history dates during critical, dry, below normal, above normal, and wet water year types on the lower Tuolumne River by CDFG (1993).

Schedule	Critical	Dry	Below Normal	Above Normal	Wet
October 1 - October 14	80 cfs 2,221 ac-ft	150 cfs 4,164 ac-ft	200 cfs 5,552 ac-ft	250-1,480 cfs 9,380 ac-ft	300-1,450 cfs 10,609 ac-ft
October 15 - December 31	80 cfs 12,374 ac-ft	150 cfs 23,200 ac-ft	175-1,075 cfs 31,133 ac-ft	250-1,480 cfs 43,546 ac-ft	300-1,450 cfs 50,962 ac-ft
January 1 - March 31	80 cfs 14,278 ac-ft	150 cfs 26,769 ac-ft	175 cfs 31,231 ac-ft	250 cfs 44,616 ac-ft	300 cfs 53,539 ac-ft
April 1 - May 31	50-605 cfs 22,764 ac-ft	170-985 cfs 55,217 ac-ft	201-1,428 cfs 78,939 ac-ft	500-2,520 cfs 148,568 ac-ft	500-3,000 cfs 210,992 ac-ft
June 1 - September 30	50 cfs 12,097 ac-ft	75 cfs 18,145 ac-ft	75 cfs 18,145 ac-ft	150 cfs 36,287 ac-ft	200 cfs 48,385 ac-ft
Volume (ac-ft)	63,734	127,507	165,002	282,403	374,491

ac-ft = acre-feet

In 1992, President George Bush signed into law the Reclamation Projects Authorization and Adjustment Act of 1992 (Public Law 102-575), including the Central Valley Project Improvement Act (CVPIA). The CVPIA directed the Secretary of the Interior to amend previous authorizations of California's Central Valley Project. Section 3406(b)(1) of the CVPIA directs the Secretary of the Interior (Secretary) to develop and implement a program that makes all reasonable efforts to at least double natural production of anadromous fish in California's Central Valley streams on a long-term, sustainable basis. The major program instituted to address this doubling is known as the Anadromous Fish Restoration Program (AFRP).

In 1995, the AFRP published the Working Paper on habitat restoration actions to double natural production of anadromous fish in the Central Valley of California. The Working Paper presented the best available knowledge regarding the level of restoration needed to meet the goal of at least doubling natural production of anadromous fish in the Central Valley. The Working Paper identified a Tuolumne River flow schedule (Table 4) necessary for fish doubling purposes and cites needs for additional water similar to the 1993 California Department of Fish and Game Plan of Action (CDFG 1993). Flow schedule components include adequate flow for adult migration, spawning, egg incubation, juvenile rearing, smolt emigration, and over summering habitat of yearlings. Based on instream flow studies conducted in the mid 1990s (USFWS 1994, 1995), the Plan of Action recommendations were

increased (Table 4). These flows represent ideal flows recommended for doubling anadromous fish populations in the Tuolumne River.

During the first 8 years of the SA, there were 3 wet water year types (1996, 1997, and 1998), 2 above normal (1999 and 2000), 2 dry (2001 and 2002), and 1 below normal (2003. According to the San Joaquin Basin 60-20-20 Index and frequency of occurance as identified in the SA.).

Table 4. USFWS (1995) flow schedule recommendations (in cfs) for the lower Tuolumne River by month during wet, above normal, below normal, dry, and critical water year types.

Month	Critical	Dry	Below normal	Above normal	Wet
October	150	200	300	300	750
November	150	300	350	800	1,250
December	200	350	350	1,050	1,400
January	250	400	500	1,150	1,700
February	500	700	950	1,700	2,100
March	900	1,000	1,300	1,700	2,300
April	1,500	1,900	2,350	2,450	2,950
May	1,850	2,500	3,350	4,200	5,150
June	1,000	1,550	2,600	3,250	5,000
July	200	250	650	900	2,150
August	50	100	100	200	450
September	50	100	150	150	350
Total (taf)	155	327	355	737	1,291

taf = thousand acre-feet

Wet Water Year Types - 1996, 1997, 1998

The SA flow schedule dictates a total of 300,923 acre-feet of water during wet year types (Table 2). Actual SA flows, the SA flow designations, and the USFWS flow recommendations for each of the 4 wet years are presented in Figure 3. The minimum flow requirement under the SA between October and May 31 was 300 cubic feet per second (cfs), and the minimum during the remainder of the water year was 250 cfs. Additional allotments of pulse flow water, specific to the wet water year type were also allocated for the fall attraction and spring outmigration pulse flows (Table 2). In all three wet years observed, peak outflow occurred in the late-fall and winter periods (November to March), with secondary peaks observed in April and May during 2 of the 3 years. In all 3 years, flow peaks occurred several months prior to the maximum discharge recommended by the AFRP working paper flow recommendations during the fall spawning season and the juvenile

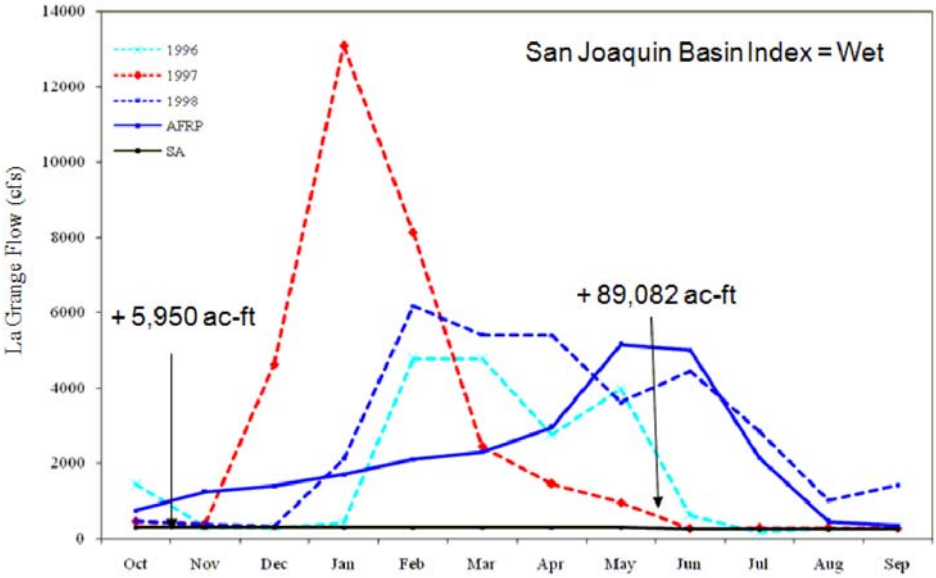

Figure 3. Tuolumne River flow at La Grange during 1996, 1997, and 1998 water years published in the USGS Surface Water database (broken lines), flow recommended by USFWS (1995) to double the natural production of anadromous fish on the Tuolumne River (solid blue line), and FERC Settlement Agreement flow requirements (solid black line). Additional acre-feet designations are to be used at the discretion of the Tuolumne River Technical Advisory Committee.

outmigration season (Figure 3). Because the SA was not implemented until July 1996, required flows prior to that date were scheduled under the prior FERC license.

Above Normal Water Year Types - 1999, 2000

The SA flow schedule also dictates a total of 300,923 acre-feet of water during above normal water year types, consisting of October 15 to May 31 base flows at 300 cfs and 250 cfs during the summer (Table 2). Additional allotments of pulse flow, specific to the wet water year type (Table 2) were also allocated for the fall Chinook attraction and spring juvenile outmigration pulse flows. Trends during the 1999 and 2000 water years appeared similar to the wet water types but of a lower magnitude. Peaks occurred during the winter months, yet subsided more quickly (Figure 4). Flow during the two above normal water year types peaked in late-winter (February and March) and continued to decline to base flow conditions in June. The temporal distribution of flow again was shifted several months prior to the AFRP flow objective.

Below Normal Water Year Types - 2003

The below normal water year type observed during 2003 required a total volume of 165,002 acre-feet, slightly more than half the volume allotted during wet water year types and consisted of a 200 cfs spawning flow, 175 cfs base flow between October 16 and May

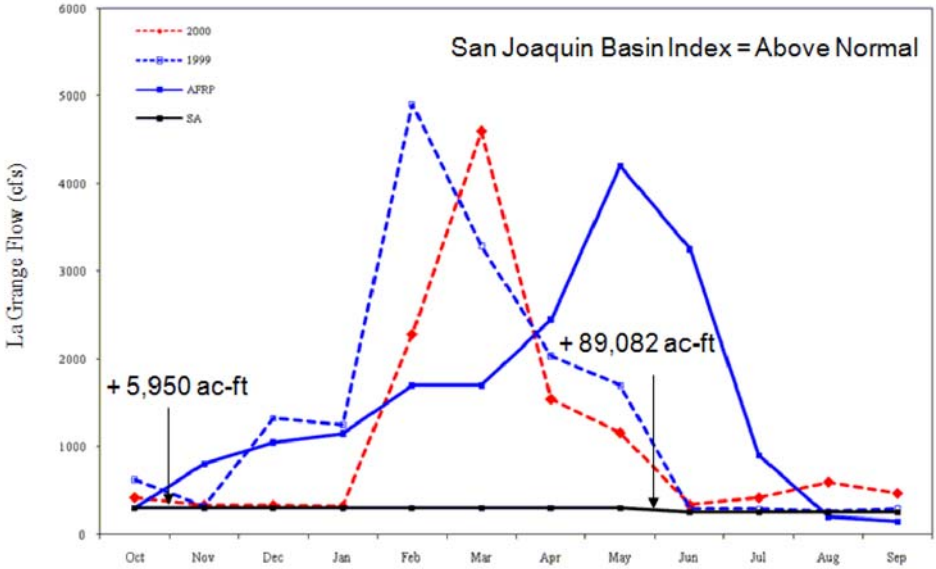

Figure 4. Tuolumne River flow at La Grange during 1999 and 2000 water year published in the USGS Surface Water database (broken lines), flow recommended by USFWS (1995) to double the natural production of anadromous fish on the Tuolumne River (solid blue line), and FERC Settlement Agreement flow requirements (solid black line). Additional acre-feet designations are to be used at the discretion of the Tuolumne River Technical Advisory Committee.

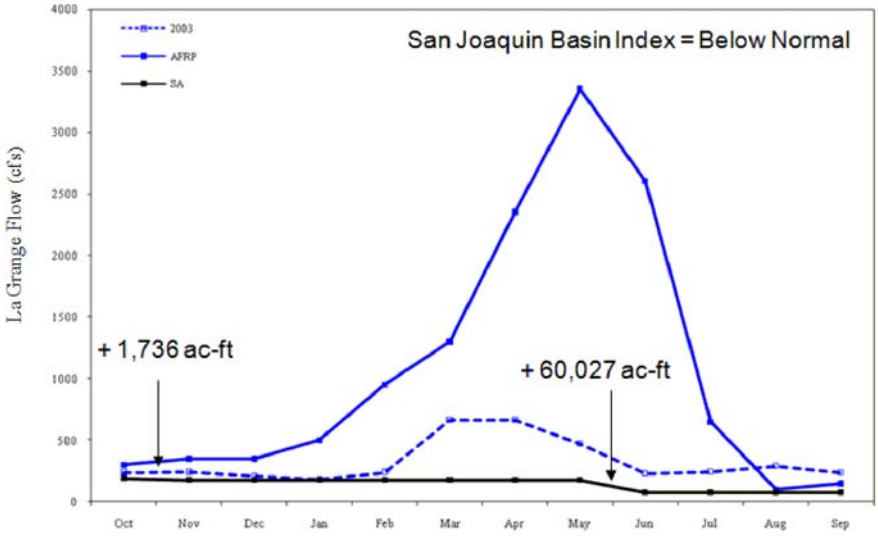

Figure 5. Tuolumne River flow at La Grange during 2003 water year recorded in California Data Exchange Database (broken blue line), flow recommended by USFWS (1995) to double the natural production of anadromous fish on the Tuolumne River (solid blue line), and FERC Settlement Agreement flow requirements (solid black line). Additional acre-feet designations are to be used at the discretion of the Tuolumne River Technical Advisory Committee.

31, and 75 cfs summer flow base (Table 2). Additional fall Chinook attraction and spring juvenile Chinook outmigration pulse flows are also provided in Figure 5 and Table 2. Because no significant storms delivered water during winter 2003, flows remained at base level until a small peak in March and April (Figure 5). Late storms during 2003 gave the TRTAC some interpolation water to be used upon agreement between the USFWS, CDFG, and the Licensees.

Dry Water Year Types - 2001, 2002

The SA dictates a total volume to be released of 127,507 cfs and a spring pulse flow of 37,060 acre-feet during median dry water year types (Table 2). Base flow conditions are 150 cfs during the spawning and rearing season and 75 cfs during summer. Because 2000 was an above normal water year, spawning flows during fall 2001 remained above base flow levels until early winter, peaking in February. Flows then dropped approximately 500 cfs and were held until May and June when dropped to base levels. The 2002 water year followed the 2001 dry water year and thus continued with fall base flows until a series of storms occurred in April and May producing a low runoff peak for outmigration. Flows quickly dropped in June to summer base flows. Both years had peaks of low magnitude falling considerably short of the AFRP recommended flows for doubling (Figure 6).

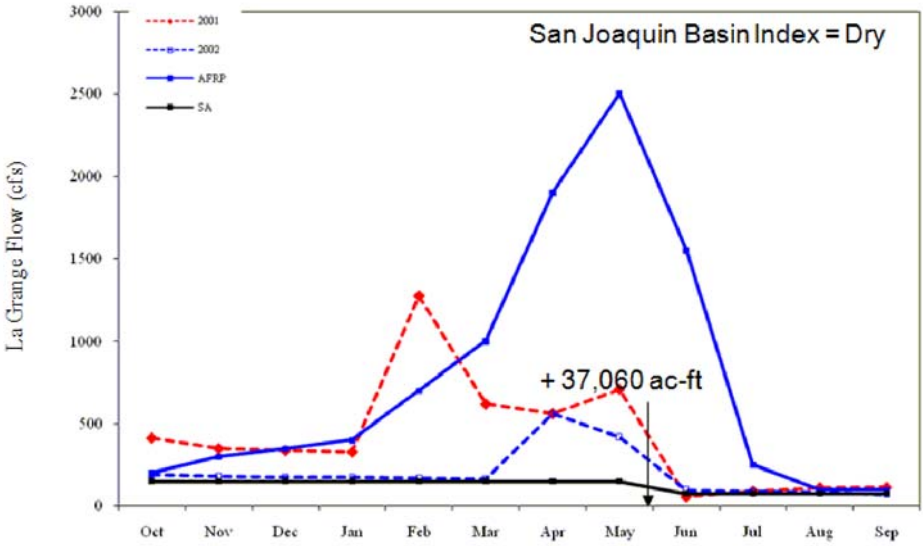

Figure 6. Tuolumne River flow at La Grange during 2001 and 2002 water years published in USGS Surface Water Database (broken lines), flow recommended by USFWS (1995) to double the natural production of anadromous fish on the Tuolumne River, (solid blue line) and FERC Settlement Agreement flow requirements (solid black line). Additional acre-feet designations are to be used at the discretion of the Tuolumne River Technical Advisory Committee.

Salmonid Population Status

The annual escapement of fall-run Chinook salmon in the Tuolumne River continues to exhibit a cyclical pattern of varying high and low escapements presumably due to Pacific Ocean conditions and inland drought cycles (Figure 7) as is the case in the nearby Stanislaus and Merced rivers (CDFG 2008). Fall-run Chinook populations on the Tuolumne River appear to be exhibiting overall downward trends (Figure 7). Peak adult population estimates exceeded 40,000 fall-run Chinook salmon four times between 1952 and 1984. Wet year clusters between 1952-1960, 1964-1972, and 1980-1988 averaged 28,008, 11,487, and 13,191, respectively, while the average for the wet and above normal water year cluster between 1996 and 2000 fell to 9,305. Since 2000, escapement dropped quickly from a high of 8,782 in 2001 to a low of 1,984 in 2004 (CDFG 2008). The long term average appears to be declining and low escapement periods appear to be more extended and more severe in recent years (Figure 7).

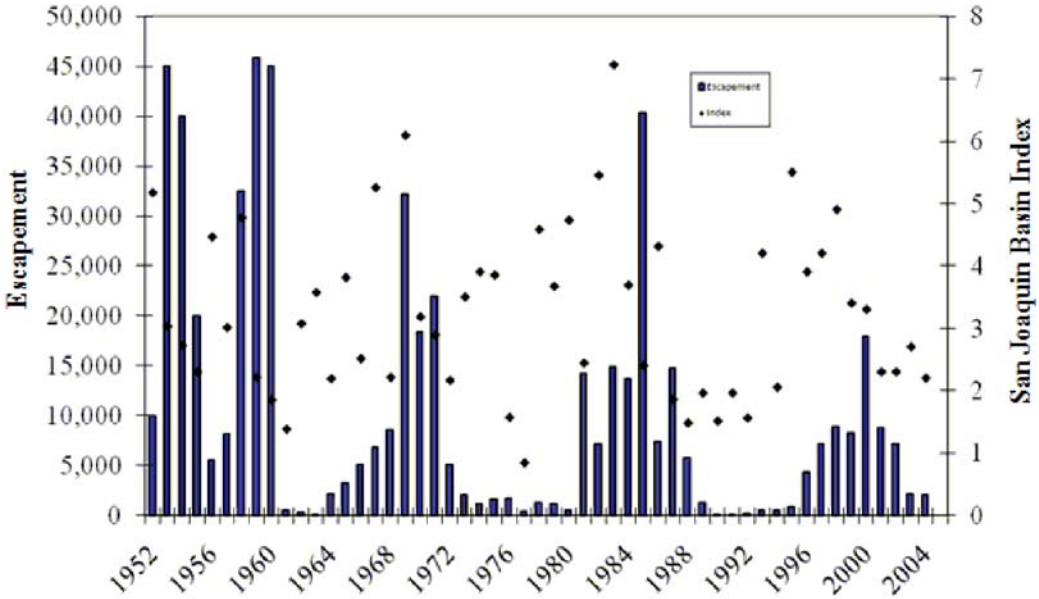

Figure 7. Fall-run Chinook salmon escapement in the Tuolumne River (blue bar) and San Joaquin Valley 60-20-20 Hydrologic Classification Index (black diamond) between 1952 and 2004.

A total of 500 spawners has been suggested to maintain population viability (Allendorf et al. 1997). Escapement dropped below 500 on the Tuolumne River twice in the 1960s, once in the 1970s, and 4 times in the 1990s. These trends suggest the Tuolumne River fall-run Chinook salmon population continues to exhibit downward trends resulting in decreased viability and resilience. In addition, Allendorf et al. (1997) identified the Tuolumne River fall-run Chinook salmon population at a high risk of extinction.

Populations of Central Valley steelhead are poorly documented on the Tuolumne River and currently are rarely encountered; however, recent evidence documents their presence (Zimmerman et al. 2009). Their rarity is thought to be primarily due to limited habitat resulting from low-flow summer conditions, as steelhead require different streamflow conditions than Chinook salmon.

DISCUSSION

Annual returns of adult fall-run Chinook salmon on the Tuolumne River since 1952 show signs of downward trends and decreased population viability and resilience. This is exhibited by decreased annual peaks of escapement and an increased prevalence of escapement less than 500 fish. An overall downward trend in the Tuolumne River population is evident.

After reviewing the actual streamflow between 1996 and 2004, the hydrographs appear to be different than the anticipated flow schedule in the SA in terms of timing. They also differ from federal and state fishery agency recommendations in terms of timing and magnitude. As a result, the timing and amount of streamflow on the lower Tuolumne River has not met expectations of fishery managers. It may be that the flow schedule would have provided additional benefits for fall-run Chinook salmon if they had been released at the intended frequency and magnitude originally established in the SA.

Of additional importance is that in 6 of the 8 years, large flow increases occurred during the fall-run egg incubation period. As a result, peak flows did not aid juvenile salmon migration. In addition, spring flows were truncated during 7 of 8 years, resulting in relatively less flow during the juvenile migration period. This might be overcome in the future if winter outflows are released during the juvenile migration period. More flexibility to adjust the flow schedule would benefit Chinook salmon requirements to rear and migrate from the Tuolumne River. This recommendation may not be feasible due to dam safety issues or other factors controlling the release of flood flows during winter months; however, other flow-related settlements incorporate flexibility for unplanned situations. For example, the Lower Yuba River Fisheries Agreement (Yuba County Water Agency 2007) has specific provisions in the settlement allowing altered flow schedules in the event they are needed, and the Mokelumne River Settlement (East Bay Municipal Utility District 1996) incorporates adaptive management provisions allowing flow changes if needed. In addition, the San Joaquin River Settlement (Natural Resources Defense Council vs. Rodgers 2006) flow schedule includes a flexible flow period allowing the flexibility to shift flows several weeks to accommodate changing fisheries needs. Impact assessments are also needed addressing the relative benefits of other scheduled hydrograph components (i.e., adult migration pulse flows).

Shifting a small amount of water from the spring or summer water components to contribute to pulse flows for returning adult salmon often occurs with little information regarding the benefits of pulse flows from a fish population perspective. Relatively small amounts of interpolation water were used to augment pulse flows or flow schedule components during some years (true-up process). Documentation of the interpolation water use and the decisions made to augment the flow schedule is sparse and definitive amounts often have not been recorded, however the portion of water used to adjust the flow schedule is relatively small. The consequences of changes to each of the hydrograph components in terms of fisheries impacts on the Tuolumne River are not clearly understood. Suggestions

for improvement include the development of conceptual and quantitative models and field studies to develop flow habitat relationships.

Since implementation of the SA in 1996, Central Valley steelhead were listed as threatened under the Federal Endangered Species Act (March 19, 1998). The significance of Central Valley steelhead in the Tuolumne River has been controversial and the addition of steelhead that require over summer flows highlights the problem of the lack of SA flexibility. Low summer base flow conditions in the Tuolumne River often expose Central Valley steelhead to elevated temperatures, restricting their movement and habitat. The SA does not mandate the storage and or shifting of water to spring and summer flow periods for Chinook salmon or other species such as Central Valley steelhead. To address newly arising concerns such as Central Valley steelhead, more management flexibility would be beneficial.

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