Chapter 11 Upstream Effects

This chapter focuses on the Central Valley Project (CVP) and State Water Project (SWP) project operations and how the operations affect flow and water temperature in river reaches downstream of project reservoirs. The following effects discussion refers to the reservoir release exceedance charts (monthly flow values) and water temperature exceedance charts (daily temperature model for Sacramento River and Clear Creek and monthly model for other rivers) found in Chapter 10. The amount and temperature of the water in the areas inhabited by the species are both elements of critical habitat that affect spawning, rearing, migration, and foraging. Recommended temperature ranges and flows for the species are compared to the exceedence charts. Modeling tools are used to help estimate effects on species and lifestages where available. Because the monthly model presents longer term trends, daily temperature measurements are presented herein to illustrate the potential range of variability within particular months. The modeling displays more of a net change by month and shows the general direction of change useful for comparing the water operations scenarios.

Three models, addressing portions of the Chinook salmon lifecycle, were used to evaluate the effects of operations on Chinook salmon in the Sacramento River. The Reclamation Mortality Model is used to compare the effects of water temperature on Chinook salmon egg mortality between scenarios for those rivers and salmonid runs for which the model has been developed. The model is only available for fall-run Chinook salmon on rivers other than the Sacramento. Past reviews of the effects analyses recommended additional quantitative assessment approaches to address lifestages beyond those addressed in the egg mortality model. The Salmod Model is being used to compare effects of water temperature and flow differences between scenarios on yearly juvenile winter-run and spring-run Chinook salmon production in the Upper Sacramento River. The Interactive Object-Oriented Salmon Simulation (IOS) Model (Appendix N) is used to compare the effects of the operational scenarios throughout the CVP/SWP system on the entire life cycle of winter-run Chinook salmon and provides an estimate of changes in escapement through time.

Water Temperature

Water temperature is critical to the populations of listed species, particularly Chinook salmon, coho salmon, and steelhead, present in the rivers considered in this consultation. Water temperature targets from the 2004 Operations Criteria and Plan (OCAP) Biological Opinion (BO) are shown in Table 11-1 and used in the analyses presented in this BA. The temperature targets vary from river to river based on the species and life stage needing protection. We are selecting the most temperature sensitive lifestage present in the river at a given time for analyses. The Upper Sacramento River has incubating winter-run Chinook eggs during the summer. Eggs have the coolest temperature needs and water temperatures naturally rise to the highest levels during the heat of summer, therefore the most stringent temperature targets are for eggs incubating during the summer in the Sacramento River. Steelhead rearing occurs in the Sacramento River, Clear Creek, Feather River, American River, and Stanislaus River. The generally accepted upper mean daily water temperature level for steelhead rearing in the Central Valley is 65 °F. Therefore, CVP/SWP water management tries to maintain 65 °F in the controllable reaches of the rivers where steelhead are present during the warmer months of the year. The American River is temperature limited in that the coldwater pool volume often cannot maintain the desired temperatures so the target recognizes this in an effort to spread the available coldwater out throughout the needed time period.

Table 11-1. Temperature targets from 2004 OCAP BO used as evaluation criteria in this BA. Temperature targets are mean daily. Target points in the Sacramento and American River are determined yearly with input from the Sacramento River temperature group and American River ops group.

River	Target Species and Lifestage	Temperature Target Point	Miles Below Dam	Date	Temperature Target	Comment
Sacramento	Winter run egg incubation	Balls Ferry	26	4/15 - 9/30	56	Location depends on coldwater availability
	Winter run egg incubation	Bend Bridge	44	4/15 - 9/30	56	Location depends on coldwater availability
	Spring run and winter run	Balls Ferry	26	10/1 - 10/31	60	Location depends on coldwater availability
	Spring run and winter run	Bend Bridge	44	10/1 - 10/31	60	Location depends on coldwater availability
Clear Creek	Spring run prespawn and steelhead rearing	Igo	7.5	6/1 - 9/15	60	
	Spring run spawning and steelhead rearing	Igo	7.5	9/15 - 10/31	56	
Feather River	steelhead rearing	Robinson's Riffle	6	6/1 - 9/30	65	
American River	steelhead rearing	Watt Avenue	13.4	plan May 1	68	Target based on yearly plan
Stanislaus River	steelhead rearing	Orange Blossom	12	6/1 - 11/30	65	

Historic Water Temperature Data Summary (Figures 11-1 through 11-25)

The figures listed below show the mean daily temperature at monitoring sites up and down the rivers. This shows the difference in water temperatures at different points in the river. These plots of actual measured data are presented to show the actual temperatures experienced by the species from day to day. The temperature gradient from upstream to downstream and the daily temperature fluctuations will likely stay about the same in the future, changing in the same trend (upward or downward) with the mean daily and mean monthly temperatures produced by the temperature models. These plots are a part of the baseline in that the conditions occurred under past operations, but they are presented here in the effects chapter because the finer details of daily temperature fluctuations and longitudinal temperature gradients under different flow conditions are more accurately represented by past real time data than predictive models.

- Figure 11-1 and Figure 11-2 - Sacramento River
- Figure 11-12 and Figure 11-13 - Clear Creek
- Figure 11-16 and Figure 11-17 - American River
- Figure 11-20 and Figure 11-21 - Stanislaus River
- Figure 11-26 and Figure 11-27 - Trinity River

Although the water temperature targets are based on mean daily temperatures, the fish respond to the temperature fluctuations that occur throughout the day. The figures listed below show past temperature data with daily maximum, minimum, and mean in selected dry and wet year types with available temperature data. Because temperatures become more flow dependent in intermediate distances below the dams, the flows are also displayed. Higher flows maintain water temperatures close to the reservoir release temperature for a longer distance downstream than do lower flows. Higher flows can also deplete the coldwater pool from reservoirs quicker in years when coldwater availability is a limiting factor for fish survival. Temperatures are generally more of an issue during the warmer months of the year, but can also be an issue into the fall and winter when reservoirs run out of cold water and maintain and release warm water built up during the summer.

- Figure 11-3, Figure 11-4, Figure 11-9, Figure 11-10, and Figure 11-11 - Sacramento River
- Figure 11-14 and Figure 11-15 - Clear Creek
- Figure 11-18 and Figure 11-19 - American River
- Figure 11-22, Figure 11-23, Figure 11-24 and Figure 11-25 - Stanislaus River and San Joaquin River
- Figure 11-26, Figure 11-27, Figure 11-28 and Figure 11-29 - Trinity River

Figure 11-5 and Figure 11-7 show the historical water temperature exceedences in the Sacramento River. Figure 11-6 and Figure 11-8 show water temperature exceedences through all years in the Sacramento River with modeling study 7.0, which approximates current operations (as described in Chapter 9).

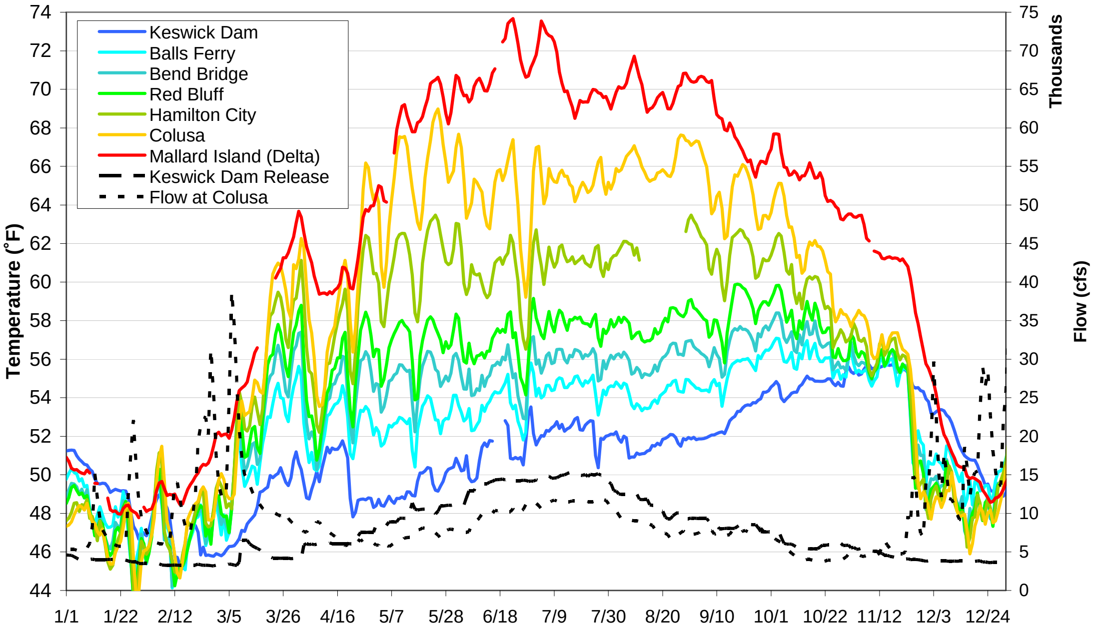

Figure 11-1. Sacramento River mean daily temperature and flow at selected locations in a dry water year, actual measured water temperatures (2001).

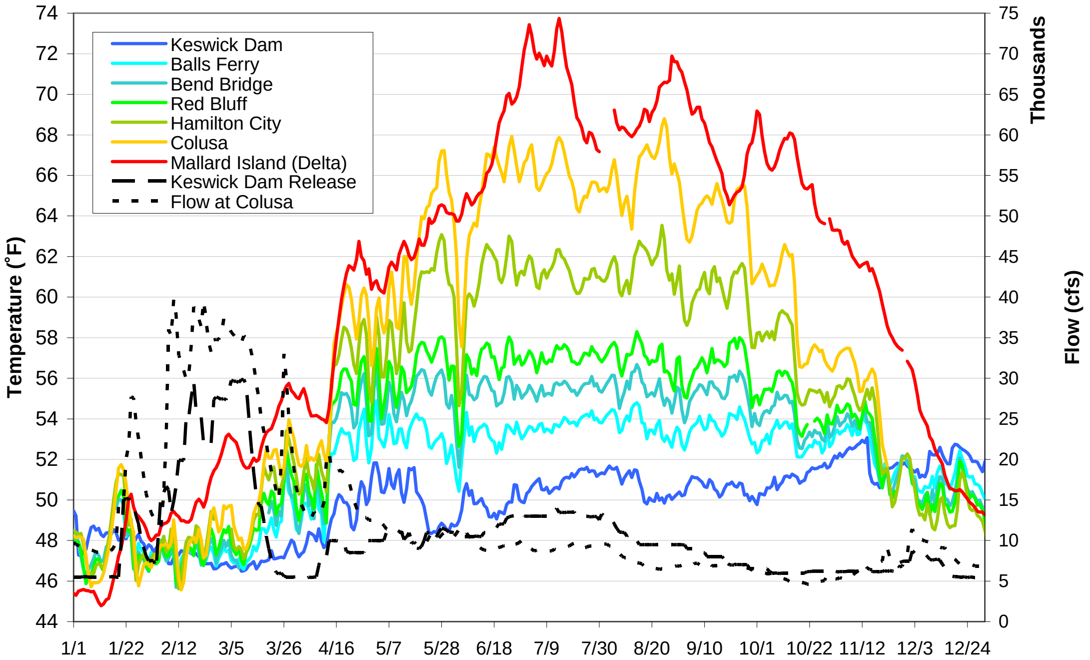

Figure 11-2. Sacramento River mean daily temperature and flow at selected locations in a wet water year, actual measured water temperatures (1999).

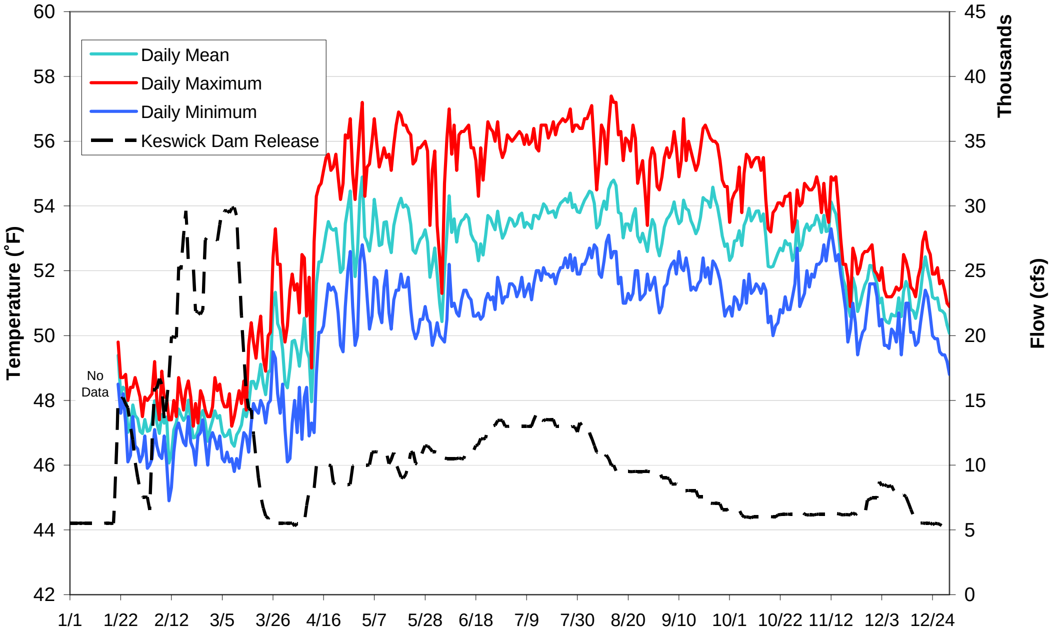

Figure 11-3. Sacramento River at Balls Ferry daily temperature range and flow in a wet water year, actual measured water temperatures (1999).

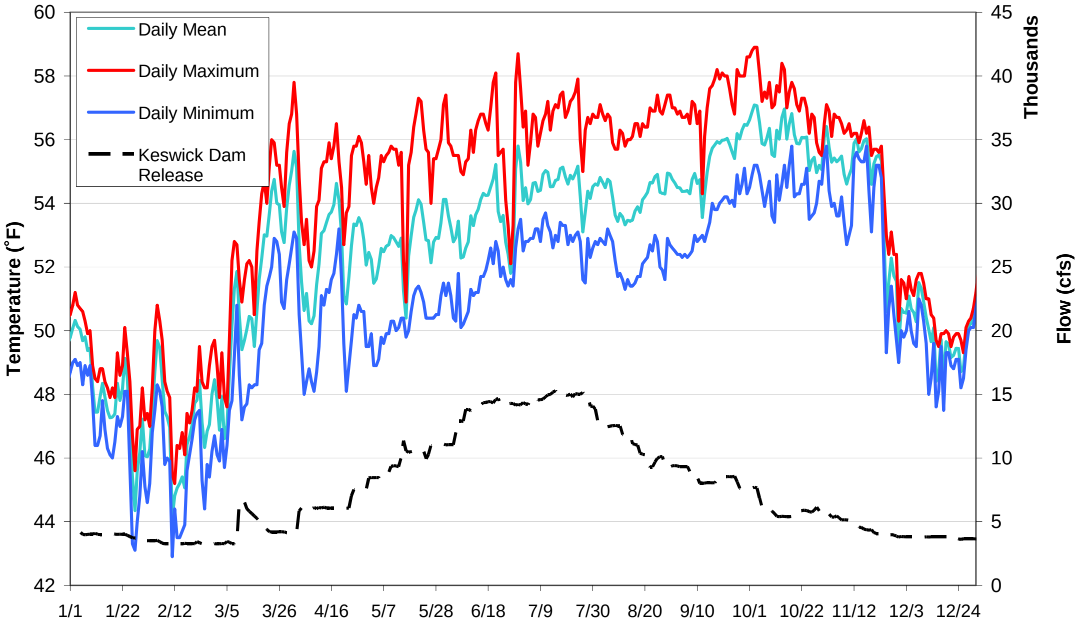

Figure 11-4. Sacramento River at Balls Ferry daily temperature range and flow in a dry water year, actual measured water temperatures (2001).

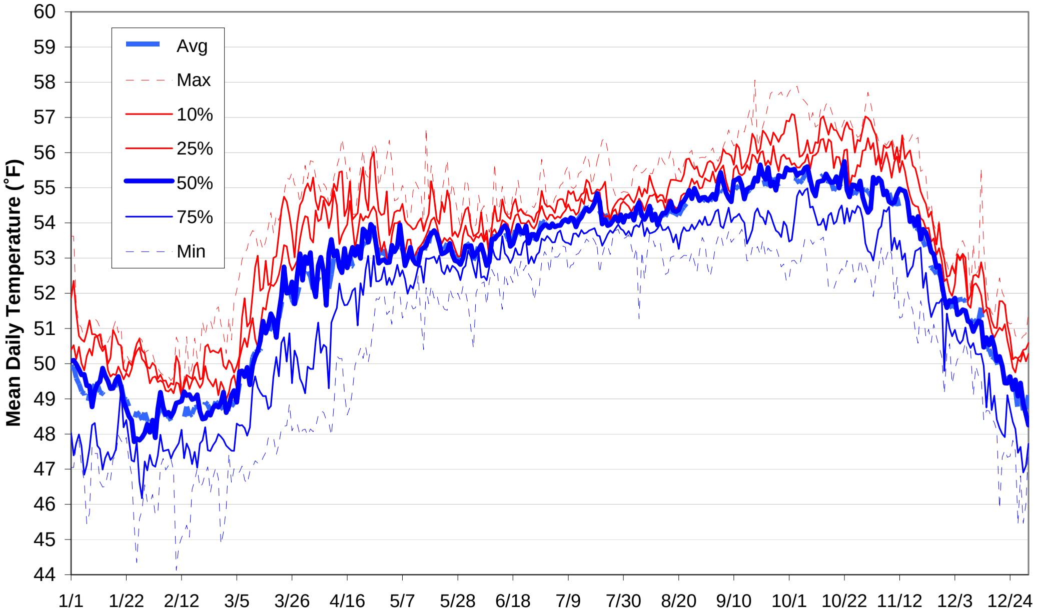

Figure 11-5. Sacramento River at Balls Ferry seasonal temperature exceedence, 1997-2007 (actual temperatures, not modeled).

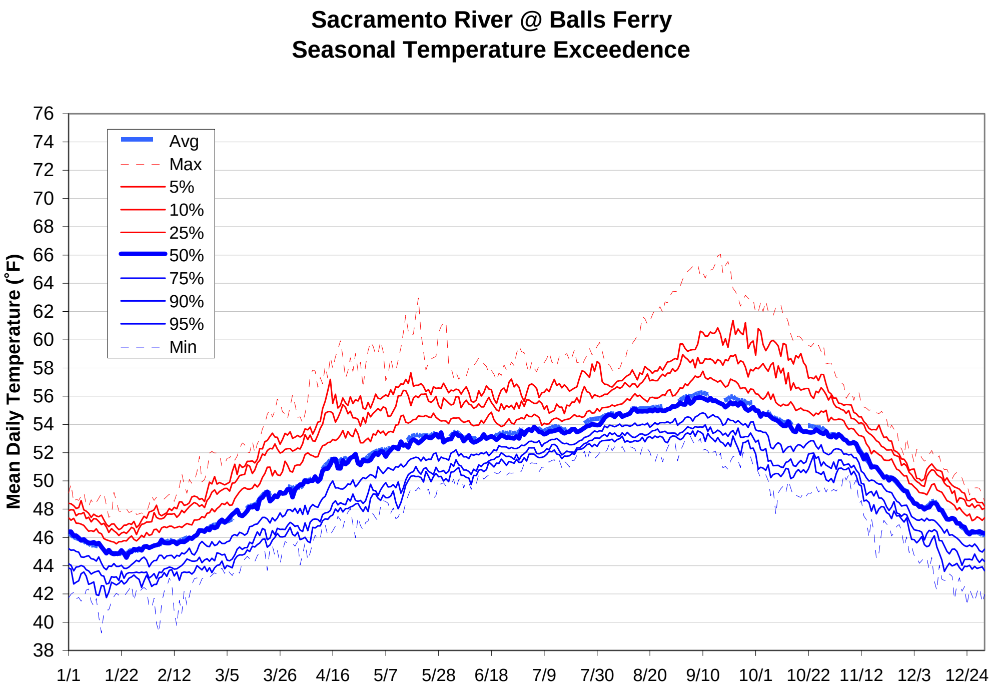

Figure 11-6. Sacramento River at Balls Ferry seasonal temperature exceedence in study 7.0 (modeled temperatures with current operations throughout the 82 year CalSim-II modeling period).

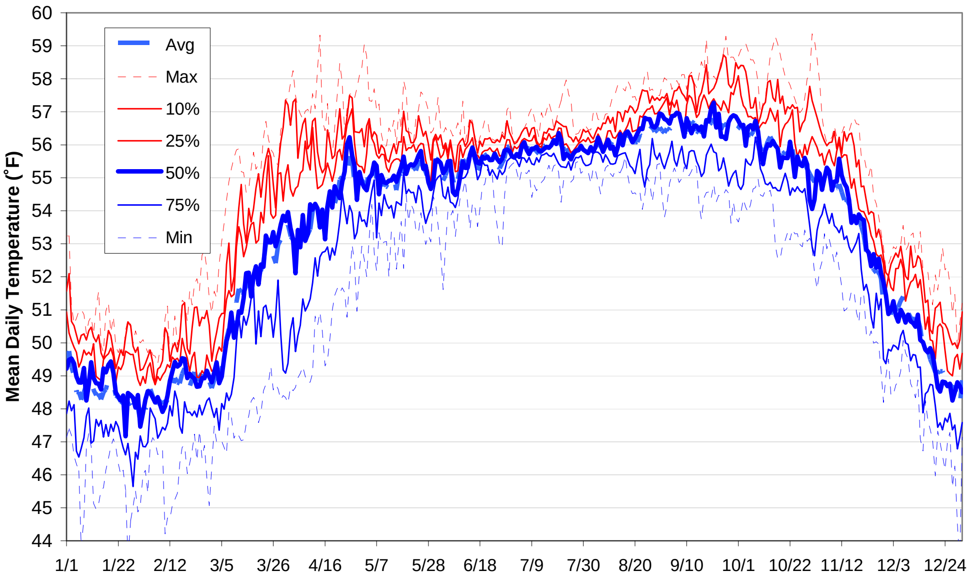

Figure 11-7. Sacramento River at Bend Bridge seasonal temperature exceedence, 1997-2007 (actual temperatures, not modeled).

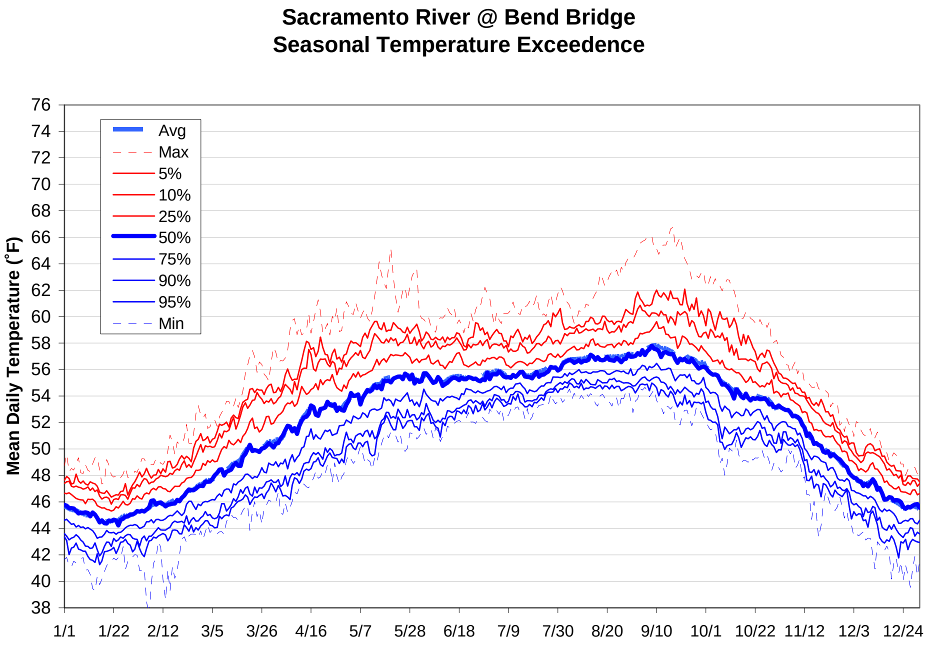

Figure 11-8. Sacramento River at Bend Bridge seasonal temperature exceedence in study 7.0 (modeled temperatures with current operations throughout the 82 year CalSim-II modeling period).

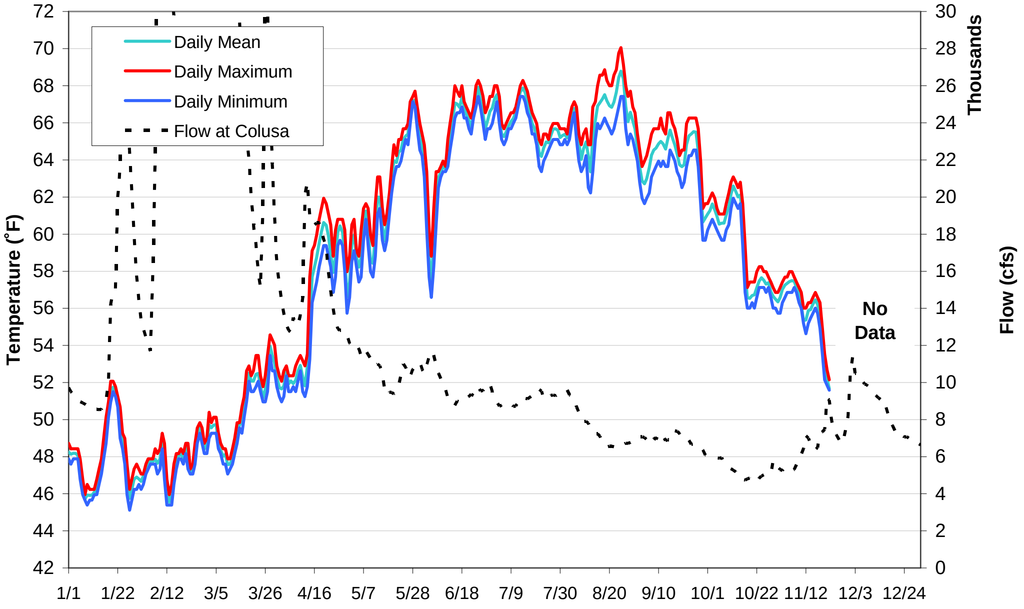

Figure 11-9. Sacramento River at Colusa daily temperature fluctuation and flow in a wet water year, actual measured water temperatures (1999).

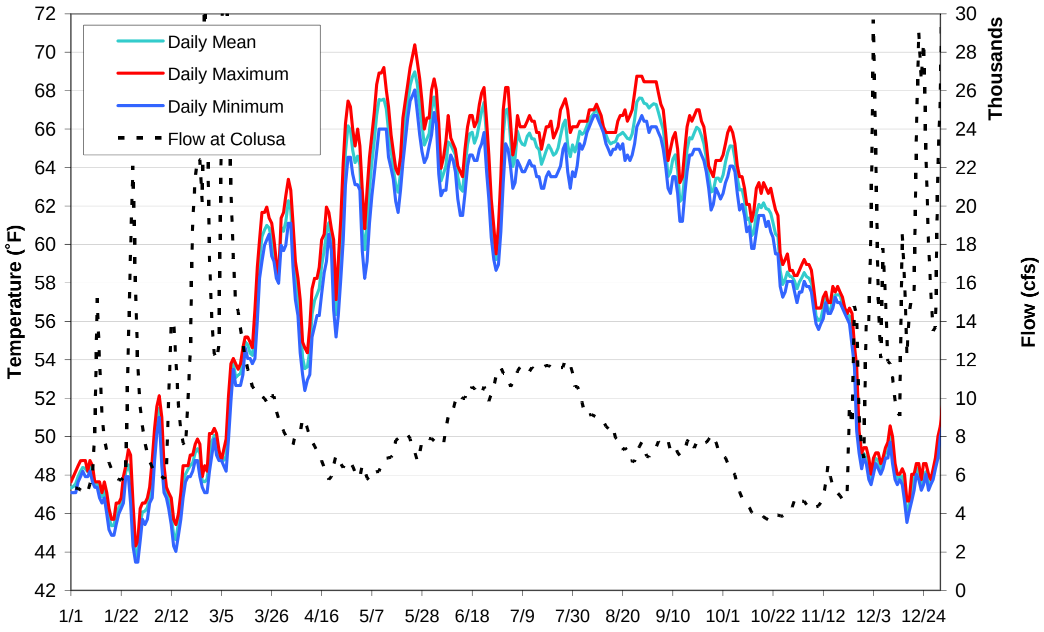

Figure 11-10. Sacramento River at Colusa daily temperature fluctuation and flow in a dry water year, actual measured water temperatures (2001).

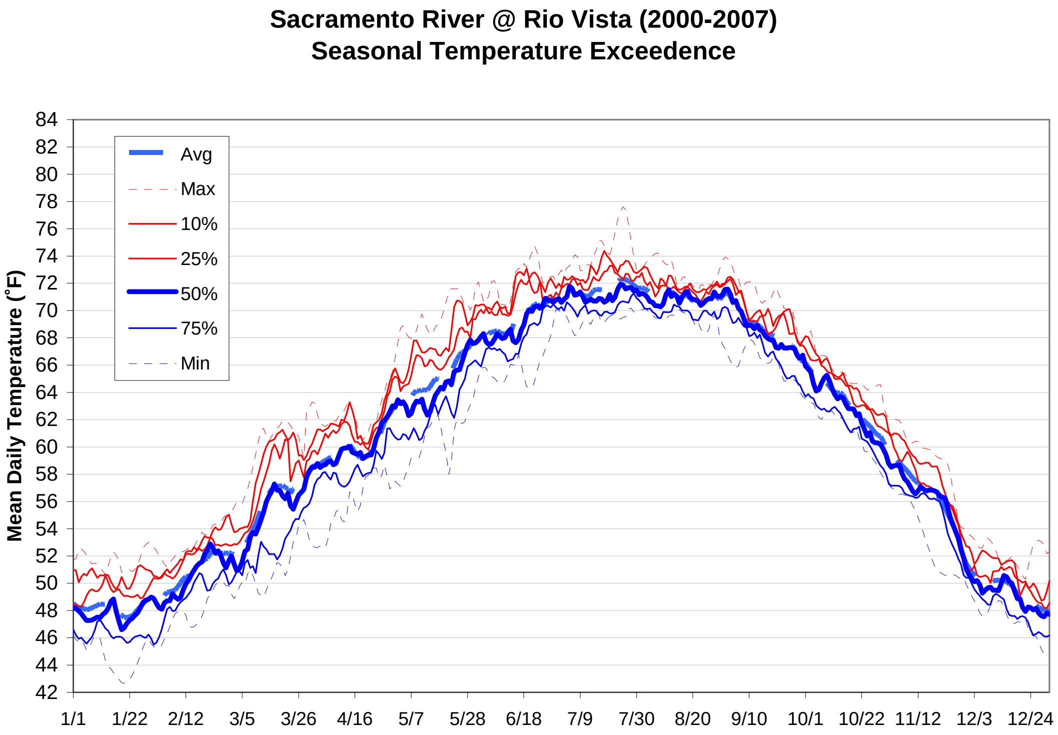

Figure 11-11. Sacramento River at Rio Vista water temperature exceedence for 2000 – 2007, actual measured temperatures.

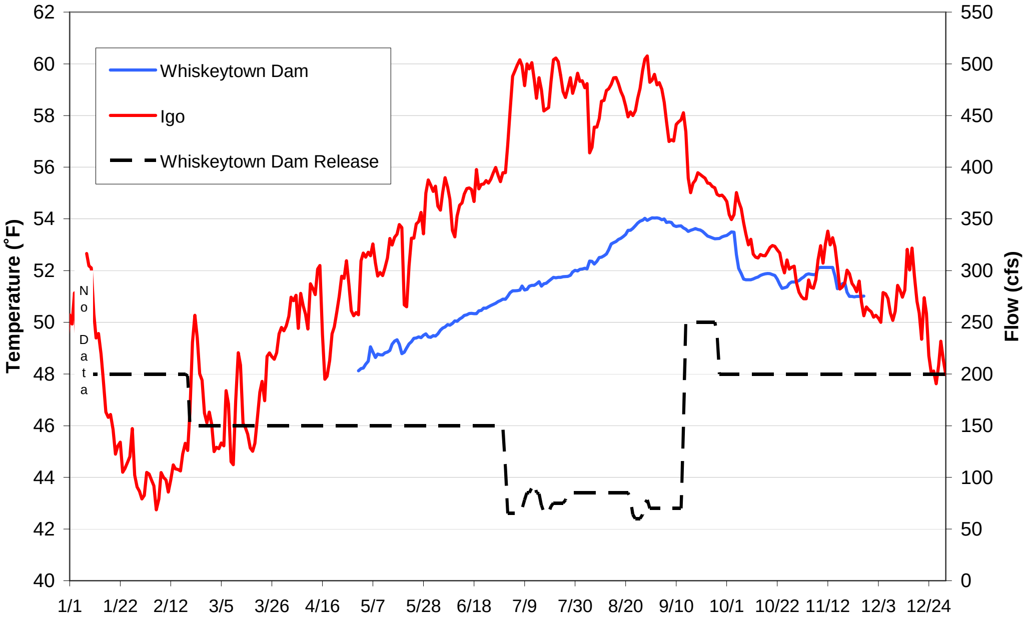

Figure 11-12. Clear Creek mean daily temperature at Whiskeytown Dam and Igo in a dry year, actual measured water temperatures (2002).

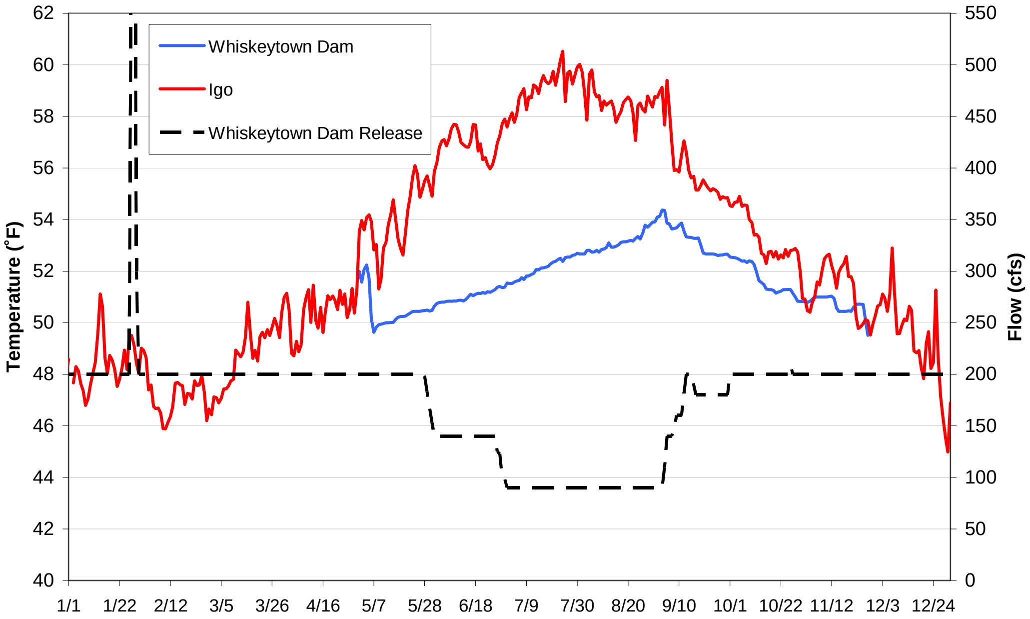

Figure 11-13. Clear Creek mean daily temperature at Whiskeytown Dam and Igo in an above normal water year, actual measured water temperatures (2003).

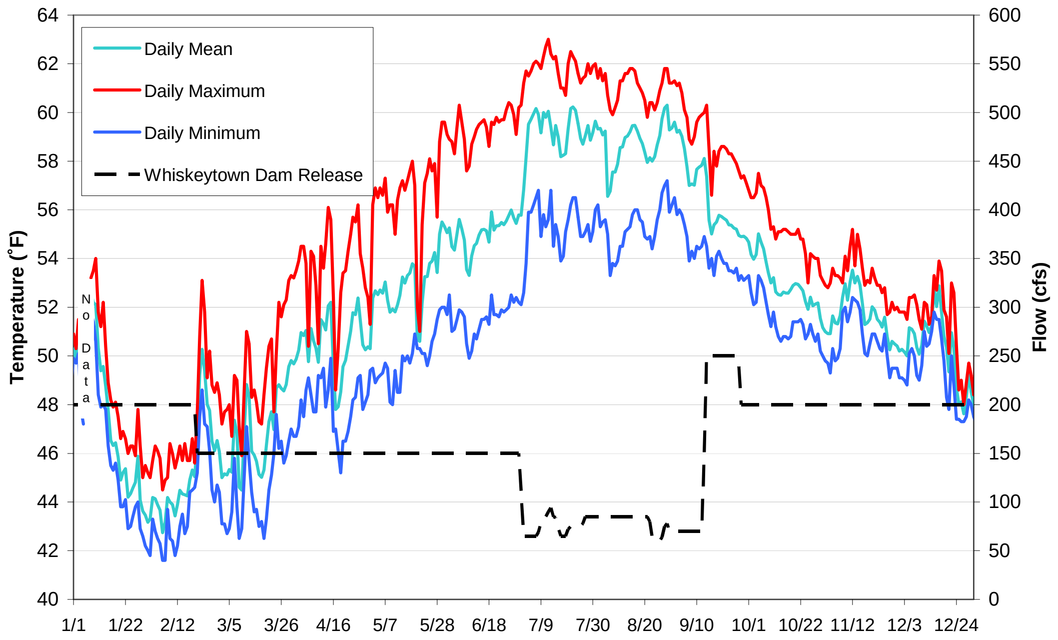

Figure 11-14. Clear Creek at Igo daily temperature fluctuation and flow in a dry water year, actual measured water temperatures (2002).

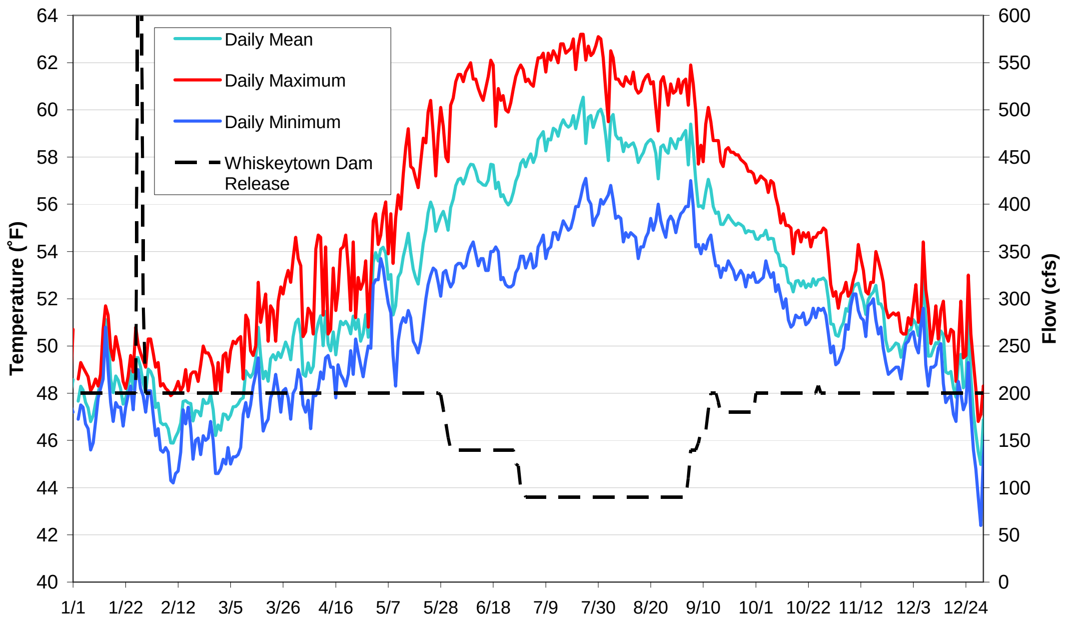

Figure 11-15 Clear Creek at Igo daily temperature fluctuation and flow in an above normal water year, actual measured water temperatures (2003).

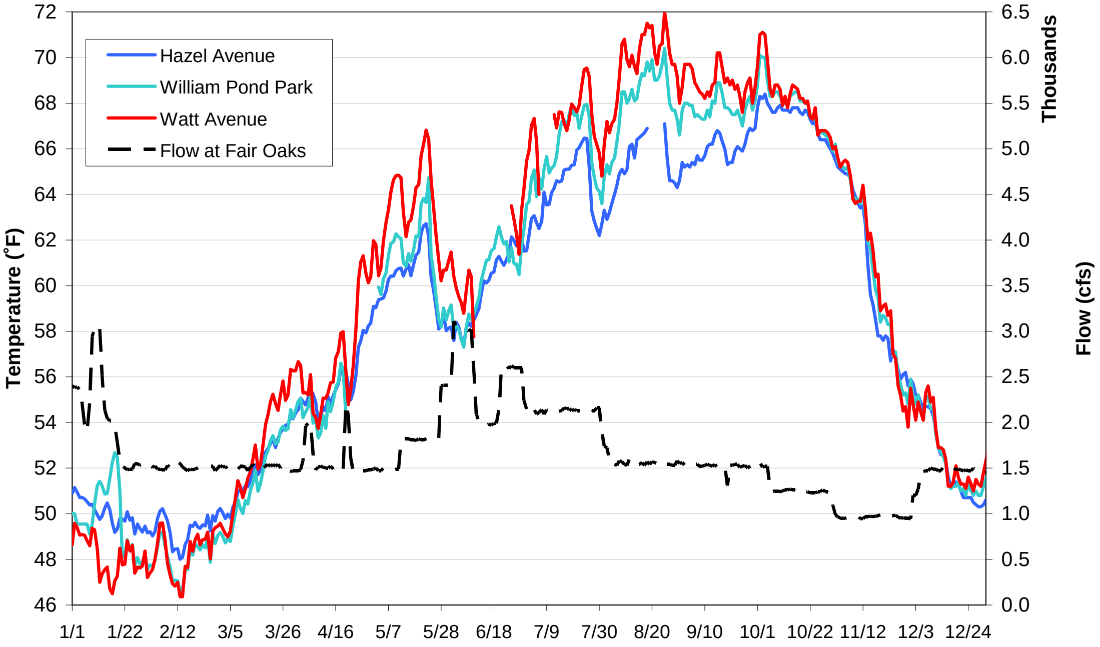

Figure 11-16. American River temperature and flow at monitoring sites in a dry year, actual measured water temperatures (2001).

There is a large “thermal lag” present in the American River downstream of Folsom Dam. The result is that fall temperatures in the river downstream of Folsom Dam are higher than they would be without the dam in place. The reservoir holds a summer’s worth of thermal loading and as fall meteorological conditions cool, the reservoir’s large thermal mass does not respond quickly – maintaining elevated temperatures. Note how Watt Avenue temperatures are cooler than Hazel Avenue – indicating cooling with distance downstream. Elevated fall temperatures may be a contributing factor to fisheries challenges in the American River. This is present in other systems too (like the Stanislaus), but occurs later in the year and not to the extreme that occurs on the American River.

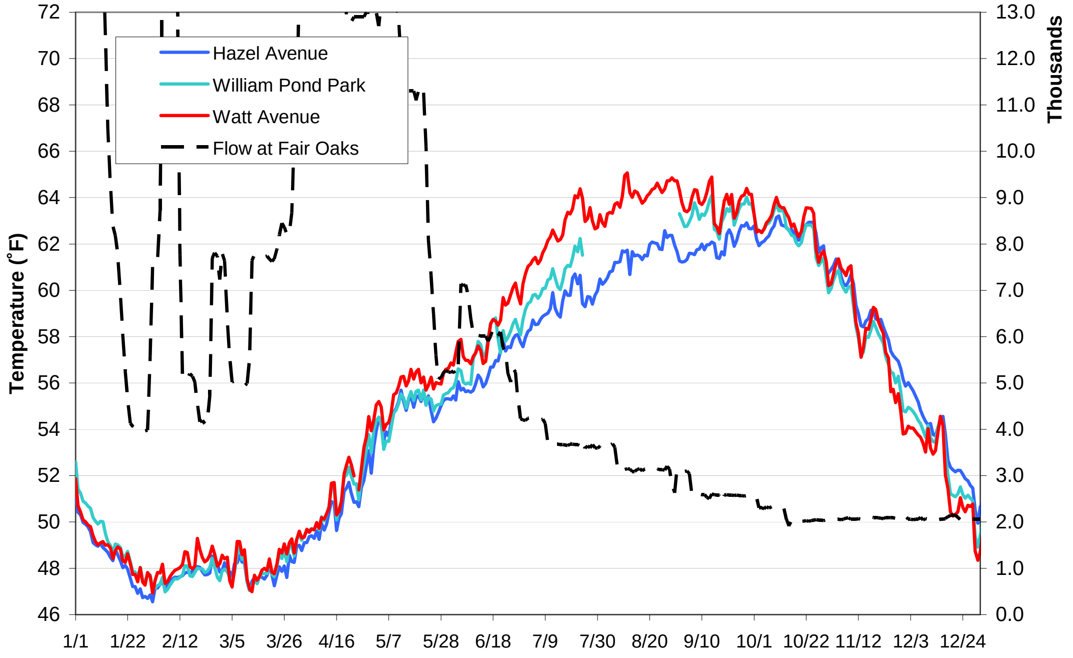

Figure 11-17. American River temperature and flow at monitoring sites in a wet year, actual measured water temperatures (2006).

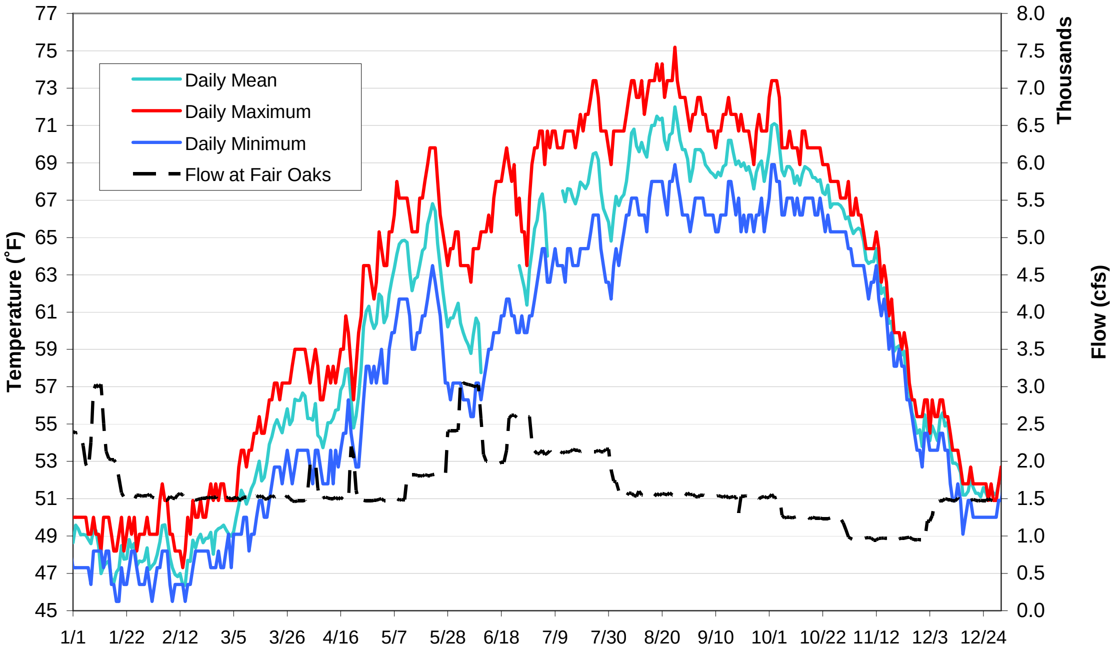

Figure 11-18. American River at Watt Avenue daily temperature fluctuation and flow in a dry year, actual measured water temperatures (2001).

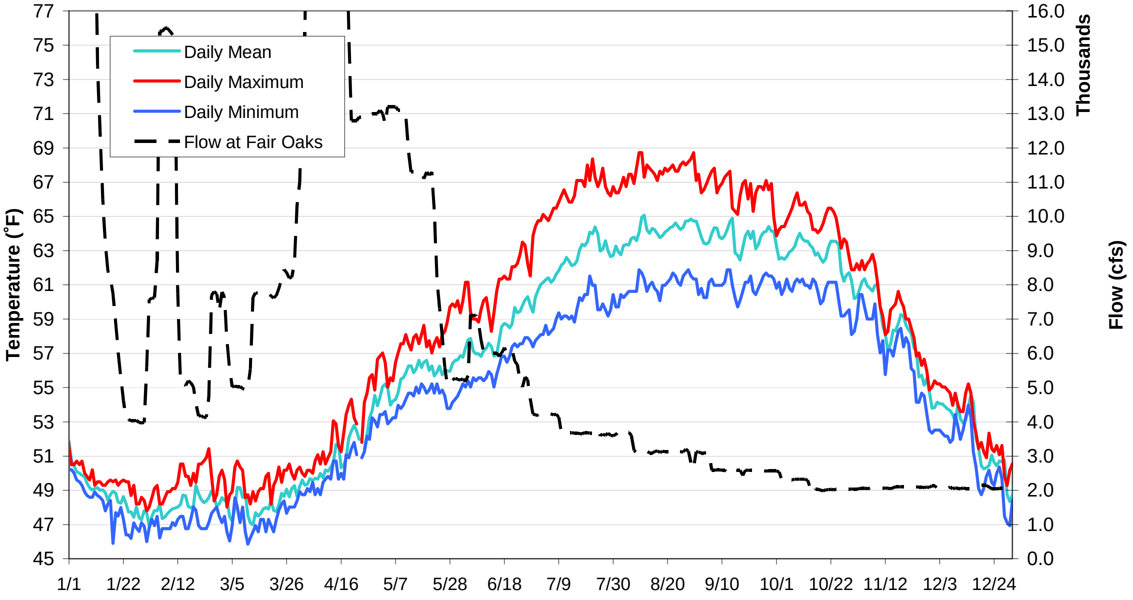

Figure 11-19. American River at Watt Avenue daily temperature fluctuation and flow in a wet year, actual measured water temperatures (2006).

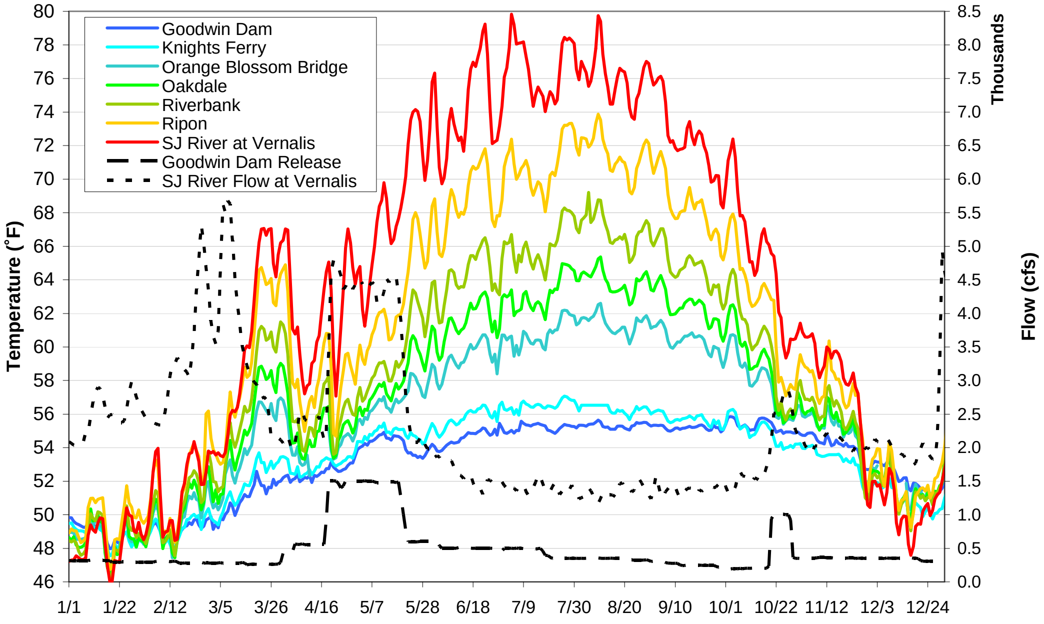

Figure 11-20. Stanislaus and San Joaquin River temperatures and flow at selected locations in a dry year, actual measured water temperatures (2001).

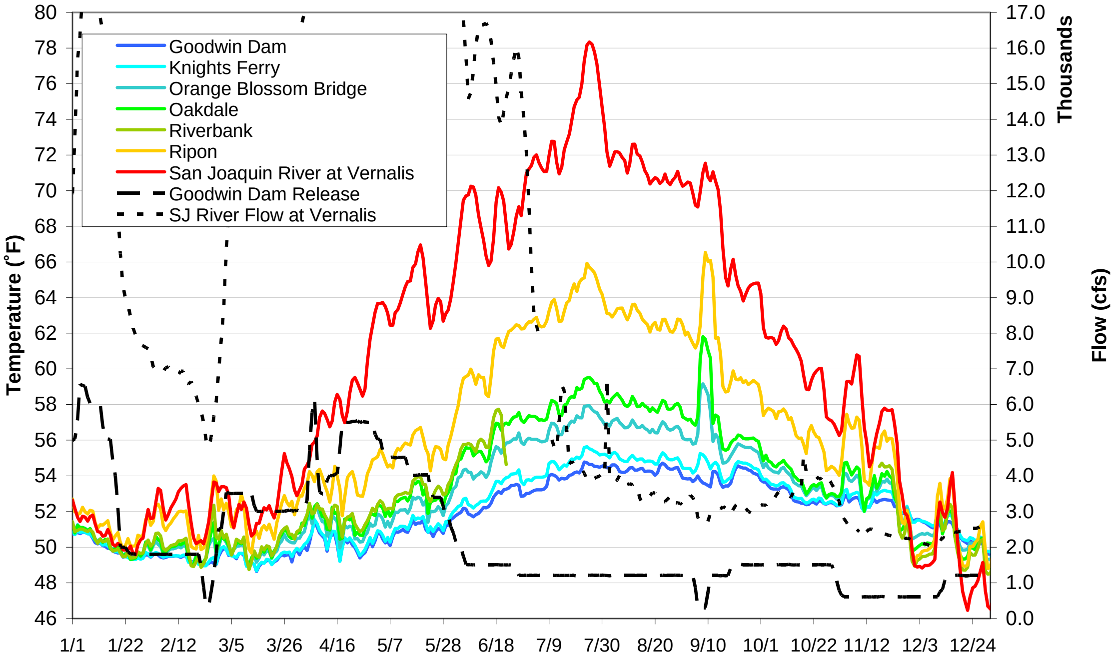

Figure 11-21. Stanislaus and San Joaquin River temperatures and flow at selected locations in a wet year, actual measured water temperatures (2006).

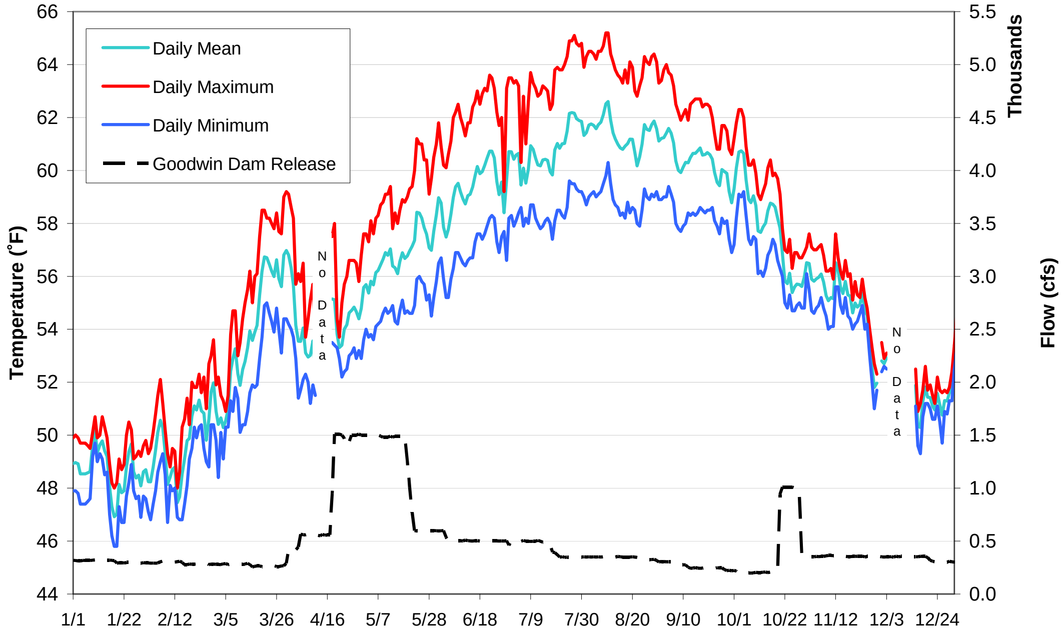

Figure 11-22. Stanislaus River at Orange Blossom Bridge daily temperature fluctuation and flow in a dry water year, actual measured water temperatures (2001).

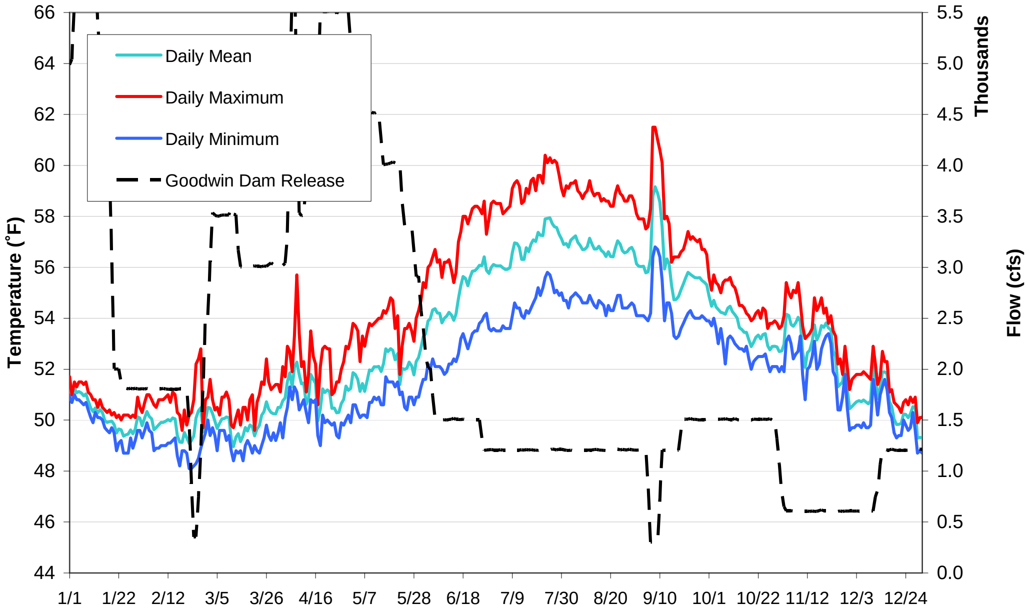

Figure 11-23. Stanislaus River at Orange Blossom Bridge daily temperature fluctuation and flow in a wet water year, actual measured water temperatures (2006).

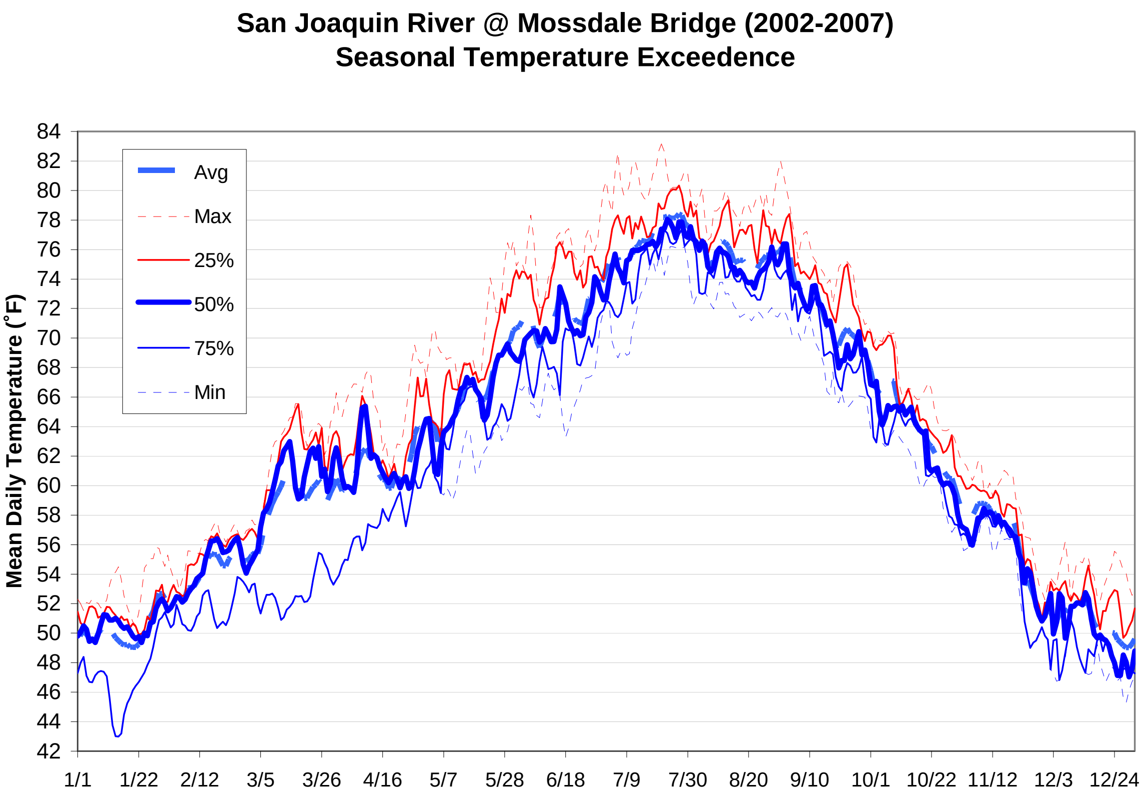
San Joaquin River @ Mossdale Bridge (2002-2007)
Seasonal Temperature Exceedence

Figure 11-24. San Joaquin River at Mossdale Bridge water temperature exceedence for 2002 – 2007, actual measured water temperatures.

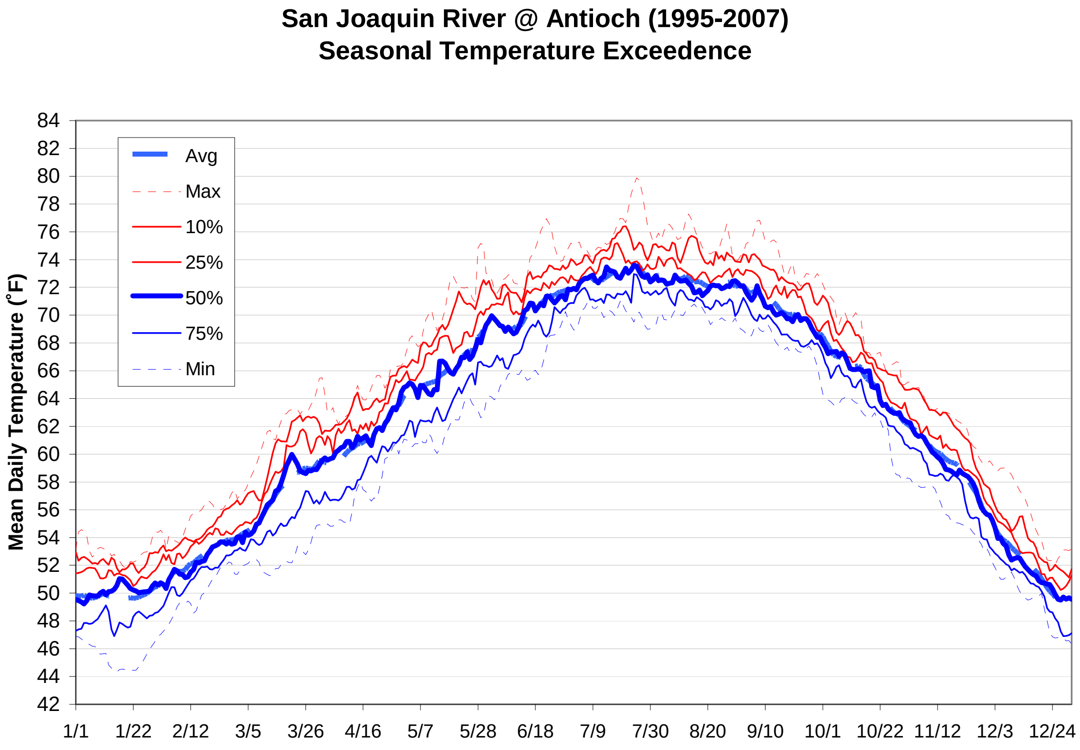

Figure 11-25. San Joaquin River at Antioch water temperature exceedence for 1995 – 2007, actual measured water temperatures.

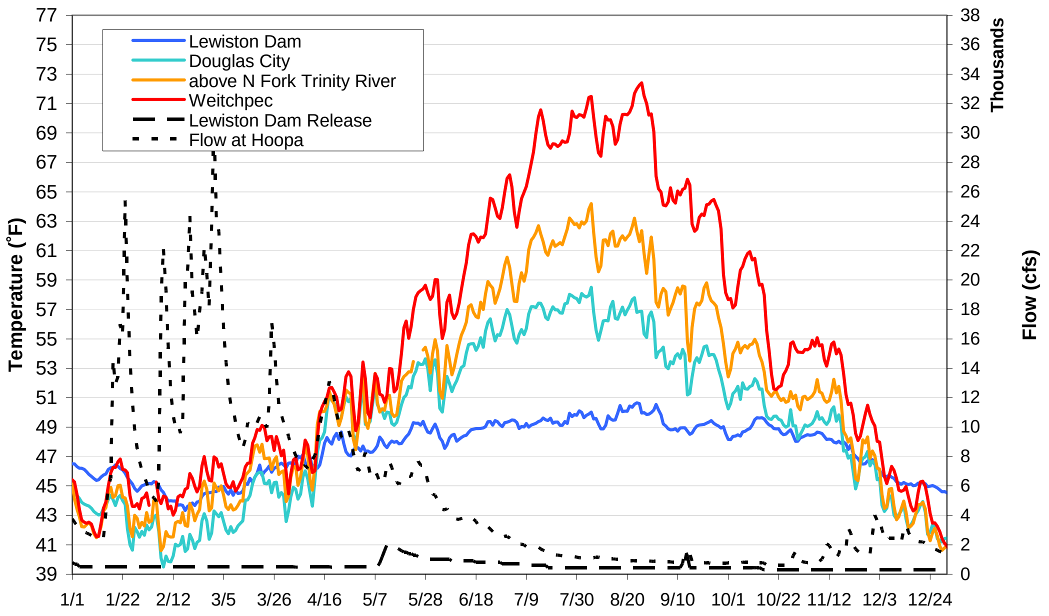

Figure 11-26. Trinity River water temperatures and flow at monitoring sites in a wet year type, actual measured water temperatures (1999).

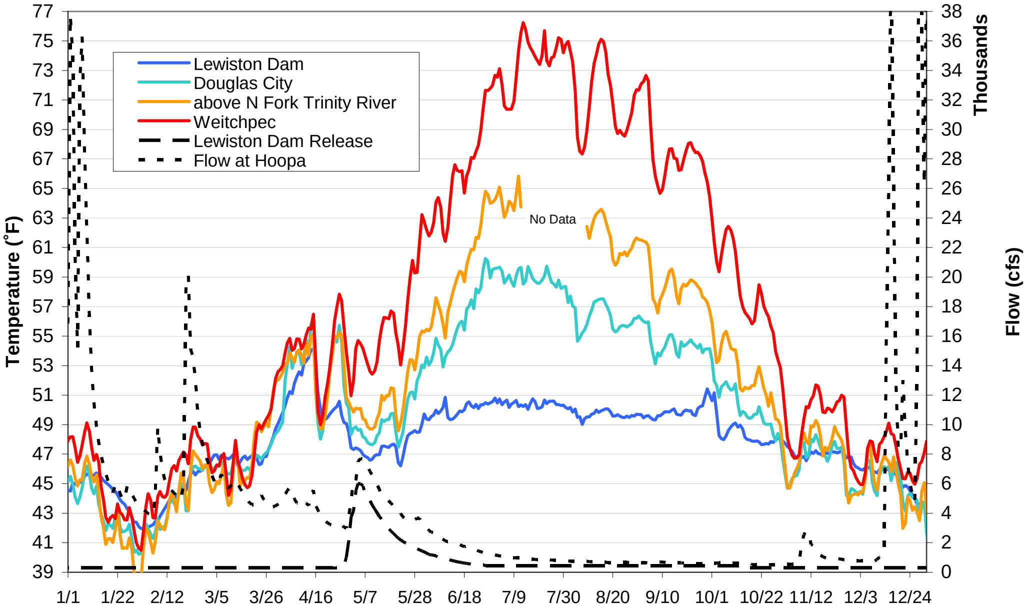

Figure 11-27. Trinity River water temperatures and flow at monitoring sites in a dry year type, actual measured water temperatures (2002).

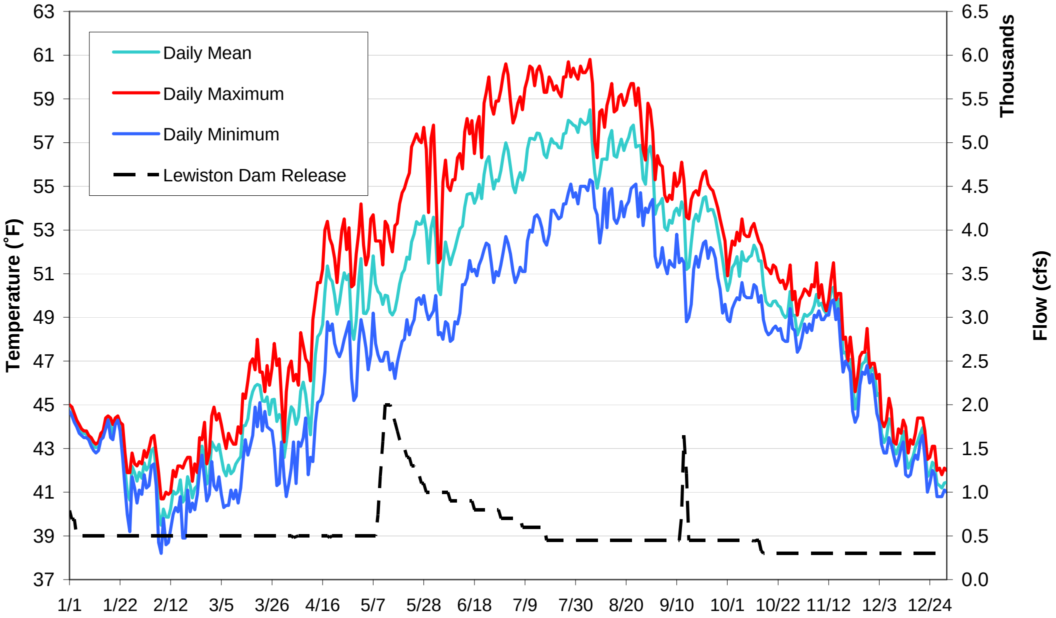

Figure 11-28. Trinity River at Douglas City daily temperature fluctuation and flow in a wet year, actual measured water temperatures (1999.

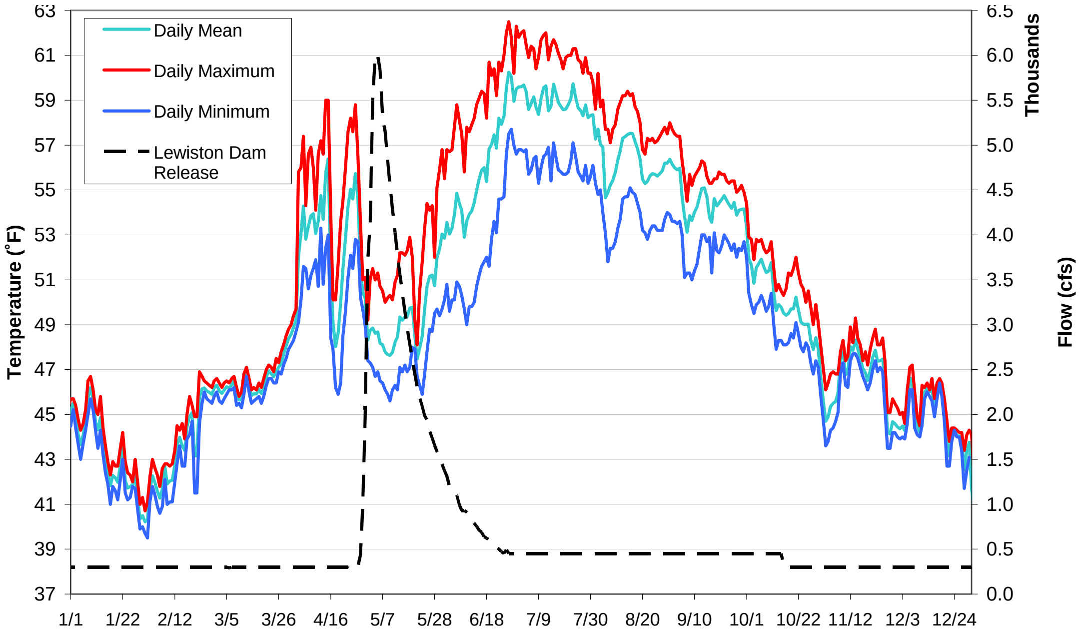

Figure 11-29. Trinity River at Douglas City daily temperature fluctuation and flow in a dry year, actual measured water temperatures (2002).

OCAP Modeling Studies

The modeling studies referenced in this chapter refer to the CalSim-II studies described in the project description (Chapter 2). Table 11-2 is a brief summary of differences between the studies.

Table 11-2. Summary of differences between the OCAP modeling studies.

	CVPIA 3406 (b)(2)	Level of Development	EWA	SDIP Stage 1	Freeport	Intertie	Climate and Sea Level Rise
Study 3a Today EWA	May 2003	2001	Full				
Study 6.0 Today EWA	May 2003	2005	Full				
Study 7.0 Today EWA	May 2003	2005	Full				
Study 7.1 Today Limited EWA	May 2003	2005	Limited	X	X	X	

	CVPIA 3406 (b)(2)	Level of Development	EWA	SDIP Stage 1	Freeport	Intertie	Climate and Sea Level Rise
Study 8.0 Future Limited EWA	May 2003	2030	Limited	X	X	X	
Study 9.0 Future D1641 SA Climate Change		2030		X	X	X	No Sea Level Rise
Study 9.1 Future D-1641		2030		X	X	X	1ft Sea Level Rise and 4" amplitude
Study 9.2 Future D-1641		2030		X	X	X	Wetter, Less Warming Climate Change with 1ft Sea Level Rise and 4" amplitude
Study 9.3 Future D-1641		2030		X	X	X	Wetter, More Warming Climate Change with 1ft Sea Level Rise and 4" amplitude
Study 9.4 Future D-1641		2030		X	X	X	Drier, Less Warming Climate Change with 1ft Sea Level Rise and 4" amplitude
Study 9.5 D-1641 Future		2030		X	X	X	Drier, More Warming Climate Change with 1ft Sea Level Rise and 4" amplitude

Trinity River

Adult Coho Salmon Migration, Spawning, and Incubation

Adult coho typically enter the Klamath River and the mouth of the Trinity River starting in September with peak upstream migration occurring in October and November. Flows during this time would be a minimum of 450 cfs until October 15 in all year types and would not change between the current operations and future operations scenarios. Flows decrease to a 300 cfs spawning baseflow on October 15. Based on past observations of spawning salmonids in the Trinity River, it was concluded that this flow would provide adequate in stream conditions for the upstream migration and spawning of coho salmon.

For purposes of this assessment, water temperatures at or below 60 °F are assumed to provide suitable conditions for adult coho salmon migration. Water temperatures at or below 56 F are assumed to be suitable for egg incubation. Water temperatures early in the upstream migratory period, in September, would often be above preferred ranges near the mouth of the Trinity, but dam operations cannot efficiently control water temperature at the mouth, 110 miles below Lewiston Dam. Releases would always be 450 cfs in September. Temperatures were modeled down to the North Fork of the Trinity River. This is the reach where Trinity operations have the greatest temperature effect. Temperatures in September would be below 60 °F at Douglas City in September of about 95 percent of years and suitable for holding and migrating adult coho. During a few dry years temperatures could exceed 60 °F in September. Temperatures under future operations are projected to be slightly cooler. Between October and May mean monthly temperatures at Douglas City would always be maintained at or below 60 °F under all scenarios. During November when spawning initiates, average monthly temperatures would be almost always below 50 °F at Douglas City. Flows during spawning and incubation would be maintained at 300 cfs, which has been shown to provide suitable conditions for spawning and incubation of coho salmon. Most coho spawning in the mainstem occurs between Lewiston Dam and Douglas City with the greatest concentration in the first few miles below the dam. This distribution favoring upstream areas is probably influenced by the large hatchery component of the population. Based on these results we conclude that current and future operations are not likely to adversely affect coho salmon adult migration, spawning, egg incubation, or critical habitat in the Trinity River.

Coho Salmon Fry, Juveniles, and Smolts

The Trinity River supports young coho salmon rearing in the mainstem year round. Nearly all coho rearing during the summer occurs upstream of Douglas City, in the vicinity of the high density spawning. A critical seasonal period for juvenile coho rearing in California is generally June through September of dry years when water temperatures are at the high end of what is considered to be the optimal range for coho rearing. Water temperatures in the Trinity River between Lewiston and Douglas City are cooler than most coho streams in summer. Welsh et al. (2001) found coho in streams with mean weekly average temperatures of less than 62 °F. For purposes of this BA average monthly water temperatures of less than 62° F are assumed to support suitable juvenile coho rearing. Temperatures at Douglas City would be below 60 °F in over 95 percent of years but could rise above 62 °F (monthly average) in June through September in up to 5 percent of years. Temperatures between the studies are essentially unchanged. Based on these results we conclude that current and future oprations are not likely to affect coho salmon rearing or critical habitat in the Trinity River.

The spring high flows are provided to mimic the natural hydrograph during the snowmelt period (Figure 11-30). The flow schedule each year is determined through deliberations conducted by the Trinity River Restoration Program. These flows should increase survival of out-migrating coho smolts. The higher flows are intended to return more natural geomorphic processes to the Trinity River (USDI 2000). These flows should benefit coho salmon through the long-term habitat values provided. The flows are designed to discourage riparian vegetation establishment down to the edge of the lower flow channel margins and to scour the bed to maintain spawning and rearing habitat (USDI 2000). Off channel habitats out of the main river flow are important for sustaining juvenile coho salmon through the winter months when water is cooler. Off-channel habitats may potentially be created by the higher flows and are being created mechanically. Stranding of coho fry can occur when the flows are lowered following the restoration program prescribed flows (Chamberlain 2003). Flows are essentially unchanged between the studies and the spring pulse flows prescribed for the restoration program are the same under all scenarios. These flows along with physical habitat restoration projects are intended to increase the amount of fish habitat and increase fish production. Based on the potential stranding risk, we conclude that current and future operations may affect, but are not likely to adversely affect, juvenile coho.

High flows down the Trinity will occur during safety of dams releases during high runoff events, generally between December and May, to prevent overtopping of the dam. These safety of dams releases occur during about 10-20 percent of years depending on the month. Depending on timing of these releases, they can help or hurt juvenile coho. Additional rearing habitat is available during the higher releases but when the releases are subsequently lowered some stranding can occur where off-channel areas are isolated from the river. The higher releases make it easier for smolts to outmigrate from the river when the timing of the flows coincides with a period when fish are ready to outmigrate. Stranded fish tend to receive a lot of attention because they are visible and easy to count while benefits of the pulsed higher flows to the fish population are not as easily quantified. Based on the risk of stranding, we conclude that current and future operations may affect, but are not likely to adversely affect, juvenile coho salmon or their critical habitat.

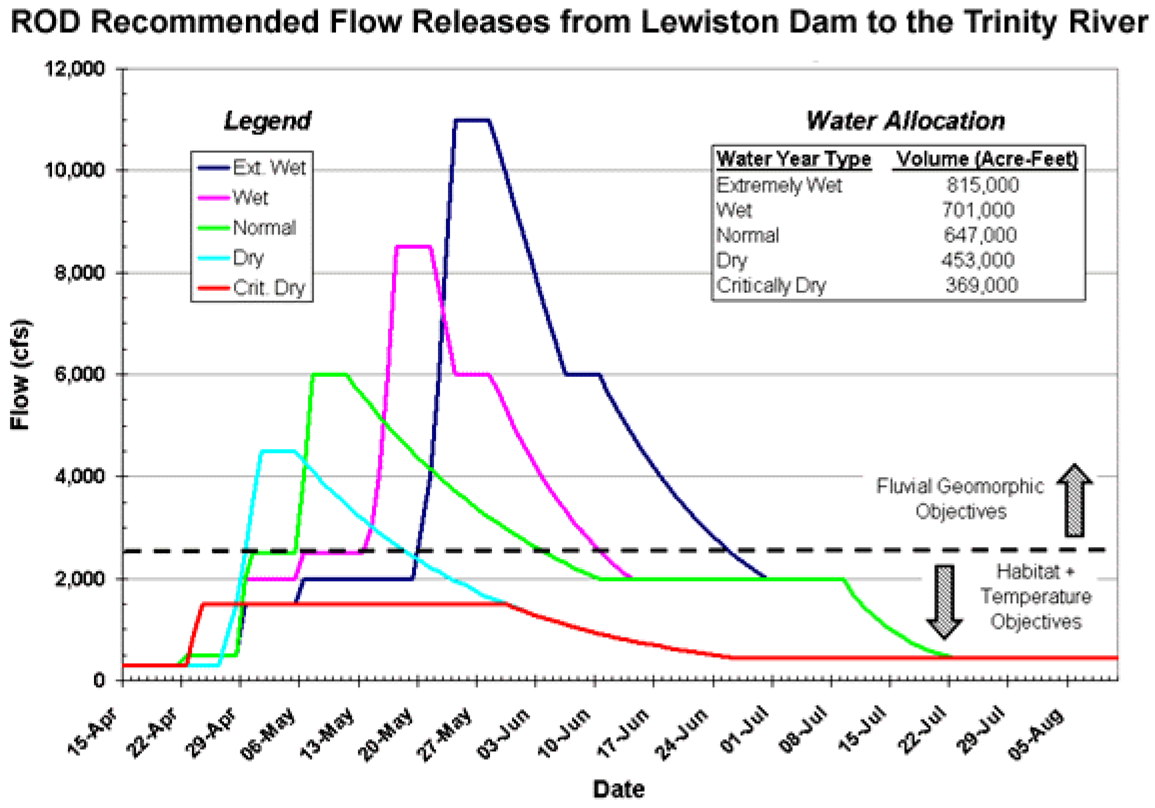

Figure 11-30. Trinity River Restoration Program recommended flow releases from Lewiston Dam to the Trinity River including functional performance ranges.

Clear Creek

Adult Salmon and Steelhead Migration, Spawning, and Incubation

There would be little, if any, difference in flows between current and future operations under all scenarios. Water temperature at Igo would be about the same in all years as well. No change in effect on steelhead or spring-run Chinook or critical habitat is anticipated. Salmonid populations in Clear Creek have been increasing under the current flow regime and physical channel restoration actions (DeStaso 2008) and depending on ocean conditions should have the capability to make continued increases to carrying capacity.

For purposes of this BA, suitable water temperatures for adult migration of both Chinook salmon and steelhead are assumed to be 60 F or less (Table 11-1). Suitable water temperatures for egg incubation are assumed to be 56 F or less (Table 11-1). Most steelhead adults are expected to migrate upstream in Clear Creek during December through March to spawn with spawning potentially stretching into April. Water temperatures between December and April are projected to be within the preferred range for steelhead spawning and incubation between Whiskeytown Dam and Igo (Figure 11-31 and Figure 11-32). Figure 11-31and Figure 11-32 show Study 7.0 only, but Studies 6.0, 7.1, and 8.0 are the same as Study 7.0 in Clear Creek. Flow releases from

Whiskeytown Dam into Clear Creek during upstream migration are expected to be 200 cfs in about 75 percent of the years during steelhead upstream migration in all scenarios. During the drier years releases are expected to be lower, as low as 30 cfs in the driest years in all scenarios. Optimal spawning flows were estimated to be 87 cfs upstream of the old Saeltzer Dam site and 250 cfs downstream of the old dam site (Denton 1986). Nearly all steelhead/rainbow spawning documented in redd surveys occurs close to Whiskeytown Dam (Jess Newton, personal communication, April 2003). During most years flows should be suitable for spawning in upstream areas but during dry years flows for attraction, holding, and upstream migration could be less than optimal. Tributary inflows downstream of Whiskeytown Dam provide some variation in the lower river hydrograph for increased attraction and migratory flows during rainfall events.

Spring–run Chinook salmon enter Clear Creek from April through September and spawn during August and September. Flow releases would be 200 cfs over 80 percent of the time in April, May, and June. Flows in July and August would always be 85 cfs in all years. September flows would be 150 cfs except during the driest 4 percent of years when they would be 30 cfs. These flows should provide adequate habitat for Chinook salmon upstream of the former Saeltzer Dam site. During the driest years the 30 cfs flows would not accommodate a large number of spawners so depending on run size more competition for spawning sites and superimposition may occur. Spring–run may benefit from a spawning attraction release during the late spring period to assist in upstream migration and passage through the bedrock chute area. This may be provided by CVPIA section 3406(b)(2) water. Flows during dry years could be as low as 30 cfs. These flows may be too low for spring–run to migrate upstream. Chinook may not be able to make it past the bedrock chute area at this flow. The area of Clear Creek upstream of the Clear Creek road bridge to Whiskeytown Dam is considered to be spring–run habitat (Jim DeStaso, personal communication). Denton (1986) estimated optimal flows for salmon in this reach would be 62 cfs for spawning and 75 cfs for rearing based on the IFIM study, provided suitable incubation and rearing temperatures were provided. Spring–run begin spawning in Clear Creek in September. The flows of 30 cfs in dry years would be below the optimum flow for Chinook spawning. Unless the spring–run population increases above present levels, spawning habitat availability should not be limiting, as long as the fish are able to migrate to the habitat at the lower flow levels. Water temperatures at Igo sometimes exceed optimal spawning and incubation temperatures of less than 56 °F. Most spring–run would likely spawn upstream closer to Whiskeytown Dam where optimal spawning and incubation temperatures can be provided year round. NOAA Fisheries (2003) states that the Denton (1986) flow recommendations are not applicable and that there are no applicable studies completed that can be used to describe the effect of operations on rearing, emigration, and spawning. Therefore use of the Denton (1986) recommendations may be somewhat subjective but in the absence of other on-the-ground recommendations we used Denton (1986). A new instream flow study is currently being conducted by the Fish and Wildlife Service and is scheduled for completion in 2010.

High flow events during the incubation period have the potential to scour redds and injure pre-emergent fry. High flow events in excess of 1,000 cfs often occur during heavy rain in the winter and spring (Figure 6-6). Whiskeytown Reservoir releases remain constant during all but the heaviest runoff periods when the reservoir overflows through the glory hole outlet. High flow events in Clear Creek are now smaller than those that occurred prior to flow regulation in the system. Clear Creek fishery studies found that spawning gravel in Clear Creek could be improved by adding spawning gravel below Whiskeytown Dam and allowing high flows to deposit it in downstream spawning areas. High flow events of approximately 3,000 cfs or greater, which occur infrequently, are needed to wash the artificially deposited gravel downstream (Table 11-3). Lansdslides deposited fine sediment into Clear Creek and may be affecting juvenile production (DeStaso 2008). The high flow events can be beneficial in washing the fine sediment downstream out of spawning areas.

Table 11-3. Estimated bed mobility flows for affected Central Valley Rivers.

River and reference	Bed load movement initiated, cfs	Bed mobility flow that may scour some redds, cfs
Sacramento River (Buer 1980 and pers. comm. 2003)	25,000	40,000 – 50,000
Clear Creek (McBain&Trush and Matthews 1999)	2,600 (up to 11 mm particles)	3,000 – 4,000 coarse sediment transport (32 mm)
Feather River		
American River (Ayres Associates 2001)	30,000 – 50,000	50,000
Stanislaus River (Kondolff et al 2001)	280 cfs for gravel placed in river near Goodwin Dam	5,000 – 8,000 to move D_{50}
Trinity River (USDI 2000)	6,000 cfs to move D_{84}	11,000 cfs to scour point bars

Steelhead fry are expected to emerge from redds from approximately mid-February through May. Release temperatures from Whiskeytown Dam are modeled to remain at optimal levels throughout this period. Most fry will likely remain in upstream areas near where they were spawned, at least through the early rearing period until early summer. Spring–run Chinook fry emerge from redds between December and February, depending on water temperature where they are spawned. Water temperatures during this period are optimal for survival of fry.

Salmon and Steelhead Fry, Juveniles, and Smolts

The freshwater life stages of steelhead and Chinook salmon could occupy Clear Creek throughout the year. For purposes of this BA, suitable water temperatures for junvenile salmon and steelhead rearing are assumed to be 60° F (Table 11-1). Mean monthly temperatures of Whiskeytown Reservoir releases are modeled to be in the preferred range for growth and development of steelhead (45 °F to 60 °F) and of Chinook salmon (50 °F to 60 °F) throughout the year under all hydrologic conditions. Whiskeytown releases are expected to be about the under current and future conditions for all months. The average monthly temperatures are always within the range that the species have been shown to survive and grow well with adequate food supplies (Myrick and Cech 2001). Based on observations of juvenile salmonids and their prey in streams further north, food availability does not appear to be a limiting factor to salmon or steelhead in the upstream rearing areas of any of the affected Central Valley streams.

Optimal rearing and emigration flows have not been estimated for Clear Creek. We expect that the modeled flows will be suitable for the rearing, smoltification, and emigration of steelhead and Chinook salmon during most years. During the driest years flows during summer and fall could be limiting for steelhead rearing and for spring–run Chinook that hold over in Clear Creek through the summer. During dry years, a source of somewhat higher flows for out migration could be provided by brief tributary inflows during rainfall events, but these would be dependent on the weather.

There would be no difference in flows between current and future operations under all scenarios. No change in effect on fish is anticipated. Water temperature below Igo would be about the same in all years as well. Based on results of these current and future conditions, we conclude that operations affecting habitat conditions in Clear Creek are likely to affect salmon and steelhead, but are not likely to adversely affect salmon and steelhead rearing in Clear Creek.

Stranding of fry and juvenile steelhead and Chinook salmon could occur following high flow events if river stages drop rapidly and isolate fish in stream margins that are not connected to the main channel. Whiskeytown Reservoir releases typically remain constant under the majority of flood events. If uncontrolled spills do occur, they are made through the “glory hole” at Whiskeytown Reservoir. The reservoir attenuates flood flows by spreading stage changes over the entire surface area and the glory hole naturally dampens the change in rate of flow along with the changes in reservoir water surface elevation. Rapid decreases in river stage following high flow events are typically the result of unimpaired flows from local and tributary inflows downstream from Whiskeytown Reservoir. Flow changes under proposed operations are less than those that occurred prior to flow regulation. Based on the risk of juvenile salmon and steelhead stranding with Clear Creek, we conclude from this assessment that operations are not likely to change stranding conditions.

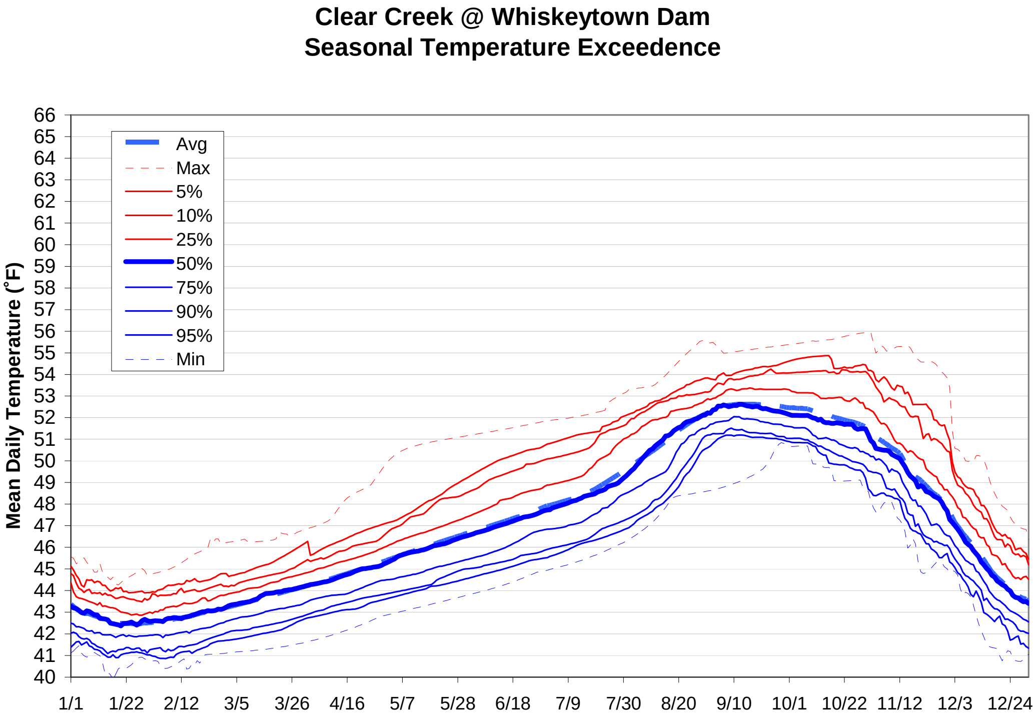

Figure 11-31. Water temperature exceedence in Clear Creek at Whiskeytown Dam in OCAP modeling study 7.0 in throughout the CalSim-II modeling hydrological record.

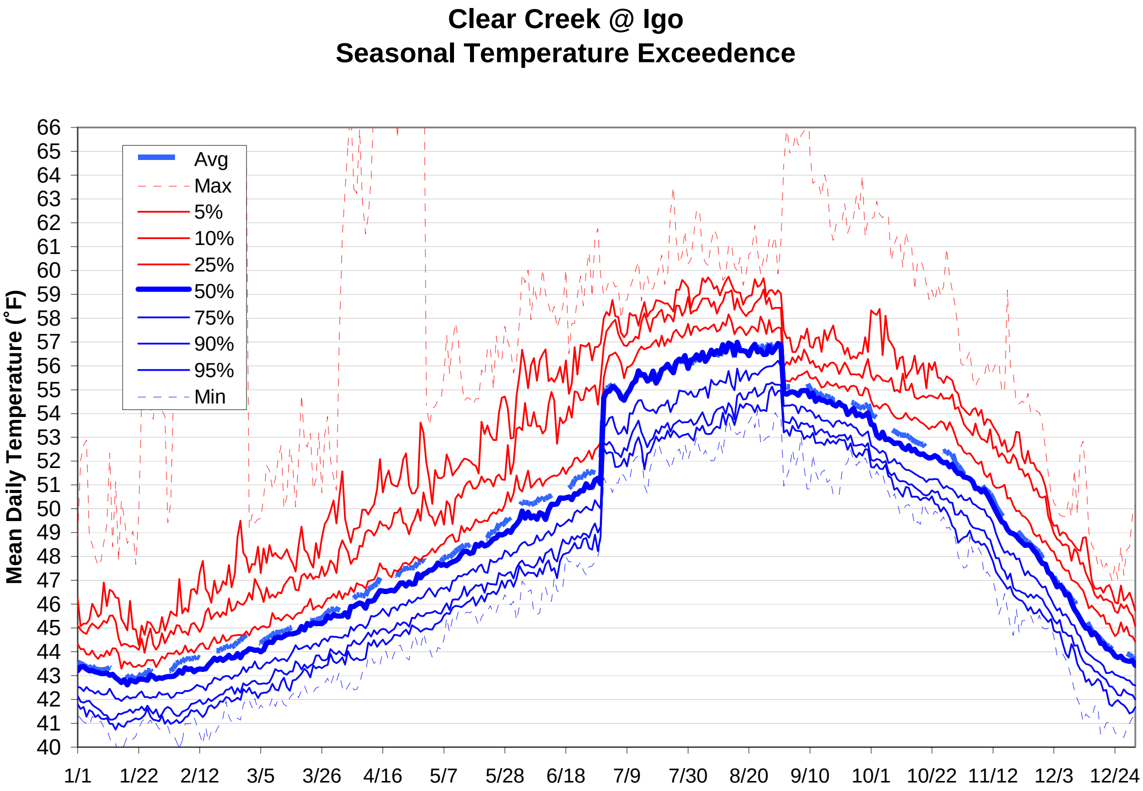

Figure 11-32. Water temperature exceedence in Clear Creek at Igo in OCAP modeling study 7.0 throughout the CalSim-II modeling hydrological record.

Implementation of the Trinity River Restoration Program Record of Decision increased flows in the lower Trinity River and decreased diversions into the Sacramento River Basin. Now less water passes through Whiskeytown Reservoir than prior to the Trinity decision (Table 11-4). Because less cool Trinity River water passes through Whiskeytown Reservoir there may be increased heating of the water as it passes through with the lower thermal mass. This appeared to result in a slightly warmer release into lower Clear Creek in 2005 than in prior years. The warmer temperatures occurred primarily during September and October (Figure 11-33 and Figure 11-34). This period coincides with the incubation period for spring run Chinook salmon when the target temperature is a mean daily average of 56 °F or below at Igo (NMFS 2004). The mean of the mean daily temperatures during the period June 1 through September 15 in 1996 through 2004 was 58.1 °F and in 2005 it was also 58.1 °F. The mean of the mean daily temperatures during the period September 15 through October 31 in 1996 through 2004 was 54.2 °F. The mean of the mean daily temperatures for this same period in 2005 was 56.7 °F. The warmer temperatures that occurred in the latter part of the temperature control season in 2005 are a tradeoff for the improved flow and temperature conditions being provided in the Trinity River.

The higher temperatures in 2005 occurred during the spring-run egg incubation period and on average exceeded the 56 °F target temperature by 0.7 °F. Chinook salmon eggs in other rivers (eg. American River) survive at high rates, at least in the hatchery, when spawned at 60 °F as long as the water temperature quickly declines to 56 °F or less. Temperatures in Clear Creek declined to 50 °F by the end of November in 2005. Therefore, effects of the slightly higher temperatures during early incubation for spring-run Chinook in 2005 were expected to be negligible. Similar temperature conditions will likely occur in future years.

A larger volume of water from the Trinity River goes to the Sacramento River through the Spring Creek tunnel than goes to Clear Creek. The Spring Creek tunnel water is used primarily to help cool the Sacramento River during the heat of the summer for winter run Chinook spawning and incubation. The higher volume going to the Sacramento River necessitates operating the system primarily for Sacramento River temperature targets. Clear Creek receives the same temperature water as what goes to the Sacramento River. This has generally provided suitable Clear Creek temperature conditions most of the time in the past. Daily temperature fluctuation in Clear Creek at Igo peaks in June and July when days are the longest at around 8 °F difference between the high and low temperature for the day (Figure 11-14 and Figure 11-15).

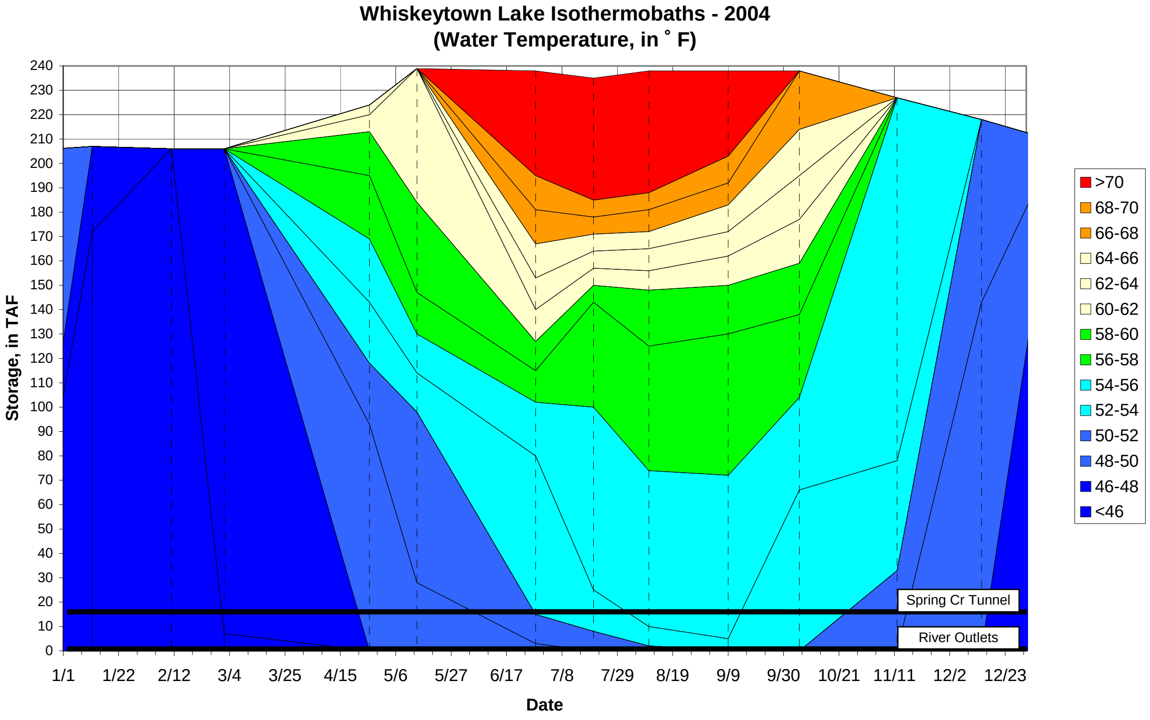

Figure 11-33. Whiskeytown Lake isothermobaths in 2004.

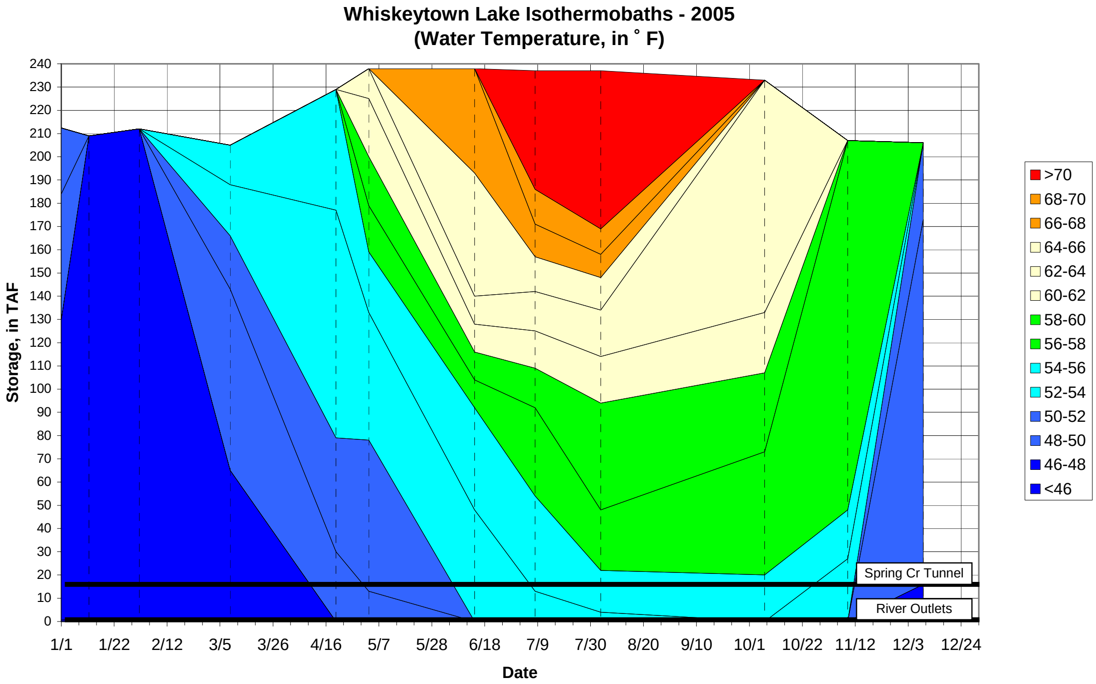

Figure 11-34. Whiskytown Lake isothermobaths in 2005. Water temperatures in degrees Fahrenheit.

Table 11-4. Spring Creek tunnel release volume, 1999-2004 compared to 2005.

Spring Creek Tunnel Volume (thousand acre feet)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
2005	28.7	26.2	60.2	10.0	60.2	47.7	51.7	70.2	68.7	62.6	79.6	109.2	675
2004	54.4	111.7	202.6	123.8	19.4	89.0	133.6	89.8	95.0	156.3	8.7	26.3	1,111
2003	84.0	84.1	86.7	47.7	114.2	109.4	92.8	150.7	137.1	122.2	65.9	49.5	1,144
2002	71.1	27.6	23.2	7.2	41.1	103.8	131.2	131.0	57.8	80.8	16.4	84.0	775
2001	36.9	68.9	75.2	18.7	32.0	92.4	159.2	154.0	108.2	121.6	0.0	53.9	921
2000	83.3	178.2	148.9	122.3	158.7	167.6	193.8	203.4	117.5	31.6	5.4	16.8	1,428
1999	102.0	85.9	130.6	100.0	95.1	128.9	142.0	95.5	91.0	31.7	45.8	39.8	1,088
AVG 99-04 =	72.0	92.7	111.2	70.0	76.8	115.2	142.1	137.4	101.1	90.7	23.7	45.1	1,078
2005 % Diff	-60%	-72%	-46%	-86%	-22%	-59%	-64%	-49%	-32%	-31%	236%	142%	-37%

Based on results of the flow and temperature analysis for juvenile Chinook salmon and steelhead rearing in Clear Creek, we conclude that because operations in the base and future conditions will be the same there will be no change in effect to these species or their critical habitat in Clear Creek. Spring-run Chinook and steelhead populations should be maintained or increase.

Sacramento River

Adult Chinook Salmon and Steelhead Migration, Spawning, and Incubation

Adult steelhead are expected to migrate upstream past Red Bluff primarily from August through December and spawn in the Sacramento River from December through April with peak activity occurring from January through March (McEwan 2001). During the upstream migration time period flows are high during August as water deliveries are being made. Flows get gradually lower as water deliveries are reduced and weather cools so less water is needed for temperature control. Flows are expected to affect upstream migrating steelhead only to the extent that they affect water temperatures. The minimum Keswick release is 3,250 cfs. Steelhead spawning weighted usable area peaks at 3,250 cfs in the upper river reaches and peaks at about 13,000 cfs in the lower reach, forty miles further downstream, but with a low variability in availability (FWS 2003). Based on the results of the PHABSIM analysis there is no evidence that the 3,250 cfs flow level does not provide adequate physical habitat to meet the needs of all steelhead life stages in the Sacramento River. Flows during the summer greatly exceed this amount to meet temperature requirements for winter–run Chinook spawning. The winter–run Chinook temperature objectives during the summer and run-of-the-river temperatures the rest of the year result in water temperatures suitable for year-round rearing of steelhead in the upper Sacramento River. This reach of the Sacramento River provides the best steelhead habitat and greatest use. Therefore, we have concluded the current and future operations are not likely to adversely affect steelhead adults or their critical habitat in the upper Sacramento River.

Winter–run Chinook migrate upstream during December through June. Spring–run Chinook migrate from March into October, although the run is nearly complete by the end of June. Fall–run and late fall–run are migrating between about July and December so that Chinook salmon are migrating upstream in the Sacramento River during all months of the year (Figure 16-6). Winter–run spawning peaks in May through July and spring–run spawning peaks in August and September. Redd counts in recent years (2001 – 2007) showed no spawning peak in the Sacramento River during the expected spring–run Chinook salmon spawning period until October when the redds were considered fall–run redds (DFG aerial redd count survey data). Keswick average monthly releases between January and October range from a low of 3,250 cfs during dry years in all scenarios in January – April and October to a high of 54,000 cfs during flood control releases in the wettest years in January and February. The largest difference in flow between the current and future operations will be slightly higher releases in July and slightly lower releases in September, October, and June in the future. Flows at the low end of the range of projected flows (3,250 cfs) provide enough spawning area for approximately 14,000 winter–run Chinook (FWS 2003). Under higher levels of escapement spawning habitat at a minimum flow of 3,250 cfs may become limiting in the future. If escapement increases significantly to near recovery goals, the flow-versus-habitat relationships should be reassessed at the higher escapement levels. During the winter run spawning season flows would be high enough for temperature control to provide adequate spawning habitat within river reaches where winter-run spawn.

The lower flows in September and October would lower the amount of spring–run Chinook salmon spawning habitat. Spring–run spawning habitat was not estimated but is not limiting the population because few Chinook spawn in the mainstem Sacramento River during the spring–run spawning period, (i.e. there is plenty of space with suitable spawning habitat for the ones that are there).

During very wet years monthly flows as high as 53,000 cfs could occur during upstream migration for adult winter–run Chinook. During winter–run Chinook spawning, flood control peak flows above 50,000 cfs could occur and when combined with tributary inflow could potentially affect redd survival (Table 11-3). Attempts are made to spread flood control releases out when possible. When the high peaks occur egg-to-fry survival could decrease for a brood year due to redd scouring or entombment. Long-term habitat benefits from high flood control flows should include gravel recruitment from streamside sources enhancing spawning gravel, instream woody debris recruitment, and establishment of new cottonwood seedlings. The population effects should be maintained or better egg-to-smolt survival rates in the future. Flood control releases would rarely occur during winter-run Chinook spawning and they are the one run with the least exposure to redd scour risk.

Most of the winter–run Chinook spawning (98 percent) in recent years with better access to upstream habitat has occurred upstream of Balls Ferry (Figure 11-38). Water temperatures during winter–run spawning season can be maintained below 56 °F down to Balls Ferry in about 90 percent of years in May through August and 50 percent of years in September. Temperatures in the future modeling scenarios (7.1 and 8.0) would be slightly increased (1 – 2 °F) in the driest 10 percent of years with the greatest increase in September (Figure 11-35). Temperatures at Bend Bridge in about 20 percent of years in May, 30 percent of years in June, 40 percent of years in July, and 80 percent of years in August and September would exceed 56 °F (Figure 11-36). They would exceed 56 °F about 20 percent of years in October. The highest water temperatures of the year would occur in August through October during dry years as the cold-water pool is depleted. During the years when 56 °F cannot be maintained the cold-water pool storage in Shasta Reservoir would not be sufficient to maintain cool temperatures throughout the summer and decisions would have to be made as to how to allocate the available cool water throughout the warm weather period. Figure 11-37 shows that end of September storage would be reduced in the future compared to current operations in the drier 70% of years. End of September storage would be below 1.9 million acre feet in about 10% of years in the future.

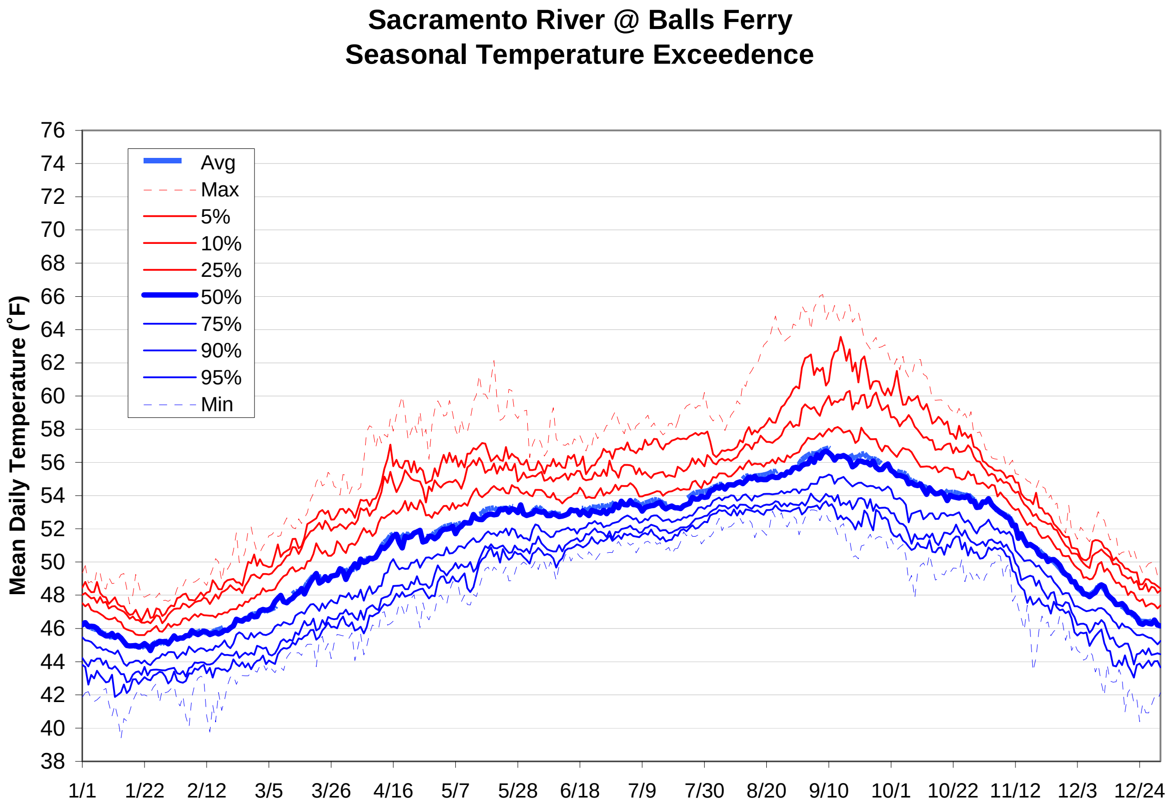

Figure 11-35. Water temperature exceedence at Balls Ferry under study 8.0 from CalSim-II and weekly temperature modeling results.

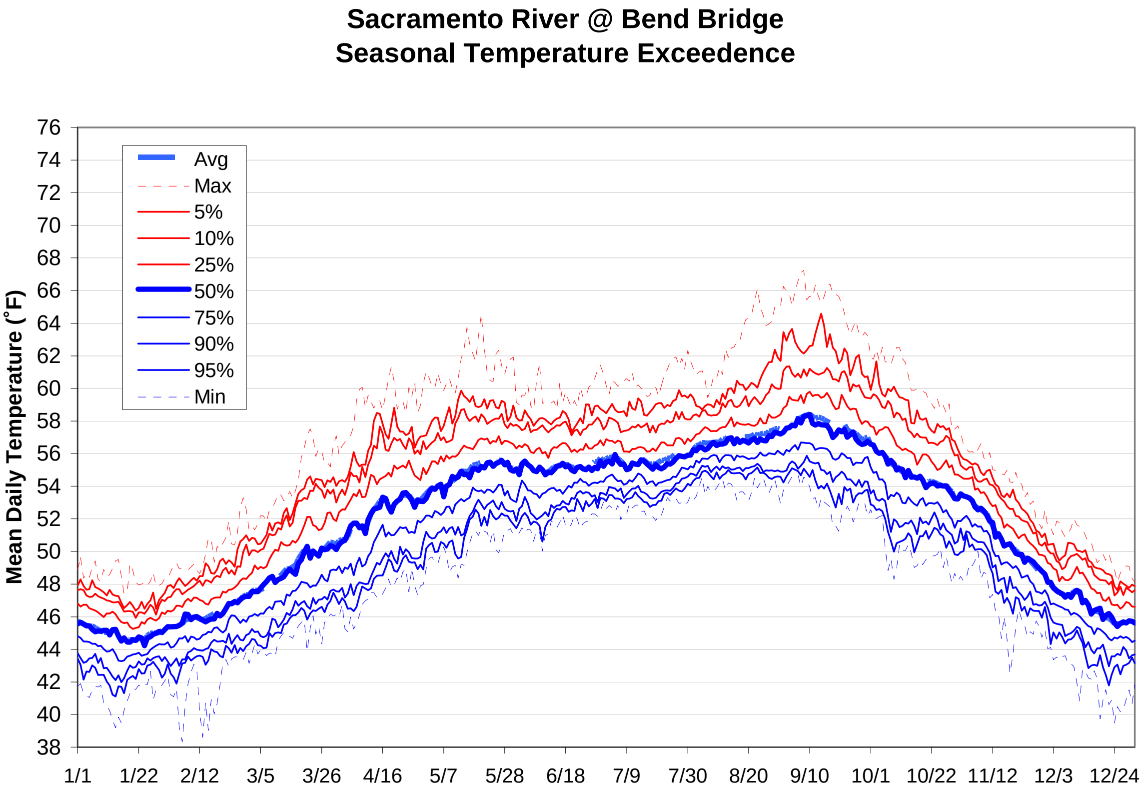

Figure 11-36. Water temperature exceedence at Bend Bridge under study 8.0 from CalSim-II flow and weekly temperature modeling results.

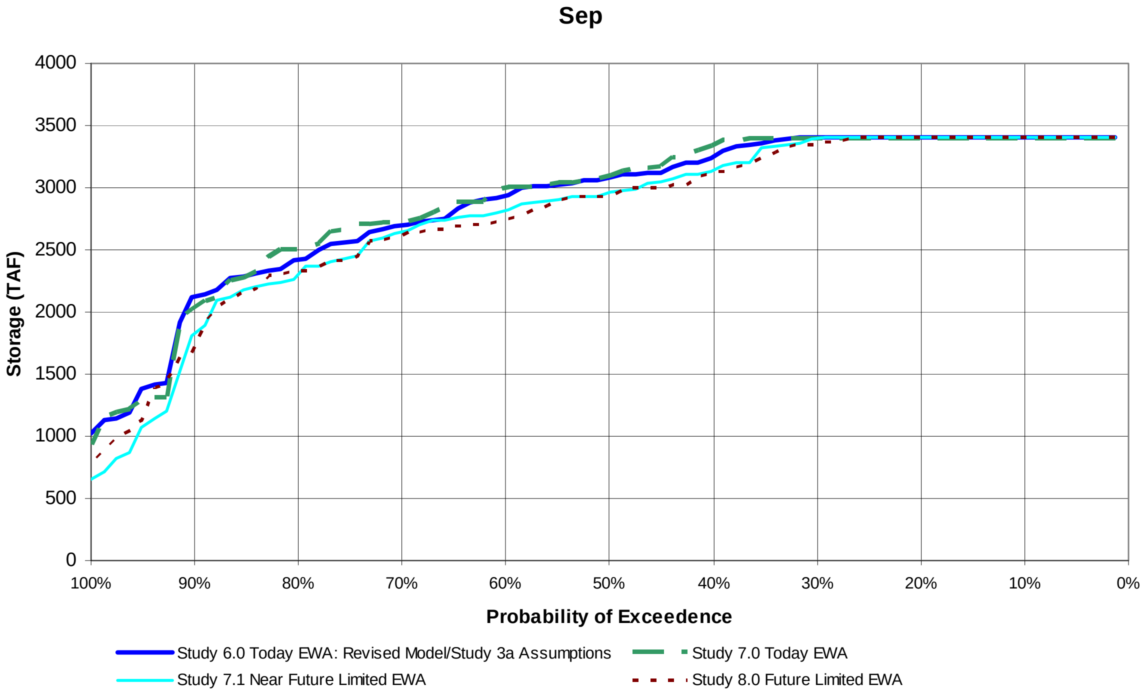

Figure 11-37. September storage in Shasta Reservoir. Study 6.0 represents 2004 operations, study 7.0 repesents current operations, 7.1 represents near future operations, and 8.0 represents future operations.

Increased flows for the Trinity River restoration program have decreased the ability to maintain cool temperatures for winter-run Chinook and other species in the Sacramento River. The egg incubation lifestage requires the coolest water temperatures for Chinook salmon. Therefore, operations strive to provide temperatures suitable for successful egg to fry survival. Since temperature requirements are less stringent for later lifestages it is assumed that providing egg incubation temperatures in the controllable section of the Sacramento River will adequately protect the later lifestages. Effects of water temperature on egg incubation are evaluated using the Reclamation water temperature related egg mortality model. The model is described in Appendix L. Figure 11-43 shows the average percent mortality of Chinook salmon eggs and pre-emergent fry in the Sacramento River through all years modeled based on water temperature while eggs are in the gravel. The model projects that water temperature related mortality would be slightly higher for all runs in the future (study 7.1 and 8.0) than under current operations (study 7.0). The greatest change in mortality would occur in critical year types and is greatest for spring–run. Mortality would be higher under near future operations (Study 7.1) than under future operations (Study 8.0).

During dry years only about one percent of winter–run eggs are projected to suffer mortality but in critically dry years about 10 to 15 percent would suffer mortality on average (Figure 11-39). This is an increase from 7 percent under current operations. Mortality would occur primarily in six of the years used in the modeling (Figure 11-40). The hydrological period contains twelve critically dry years, which is 15 percent of the years used in modeling.

During dry years about a 18 percent of spring–run eggs could suffer mortality under current operations and 23 percent under future operations (Figure 11-41). During critically dry years about 49 percent mortality occurs for current operations (study 7.0) and about 65 percent in future scenarios.

Higher egg mortality occurs for spring-run than for winter-run because temperature management in the Sacramento River focuses on the winter run spawning and egg incubation period. Eight years in the hydrological record would have spring-run egg mortality of over 50 percent (Figure 11-42). Cold water is largely depleted by the end of the winter-run incubation period in these dry years, resulting in warmer water during spring-run Chinook egg incubation. A relatively small percentage of the total Central Valley spring–run population spawns in the mainstem Sacramento River. Therefore tradeoffs required to balance the cold water needs of winter-run Chinook and spring-run Chinook should continue to favor winter-run because the entire winter-run population spawns in the Sacramento River. The effects of changes in temperature patterns are of greater consequence to the winter-run population than to the spring-run population.

The Sacramento River exhibits a range of daily temperature fluctuation depending on distance downstream from the dam and whether water comes out of Keswick during day or at night. The effect at Colusa (Figure 11-9 and Figure 11-10) compared to Balls Ferry (Figure 11-3 and Figure 11-4) shows a greater daily temperature fluctuation upstream at Balls Ferry than downstream at Colusa.

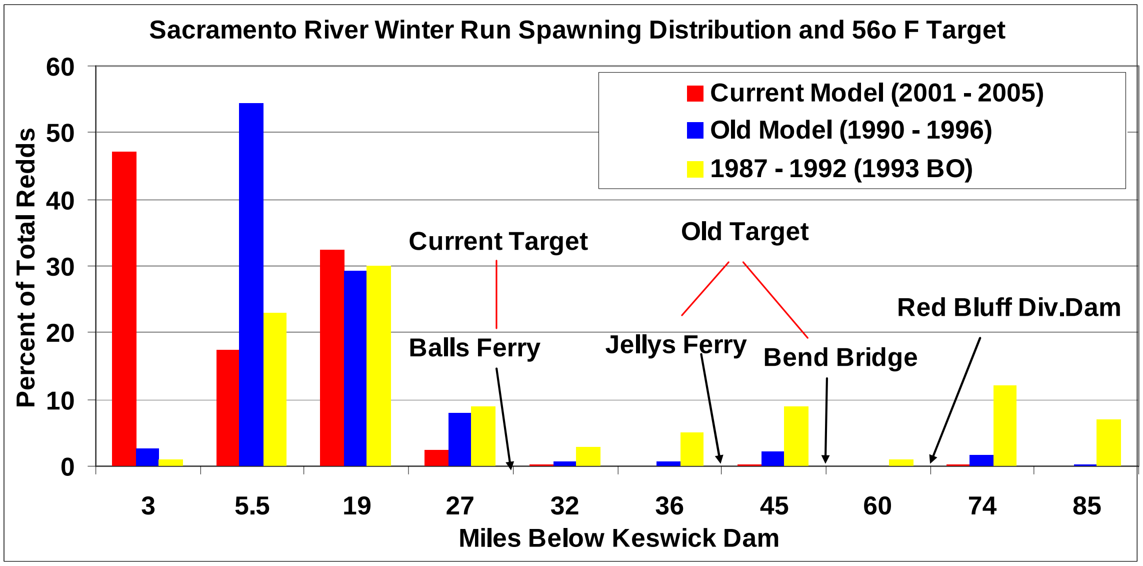

Figure 11-38. Winter-run Chinook salmon spawning distribution through time relative to water temperature targets.

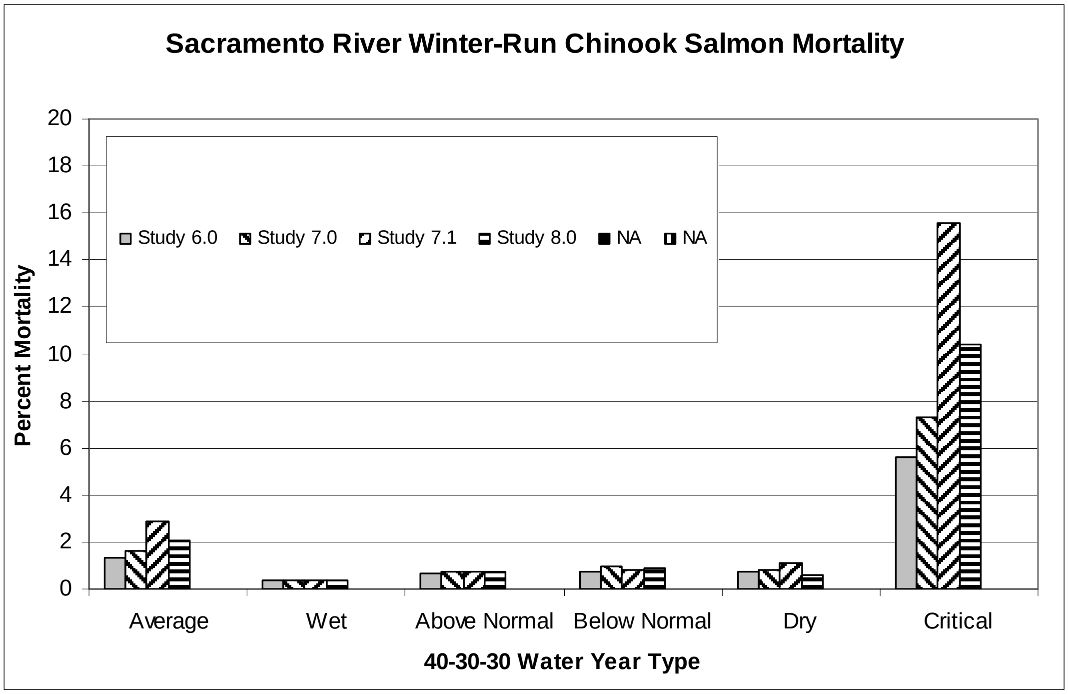

Figure 11-39. Winter run Chinook average egg mortality by water year type from Reclamation egg mortality model. Study 6.0 represents 2004 operations, study 7.0 represents current operations, 7.1 represents near future operations, and 8.0 represents future operations.

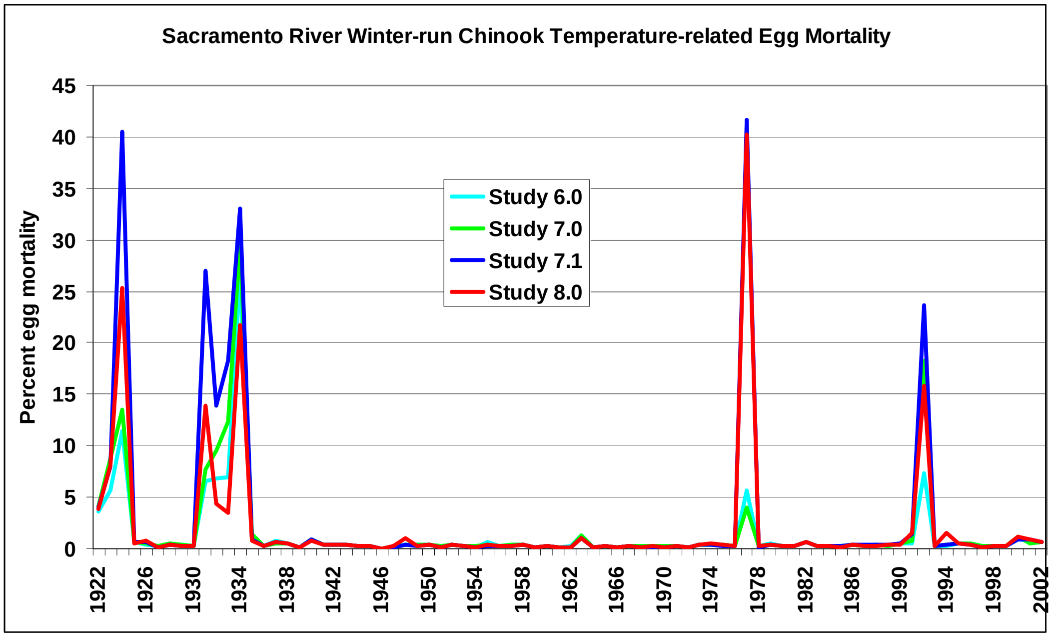

Figure 11-40. Winter run Chinook egg mortality from Reclamation egg mortality model by year in hydrological record. Study 6.0 represents 2004 operations, study 7.0 represents current operations, 7.1 represents near future operations, and 8.0 represents future operations.

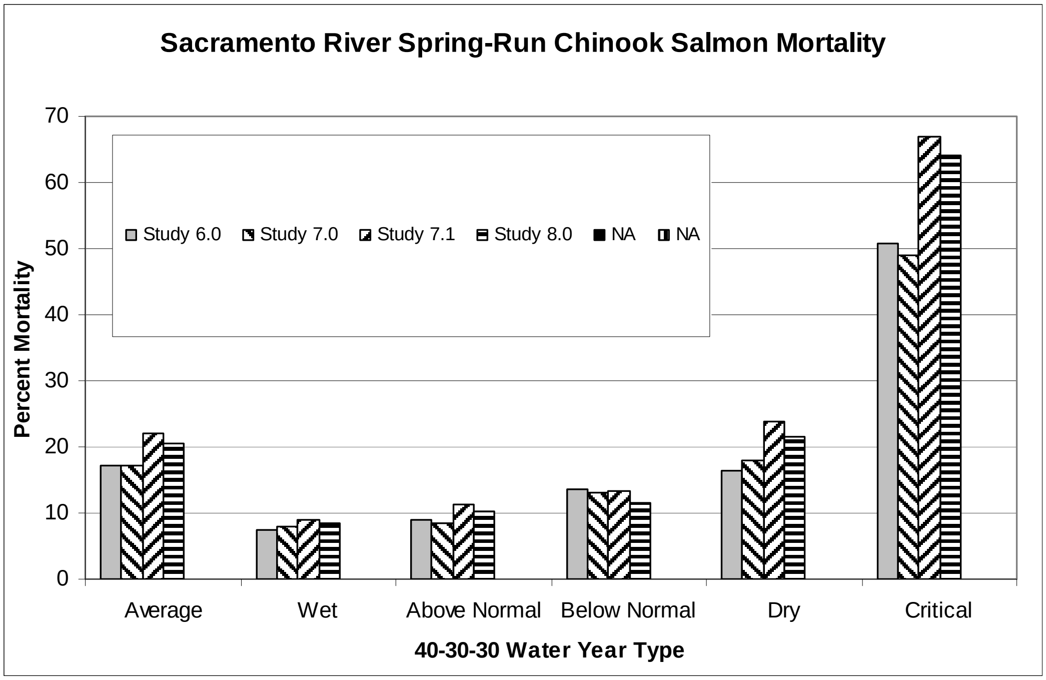

Figure 11-41. Spring run Chinook egg mortality from Reclamation egg mortality model by water year type. Study 6.0 represents 2004 operations, study 7.0 represents current operations, 7.1 represents near future operations, and 8.0 represents future operations.

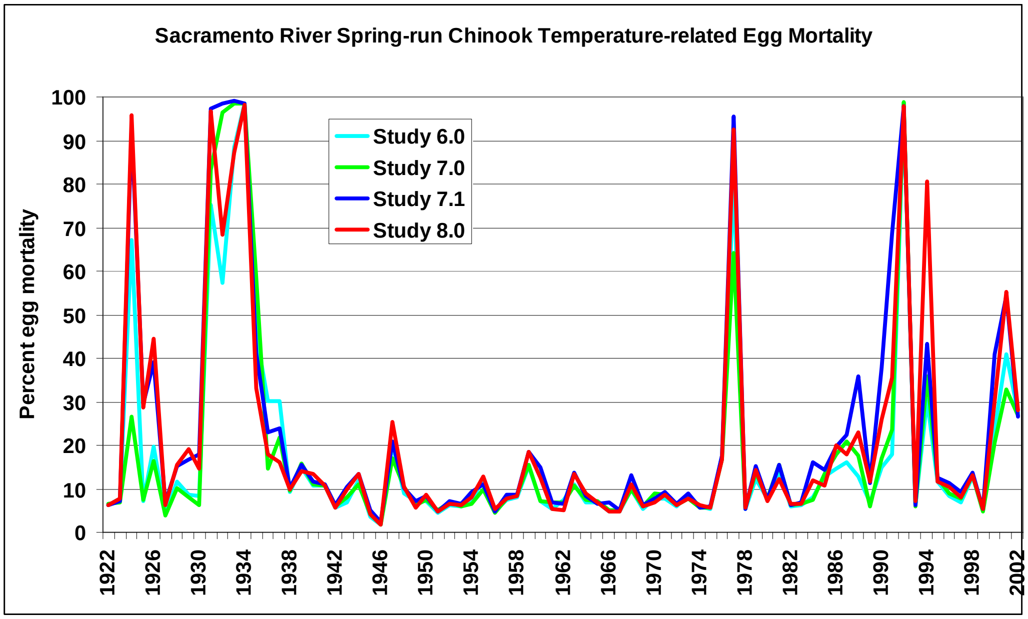

Figure 11-42. Spring-run Chinook egg mortality from Reclamation egg mortality model by year in hydrological record. Study 6.0 represents 2004 operations, study 7.0 represents current operations, 7.1 represents near future operations, and 8.0 represents future operations.

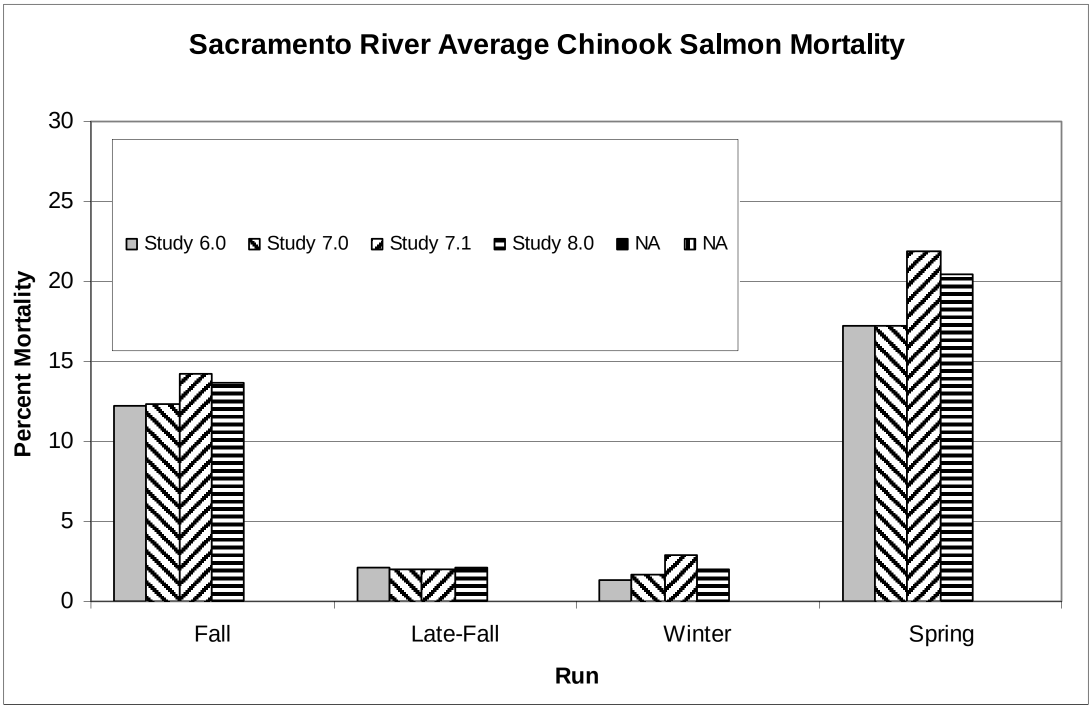

Figure 11-43. Average yearly egg mortality from Reclamation egg mortality model between studies for all four runs in the Sacramento River. Study 6.0 represents 2004 operations, study 7.0 represents current operations, 7.1 represents near future operations, and 8.0 represents future operations.

Salmod Modeling Results (Sacramento River Only)

Salmod is a computer model that simulates the dynamics of freshwater salmonid populations. Salmod was applied to this project because previous reviews recommended a broader quantitative approach to the assessment than was provided by Reclamation's salmon egg mortality model. Model documentation is included in Appendix P. Salmod was developed for the Trinity River and has been adapted for use on the Sacramento River with fish and habitat data specific to the Sacramento River. A thorough review and update of model parameters and techniques on the Klamath River enabled a smooth transfer of relevant model parameters to the Sacramento River (Bartholow, 2003). Salmod was modified from the original for the Shasta Lake Water Resources Investigation in response to concerns posed by DFG, and from the original version used for the Sacramento River, which was set for Keswick Dam to Battle Creek. The study area for the Salmod analysis covers a 53-mile stretch of the Sacramento River from Keswick Dam to just above the Red Bluff Diversion Dam (RBDD). Keswick Dam forms the upstream boundary of anadromous fish migration in the Sacramento River, and the RBDD marks the current downstream limit of habitat that has been consistently classified by mesohabitat type and evaluated by the USFWS to estimate flow versus habitat availability relationships (data needed to run the model).

Results from SALMOD are best evaluated by examining the direction of change between operational scenarios rather than looking at absolute numbers of fish. Percent change from study 7.0 to study 6.0, 7.1 and 8.0 are presented as a representation of magnitude of potential change.

Salmod Inputs

Salmod was run using a spawning population of 8,591 winter run (the average escapement from 1999-2006) and 1,000 spring run (Table 11-5). Input variables, represented as weekly average values, include streamflow from CalSim-II modeling results, water temperature from the Sacramento River daily model, and number and distribution of adult spawners from DFG aerial redd survey data. The study area is divided into individual mesohabitats (i.e., pool, riffle, and run) categorized primarily by channel structure and hydraulic geometry, but modified by the distribution of features such as fish cover. Habitat quality in all computational units of a given mesohabitat type changes similarly in response to discharge variation.

Even though Salmod can simulate small numbers of fish, it is not prudent to do so. Because the model is deterministic, it relies on parameters that represent population means derived, or supported, by the "law of large numbers." When populations are low, mean responses are quickly affected by environmental stochasticity and individual variability, factors Salmod was not designed to address. The recent average escapement for spring run Chinook to the mainstem river was less than 500 adult spawners, which may be inappropriate because the number of spawners is low. The term "low" is arbitrary, but populations under 500 were identified as being too low for accurate results using Salmod. A starting adult population of 1,000 spring run was used.

Table 11-5. Number and Distribution of Spawning Fish (Adult Male and Female) Incorporated into Salmod Model.

Reach	Fall-Run	Late Fall-Run	Winter-Run	Spring-Run
California Department of Fish and Game (Grand Tab, 1999 – 2006 Average Escapement broken down into spawning distribution from redd surveys)				
Keswick to ACID	6,658	4,725	3,591	43
ACID to Highway 44 Bridge	4,011	2,096	1,761	188
Highway 44 Bridge to Airport Road Bridge	7,175	3,123	3,041	324
Airport Road Bridge to Balls Ferry Bridge	12,405	2,507	163	174
Balls Ferry Bridge to Battle Creek	8,337	767	9	106
Battle Creek to Jellys Ferry Bridge	12,146	282	9	150
Jellys Ferry Bridge to Bend Bridge	8,789	130	17	14
Bend Bridge to Red Bluff Inundation Zone	5,044	67	0	0
Total Adult Spawners	**64,565**	**13,697**	**8,591**	**1,000**
Potential Eggs	**154,955,000**	**32,865,000**	**12,369,000**	**2,400,000**

Salmod Results

Winter Run

The main output from Salmod is the number of juvenile Chinook emigrating past Red Bluff. It is more useful to examine the change in production between operational scenarios than to look at absolute fish numbers for evaluating effects of water operations. Figure 11-44 shows that there is not much change between current and future operations during most years but in a few critically dry years, when cold water is limited, production is decreased by about 10 to 40 percent. The greatest reductions occur in under near future operations. Starting with an escapement of 8,591, the number of juvenile winter Chinook emigrating remained relatively constant at around four million through most years. Years of low production were 1977, 1935, 1925, 1932, and 1992 (Figure 11-45). These are critically dry year types when egg mortality due to water temperature would be high (Figure 11-46 and Figure 11-47). Study 7.1 experienced the lowest production during each of these dry years and study 7.0 generally had the highest production. Winter-run fry mortality due to water temperature occurred in the same years as egg mortality (Figure 11-48). Mortality of winter-run fry and presmolts due to habitat availability (space) fluctuated slightly but there were no outstanding years or operational scenarios that would appear to have exceptional population level effects (Figure 11-49 and Figure 11-50).

Study 7.0 had higher presmolt mortalities in 1933 and 1978. The juvenile lifestage mortality was generally a small proportion of total passage past Red Bluff. There was little mortality of presmolts or immature smolts due to water temperature in any year under any of the scenarios.

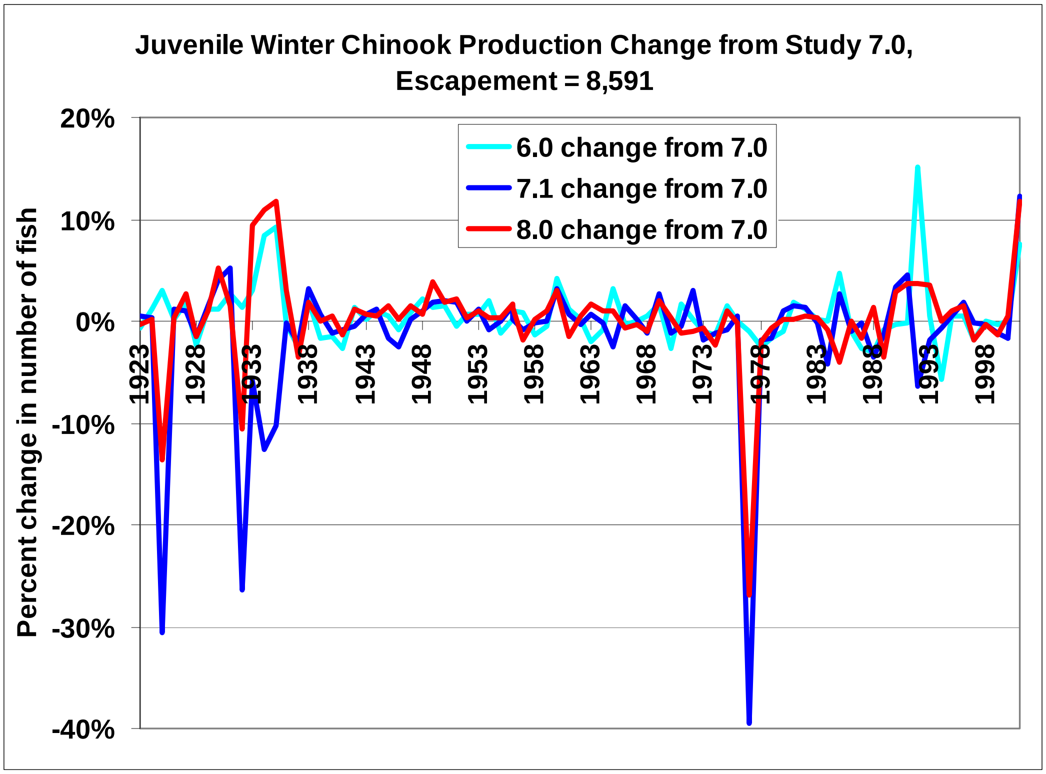

Figure 11-44. Percentage change in juvenile winter-run Chinook production past Red Bluff of operational scenarios compared with the current scenario from the SALMOD model. Study 6.0 represents 2004 operations, 7.0 represents current operations, 7.1 represents near future operations, and 8.0 represents future operations

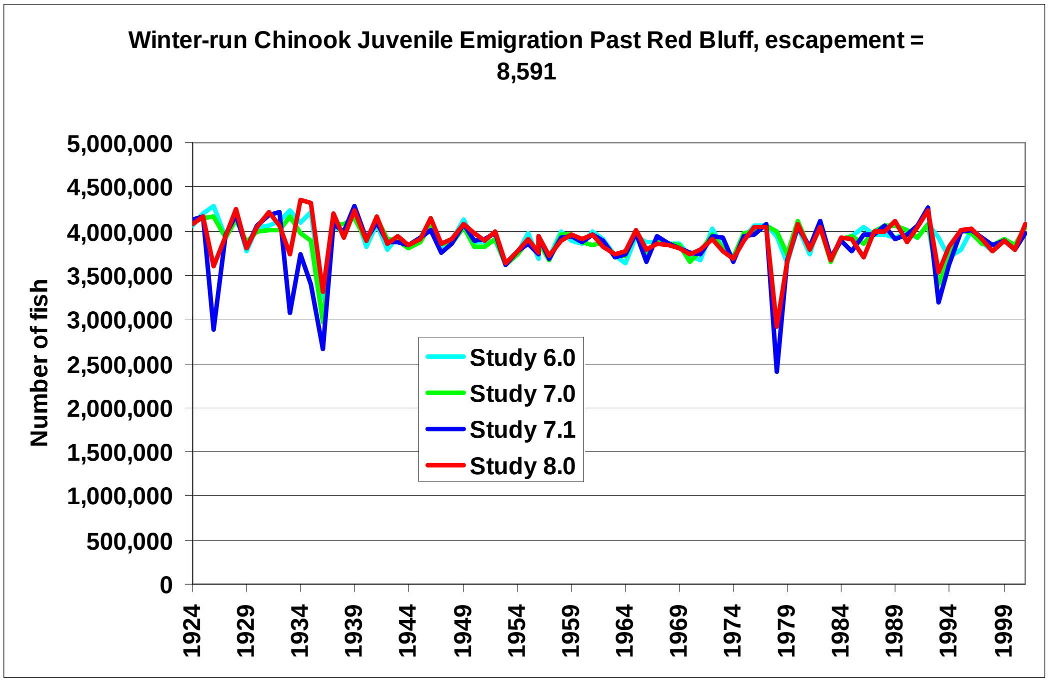

Figure 11-45. Winter-run Chinook juveniles emigrating past Red Bluff by operational scenario, 1923-2002 from SALMOD model. Study 6.0 represents 2004 operations, 7.0 represents current operations, 7.1 represents near future operations, and 8.0 represents future operations.

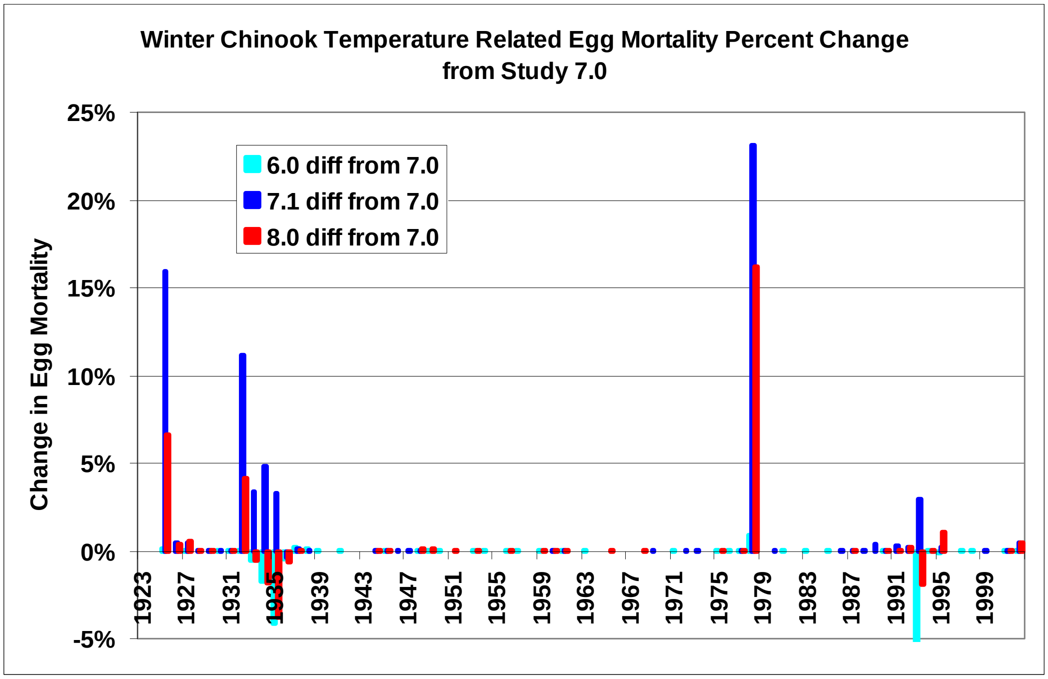

Figure 11-46. Percentage change in juvenile winter-run Chinook egg mortality in operational scenarios compared with the current scenario from the SALMOD model. Study 6.0 represents 2004 operations, 7.0 represents current operations, 7.1 represents near future operations, and 8.0 represents future operations

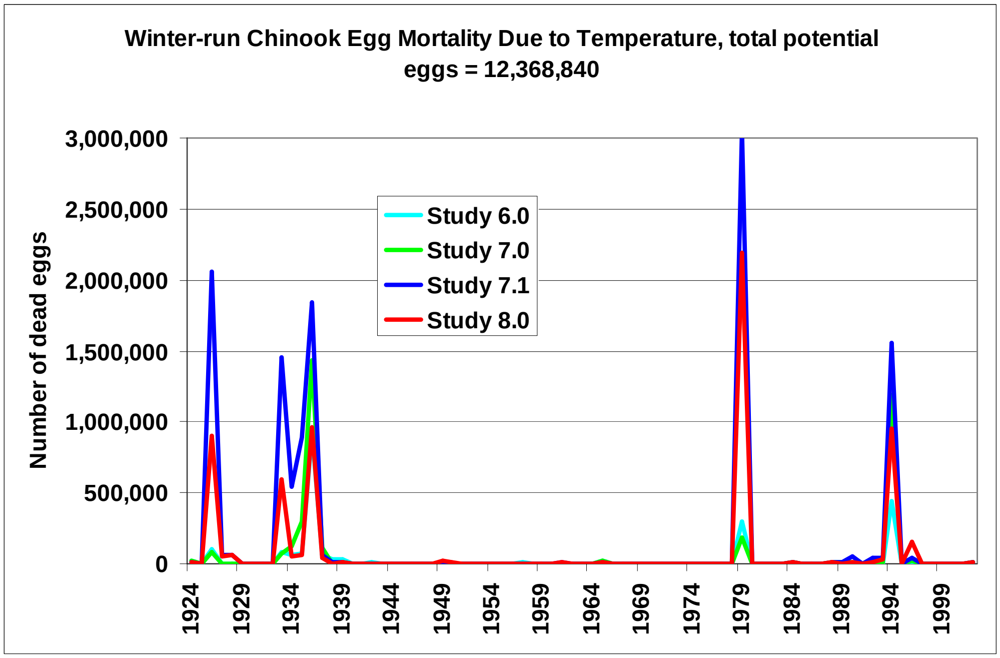

Figure 11-47. Winter-run egg mortality due to water temperature by operational scenario with 12,368,840 total potential eggs, 1923-2002 from SALMOD model. Study 6.0 represents 2004 operations, 7.0 represents current operations, 7.1 represents near future operations, and 8.0 represents future operations.

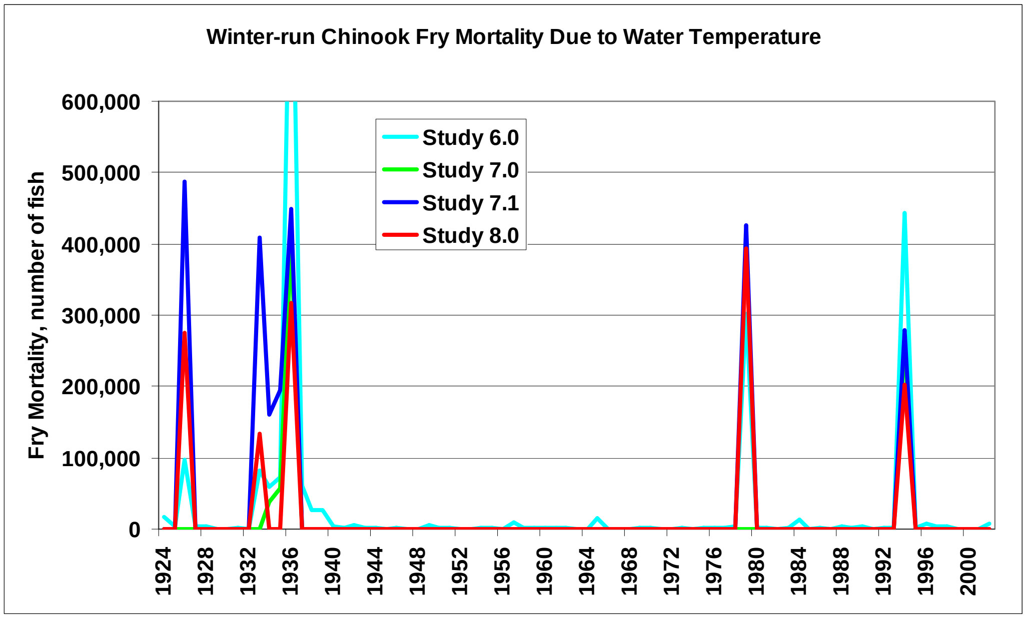

Figure 11-48. Winter-run Chinook fry mortality due to water temperature by operational scenario. Study 6.0 represents 2004 operations, 7.0 represents current operations, 7.1 represents near future operations, and 8.0 represents future operations.

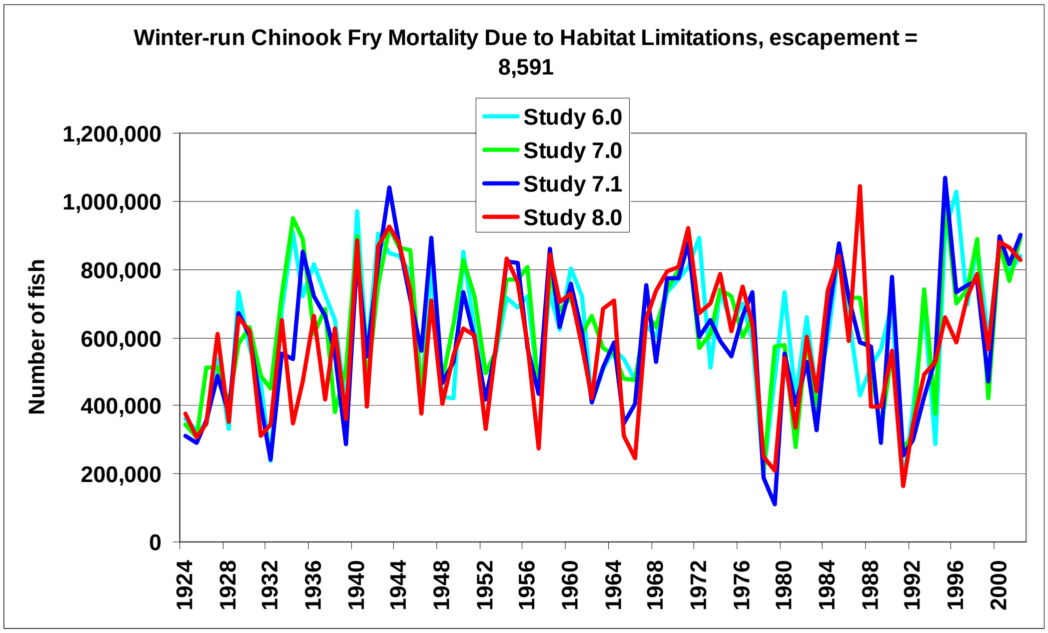

Figure 11-49. Winter-run Chinook salmon fry mortality due to habitat limitations by water operational scenario, 1923-2002 from SALMOD model. Study 6.0 represents 2004 operations, study 7.0 represents current operations, 7.1 represents near future operations, and 8.0 represents future operations.

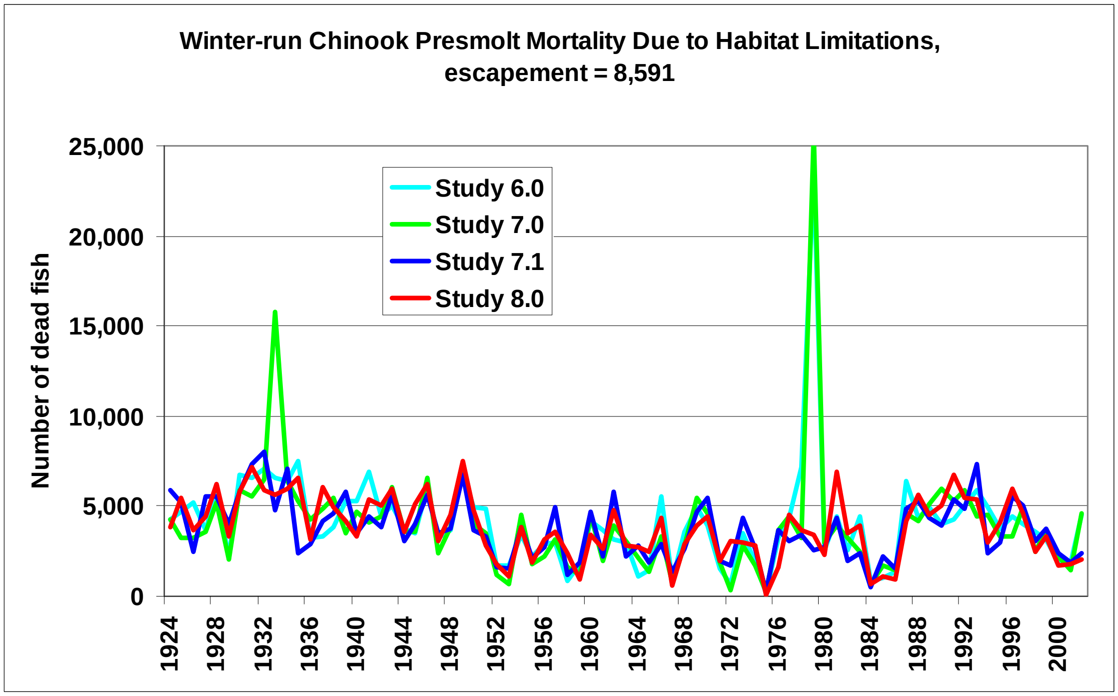

Figure 11-50. Winter-run Chinook presmolt mortality due to habitat limitations by operational scenario, 1923-2002 from SALMOD model. Study 6.0 represents 2004 operations, 7.0 represents current operations, 7.1 represents near future operations, and 8.0 represents future operations.

Spring Run

Figure 11-51 shows the percent change in spring-run Chinook production for study 6.0, 7.1 and 8.0 compared with study 7.0. As with winter-run, the main differences are in the critically dry water years. The number of Sacramento River spring-run Chinook emigrating remained relatively constant at 800-900,000 through most years (Figure 11-52). Years of low production were 1932, 1935, 1934, 1925, 1978, 1993, 1933, 1927, and 2002 (Figure 11-51). These are critically dry year types when egg mortality due to water temperature would be high (Figure 11-53). There were not major differences in mortality among the studies. Study 7.0 had the highest mortality in some years and study 7.1 and 8.0 were highest in others. Mortality of spring-run fry due to habitat availability (space) fluctuated slightly but there were no outstanding years or operational scenarios that would appear to have exceptional population level effects (Figure 11-54). The years of very low fry mortality were the ones when most of the mortality occurred to the eggs from high water temperature. There was no mortality of presmolts or immature smolts due to habitat availability. There was no mortality of fry, presmolts, or immature smolts due to water temperature in any year under any of the scenarios.

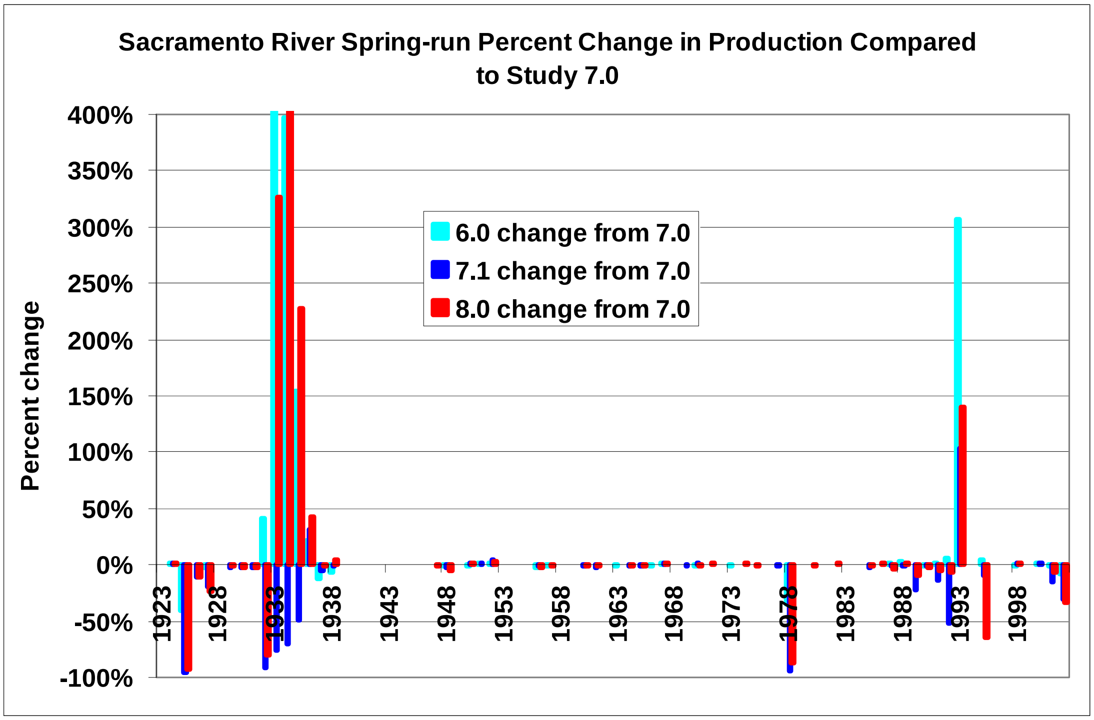

Figure 11-51. Percentage change in juvenile spring-run Chinook production past Red Bluff of future operational scenarios compared with the current scenario from the SALMOD model. Study 7.0 represents current operations, 7.1 represents near future operations, and 8.0 represents future operations.

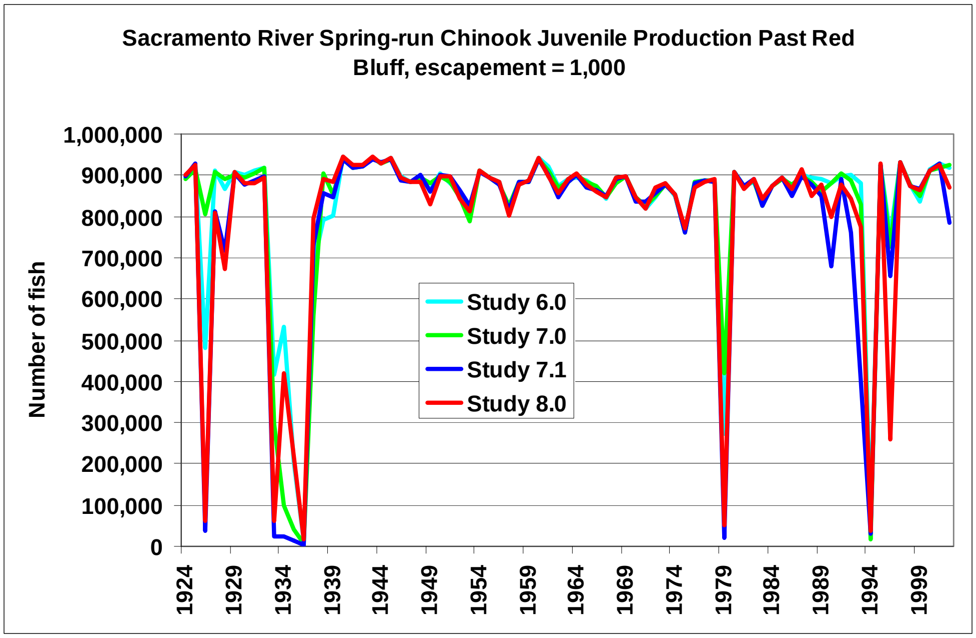

Figure 11-52. Juvenile Sacramento River Spring-run Chinook production emigrating past Red Bluff by operational scenario with 1,000 spawners, from Salmod model. Study 6.0 represents 2004 operations, 7.0 represents current operations, 7.1 represents near future operations, and 8.0 represents future operations.

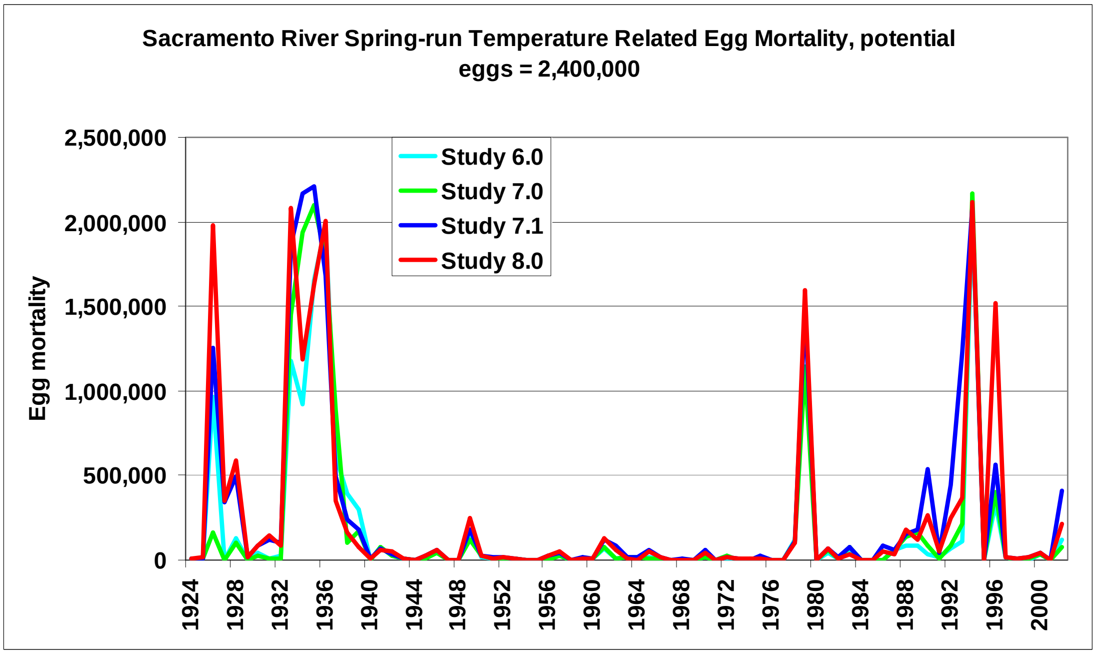

Figure 11-53. Sacramento River spring-run egg mortality due to water temperature by operational scenario with 2,400,000 total potential eggs, 1923-2002 from SALMOD model. Study 6.0 represents 2004 operations, 7.0 represents current operations, 7.1 represents near future operations, and 8.0 represents future operations.

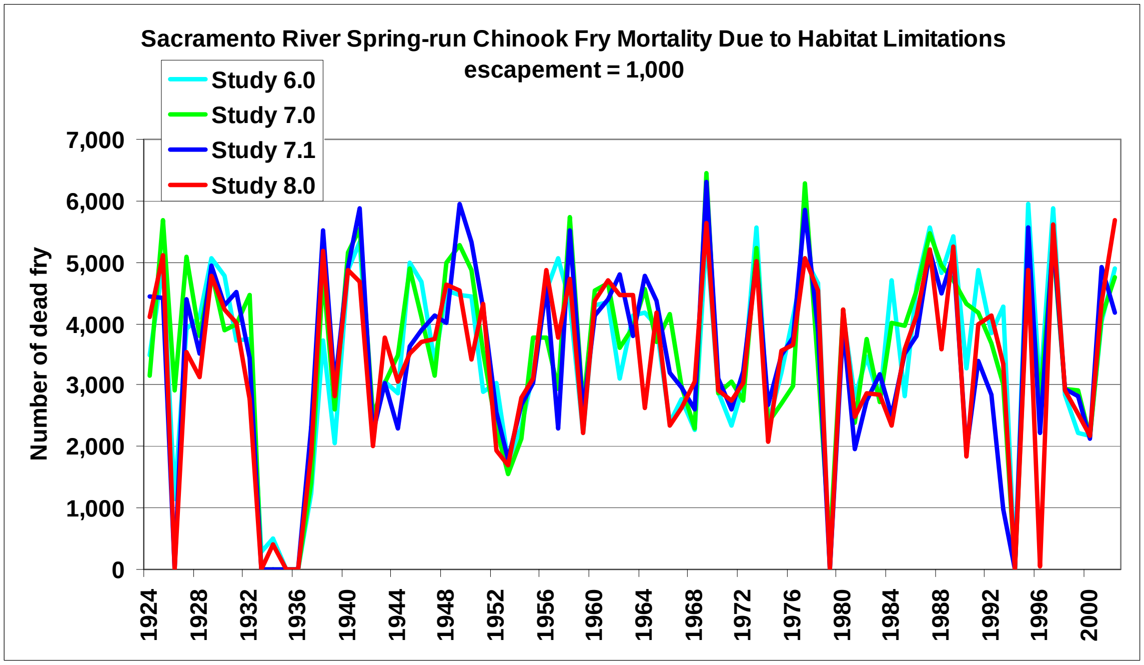

Figure 11-54. Spring-run Chinook salmon fry mortality due to habitat limitations by water operational scenario, 1923-2002 from SALMOD model. Study 6.0 represents 2004 operations, 7.0 represents current operations, 7.1 represents near future operations, and 8.0 represents future operations.

Interactive Object-Oriented Salmon Simulation (IOS) Winter-Run Life Cycle Modeling Results

The IOS Winter-Run Life Cycle model was used to evaluate the influence of different Central Valley water operations on the life cycle of Sacramento River winter-run Chinook Salmon over an 80 year period using simulated historical flow and water temperature inputs. The model was used to provide a quantitative estimate of project effects to lifestages other than that provided by the Reclamation egg mortality model and to provide a feedback loop from one cohort to the next which is not available in Salmod. The IOS model was seeded with 5,000 spawners for the first four years then allowed to cycle through multiple generations during years 1923-2002. Four runs of the IOS model were completed, each under a different water operation scenario: 1) Study 7.0, 2) Study 6.0, 3) Study 7.1, and 4) Study 8.0.

The effect of different water operation scenarios on the Sacramento River winter-run Chinook salmon population was evaluated by comparing abundance and survival trends at various life stages among the three runs of the IOS Model. The annual abundance of returning spawners and juveniles out-migrating past RBDD were reported for each model run. Trends in survival through time at various life stages were examined to explain patterns seen in yearly escapement under each water operation scenario. Average differences in winter-run survival between water operation scenarios were translated into average differences in annual escapement to better evaluate the potential impact each water operation scenario has on the winter-run abundance in the Sacramento River. Finally, predicted monthly spatial distribution of juvenile salmon during model runs was reported.

Model Settings

Reach specific, daily CalSim-II discharge (CalSim-II monthly results disaggregated to daily) and daily HEC-5Q water temperature provided the basic inputs for model runs. In addition, monthly average Delta conditions (inflow, exports, DCC operations, temperature) were provided by CalSim-II. Most model settings and functional relationships were set as described in detailed IOS model documentation (http://www.fishsciences.net/projects/NODOS/winter_run_IOS_model_documentation.pdf). Other model settings were set specifically for this analysis and at constant values throughout the 80-year run of the IOS model. The use of constant values for parameters with little uncertainty or with lesser management significance is desirable because it simplifies the model and facilitates easier interpretation of results. The RBDD and ACID dams were set to be "open" to allow adult spawners access to upstream spawning reaches. Annual hatchery supplementation was set at zero. Adult harvest rates were set at approximate historical averages. Age-3 and age-4 ocean harvest rate was set at 0.3 and 0.5, respectively. In-river sport harvest was set at 0.10. The first four years of the model run were each seeded with 5,000 adult spawners.

Results

Measures of winter-run Chinook salmon abundance increased through time under water operation scenario 7.0; ultimately ending near 45,000 adult spawners in 2002 (Figure 11-55). Similarly, passage of juveniles past RBDD increased through time and ended around 14 million in 2002.

Even with large inter-annual variations in winter-run escapement and juvenile RBDD, winter-run abundance appears to show a strong increasing trend through time under water operation scenarios 6.0, 7.1, and 8.0 (Figure 11-55; Figure 11-56). Winter-run abundance increased at a similar rate for all three alternative water scenarios until the late 1970's when the escapement trend for study 6.0 continued to increase, while the escapement levels for studies 7.1 and 8.0 seemed to level off (Figure 11-55; Figure 11-56). For studies 7.1 and 8.0, winter-run abundance began at the initial spawner seeding level of 5,000 fish and slowly grew through time to end at approximately 35,000 fish in 2002 (Figure 11-55). For study 6.0, winter run abundance reached approximately 35,000 fish in the late 1970's and continued to increase to approximately 45,000 fish by 2002 (Figure 11-55).

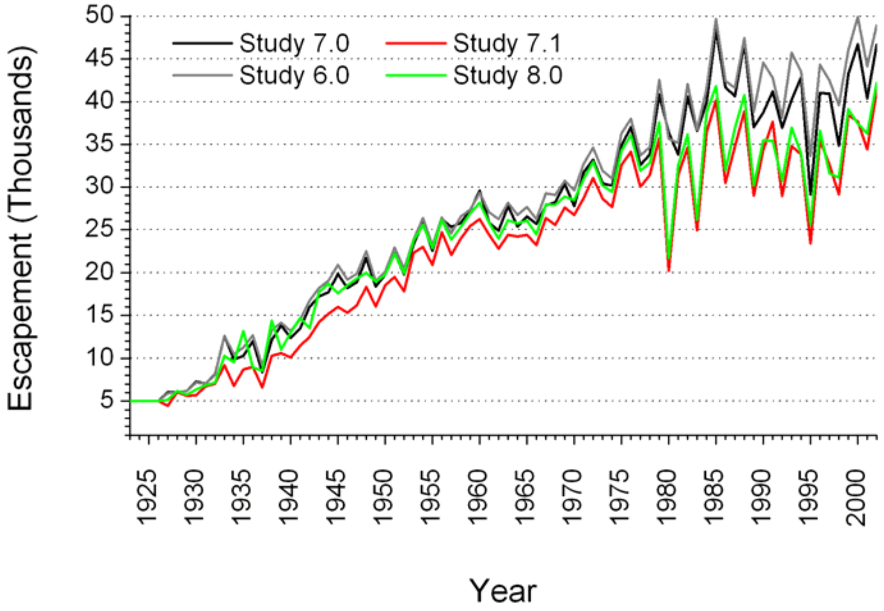

Figure 11-55. Annual winter-run Chinook salmon escapement under four OCAP water operation scenarios, 1923-2002 from IOS model. Study 7.0 represents current operations, 6.0 represents 2004 operations, 7.1 represents near future operations, and 8.0 represents future operations.

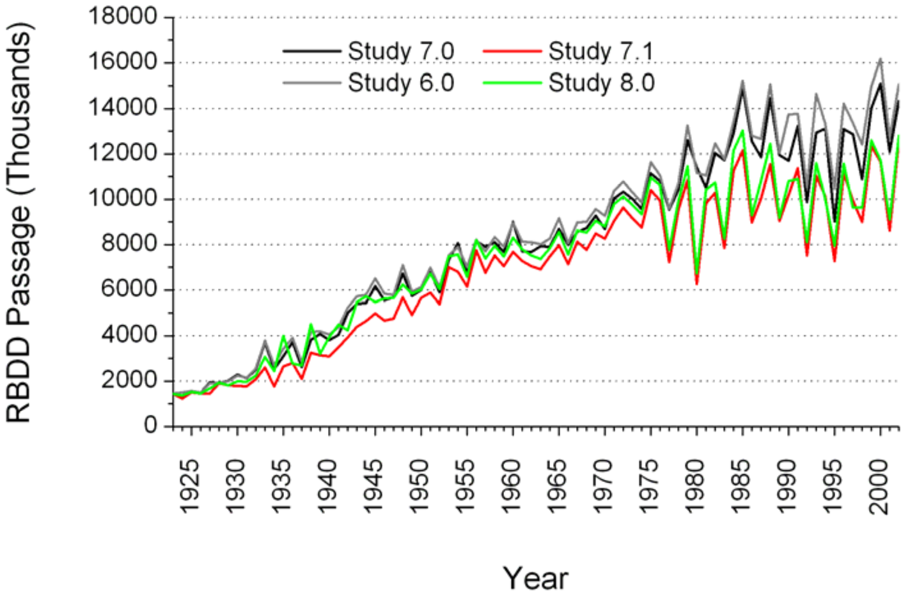

Figure 11-56. Annual Passage of winter-run Chinook Salmon juveniles past Red Bluff Diversion Dam (RBDD) under four OCAP water operation scenarios, 1923-2002 from IOS model. Study 7.0 represents current operations, 6.0 represents 2004 operations, 7.1 represents near future operations, and 8.0 represents future operations.

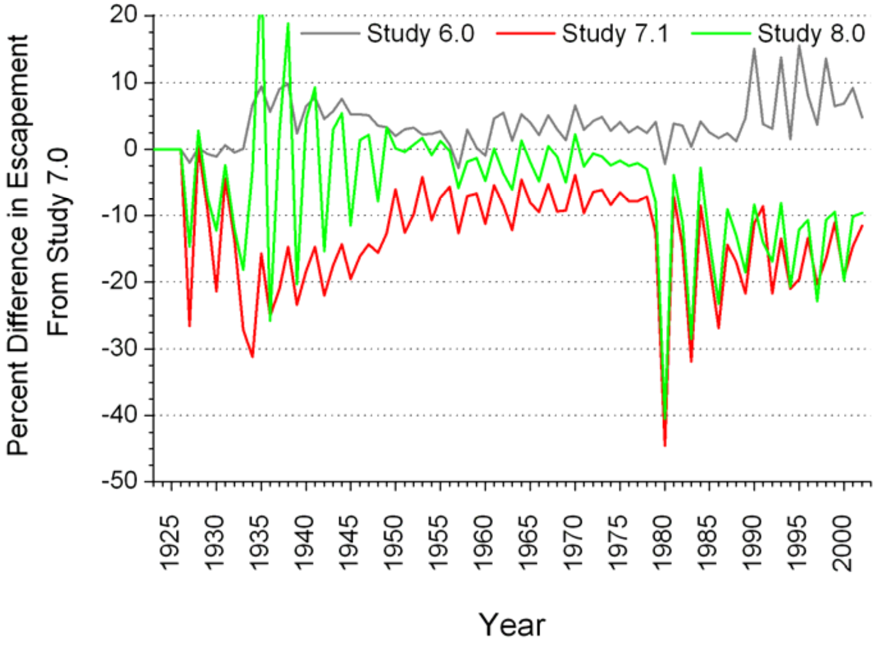

Figure 11-57. Annual percent difference in juvenile survival from emergence to RBDD from water operation scenario 7.0 for water operation scenarios 6.0, 7.1, and 8.0, 1923-2002 from IOS model. Study 7.0 represents current operations, 6.0 represents 2004 operations, 7.1 represents near future operations, and 8.0 represents future operations.

Annual differences in escapement from water operation scenario 7.0 follow different trends through time for each alternative water operation scenario (Figure 11-57). For study 6.0, the annual percent difference in escapement from study 7.0 increased from zero to near 10% in the late 1930’s, then fluctuated near 3% until 1990 when the escapement difference from study 7.0 began fluctuating above 10% and continued through 2002 (Figure 11-57). For study 7.1, the annual percent difference in escapement from study 7.0 fluctuates wildly in the early years from -25% to +20%, stabilizes near 0% from 1948-1978, then decreases and fluctuates around -15% for the remainder of the model run (Figure 3). For study 8.0, the annual percent difference in escapement from study 7.0 decreases to -30% by 1935, then rebounds and fluctuates around -8% until a large decrease in 1980 and fluctuation around -15% for the remainder of the model run (Figure 11-57). The annual differences from study 7.0 for studies 7.1 and 8.0 appear almost identical for years 1980 to 2002 (Figure 11-57).

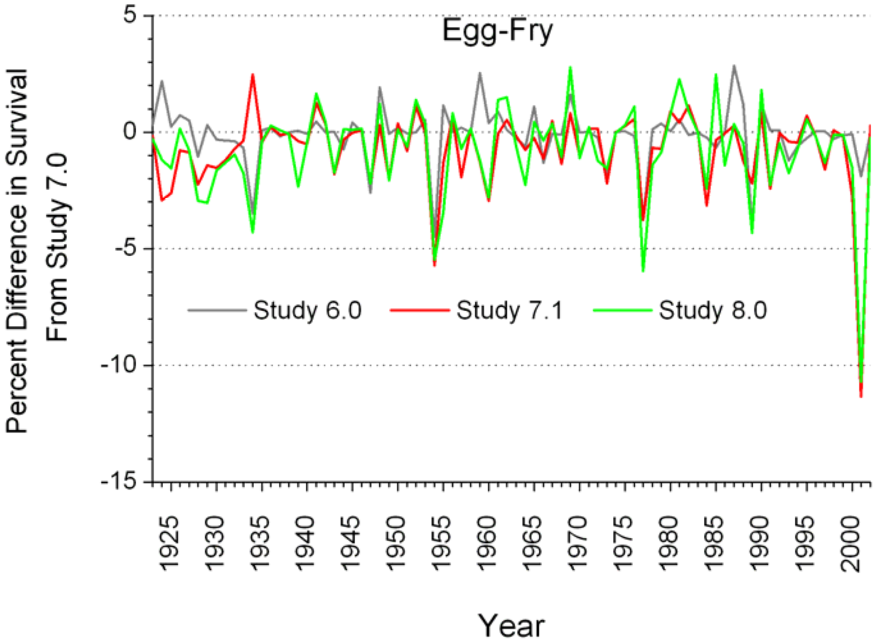

Figure 11-58. Annual percent difference in egg-fry survival from water operation scenario 7.0 for water operation scenarios 6.0, 7.1, and 8.0, 1923-2002 from IOS model. Study 7.0 represents current operations, 6.0 represents 2004 operations, 7.1 represents near future operations, and 8.0 represents future operations.

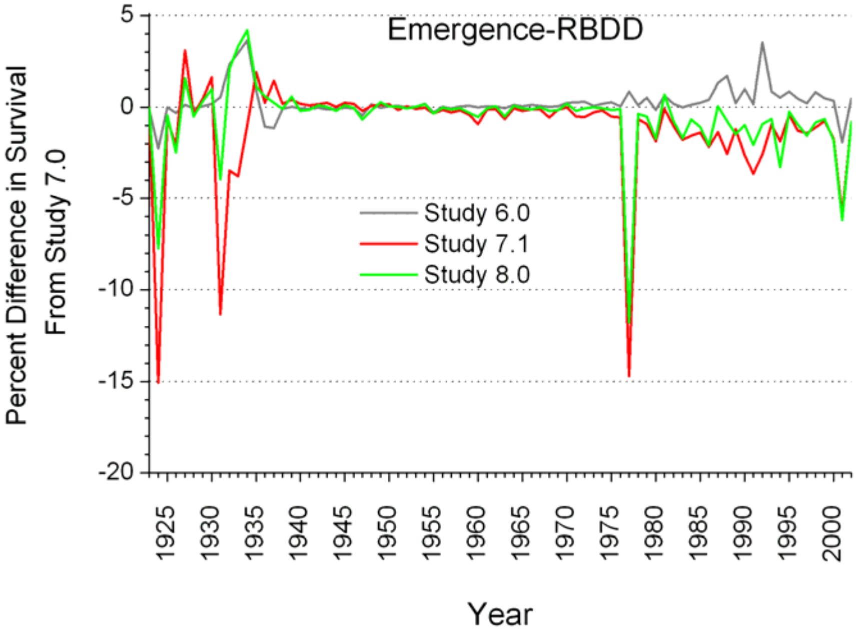

Figure 11-59. Annual percent difference in survival from emergence to RBDD from water operation scenario 7.0 for water operation scenarios 6.0, 7.1, and 8.0, 1923-2002 from IOS model. Study 7.0 represents current operations, 6.0 represents 2004 operations, 7.1 represents near future operations, and 8.0 represents future operations.

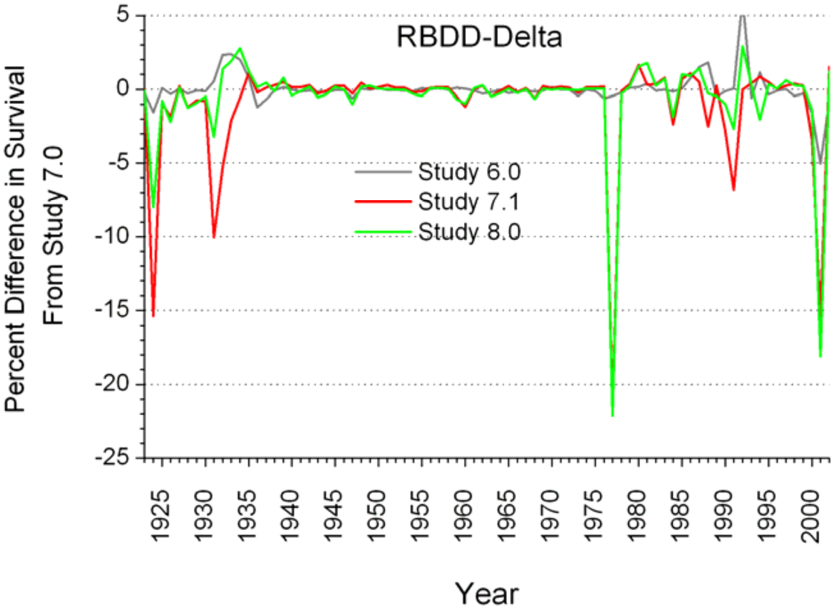

Figure 11-60. Annual percent difference in survival from RBDD to the Delta from water operation scenario 7.0 for water operation scenarios 6.0, 7.1, and 8.0, 1923-2002 from IOS model. Study 7.0 represents current operations, 6.0 represents 2004 operations, 7.1 represents near future operations, and 8.0 represents future operations.

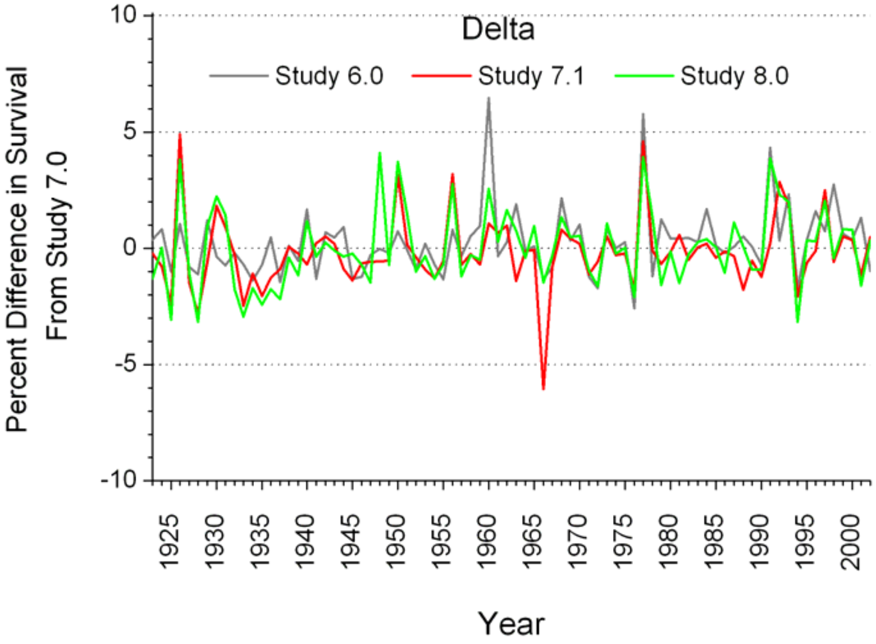

Figure 11-61. Annual percent difference in juvenile Delta survival from water operation scenario 7.0 for water operation scenarios 6.0, 7.1, and 8.0, 1923-2002 from IOS model. Study 7.0 represents current operations, 6.0 represents 2004 operations, 7.1 represents near future operations, and 8.0 represents future operations.

The observed phases in differences in annual escapement from study 7.0 for study 6.0 during the 80-year model run as seen in Figure 3 may be a result of in-river survival trends of juveniles seen in Figure 11-59 andFigure 11-60. The percent difference in survival from study 7.0 for study 6.0 for fry emergence to RBDD passage and RBDD to Delta arrival show an increase in years 1932-1934 (Figure 11-59; Figure 11-60). Because 96 percent of returning spawners are age-3 it is likely that this increase in juvenile in-river survival resulted in the increased difference from study 7.0 observed in adult escapement in the late thirties. Likewise, the later increase in differences in juvenile in-river survival from study 7.0 from 1987 through the late nineties correspond to an increase in differences in adult escapement from study 7.0 for years 1990-2002 (Figure 11-57; Figure 11-59; Figure 11-60).

The two observed differences in annual escapement from study 7.0 for studies 7.1 and 8.0 during the 80-year model run as seen in Figure 11-57 also appear to be predominantly a function of in-river survival trends of juveniles seen in Figure 11-59 andFigure 11-60. The percent differences in survival from study 7.0 for studies 7.1 and 8.0 for fry emergence to RBDD passage and RBDD to Delta arrival show a sudden, dramatic decrease in 1977 (Figure 11-59; Figure 11-60). Because 96 percent of returning spawners are age-3 it is likely that this large difference in juvenile in-river survival resulted in the large difference observed in adult escapement in 1980 (Figure 11-57). Likewise, the long stable period in differences in juvenile in-river survival from study 7.0 prior to 1977 correspond to a period of increasing stabilization in differences in adult escapement from study 7.0 during a similar time period (Figure 11-57; Figure 11-59; Figure 11-60).

However, unlike in-river juvenile survival, egg-fry survival and Delta survival do not appear to contribute strongly to the trend seen in the observed phases in differences in annual escapement from study 7.0 for studies 6.0, 7.1, and 8.0 during the 80-year model run (Figure 11-57;Figure 11-58;Figure 11-61). Despite large inter-annual variation, the percent differences in survival from study 7.0 for studies 6.0, 7.1, and 8.0 for egg-fry survival and Delta survival show no distinct trend through time (Figure 11-58; Figure 11-61).

Table 11-6. Average survival proportions under four OCAP water operation scenarios and percent difference in average survival from study 7.0 for studies 6.0, 7.1, and 8.0, 1923-2002 fro IOS model. . Study 7.0 represents current operations, 6.0 represents 2004 operations, 7.1 represents near future operations, and 8.0 represents future operations.

	Study 7.0	Study 6.0		Study 7.1		Study 8.0	
Survival	Avg. Survival	Avg. Survival	% Diff.	Avg. Survival	% Diff.	Avg. Survival	% Diff.
Egg-Fry	0.273	0.2731	-0.1	0.2713	-0.8	0.2712	-0.8
Emergence-RBDD	0.546	0.5472	0.3	0.5397	-1.1	0.5426	-0.6
RBDD-Delta Arrival	0.3288	0.3289	0.0	0.3256	-1.0	0.3269	-0.6
Delta	0.709	0.7104	0.3	0.7073	-0.2	0.7088	0.0
Overall	**0.0491**	**0.0492**	**0.1**	**0.0478**	**-2.7**	**0.0482**	**-1.8**

For study 6.0, the average survival values across all life stages and spatial locations were very similar to study 7.0 during the 80-year model run (Table 11-6). The overall average survival (egg deposition to Bay arrival) was 0.1% higher for study 6.0 than study 7.0 (Table 11-6). Studies 7.1 and 8.0 had slightly lower average survival values across all life stages and spatial locations than study 7.0 (except Delta survival for study 8.0) during the 80-year model run (Table 11-6).

We translated differences in average survival between study 7.0 and studies 6.0, 7.1 and 8.0 into average differences in the number of smolts entering the ocean and number of adult spawners to better evaluate the impact each water operation scenario may have on winter-run abundance in the Sacramento River. We found that study 6.0 produced on average 87,000 more smolts entering the ocean and ultimately 1,800 more adult spawners annually than study 7.0. Study 7.1 produced on average 300,000 fewer smolts entering the ocean and ultimately 6,200 fewer adult spawners annually than study 7.0. Study 8.0 produced on average 176,000 fewer smolts entering the ocean and ultimately 3,600 fewer adult spawners annually than study 7.0.

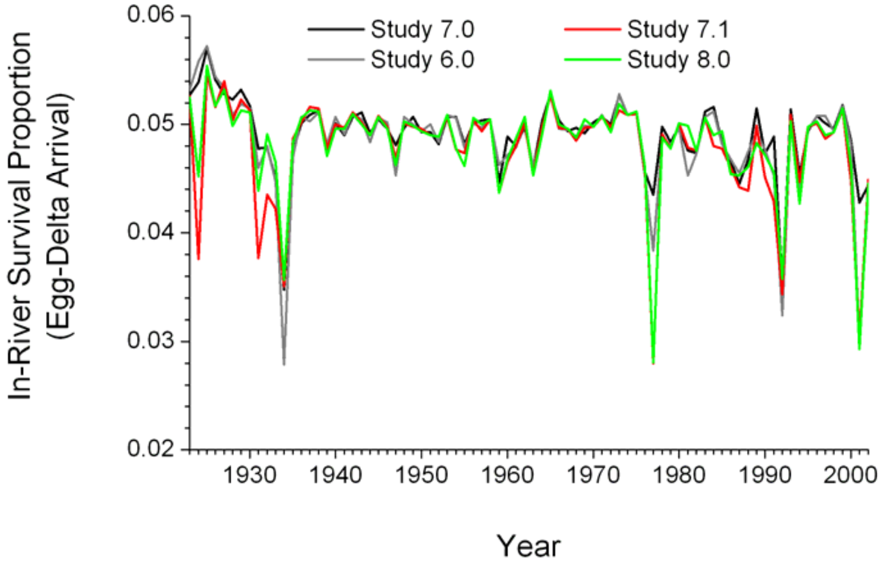

Figure 11-62. Annual winter-run Chinook salmon in-river survival (egg-Delta arrival) under four OCAP water operation scenarios, 1923-2002 from IOS model. Study 7.0 represents current operations, 6.0 represents 2004 operations, 7.1 represents near future operations, and 8.0 represents future operations.

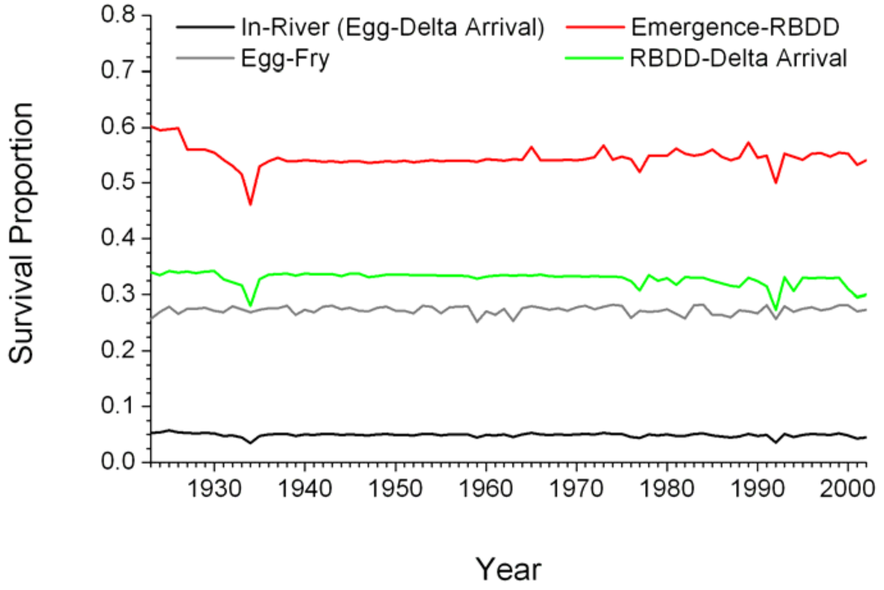

Figure 11-63. Annual winter-run Chinook salmon in-river survival (egg-Delta arrival) for water operation scenario 7.0 and its three components: 1) egg to fry, 2) fry emergence to RBDD, and 3) RBDD to Delta arrival, 1923-2002 from IOS model.

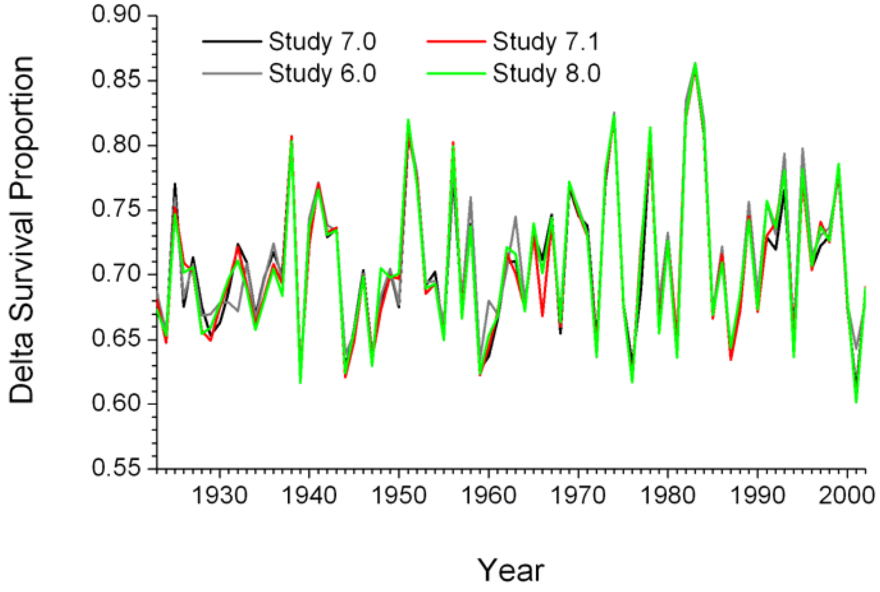

Figure 11-64. Annual winter-run Chinook salmon Delta survival under four OCAP operation scenarios, 1923-2002 from IOS model. Study 7.0 represents current operations, 6.0 represents 2004 operations, 7.1 represents near future operations, and 8.0 represents future operations.

PRE-SMOLTS

	Location													
Name	RM Start	RM End	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
Segment 1	302	271.3	▨	▨	▨	▨								
Segment 2	271.3	243		▨	▨	▨	▨							
Segment 3	243	220.4		▨	▨	▨	▨	▨						
Segment 4	220.4	171		▨	▨	▨	▨	▨	▨					
Segment 5	171	46.5			▨	▨	▨	▨	▨	▨				
Delta	N/A	N/A			▨	▨	▨	▨	▨	▨	▨	▨		

SMOLTS

	Location													
Name	RM Start	RM End	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
Segment 1	302	271.3												
Segment 2	271.3	243												
Segment 3	243	220.4						▨	▨					
Segment 4	220.4	171						▨	▨	▨	▨			
Segment 5	171	46.5						▨	▨	▨	▨			
Delta	N/A	N/A						▨	▨	▨	▨	▨		
Ocean Entry	N/A	N/A						▨	▨	▨	▨	▨	▨	

Figure 11-65. Monthly spatial distribution of winter-run Chinook salmon pre-smolts and smolts in the IOS Winter-Run Life Cycle Model during OCAP Biological Assesment model runs from IOS model.

Discussion

We observed an increasing trend in winter-run escapement through time for all four water operation scenarios. Although trends in escapement were similar for all studies, by the end of the 80-year model run escapement was higher for studies 7.0 and 6.0 than studies 7.1 and 8.0. It should be noted that escapement trends are sensitive to factors external to OCAP related environmental conditions. For example, increased harvest rate or loss of winter run hatchery contribution could easily lead to a different population trajectory. In evaluating effects of the proposed actions, differences between the four studies rather than absolute trends should be examined.

We found that study 6.0 produced on average 87,000 more smolts entering the ocean annually than study 7.0. Increased smolt production led to an average annual escapement increase of approximately 1,800 adult winter-run Chinook in years 1923-2002 for study 6.0. While studies 7.1 and 8.0 annually produced on average 300,000 and 176,000 fewer smolts than study 7.0, respectively. For studies 7.1 and 8.0, reduced smolt production led to an average annual escapement reduction of approximately 6,200 and 3,600 adult spawners, respectively.

Study 6.0 survival proportions across all life stages and spatial locations were almost identical to those observed in study 7.0. Increased abundance of smolts and spawning adults in Study 6.0 apparently results from slightly improved in-river juvenile survival. Unlike studies 7.1 and 8.0 (discussed below), water year type doesn’t appear to be driving the differences in survival between study 6.0 and 7.0.

Differences between study 7.0, and studies 7.1 and 8.0 appears to be driven largely by decreased in-river survival among juveniles during critically dry water years. The year with the largest difference in juvenile in-river survival between 7.0 and studies 7.1 and 8.0 was 1977. Adult escapement in 1980, 3 years later, exhibits the largest difference in adult abundance between study 7.0 and studies 7.1 and 8.0. 1977 is the most critically dry water year during the 80-year period of 1923-2002 (Table of Water Year Type). Our results suggest that winter-run abundance may exhibit a greater sensitivity to critically dry water years under water studies 7.1 and 8.0 relative to 7.0.

Conclusion

The IOS model was designed to serve as a quantitative framework for estimating the long-term response of Sacramento River Chinook populations to changing environmental conditions (e.g. river discharge, temperature, habitat quality at a reach scale). Life cycle models are well-suited for such evaluations because they integrate survival changes at various life stages, across multiple habitats, and through many years.

In applying the IOS winter run Chinook model to predicted environmental conditions under four alternative operational scenarios, we found that escapement increased for all four studies. Escapement for study 6.0 was similar to study 7.0 throughout the 80-year model run, with average annual escapement slightly higher for study 6.0 (Figure 11-57). However, escapement for studies 7.1 and 8.0 was typically lower than study 7.0 by approximately 15 percent (Figure 11-57). Winter-run Chinook salmon abundance demonstrated considerable sensitivity to critically dry water years for studies 7.1 and 8.0 relative to study 7.0. The primary mechanism for this observed difference appears to have been reduced survival of juvenile winter-run during critically dry water years for studies 7.1 and 8.0.

While differences in survival between operational scenarios were seemingly minimal, (e.g. seeTable 11-6), the IOS model effectively integrates these incremental effects over many salmon generations. This long-term, life cycle approach indicates that episodic reduction in juvenile survival (particularly in critically dry years) leads to an average annual reduction of 6,200 adult spawners for 7.1 and 3,600 for 8.0 (relative to study 7.0). The effect of this reduced escapement through an 80-year period of simulation is sensitive to effects external to the proposed action. For example, increased harvest rate or loss of winter run hatchery supplementation would exacerbate the effects reported here.

In evaluating effects of the proposed actions, differences between the four studies should be favored over analysis of absolute trends. It should also be noted that IOS model results reported here do not include confidence intervals or other measures of uncertainty. As such, quantitative results should be interpreted cautiously, with preference given to general trends rather than specific, numeric values.

Red Bluff Diversion Dam

Reclamation plans to continue the current May 15-September 15, gates lowered period at RBDD under current and near future operations and extend to a ten month gates out period under future operations. The gates will be in a closed position during the tail end of the winter–run upstream migration and during much of the upstream migration season for spring–run. Approximately 15 percent of winter–run and 70 percent of spring–run that attempt to migrate upstream past RBDD may encounter the closed gates (TCCA and Reclamation 2002). This is based on run timing at the fish ladders (ie. after the delay in migration has occurred) when the gates were lowered year round so a delay is built into the run timing estimate. The percentage, especially for winter-run Chinook is likely lower than 15 percent. Over 90 percent of the spring–run population spawns in tributaries downstream of RBDD. Most of the spring–run that do pass RBDD pass before May 15. The downstream tributary runs never encounter the gates. When the gates are closed, upstream migrating Chinook salmon have to use the fish ladders to get past RBDD. Vogel et al (1988) found the average time of delay for fish passing through RBDD was three to13 days depending on the run. Spring–run had the highest average delay but that mean value was influenced by a single fish that stayed downstream of the dam for 50 days. Recent radio tagging data indicate an average delay of 21 days (TCCA and Reclamation 2002). Winter-run consistendly experienced the greatest delays, likely due to the higher winter discharge rates making fish ladder entrances harder to find. Delay for spring-run Chinook was influenced by the fact that the area below RBDD is a suitable over-summering habitat in normal and wetter years. Spring-run tend to “hole up” and hang out for long periods of time during the pre-spawning season in the summer months. Although studies have shown that fish do not immediately pass the fish ladders, the extent that delayed passage affects ultimate spawning success is unknown. Some Chinook immediately pass RBDD when they arrive. For example, in 2008, 18, 36, and 14 Chinook salmon passed the fish ladders on May 15, 16, and 17 respectively, after the gates were lowered on May 15. The five year average is passage of 219 Chinook on those days (Red Bluff Fish and Wildlife Office fish passage monitoring data).

Average monthly water temperatures at Red Bluff would be maintained at suitable levels for upstream migrating and holding Chinook through July of all years (Figure 11-66). Fish delayed by

RBDD should not suffer high mortality due to high temperatures unless warmer than average air temperatures warm the water significantly above the monthly average temperatures predicted by the model. Average monthly water temperatures during August and September could be greater than 60 °F in about 10 percent of years. Study 7.1 shows the highest temperature in these 10% of years. During these years delays at RBDD would be more likely to result in mortality or cause sufficient delay to prevent migration into tributaries. The lower reaches of small tributaries can become too warm for salmon passage in mid-summer of some years. Effects to fish from warmer temperatures later in the summer when they are delayed below the dam would affect primarily fall–run fish. This is much less of a problem since the installation of the Shasta temperature control device. Elevated temperatures downstream of RBDD were the big problem for delayed fish prior to improvements in temperature control capability. The proportion of the spring–run and winter–run populations that encounter closed gates is small so effects of delays at RBDD during these dry years would not be as great as the population effect of higher than optimal spawning and incubation temperatures in critically dry years.

The ten month gates out period under future operations would extend from Labor Day to July 1 with a seven day closure over Memorial Day. This period would eliminate the potential migratory delay to upstream migrating spring-run Chinook salmon and winter-run Chinook salmon, improving migratory conditions for a small proportion of the adult winter-run population and the proportion of the spring-run population that utilizes habitats upstream of RBDD (about 10% of the Central Valley spring-run population).

The spring–run population upstream of RBDD has not exhibited patterns of abundance similar to the tributaries from what appears to have been a down cycle that should have ended shortly after the by-passes at Shasta Dam for temperature control began (1987) and shortly before the full eight months gates out operation began (1995). During this same period, spring–run downstream of the RBDD have increased about 20 fold, suggesting that some upstream event other than the RBDD operations have caused the decline in the spring–run population (TCCA and Reclamation 2002). This may be an artifact of a change in sampling protocols, but remains an unknown. It is also possible that some spring-run destined for the upper Sacramento River get delayed at RBDD so head back downstream and enter tributaries to spawn.

Early migrating steelhead encounter the lowered gates at RBDD. Approximately 84 percent of adult steelhead immigrants pass RBDD during the gates-out period based on average run timing at RBDD. Although the historical counts of juvenile steelhead passing RBDD do not differentiate steelhead from resident rainbow trout, approximately 95 percent of steelhead/rainbow trout juvenile emigrants pass during the gates-out period based on historical emigration patterns at RBDD (DFG 1993, as summarized in FWS 1998). Effects of RBDD operation on steelhead run timing would be unchanged from the current condition. About 16 percent of steelhead would still be delayed until the future gate operations are implemented when the gates would come out a week or two earlier. Because this is the early part of the steelhead run, well before the spawning period, and temperatures are generally suitable for holding below RBDD we believe that steelhead that do not use the ladders hold successfully until the gates are raised and the continue their upstream migration. No mortality to adult steelhead is expected to occur due to gate operations.

Fry, juveniles, and smolts that pass RBDD when the gates are lowered are more susceptible to predation below the gates because pike minnows and striped bass congregate there. The predation situation at RBDD has improved since gate operations were changed so that not as many predator species now stop at RBDD during their upstream migrations (CH2M Hill 2002). The predation situation as it is now would likely continue through near future operations but under the 10 month gates out period the amount of time predators would be attracted to the gates in place situation would be reduced by 58 percent.

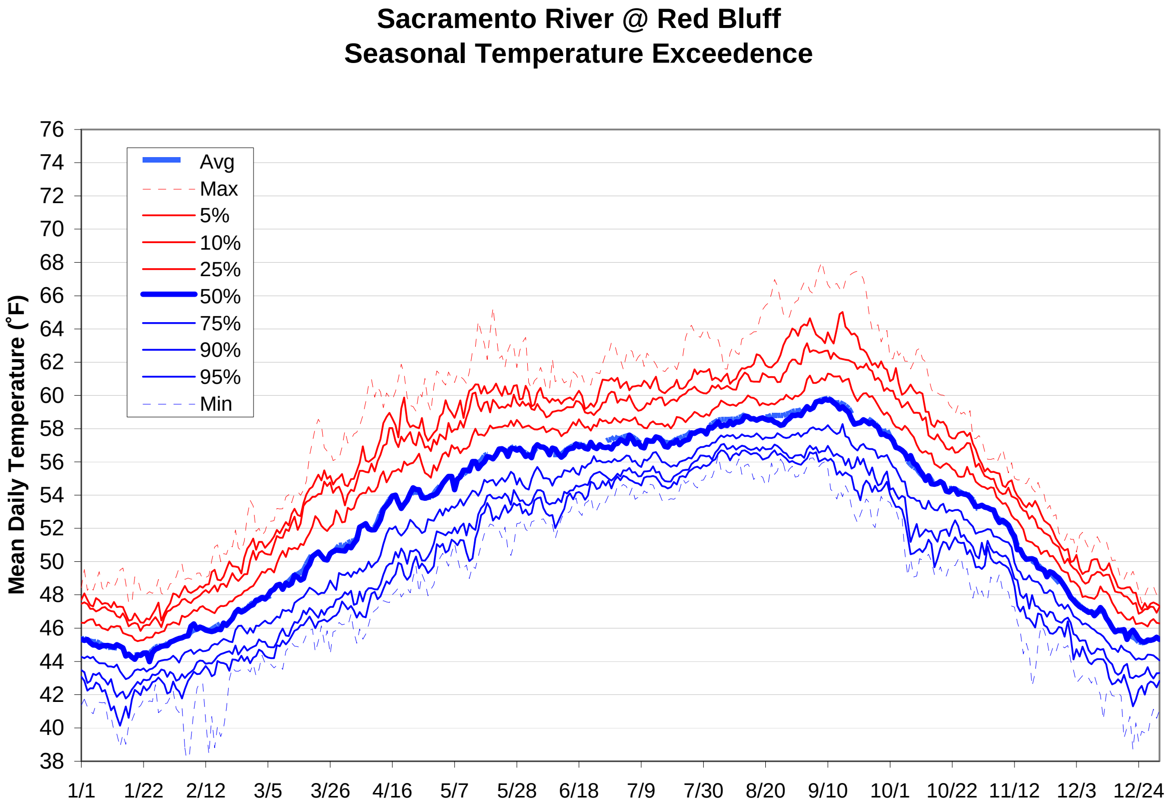

Figure 11-66. Water temperature exceedence at Red Bluff under study 8.0 from CalSim-II and weekly temperature modeling results.

Green Sturgeon

The Sacramento River provides spawning, adult holding, foraging, and juvenile rearing habitat for green sturgeon. Specific spawning areas have not been identified but some do spawn upstream of Red Bluff Diversion Dam as evidenced by catches of green sturgeon in rotary screw traps at RBDD. Acoustically tagged green sturgeon were detected upstream of RBDD in 2007. Green sturgeon water temperature requirements are less stringent than winter-run Chinook salmon. Water temperatures greater than 63 ºF can increase mortality of sturgeon eggs and larvae (PSMFC 1992). Effects to green sturgeon life stages in the Sacramento River are believed to be covered by operating to target water temperatures for winter-run Chinook. During the green sturgeon incubation period, temperatures at Hamilton City, about 100 miles below Keswick Dam, would be maintained below 63 °F. Water temperatures are not likely to adversely affect green sturgeon in the reaches of the river where temperature control operations are most effective.

Green sturgeon upstream spawning migrations occur near the time the Red Bluff gates are lowered for the summer irrigation season on May 15. The gates of the dam are lowered during the last third of the spawning period. Most sturgeon make it past before gate closure but some do get blocked and congregate downstream of the dam as occurred in May of 2007 and 2008. During an emergency closure to meet high irrigation demands, ten green sturgeon carcasses were found downstream of RBDD between May 18 and early June in 2007. These sturgeon may have been killed when they attempted to pass downstream past the dam but were lodged in gate openings of a smaller height than the depth of their bodies. Reclamation worked with other agencies to review the gate operation protocol to reduce this type of effect. The new protocol is for all gates in operation to be open to a minimum height of 12 inches to reduce the possibility of injury should adult green sturgeon pass beneath the gates. There would still be turbulence below the gates after passage that could injure sturgeon, but the chance for impingement in the gates when sturgeon are swept under by high velocities is reduced. The gates would still pose a barrier to upstream migrating green sturgeon because velocities under the gates are too high for sturgeon passage. White sturgeon passage through fish ladders on the Columbia River has been documented (Parsley et al 2007) but none has been documented at the Red Bluff ladders. Sturgeon that are blocked would need to spawn in habitats downstream of the dam. Green sturgeon have been documented holding and spawning in large pools downstream of RBDD. Reclamation tracked acoustically tagged green sturgeon during 2007 and identified three that passed the gates during the gates closed period (Table 11-7). This was prior to the time the new 12-inch minimum gate opening protocol was developed. The new protocol should reduce the chance of injury to adult green sturgeon in the future. The chance of injury would be reduced because the body depth of green sturgeon is less than 12 inches. They may be swept under the gates in the high velocity water but should not become stuck due to gate opening height being too small. Monitoring is underway to better quantify effects of RBDD on adult green sturgeon. Numerous adult green sturgeon were present in the river during 2008 monitoring and no gate related mortality has been detected to at least the end of July. We conclude the new protocol will reduce adverse effects on adult green sturgeon.

The ten month gates out period in the future will remove the barrier to upstream migrating green sturgeon and remove the potential for injury to a majority the downstream migrating adult green sturgeon.

Table 11-7. Acoustic tagged adult green sturgeon that passed downstream under the RBDD gates in 2007 and height of opening under gates in feet.

GS #	Date of Passage	Gate Opening (feet)										
		No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11
#3	May 18	1.2	0.2	1.1	0.2	0.2	0.2	0.1	0.3	1.2	0.4	1.2
#2	May 21	1.1	0.3	1.1	0.3	0.3	0.3	0.2	0.2	1.2	0.5	1.5
#1	June 10	1.1	0.8	0.9	0.7	0.0	0.0	0.0	0.9	0.9	0.9	1.7

Red Bluff Research Pumping Plant

The Red Bluff Research Pumping Plant will continue to be operated to supply water to the Tehama-Colusa and Corning Canals when the RBDD gates are raised. Reclamation monitors fish entrainment at the downstream side of three of the four pumps in operation. The fourth pump which was installed in the spring of 2006 has no infrastructure for monitoring entrainment. We used this entrainment data for the three previous existing pumps to estimate total entrainment since operation and monitoring of the pumps began in 1997. Data on amount of pumping time for all four pumps and amount of time entrainment monitoring occurred was summed each year to determine the proportion of the time entrainment was monitored. The sum of fish entrained was divided by proportion of pumping time that monitoring occurred to estimate total entrainment each year. Table 11-8, Table 11-9, and Table 11-10 show the estimates of entrainment and mortality of winter-run, spring-run, and steelhead respectively. Chinook were assigned to runs based on size at age data. Borthwick and Corwin (2001) found that the average mortality of Chinook salmon entrained through the pumps was 0.9 percent during short trials so this percentage was used to estimate mortality for each year. Higher mortality occurs when entrainment is monitored for longer periods of time (eg 24 hours) but this is due to the presence of sampling gear and the entrainment of debris in the holding tanks which does not occur during normal pumping operations. Future pumping operations with all four pumps will be similar so we expect a similar range of fish entrainment and mortality as occurred in 1997 through 2007. Entrainment will vary with the population of fish in the river. Fish that pass through the pumps return to the river through the same passage used by fish diverted from the canal when RBDD gates are lowered.

Four juvenile sturgeon have been captured since monitoring began. These occurred in May and June of 1997 (2 sturgeon), 1998, and 1999. These were all captured alive. Due to the low number captured no estimate of total sturgeon entrainment was made. Future impacts of the pumps to green sturgeon are likely to be similarly low.

It should be noted that during the initial years of pump evaluations the pumps were run during the winter when water is generally not being diverted to supply the water needs of the Tehama-Colusa and Corning canals. Pumps will generally not be run during times of the year when water is not needed to supply the canals. They would only be run to conduct additional effects evaluations but none are currently planned.

Borthwick and Corwin (2001) estimated the proportion of fish in the river that were diverted compared to the proportion of water diverted. The proportion of fish diverted was consistently less than the proportion of river flow diverted and was similar to the results of Hanson (2001). This is likely due to the location of the pump intakes which are near the bottom of the river.

Table 11-8. Estimated entrainment and mortality of winter-run sized Chinook salmon at Red Bluff Pumping Plant pumps.

Winter Run sized fish

Month

	1	2	4	7	8	9	10	11	12	Total	Mortality
1997	0	2	0	0	0	400	304	149	6	862	**8**
1998	0	0	2	25	161	753	227	17	0	1,186	**11**
1999	0	0	0	0	0	330	295	5	0	630	**6**
2000	0	0	0	0	0	144	148	0	0	292	**3**
2001	7	0	0	0	0	751	731	0	0	1,488	**13**
2002	0	0	0	0	0	544	719	0	0	1,262	**11**
2003	0	0	0	0	0	1,558	981	0	0	2,539	**23**
2004	0	0	0	0	0	2,886	232	0	0	3,119	**28**
2005	0	0	0	0	0	2,123	1,381	0	0	3,504	**32**
2006	0	0	0	0	29	2,984	1,809	0	23	4,845	**44**
2007	0	0	0	0	0	329	105	22	0	456	**4**
Total	**7**	**2**	**2**	**25**	**190**	**12,803**	**6,931**	**194**	**30**	**20,184**	**182**

Table 11-9. Estimated entrainment and mortality of spring-run sized Chinook salmon at Red Bluff Pumping Plant pumps.

Spring Run sized fish

Month

	1	2	3	4	5	10	11	12	Total	Mortality
1997	0	2	4	243	0	0	115	290	654	**6**
1998	2	0	21	2	0	6	25	0	57	**1**
1999	5	0	5	0	0	3	0	0	13	**0**
2000	117	0	19	47	4	0	0	0	187	**2**
2001	0	0	0	75	0	0	0	0	75	**1**
2002	0	0	0	87	0	0	0	0	87	**1**
2003	0	0	0	6	0	112	0	0	118	**1**
2004	0	0	0	70	0	0	0	0	70	**1**
2005	0	0	0	271	15	5	0	0	291	**3**
2006	0	0	0	0	0	12	0	17	29	**0**
2007	7	22	37	247	15	7	150	0	486	**4**
Total	**133**	**27**	**90**	**1,052**	**38**	**155**	**301**	**319**	**2,115**	**19**

Table 11-10. Estimated entrainment and mortality of steelhead at Red Bluff Pumping Plant pumps.

Steelhead
Month

	1	2	3	4	5	6	7	8	9	10	11	Total	Mortality
1997	0	11	0	4	4	6	2	4	9	2	15	57	**1**
1998	47	0	6	0	2	4	2	13	4	2	0	81	**1**
1999	0	3	5	0	8	3	3	0	33	0	0	54	**0**
2000	171	0	4	4	0	0	0	0	0	0	0	179	**2**
2001	0	0	0	41	48	0	0	0	0	7	0	96	**1**
2002	0	0	0	40	0	0	0	0	0	7	0	47	**0**
2003	0	0	0	12	12	0	0	0	12	12	0	50	**0**
2004	0	0	0	19	0	0	0	0	14	5	0	37	**0**
2005	0	0	0	24	73	0	0	0	0	0	0	97	**1**
2006	0	0	0	0	151	0	0	6	12	0	0	169	**2**
2007	0	52	0	30	15	0	0	0	7	0	7	112	**1**
Total	**218**	**66**	**15**	**175**	**313**	**13**	**7**	**23**	**92**	**35**	**22**	**978**	**9**

It is concluded that future operation of the pumps will continue to have the same level of effect on entrainment.

Estimated Loss from Unscreened Diversions on the Sacramento River

Hansen (2001) studied juvenile Chinook salmon (mean length = 102 mm) entrainment at unscreened diversions during June at the Princeton Pumping Plant (river mile 164.4) and at the Wilkins Slough Diversion (river mile 117.8). The Princeton Pumping Plant has a peak diversion capacity of 290 cfs through four 36 inch diameter pipes and one 30 inch diameter pipe. Maintenance flows are typically 120 to 180 cfs. He found that the percent of the released hatchery Chinook salmon entrained was 0.05 to 0.07 times the percent of the Sacramento River flow diverted for the two sites respectively. We use an average of percent of juveniles diverted to be 0.06 times the percentage of the Sacramento River flow diverted for calculating entrainment into unscreened diversions. We used the average juvenile Chinook salmon (for each run) and rainbow trout (resident and anadromous forms not differentiated) passage past Red Bluff Diversion Dam (Martin et al 2001 and Gaines and Martin 2002) for the brood years 1995 through 1999 as the number and timing of winter run present in the Sacramento River. All of the 123 unscreened diversions (not counting those in the process of being screened) are downstream of Red Bluff Diversion Dam (RBDD). Average Sacramento River flow at Red Bluff from CalSim-II modeling study number eight was used for the river flow past the diversions. We did not calculate a separate estimate for each study because the calculation is not precise enough to logically separate out differences in number of fish diverted from the similar Sacramento River flows between studies. Many diversions on the Sacramento River are located over 100 miles downstream of Red Bluff Diversion Dam. There is some unquantified mortality that occurs within this reach and a timing delay between the time fish pass RBDD and when they reach the diversions. This unquantified mortality and timing delay was not factored into this anlaysis.

Timing and quantity of diversions was based on the monthly average of historic diversions from Sacramento River contractors with currently unscreened diversions, 1964 through 2003 (Table 11-11).

Table 11-11. Timing and quantity of diversions based on past averages.*

Sacramento Diversion Timing						
		Project			**Base**	
	Percent	**amount, acre-ft**	**cfs**	**Percent**	**amount, acre-ft**	**cfs**
April	0.0%	20	0	11.9%	40,475	680
May	0.0%	3	0	27.0%	91,460	1,487
June	8.8%	11,264	189	26.9%	91,252	1,534
July	34.7%	44,310	721	18.6%	63,030	1,025
August	44.5%	56,845	924	11.0%	37,348	607
September	11.7%	14,922	251	2.2%	7,450	125
October	0.3%	364	6	2.4%	8,124	132

*Project diversions are the amounts of water diverted under contract with Reclamation. Base diversions are water rights diversions not associated with Reclamation.

Average summer water temperatures may be somewhat suitable down to Butte City. They are projected to average about 67 °F in June through August. Seventeen diversions are between RBDD and Butte City and probably pose the highest risk to winter-run based on location and timing of diversions.

Juvenile salmonid passage by run past RBDD is in Table 11-12 below.

Table 11-12. Timing and passage of juvenile salmonids past Red Bluff Diversion Dam. The line “% of year total” refers to the percent of the fish for the entire year that pass RBDD during that month.

Juvenile Emigration Data, Sacramento River at RBDD

Numbers of winter-run Chinook salmon passing RBDD by month, Martin et al 2001.

Brood Year	April	May	June	July	Aug	Sep	Oct	Total
BY 95	236	0	0	751	81,804	1,147,684	299,047	1,529,522
BY 96	1,378	272	0	903	18,836	228,197	24,226	273,812
BY 97	732	0	0	18,584	134,165	925,284	410,781	1,489,546
BY 98	1,754	262	0	184,896	1,540,408	2,128,386	404,275	4,259,981
BY 99	1,092	375	0	8,186	91,836	404,378	163,482	669,349
Average	**1,038**	**182**	**0**	**42,664**	**373,410**	**966,786**	**260,362**	**1,644,442**
% of year total	0.1%	0.0%	0.0%	2.2%	19.5%	50.4%	13.6%	85.7%

Numbers of fall-run Chinook salmon passing RBDD by month, Gaines and Martin 2002.

Brood Year	April	May	June	July	Aug	Sep	Oct	Total
BY 94	4,172,651	672,926	194,843	42,564	21,463	12,976	2,125	5,119,548
BY 95	692,012	340,490	143,832	82,885	19,634	3,906	721	1,283,480
BY 96	600,977	198,705	264,400	111,830	41,309	6,287	385	1,223,893
BY 97	2,667,508	200,945	588,586	265,092	97,305	5,958	0	3,825,394
BY 98	471,158	826,624	767,144	613,884	181,162	49,401	683	2,910,056
Average	**1,720,861**	**447,938**	**391,761**	**223,251**	**72,175**	**15,706**	**783**	**2,872,474**
% of year total	8.8%	2.3%	2.0%	1.1%	0.4%	0.1%	0.0%	14.7%

Numbers of late fall-run Chinook salmon passing RBDD by month, Gaines and Martin 2002.

Brood Year	April	May	June	July	Aug	Sep	Oct	Total
BY 94								
BY 95	65,895	15,975	1,688	1,974	5,213	10,061	7,295	108,101
BY 96	13,698	3,450	1,283	2,390	2,762	4,445	5,133	33,161
BY 97	19,909	8,071	14,037	29,711	47,684	32,880	12,632	164,924
BY 98	241,824	59,444	34,077	32,281	94,981	47,958	20,998	531,563
BY 99	131,113	63,611	16,968	56,119	110,316	79,303	49,215	506,645
Average	**94,488**	**30,110**	**13,611**	**24,495**	**52,191**	**34,929**	**19,055**	**268,879**

Numbers of spring-run Chinook salmon passing RBDD by month, Gaines and Martin 2002.

Brood Year	April	May	June	July	Aug	Sep	Oct	Total
BY 94								
BY 95	49,304	6,105	0	0	0	0	9,056	64,465
BY 96	136,766	3,889	404	99	0	0	491	141,649
BY 97	70,874	10,762	482	0	0	0	1,207	83,325
BY 98	20,608	3,004	110	129	0	0	26,394	50,245
BY 99	281,808	19,374	466				20,414	322,062
Average	**111,872**	**8,627**	**292**	**57**	**0**	**0**	**11,512**	**132,349**
% of year total	21.7%	1.7%	0.1%	0.0%	0.0%	0.0%	2.2%	25.7%

Numbers of O.mykiss passing RBDD by month, Gaines and Martin 2002.

Brood Year	April	May	June	July	Aug	Sep	Oct	Total
BY 94								
BY 95	5,626	39,102	2,541	2,230	22,418	34,485	1,400	107,802
BY 96	2,524	4,412	3,098	1,342	8,012	34,164	3,109	56,661
BY 97	8,183	6,796	4,951	3,686	5,282	1,758	632	31,288
BY 98	5,083	11,632	4,777	3,647	12,889	10,432	1,156	49,616
BY 99	1,571	8,040	4,465	5,092	12,810	11,605	1,146	44,729
Average	**4,597**	**13,996**	**3,966**	**3,199**	**12,282**	**18,489**	**1,489**	**58,019**

Number of fish diverted was calculated for each of the 123 unscreened diversions and then the fish numbers summed for an overall entrainment estimate. No specific information on the configuration of the diversion points relative to fish habitat was used in the entrainment estimates. Only the amount of water diverted by month was used. Entrainment separated out between project water supply diversions and base water supply diversions. The project water diversions are the ones under contract with Reclamation. Base supply is water rights water. Entrainment for the diversions upstream of Butte City is estimated to be 86 winter run from the project supply and 23 winter run from the base supply. This is the primary area where pumping occurs when winter run are likely to be present in the vicinity of the pumps because water temperatures are suitable. Water temperatures at the diversion sites may be warm for salmonids (Figure 11-67) during the summer months but this was not figured into the analysis. Past water temperature information at the sites was not available.

O. mykiss use slightly different habitats than Chinook so the past entrainment monitoring of Chinook is probably not that representative of O. mykiss, but we used it in the absence of other data. We expect that steelhead would be diverted at a lower rate than Chinook salmon because diversions are often in slack water areas where steelhead are less inclined to inhabit than Chinook.

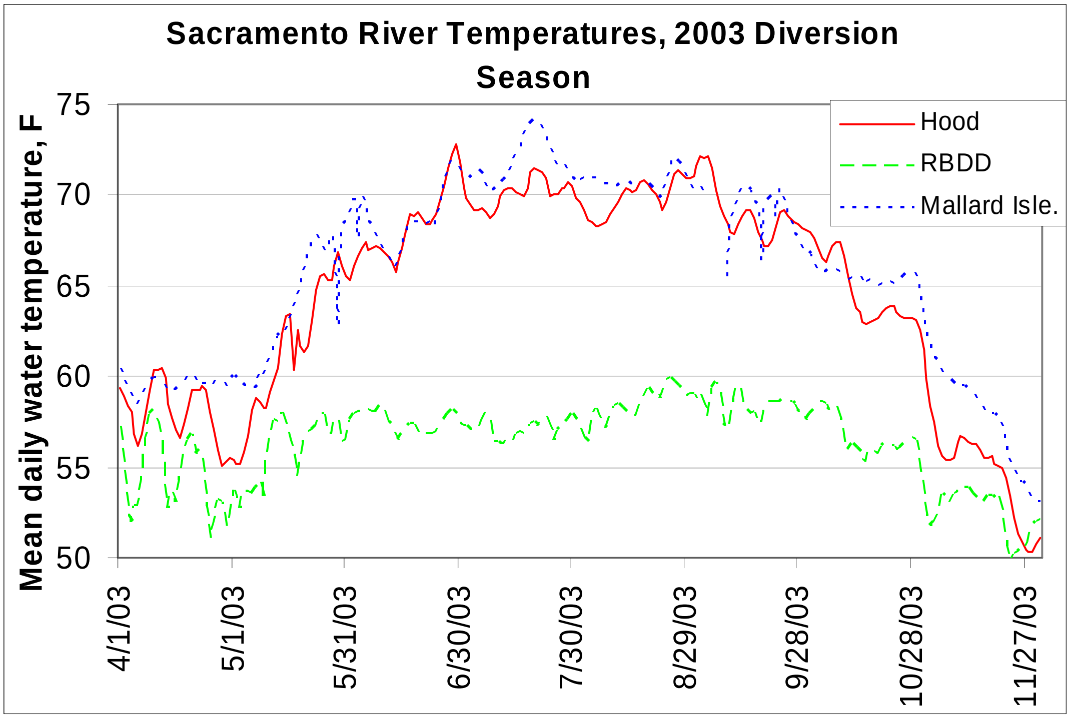

Figure 11-67. Water temperatures at Sacramento River temperature monitoring stations.

Total winter run entrainment for all diversions assuming timing of fish presence is the same in the lower river as at RBDD is estimated to be 4,455 from project pumping and 2,985 from base supply pumping, for a total of 7,440 winter run (Table 11-13). This is very likely an over estimate because the lower river is too warm through much of the summer for juvenile salmon rearing. The estimated entrainment contains six older juveniles (April through June), all from base water deliveries. The rest are fry entrained during July through October. One diversion at approximately river mile 88 accounted for 65 percent of the entrainment estimate.

The total estimated entrainment into unscreened diversions represents 0.37 percent of the estimated winter run juvenile passage past RBDD.

Spring run entrainment for all diversions is estimated to be 537 individuals with one from project water diversions and 536 from base diversions. 98 percent of the spring run diverted are estimated to be older juveniles occurring in April, May, and June.

An estimated 393 of O.mykiss would be entrained with 32 percent of them from project supply.

Table 11-13. Estimated entrainment of salmonids in unscreened diversions in the Sacramento River. Project water refers to water supplied by Reclamation and base water is water rights water.

Sac Flow @ Red Bluff, cf	10,404	9,435	11,110	13,082	9,683	6,730	7,013	
Project Water	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**Total**
% of flow diverted	0.0%	0.0%	1.7%	5.5%	9.5%	3.7%	0.1%	
% of fish diverted	0.0%	0.0%	0.1%	0.3%	0.6%	0.2%	0.0%	
Number of Fish Entrained								
Winter Run	0	0	0	141	2,139	2,162	13	4,455
Spring Run	0	0	0	0	0	0	1	1
O. mykiss	0	0	4	11	70	41	0	126
Fall Run	3	0	400	738	413	35	0	1,590
Late Fall Run	0	0	14	81	299	78	1	473
Base Water								
	April	May	June	July	August	September	October	
% of flow diverted	6.5%	15.8%	13.8%	7.8%	6.3%	1.9%	1.9%	
% of fish diverted	0.4%	0.9%	0.8%	0.5%	0.4%	0.1%	0.1%	
Number of Fish Entrained								
Winter Run	4	2	0	201	1,405	1,079	294	2,985
Spring Run	439	82	2	0	0	0	13	536
O. mykiss	18	132	33	15	46	21	2	267
Fall Run	6,750	4,237	3,245	1,050	272	18	1	15,572
Late Fall Run	371	285	113	115	196	39	22	1,140
Total (Project + Base)								
	April	May	June	July	August	September	October	
% of flow diverted	6.5%	15.8%	15.5%	13.3%	15.8%	5.6%	2.0%	
% of fish diverted	0.4%	0.9%	0.9%	0.8%	0.9%	0.3%	0.1%	
Number of Fish Entrained								
Winter Run	4	2	0	342	3,545	3,241	308	7,440
Spring Run	439	82	3	0	0	0	14	537
O. mykiss	18	132	37	26	117	62	2	393
Fall Run	6,754	4,237	3,645	1,788	685	53	1	17,162
Late Fall Run	371	285	127	196	495	117	23	1,613

Green Sturgeon at Sacramento River Sites

We estimated potential take of green sturgeon by examining screw trap catches of sturgeon at GCID and RBDD (Table 11-14, Table 11-15, and Figure 11-68). Most of the sturgeon captured in these traps are young of the year and too small to identify to species. Based on a sample of these sturgeon that have been raised to an identifiable size they appear to be mostly green sturgeon. White sturgeon spawn mostly downstream of GCID. The GCID screw trap at river mile 205 is the closest to many of the diversions so the catches from that trap were used to estimate potential entrainment. This screw trap has not been calibrated for expanding catch to total passage. We used an efficiency of 0.5 percent at the GCID screw trap for green sturgeon.

The total estimated entrainment of green sturgeon is 199 green sturgeon (Table 11-16). We used 0.06 times the percentage of the Sacramento River flow diverted (same as for Chinook) as the percentage of the green sturgeon that would be entrained when passing the monitored diversion sites. This estimate is largely dependent on an unknown screw trap efficiency and percentage of sturgeon diverted relative to flow diverted.

Table 11-14. Rotary screw trap catches of sturgeon at GCID, 1994-2005.

					Sturgeon in CDF&G Screw Trap at GCID										
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Average	Median	Std Dev
January	0	0	0	0	0	0	0	1	0	0	0	0	0.1	0.0	0.3
February	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
March	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
April	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
May	0	0	113	27	0	0	1	3	8	0	1	0	12.8	0.5	32.5
June	12	20	10	126	0	23	13	13	1	4	3	5	19.2	11.0	34.4
July	6	205	180	52	0	214	18	16	0	3	1	23	59.8	17.0	85.9
August	0	77	109	24	0	52	2	1	0	1	0	4	22.5	1.5	37.0
September	1	4	2	3	0	1	0	0	0	1	0	1	1.1	1.0	1.3
October	0	0	1	4	0	1	1	0	0	0	1	0	0.7	0.0	1.2
November	2	0	0	1	0	0	0	0	0	0	0	0	0.3	0.0	0.6
December	2	1	5	0	0	0	0	0	0	0	0	0	0.7	0.0	1.5
Total	23	307	420	237	0	291	35	34	9	9	6	33	117.0	33.5	151.2

Table 11-15. Sturgeon captured at RBDD rotary screw traps

Sturgeon Captured at RBDD Screw Traps

Year	**Months Captured**	**# of Sturgeon**
1995	June - August	1364
1996	May - August	410
1997	May - July	354
1998	July - August	302
1999	Feb - Oct	80
2000	May - June	98
2001	No sampling	
2002	May - July	35
2003	June - November	360
2004	May - July	643
2005	May - August	271
2006	June - August	191

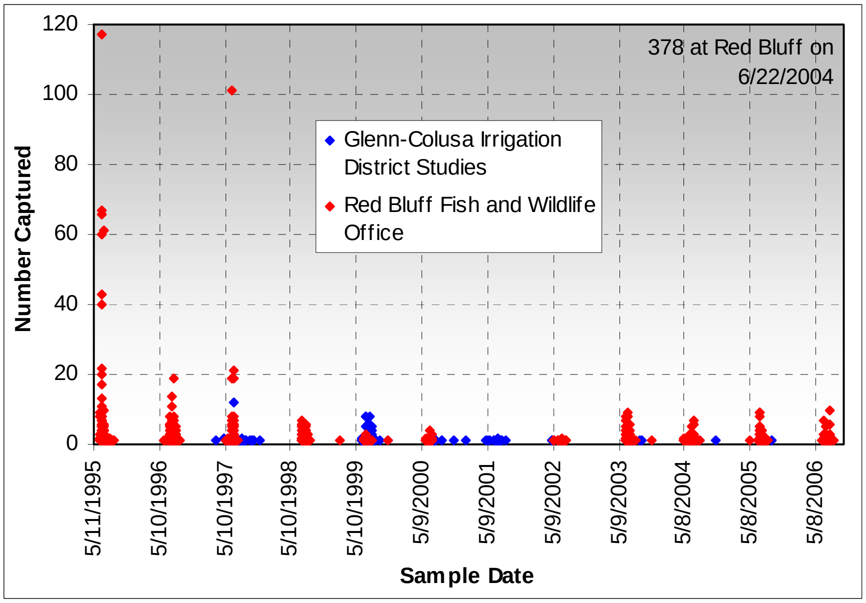

Figure 11-68. Sturgeon captured at RBDD and GCID (BDAT 8/29/2006).
***Note*: All Sturgeon, N=4,767 (green=296, white=18, unidentified=4,453)**

Table 11-16. Estimated entrainment of green sturgeon at unscreened diversions in the Sacramento River.

	April	May	June	July	August	September	October	Total
Sturgeon catch (average 94-2005	0.0	12.8	19.2	59.8	22.5	1.1	0.7	116
Total Sturgeon at 0.5% efficienc	0	2,550	3,833	11,967	4,500	217	133	23,200
Flow at RBDD	10,404	9,435	11,110	13,082	9,683	6,730	7,013	
% of flow diverted	6.5%	15.8%	15.5%	13.3%	15.8%	5.6%	2.0%	
% of fish diverted	0.4%	0.9%	0.9%	0.8%	0.9%	0.3%	0.1%	
Number of Sturgeon Diverted	0	24	36	96	43	1	0	199

Effect of Cool Summer Time Dam Releases on Steelhead Critical Habitat

The Sacramento River below Keswick Dam is managed for cool water during the summer to protect winter-run Chinook. This area was historically warmer prior to the dam and therefore was not as suitable for juvenile steelhead during the summer. Prior to dam construction most trout probably reared further upstream, above the Shasta Lake area. The cool water provided over the summer downstream of Shasta Dam for winter run Chinook has been implicated in potentially decreasing the steelhead population due to an increase in the resident trout population and predation mortality on juvenile steelhead (Cramer 2006). A similar situation occurs in the Stanislaus River downstream of Goodwin Dam and Clear Creek downstream of Whiskeytown Dam where cool water releases are maintained throughout the summer and resident rainbow trout populations are high. The larger resident trout populations may potentially compete with juvenile steelhead, reducing the juvenile steelhead population. The Cantara chemical spill occurred July 14, 1991, in the upper Sacramento River five miles upstream of the city of Dunsmuir. An estimated 309,000 trout were killed by the spill in an approximately thirty mile reach of the river, upstream of Shasta Lake (Hankin and McCanne 2000). Scale analysis and genetic analysis indicated 83-96 percent of these fish were wild (non-hatchery produced) trout. This population size amounts to 10,300 trout per mile (two trout per linear foot of river). This may be the best estimate of trout population size in any part of the Sacramento River. The population has since recovered to a similar density of trout in this reach. Water temperatures in this reach of the river are expected to be similar (or potentially higher due to Lake Siskiyou) compared to historic temperatures. The high trout population in this reach is probably similar to what existed in the upper Sacramento River historically in the presence of steelhead. Therefore we expect that the high resident trout population supported by cool water downstream of Central Valley Dams such as Keswick, Goodwin, and Whiskeytown is not a major factor in decreasing the anadromous populations in those systems. In any event the resident fish do produce anadromous individuals and maintain a supply of fish for the anadromous population. Fish from upstream do survive passage downstream during flood control operations and adults have been documented surviving downstream passage through turbines.

Zimmerman et al (2008) found that in a sample of 964 of O. mykiss otoliths from Central Valley rivers 224 were from fish who were the progeny of anadromous rainbow trout (i.e., steelhead) females and 740 were the progeny of non-anadromous rainbow trout females. This indicates relatively higher reproduction from resident trout than from the anadromous form, however because many samples were from fish in a size range not exhibited in anadromous trout in freshwater, sampling may have been biased towards resident fish.

Feather River

The operations on the Feather River for the Oroville Facilities are currently being covered under a separate Section 7 ESA consultation process for the Federal Energy Regulatory Commission (FERC) hydroelectric relicensing process. The draft NMFS BO is scheduled for release in late May 2008. Under the 2008 OCAP BA, DWR would continue to operate the Oroville Facilities to meet the same water temperature objectives at the Feather River Hatchery and Robinson Riffle under the current FERC license until the new license is issued. While simulated storage conditions in Oroville Reservoir might be different under the 2008 OCAP BA, temperature management actions would follow the procedures described in the 2006 Settlement Agreement for Licensing of the Oroville Facilities (Settlement Agreement) and in Appendix J (Feather River Temp appendix). Therefore, affects to the listed fish species under Studies 7.1 and 8.0 are expected to be the same as what is described in the Section 7 consultation document for the Oroville Relicensing Project. A brief summary of the changes affecting Chinook salmon, steelhead and green sturgeon resulting from the project are outlined below.

Under Studies 7.1 and 8.0, both of which include conditions established under the Settlement Agreement, from April 1 to September 8, DWR would release a minimum flow of 700 cfs into the Low Flow Channel (LFC) to improve habitat conditions for Central Valley spring-run Chinook salmon adult immigration and holding and juvenile rearing and emigration. From September 9 to March 31 of each year, the minimum flow in the LFC would be 800 cfs to accommodate adult spawning for spring-run Chinook salmon and steelhead. Prior to the facilities modifications included in Study 8.0, if DWR does not achieve the applicable temperatures upon release of the specified minimum flow, DWR would singularly, or in combination (a) curtail pump-back operation, (b) remove shutters on Hyatt Intake, and (c) increase flow releases in the LFC up to a maximum of 1500 cfs, or up to the total facilities releases, whichever is less. Increased flows are anticipated to decrease water temperature and thereby increase holding-habitat area, decrease egg mortality in holding adults, enhance adult spawning and egg survival, and improve rearing habitat conditions in the LFC.

Accordingly, water temperatures in Studies 7.1 and 8.0 would likely be decreased relative to Study 7.0, improving conditions for Federally listed anadromous salmonids. It is anticipated that changes in water temperature under Studies 7.1 and 8.0 would result in an overall benefit to spring-run Chinook salmon and steelhead adult immigration and holding, adult spawning and embryo incubation, and/or juvenile rearing and emigration. Increasing flows and decreasing water temperatures in the LFC would likely result in a beneficial change to green sturgeon habitat as well (DWR 2007).

American River

Adult Steelhead Migration, Spawning, and Incubation

Flows in the future would be similar to the baseline condition in all months except July through September. During July flows would be slightly higher and in August and September they would be slightly lower than under present conditions. The American River flow standard is being implemented to provide for operations consistent with the lifecycle needs of steelhead and fall-run Chinook salmon. Management for both species requires tradeoffs that benefit one species while making conditions less favorable to the other, especially regarding temperature management. The flow standard is integrated in with the CalSim-II modeling results.

The American River supports a steelhead run but no spring–run or winter–run Chinook salmon. Adult steelhead migration in the American River typically occurs from November through April and peaks in December through March (McEwan and Jackson 1996; SWRI 1997). Spawning occurs in late December to early April with the peak in late February to early March (Hannon and Deason 2007). Predicted flows could drop as low as 500 cfs in up to 10 percent of years and be as high as 33,000 cfs as a monthly average. Flows in the future will be lower in these months. Steelhead spawning habitat area peaks at 2,400 cfs (Table 4–2) but shows very little variability in spawning habitat area between 1,000 and 4,000 cfs. Flows during the spawning period would be below 2,400 cfs in about 30 to 60 percent of years, depending on the month. Average monthly flows could range up over 30,000 cfs in the wettest years with instantaneous flows likely over 100,000 cfs for flood control. The flows over about 50,000 cfs could scour some redds (Ayres Associates 2001), but will provide needed reconfiguration of the channel for long-term maintenance of good spawning and rearing habitat. At the 90 percent exceedance level flows could average as low as 500 cfs (driest years). Spawning habitat area was not predicted for flows below 1,000 cfs but spawning habitat would certainly be less and important side channel spawning habitat would be nearly absent. The steelhead population in the American River does not appear to be ultimately limited by spawning habitat availability, but by factors following fry emergence such as summer water temperatures and predation. The majority of steelhead enter the hatchery instead of spawning in the river. Efforts are underway to provide habitats such as improved spawning gravel in upstream areas and additional side channel areas to entice more steelhead to spawn in the river. The number of juvenile steelhead in the river drops quickly at the beginning of the summer, possibly due to predation. Predators likely take more steelhead when the water is warmer. Flow conditions are expected to provide suitable depths and velocities for upstream passage of adults to spawning areas within the lower American River. No migration barriers exist below Nimbus Dam, except when the hatchery picket weir is in operation.

Steelhead prefer 46 °F to 52 °F water for upstream migration. Temperatures of 52 °F or lower are best for steelhead egg incubation. However temperatures less than 56 F are considered suitable. Average temperatures at Watt Avenue are generally within this range much of the time between December and March. During dry years temperatures in November, March, April, and May would be higher than preferred and could be as high as 71 °F in May of warm dry years (Figure 11-69 and Figure 11-70). Over 90 percent of the steelhead spawning activity occurs during late December through March when temperatures are generally within an acceptable range for spawning (Hannon and Deason 2007). Steelhead eggs are in the gravel from December until mid-May. Temperatures from March through May could be above the preferred range for egg incubation at Watt Avenue in about 50 percent of years during March, and in all years in April and May. Fish surveys identify newly emerged steelhead in the American through May indicating that eggs do survive at temperatures above the preferred range. Temperatures are relatively unchanged between all modeling runs during the steelhead spawning and incubation period so there is no change in effect.

Meeting temperature objectives for steelhead during the summer and for Chinook in the fall involves trade-offs between whether to use more cool water during the summer for steelhead rearing or saving some amount of cool water until fall to increase Chinook spawning success. Reclamation manages the cold-water pool in Folsom reservoir with regular input from the American River Operations Group. Temperature shutters on each of the power penstocks are raised throughout the summer and fall when needed to provide cool water in the lower American River for steelhead and Chinook. The shutters allow releases to be made from four different levels of the reservoir, depending on the desired water temperature in the lower river.

Flood flows that are not reflected in the operations forecasts have the potential to scour steelhead redds resulting in injury and mortality of steelhead eggs and sac-fry. Frequency and magnitude of flood operations will be the same between the baseline and future scenarios. Most flood control operations are not expected to result in flow conditions that are likely to create scour (>50,000 cfs). Flow reductions following flood control releases have the potential to dewater redds constructed during the higher flow period. Higher flood control releases over a one or two-day period rather than lower releases over an extended period would preclude steelhead spawning in areas that will be later dewatered. The American River Operations Group considers the risk of redd dewatering when choosing options for flood control releases. Planning for the normal operations of Folsom Reservoir during this period considers the potential for high flood control releases during the steelhead spawning and egg incubation period. Non-flood control operations are typically designed to avoid large changes in flow that may create stranding problems. Because Folsom Reservoir is the closest water source to the Delta, releases from Folsom can be needed to maintain Delta water quality requirements when delta water quality deterioration occurs (chapter 2). Once water quality requirements are met or increased flows from other reservoirs make it to the Delta Folsom releases can be reduced to conserve storage, sometimes affecting fish or redds in the river. CVPIA section

3406(b)(2) water may be used during this period to support higher flows or avoid reductions that otherwise would be made. Dewatered steelhead redds likely lowered the number of steelhead fry produced in 2003. The limiting period to in-river steelhead production seems to occur after fry emergence. Therefore changes in operational effects on spawning and egg incubation are not expected to affect the steelhead population in the American River. It is hoped that spawning gravel introductions will improve the condition of spawning and rearing critical habitat in the American River.

Steelhead Fry, Juveniles, and Smolts

The freshwater life stages of steelhead occupy the American River throughout the year. Most literature has indicated that rearing fry and juvenile steelhead prefer water temperatures between 45 °F and 60 °F (Reiser and Bjorn 1979; Bovee 1978; Bell 1986). However, Myrick (1998) found the preferred temperatures for Mokelumne River Hatchery steelhead placed into thermal gradients were between 62.6 °F and 68 °F. NMFS generally uses a daily average temperature of 65 °F at Watt Avenue as a temperature objective for steelhead rearing in the American River and then adjusts the temperature objective and point depending on Folsom cold-water pool each year. Temperatures could exceed a monthly average of 65 °F at times between May and October with the highest temperatures of up to 75 °F in occurring in July and August of years with a low cold-water pool storage in Folsom. Temperatures are modeled to be almost always higher than 65 °F at Nimbus Dam in July through September with not much difference between the current and future scenarios (Figure 11-71 and Figure 11-72). Temperatures would exceed 70 °F during July in 20 percent of years and in August in 50 percent of years at Watt Avenue. These high summer temperatures are likely what limits the naturally spawned steelhead population in the American River by providing conditions conducive to predatory fish. Monitoring during 2001 and 2002 indicated that steelhead did not appear to be finding water cooler than that found in the thalweg and they persisted below Watt Avenue in water with a daily average temperature of 72 °F and a daily maximum over 74 °F. Water temperature in the future runs is predicted to be approximately 1 °F warmer from July to October. Temperatures the rest of the year will be relatively unchanged. The increased temperatures will put additional temperature stress on rearing steelhead during summer and adult Chinook holding and spawning. Due to the high temperatures the steelhead run in the American River will likely require continued support by the hatchery. This is an adverse effect to steelhead.

Juvenile salmon emigration studies using rotary screw traps in the lower American River at Watt Avenue generally capture steelhead fry from March through June while steelhead yearlings and smolts emigrate from late December till May, with most captured in January (Snider and Titus 2000). Specific flow needs for emigration in the American River have not been determined. Steelhead emigrate at a relatively large size so are good swimmers and presumably do not need large pulses to emigrate effectively from the American River as long as temperatures are suitable through the lower river and in the Sacramento River. Modeled flows are expected to provide suitable depth and velocity conditions for emigration during most years. Flows could drop below 1,000 cfs between December and May in about 5 to 15 percent of years depending on month. Low flows would occur slightly more often in the future than under current operations. This would probably affect juvenile salmon more than juvenile steelhead due to the high salmonid densities. The habitat is generally not fully seeded with steelhead fry. December through March forecast mean monthly temperatures are expected to be generally within the optimum smoltification and emigration range (44 °F to 52 °F) during most years but temperatures may exceed 52 °F in February in about 10 percent of years and in about 70 percent of years in March. No change in temperatures between current and future operations during December through March is expected to occur.

Rearing steelhead fry and juveniles can be exposed to stranding and isolation from main channel flows when high flows are required for flood control or Delta outflow requirements results in short duration flow increases which are subsequently reduced after the requirement subsides. After high flow events when rearing steelhead fry and juveniles issues are a concern, Reclamation coordinates flow reduction rates utilizing the B2IT and American River Operation Group adaptive management processes to minimize the stranding and isolation concerns versus current hydrologic conditions and future hydrologic projections to Folsom cold-water management. Reclamation attempts to avoid flow fluctuations during non-flood control events that raise flows above 4,000 cfs and then drop them back below 4,000 cfs as recommended by Snider et al (2002). Flow fluctuations are sometimes difficult to avoid with competing standards to meet in the Delta and upstream so some stranding will continue to occur at about the same level as under the baseline.

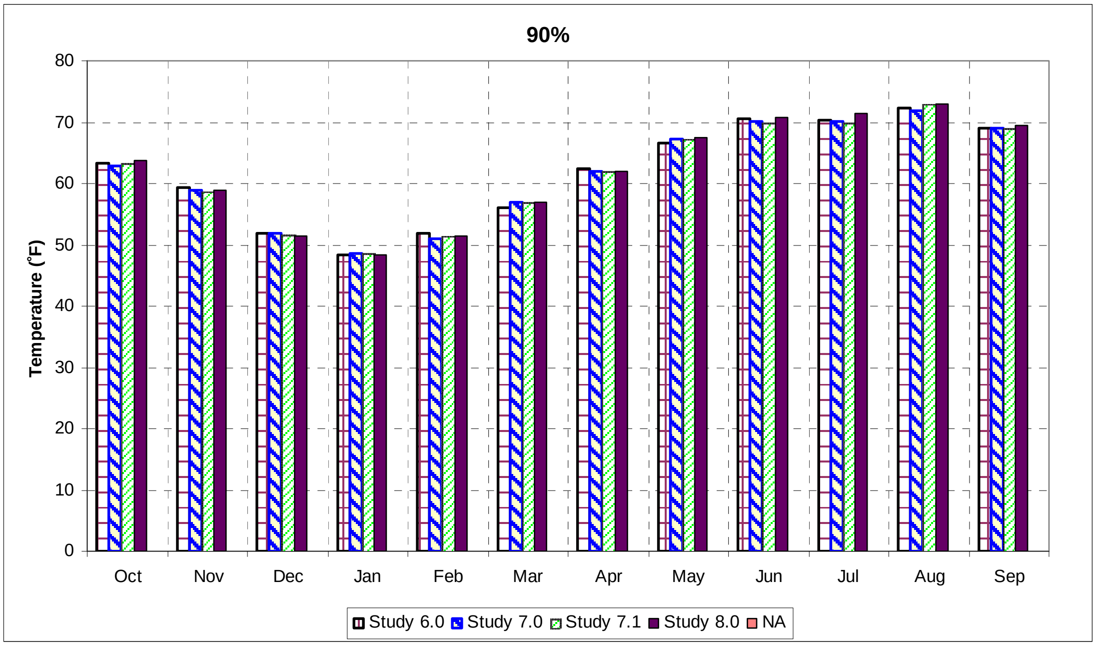

Figure 11-69. 90% exceedence level monthly water temperatures at Watt Avenue for the four OCAP scenarios (dry conditions).

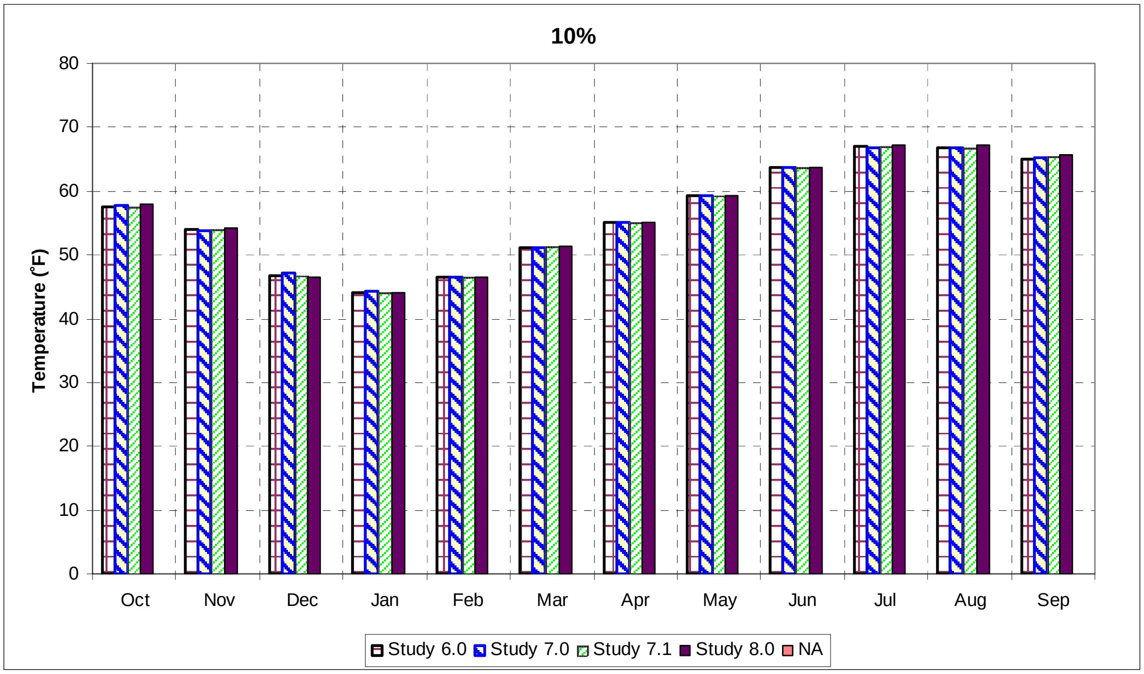

Figure 11-70. 10% exceedence level monthly water temperatures at Watt Avenue for the four OCAP scenarios (wet conditions).

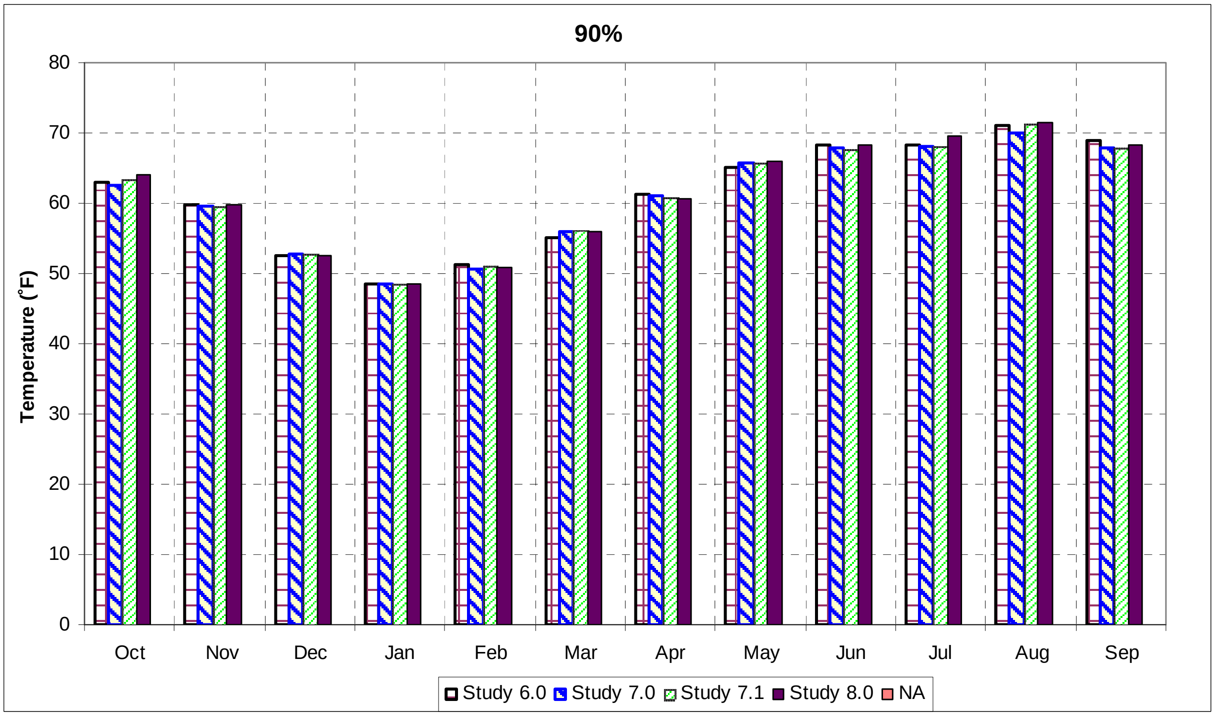

Figure 11-71. 90% exceedence level monthly water temperatures at Nimbus Dam for the four OCAP scenarios (dry conditions).

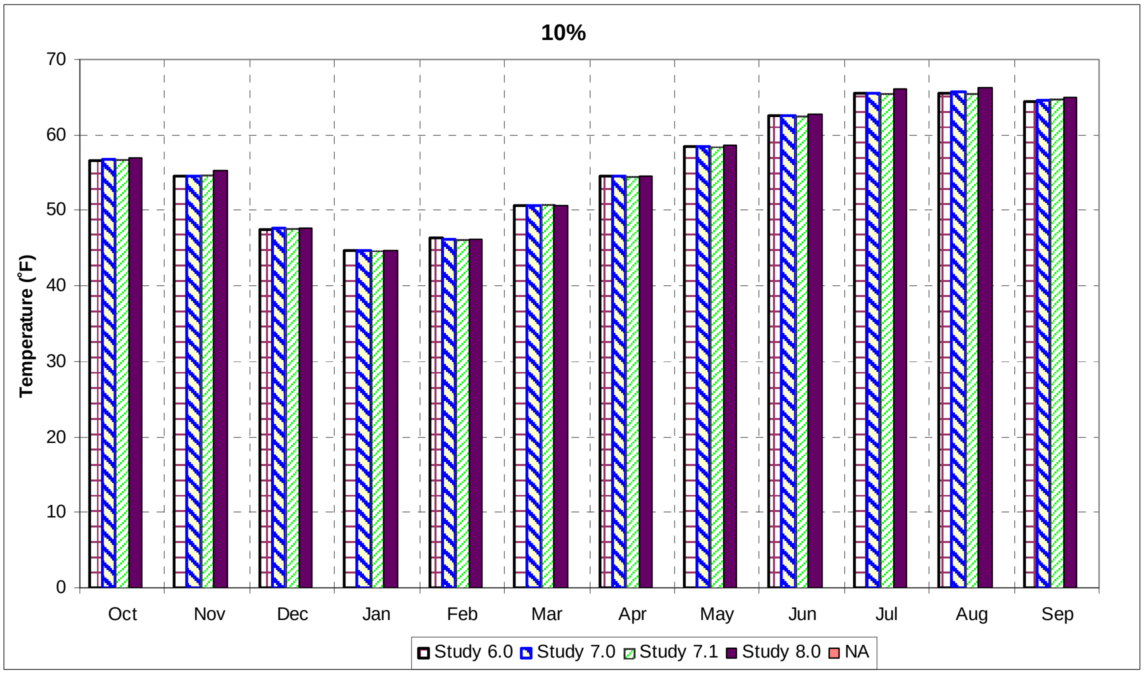

Figure 11-72. 10% exceedence level monthly water temperatures at Nimbus Dam for the four OCAP scenarios (wet conditions).

Gas Bubble Disease and IHN (effects of high releases on critical habitat)

Gas bubble disease was detected in fall-run Chinook salmon in Nimbus Hatchery during flood control releases in 2006. It likely occurred in the river as well. All salmonids are susceptible. An outbreak of infectious hematopoietic necrosis (IHN) also occurred in Nimbus and was implicated to be caused by the stress from the gas bubble disease. High mortality of the hatchery Chinook occurred from the IHN. It is not known whether wild fish in the American River also suffered mortality from IHN. Juvenile Chinook salmon from Nimbus Hatchery are stocked in Folsom Reservoir as a put and take fishery. This upstream stocking could possibly be a source of the IHN, carried into the hatchery by the water supply. The IHN virus isolated from Sacramento River and Feather River Chinook salmon causes high mortalities in Chinook salmon in California but does not readily kill steelhead (Leong 1984). Gas bubble disease can occur below the dams when high flows are released. Supersaturation of the water with dissolved gasses occurs when the water cascades down over dam spillways into the pools below with high force causing higher than normal levels of dissolved gasses in the water. Under the high flows the water quickly flows down through the reregulating reservoir (eg. Lake Natoma on the American) before the extra gasses have time to be released into the atmosphere. When the water reaches the anadromous habitat it is used by the fish and comes out of saturation inside the fish forming gas bubbles. This situation occurs during high runoff years.

Beeman and Maule (2006) studied gas supersaturation effects on migrating steelhead and Chinook during spills at Columbia River dams. They found dissolved gas levels below the dams were high enough to cause gas bubble disease. The levels decreased with increasing distance downstream of the dams. They concluded that hydrostatic compensation, through depth of the fish in the water column, along with short exposure time in the areas of highest dissolved gas levels reduced the effects of gas supersaturation exposure below those generally shown to elicit gas bubble disease signs or mortality.

Frequency of occurrence for flood control releases from the dams is illustrated in Figures 6-6 through 6-11 and Figure 6-13. This approximates the frequency with which supersaturation of water with dissolved gasses in the critical habitat near the dams can be expected to occur. The frequency and duration is expected to be about the same in the future.

Stanislaus River

Adult Steelhead Migration, Spawning, and Incubation

Steelhead life history patterns in the Stanislaus River and the rest of the San Joaquin River system are only partially understood, but studies are underway to determine steelhead populations, extent of anadromy, and run timing. Resident rainbow trout are abundant in the first 10 miles downstream from Goodwin Dam. Anglers report catches of adults that appear to them to be steelhead based on large size and coloration. Rotary screw traps at Oakdale and Caswell catch downstream migrating steelhead with smolting characteristics each year. The Stanislaus River weir has captured a few adult steelhead, mostly during the years it was operated past the first of the year (Figure 11-73). Three of these steelhead captured at the weir were identified as steelhead based on scale samples. The Stanislaus River receives the highest year-round flows during most years and has the coolest water of the three major San Joaquin tributaries. A high population of resident trout in the roughly ten river miles below Goodwin Dam in the Stanislaus River indicates critical habitat conditions are favorable year round for steelhead rearing in the Stanislaus River.

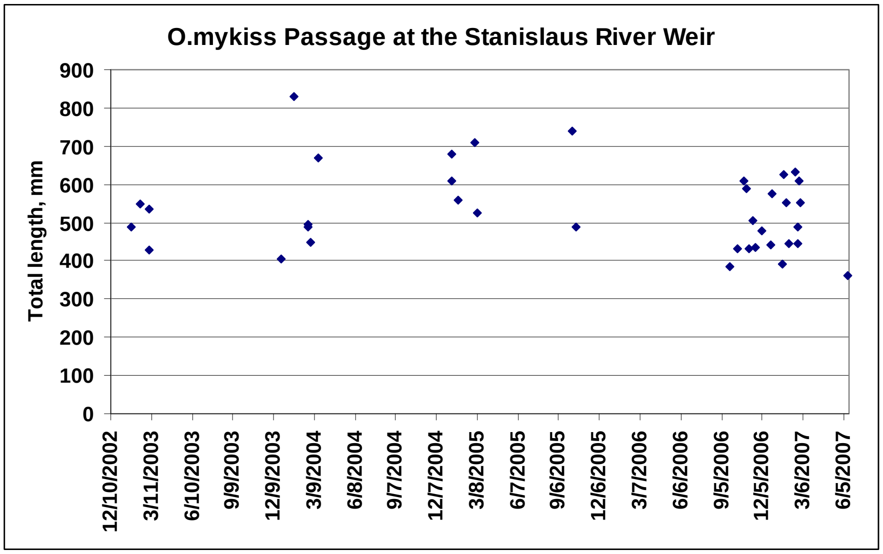

Figure 11-73. O. mykiss passage through the Stanislaus River weir.

River releases from Goodwin Dam are relatively unchanged between the three studies. Steelhead in Sacramento River tributaries migrate upstream to spawn primarily between December and March. Spawning occurs during this period and may extend through April. Based on trout fry observations in Stanislaus snorkel surveys, spawning timing appears to be about the same in the Stanislaus as in the Sacramento River tributaries. Goodwin Dam releases during this period would be mostly from 200 to 500 cfs in December and 125 to 500 cfs in January through March. Flows in April and May would be between 400 and 1,500 cfs. Steelhead spawning flows were estimated to be maximized at 200 cfs and in stream habitat for adult migration and rearing was estimated to be maximized at 500 cfs (Table 4–4). Spawning or holding habitat for adult steelhead is not likely limiting in the Stanislaus because the anadromous component of the population is not abundant. Monthly mean flows as high as 5,000 cfs and as low as 125 cfs could occur throughout the range of precipitation regimes. Flows above about 5,000 cfs could affect egg survival in redds or scour some redds (Table 11-3). Spawning occurs on a number of gravel addition sites. Bed mobility flows are likely lower at these sites until the initial high flows distribute the gravel in a more natural manner. The flows as low as 125 cfs in 90 percent exceedance years and dryer would still provide some spawning habitat for steelhead. The recommended spawning flows for rainbow trout were 100 cfs (Table 4–4). Low flows for upstream migration and attraction during dry years may result in fewer steelhead reaching the spawning areas. During years when flows are low in the Stanislaus they would likely be low in other rivers so that Stanislaus flows should still be a similar proportion of total San Joaquin River flow and Delta outflow.

During low flows from the San Joaquin River dissolved oxygen sometimes reaches lethal levels in the Stockton deep-water ship channel. The low DO can cause a barrier to upstream migrating steelhead and Chinook so that they are delayed or migrate up the Sacramento River or other tributary instead. This generally occurs prior to the time steelhead are migrating up to the Stanislaus. Flows from the Stanislaus help to address the low DO problem by meeting the Vernalis flow standard when possible, although there is not always enough water available from New Melones to meet the flow standard at all times.

Little change in Stanislaus River temperatures at Goodwin Dam is projected to occur (Figure 11-74 and Figure 11-75). Temperatures at Orange Blossom Bridge would be 52 °F or below most of the time from December to February. In March and April temperatures would exceed 52 °F in about 45-60 percent of years and in May in 90 percent of years. Because these temperatures are about the same as in past operations and the Stanislaus River supports a large trout population year round with these temperatures, these temperatures appear to provide sufficient cold water in the critical spawning habitat for the current steelhead population and there is space for additional anadromous individuals.

Steelhead Fry, Juveniles, and Smolts

Most literature has indicated that rearing fry and juvenile steelhead prefer water temperatures between 45 °F and 60 °F (Reiser and Bjorn 1979; Bovee 1978; Bell 1986). However, Myrick (1998) found the preferred temperatures for Mokelumne River Hatchery steelhead placed into thermal gradients were between 62.6 °F and 68 °F.

Snorkel surveys (Kennedy and Cannon 2002) identified trout fry starting in April in 2000 and 2001, with the first fry observed in upstream areas each year. During 2003, a few trout fry were identified as early as January but most did not appear until April as in 2000 and 2001. Rotary screw traps operated at Oakdale and Caswell capture rainbow trout/steelhead that appear to exhibit smolting characteristics (Demko and others 2000). These apparent smolts are typically captured from January to mid-April, and are 175 to 300 mm fork length. Because steelhead smolts are generally large (>200 mm) and strong swimmers, predicted Goodwin Dam releases are expected to provide adequate depth and velocity conditions for emigration at all times. Spring storms that generally occur during this period provide pulse flows from tributaries below Goodwin Dam that will stimulate and assist in out migration. The lowest flows predicted between January and April would be 125 cfs. Flows would pick up in mid-April for the VAMP period and provide an out migration pulse for any steelhead smolts still in the river that late.

Smolts are thought to migrate through the lower reaches rather quickly so should be able to withstand the few days of warmer temperatures when migrating to the estuary or ocean. The current temperature compliance point is 65 °F at Orange Blossom Bridge June 1 to November 30. Most of the steelhead spawning and rearing habitat extends from near Orange Blossom Bridge up to Goodwin Dam. This is the area with higher gradients producing riffles used by steelhead for rearing, food production, and spawning. Gradients below the vicinity of Orange Blossom Bridge are flatter with sand substrates more prevalent as you get further downstream. These habitats are less suitable for steelhead rearing. Temperatures would be below 65 °F through June in 95 precent of years (Figure 11-76 and Figure 11-77). About 5 percent of years in July, could be above 65 °F. In August and September, temperatures could exceed 65 °F at Orange Blossom in about 15 percent of years. Temperatures during summer would be about the same under future scenarios in the summer at Orange Blossom. Year round temperatures for steelhead in the upper river above Orange Blossom Bridge are suitable for steelhead rearing (Figure 11-74 and Figure 11-75).

Although Stanislaus River operation assumptions changed between scenarios, results show there are only slight changes (annual average) to flows and temperatures. Effects of the project on steelhead and their critical habitat in the Stanislaus River are expected to be about the same between the OCAP scenarios. Migratory conditions through the delta may be the most significant factor affecting the proportion of O.mykiss in the Stanislaus River that assume an anadromous lifecycle.

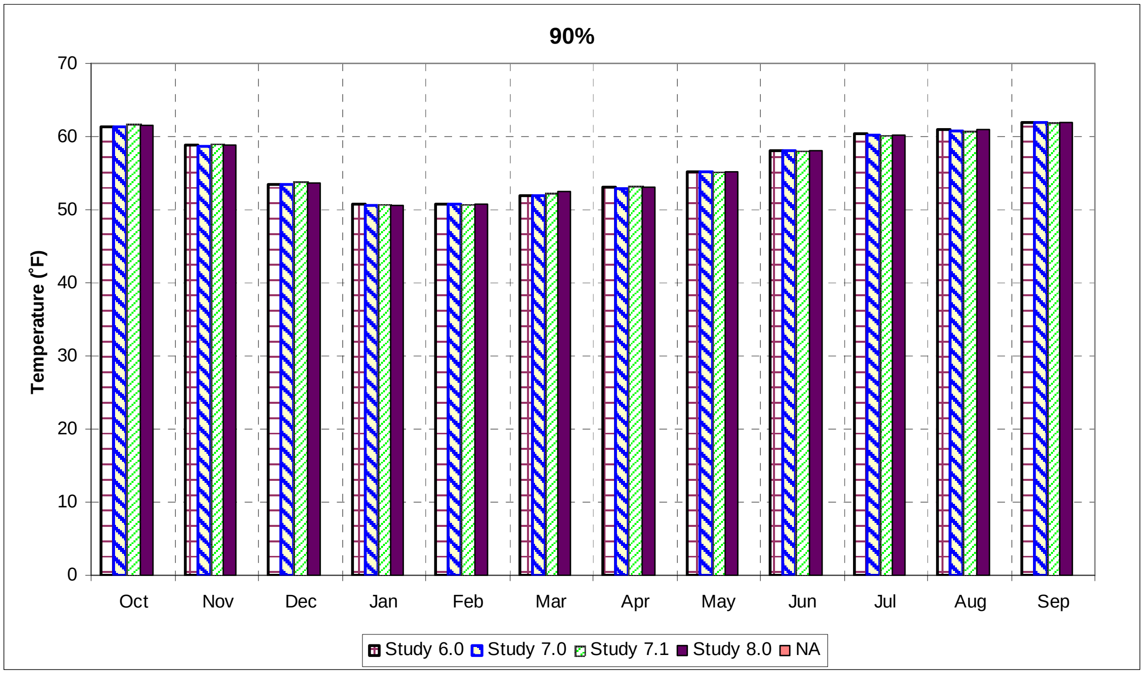

Figure 11-74. Stanislaus River at Goodwin Dam modeled water temperatures for the four studies at the 90% exceedence level (dry conditions).

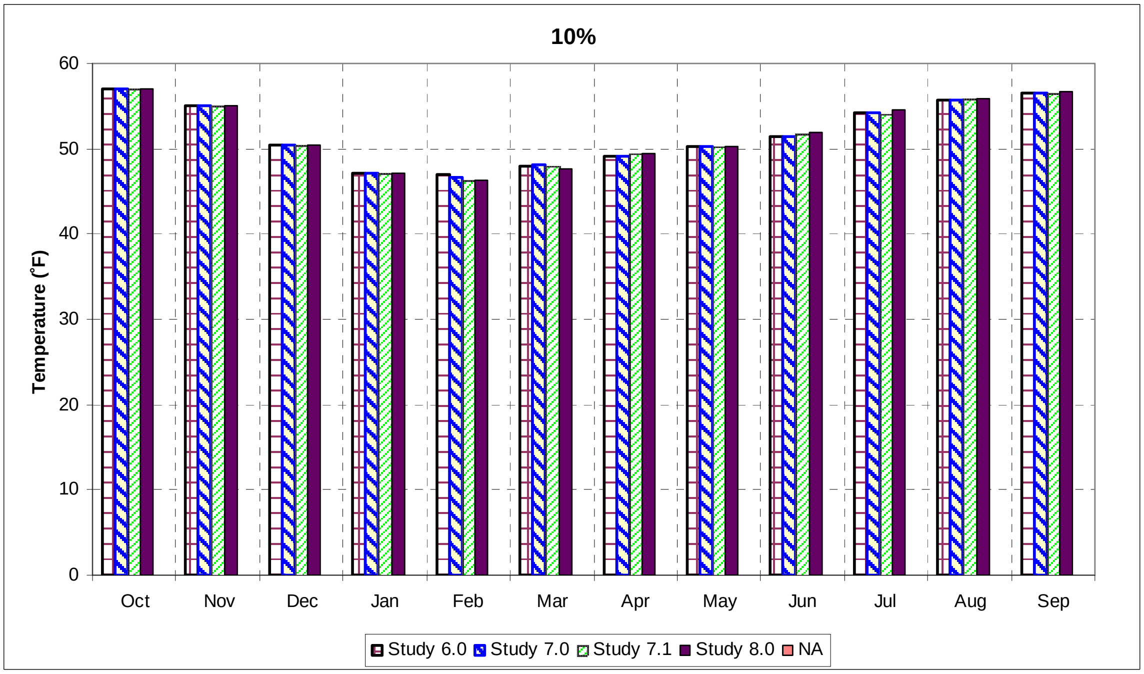

Figure 11-75. Stanislaus River at Goodwin Dam modeled water temperatures for the four studies at the 10% exceedence level (wet conditions).

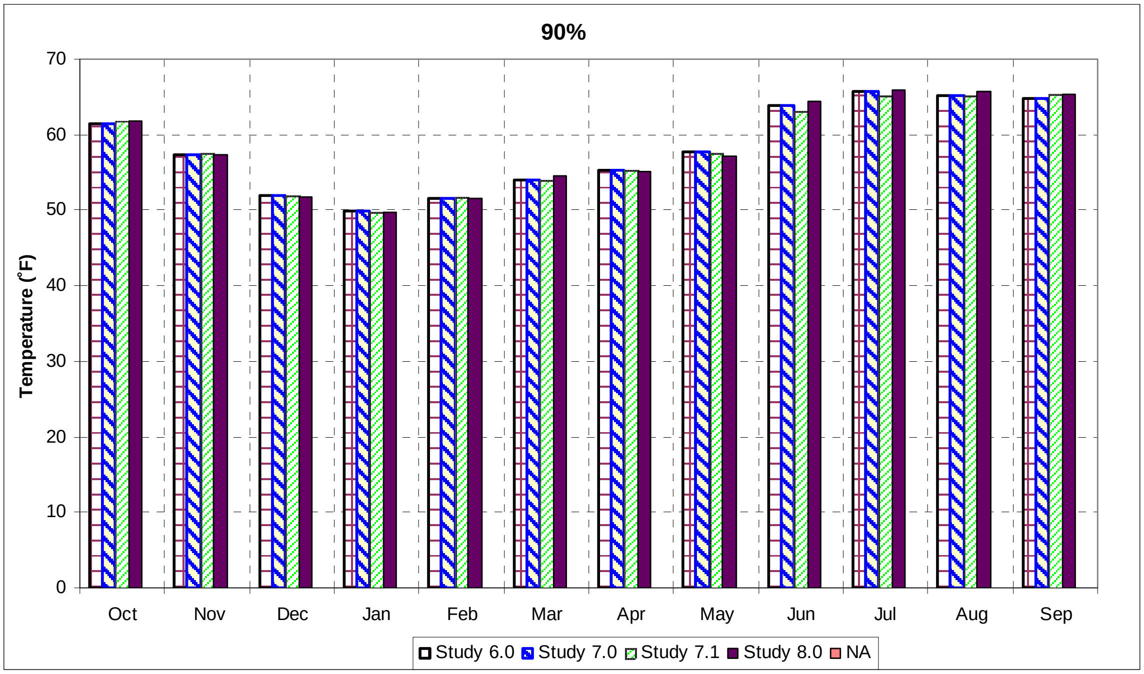

Figure 11-76. Stanislaus River at Orange Blossom Bridge modeled water temperatures for the four studies at the 90% exceedence level (dry conditions).

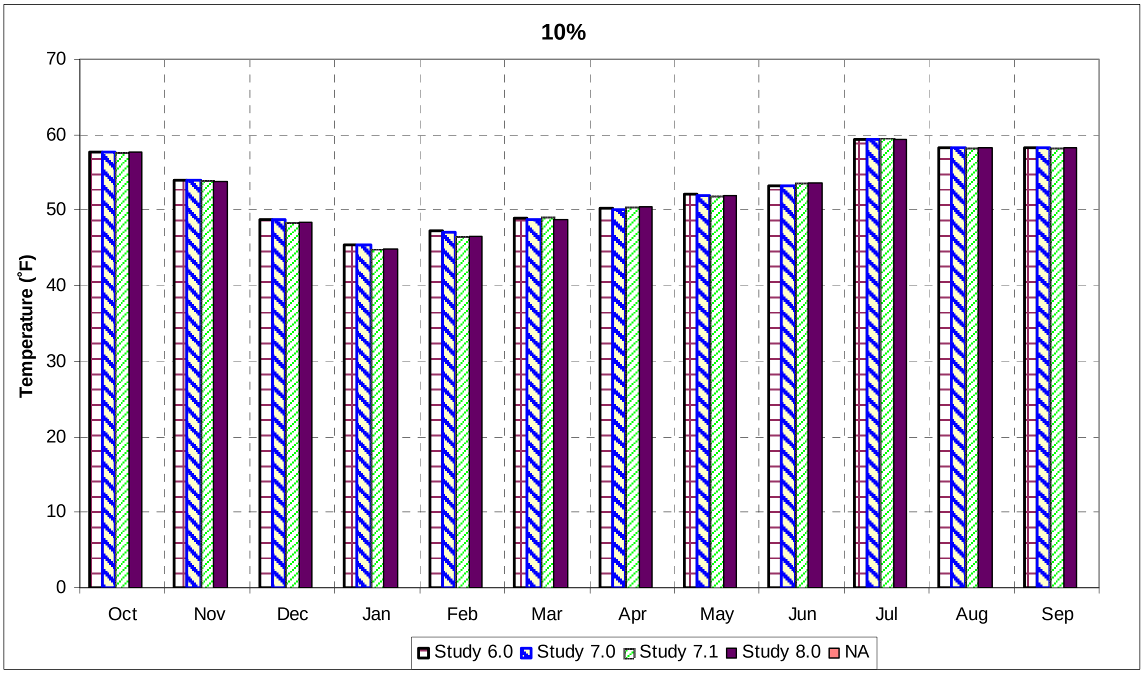

Figure 11-77. Stanislaus River at Orange Blossom Bridge water temperatures for the four studies at the 10% exceedence level (wet conditions).

San Joaquin River

Adult Steelhead Migration, Spawning, and Incubation

The modeling shows essentially no difference in flows in the San Joaquin River between the current and future modeled scenarios. Steelhead life history patterns in the San Joaquin River system are only partially understood, but studies are underway to determine steelhead populations, extent of anadromy, and run timing. Steelhead/rainbow populations exist in the San Joaquin tributaries and smolt-sized fish get captured by trawling in the lower river near Mossdale (Figure 3-17). Adult steelhead are assumed to migrate up the San Joaquin River in late fall and winter, after temperatures and dissolved oxygen conditions become suitable for migrations to occur. Spawning, although not well documented, likely occurs in the tributaries primarily from January through March. No steelhead spawning or incubation occurs in the mainstem San Joaquin River because habitat conditions (gravel and higher gradient) is not suitable in the lower river.

Supplemental water released in the Stanislaus River for Chinook salmon in October will generally provide conditions (attraction flow, lower temperature, and higher dissolved oxygen) in the lower San Joaquin River and through the Stockton Deep-water Ship Channel suitable for upstream migrating steelhead. During November and through the rest of the upstream migratory period ambient cooling generally provides suitable conditions for migrations up through the San Joaquin. Prior to the October pulse, conditions in the lower San Joaquin and Stockton Deepwater Ship Channel are sometimes unsuitable for migrating steelhead (Lee 2003). Early returning fish could be delayed or stray to the Sacramento River tributaries when San Joaquin River conditions are unsuitable. During pre-dam days temperatures were likely higher and flows in the lower San Joaquin were likely lower than what occurs currently (although dissolved oxygen was probably not as much of an issue then) so there were not likely historically steelhead returning to the San Joaquin during late summer and fall before ambient cooling and seasonally increased flows occurred.

Steelhead Fry, Juveniles, and Smolts

San Joaquin River flow and habitat conditions are not predicted to change under the future scenarios. Habitat conditions in the San Joaquin River do not appear well suited to young steelhead rearing because there are no riffles or gravel for invertebrate production and temperatures are often too high. Fry and juvenile steelhead rearing for long periods in the San Joaquin River is not likely a common occurrence. The river likely serves primarily as a migratory corridor for smolts heading to saltwater. Out migration from the San Joaquin tributaries to saltwater probably occurs from November through May. The lowest flows during this period would be about 1,200 cfs in January of 1 percent of years. The 50th percentile flows range from about 2,100 cfs in December to about 5,000 cfs in April. The larger size of steelhead smolts makes them stronger swimmers than juvenile salmon so they should be better able to out-migrate during the low water velocity years when flows are lower. Conditions in the critical habitat in the San Joaquin River during the summer and fall are not conducive to successful out migration or habitation because water is warmer and dissolved oxygen sags occur.

San Joaquin River flows from the Merced River downstream are managed for one life history type of Chinook salmon. Flows are managed for fall run Chinook salmon to enter the river in October, spawn in November, and incubate and rear in the river until late spring. A month long increased flow pulse is provided each year generally mid April to mid May to aid emigration of the large (~75-100 mm) Chinook salmon juveniles out of the river and through the Delta to the estuary. Flows prior to April 15 are managed for in-river rearing of Chinook and steelhead with no pulses, other than that provided by brief tributary inflows, to aid emigration of yearling Chinook, Chinook fry, or steelhead from the system. Little data on steelhead in the San Joaquin system exists so it is assumed that the flows that are managed for fall run Chinook will adequately support the steelhead life history. Data from the Stanislaus River weir shows that the adult steelhead population in the Stanislaus is very low compared to the large resident rainbow trout population that is evident when snorkeling the river.

Climate Change

Details on climate change sensitivity analyses are presented in Appendix R. Temperatures in California are projected to increase several degrees centigrade (°C) by the end of this century as a result of climate change. One expected consequence of this is further reduction in the State’s annual snowpack with more precipitation falling as rain, and earlier melting of snow. Warming and reduction to the State’s snowpack will affect the operation of most major multipurpose reservoirs at low and mid-elevations in the Sierra including all of those included in this consultation.

Climate change could also affect the intensity, duration, and timing of precipitation events in California as well as the spatial distribution and temporal variability of precipitation. Significant changes in one or more of these factors would present major challenges for water supply management, and therefore have an effect on future water demand patterns. However, many other factors such as population, land development and economic conditions that are not directly related to climate change will also affect future demand.

Predicting effects of climate change on Chinook salmon, steelhead, and green sturgeon is difficult due to the uncertainty of future changes. According to the DWR climate change report, Sierra watersheds with snowpack are predicted to get less snow and more rain, more winter and less spring and summer runoff, and warmer runoff. Increased water temperatures pose a threat to aquatic species that are sensitive to elevated water temperature, including anadromous fish. Increased water temperatures would decrease dissolved oxygen concentrations in water and would likely increase production of algae and some aquatic weeds. (DWR 2006)

In many low- and middle-elevation streams in California today, summer temperatures often come close to or exceed the upper tolerance limits for salmon and steelhead. Thus, anticipated climate change that raises air temperatures a few degrees celsius may be enough to raise water temperatures above the tolerance of salmon and trout in many streams, favoring instead non-native fishes such as carp and sunfish. Chinook salmon and steelhead trout that migrate upriver early in the year, spending the summer in deep, cold pools, and spawning in the summer or fall (Chinook salmon) or winter (steelhead) depend on the availability of cold water for survival over the summer months. Climate change could reduce the volume of cold water in storage in reservoirs and groundwater upwelling/springs, and tributaries since they would receive less snowmelt and have reduced carryover storage. Runoff would occur earlier in the year and require earlier releases for flood control, reducing coldwater pools for summer. Thus, the availability of cold water volumes needed to maintain releases of cold water to support salmonid and sturgeon spawning and rearing below the dams may decline. Due to the combination of anticipated warmer and shallower streams and rivers, climate change may diminish most summer habitat for steelhead and winter-run Chinook and potentially all such habitat now used by spring-run Chinook salmon (DWR, 2006).

Study 9.0 is considered the baseline for climate change scenario comparisons. Study 9.0 is the same as study 8.0 except it does not include EWA and b2. Study 9.1 is the same as 9.0 except that study 9.1 includes a one foot sea level rise. Studies 9.2, 9.3, 9.4, and 9.5 all include the one foot sea level rise and the various changes in precipitation and temperature. Figure 11-78 and Figure 11-79 show the effect of climate change scenarios on winter-run Chinook egg mortality. Results in all year types show increased mortality in studies other than the wetter, less warming scenario, when mortality would be reduced. Four years show near 100% egg mortality in the dryer, more warming scenario. Figure 11-80 and Figure 11-81 show that spring-run Chinook egg mortality in the Sacramento River would also be increased in all year types except for under the wetter, less warming scenario. Figure 11-82 shows the average egg mortality for all four runs increases in all except the wetter, less warming scenario. Figure 11-83 shows effects of the scenarios on coldwater pool volume in Shasta Reservoir. Figure 11-84 through Figure 11-89 show Chinook salmon egg mortality in the Trinity, Feather, American, and Stanislaus Rivers under the climate change scenarios. These results are for fall-run Chinook but show the likely trend for the other runs and species as well. Effects on egg incubation in coho salmon in the Trinity River would be less than for Chinook because coho spawn during the coolest time of year. Effects in the Feather River shownot much change in the wetter and less warming scenario but increased mortality for the other scenarios. Effects in the American River would likely be greater for Chinook than for steelhead but the general trend would be increased mortality under most conditions with climate change. Figure 11-88 shows effects on coldwater pool volume in Folsom Reservoir. Stanislaus River steelhead egg mortality would be less than for Chinook. The Stanislaus River shows much greater effect due to climate change scenarios than due to changes in water operations under the regular studies.

The mortality model shows projections of egg incubation success due to water temperature changes between the climate change scenarios. Additional effects to eggs could occur due to higher high flows under the increased precipitation and temperature scenarios. This could result in scouring eggs from the gravel or entombment of eggs due to additional deposition on top of redds. Effects to Chinook and steelhead adults in the rivers include a reduction in the quality and amount of holding habitat prior to spawning. These effects would be greatest for spring run Chinook because they hold over all summer in the rivers before spawning in the fall. Increasing water temperatures can increase the rate of development of eggs and result in earlier emergence timing and smaller fry. If the entire freshwater lifestages are condensed into a shorter period of time then Chinook salmon could reach the ocean earlier, potentially prior to the time of greatest productivity in the spring. If many fish enter the ocean at an earlier time then food could be limiting for the juvenile fish in the ocean. Salmonids have evolved with peak ocean entry times to coincide with periods of plankton blooms and high juvenile food availability in the ocean. The climate change scenarios could alter this pattern so that fish become out of balance with their food supply in the ocean.

Increased water temperature in the rivers under climate change scenarios would improve conditions for predatory fish such as bass. As shown in Figure 11-90 and Figure 11-91 water temperatures at Balls Ferry and at Freeport would increase. The 50% Freeport temperatures could increase by up to as much as three degrees as a monthly average in the summer. Over-summer rearing conditions for steelhead in rivers would be degraded with warmer temperatures. This would occur particularly in the American River. Conditions for over-summer rearing of juvenile steelhead in Nimbus Hatchery would be degraded. Steelhead would likely need to be moved to other hatcheries more often to be reared over the summer. Although these steelhead are not considered to be a part of the DPS, they play a large role in producing the in-river spawners. Salmonids could become more susceptible to diseases such as IHN under increased water temperatures. Salmon and steelhead would be more confined to areas closer to the dams where water is coolest during warm weather and predators would have increased food requirements in the warmer water.

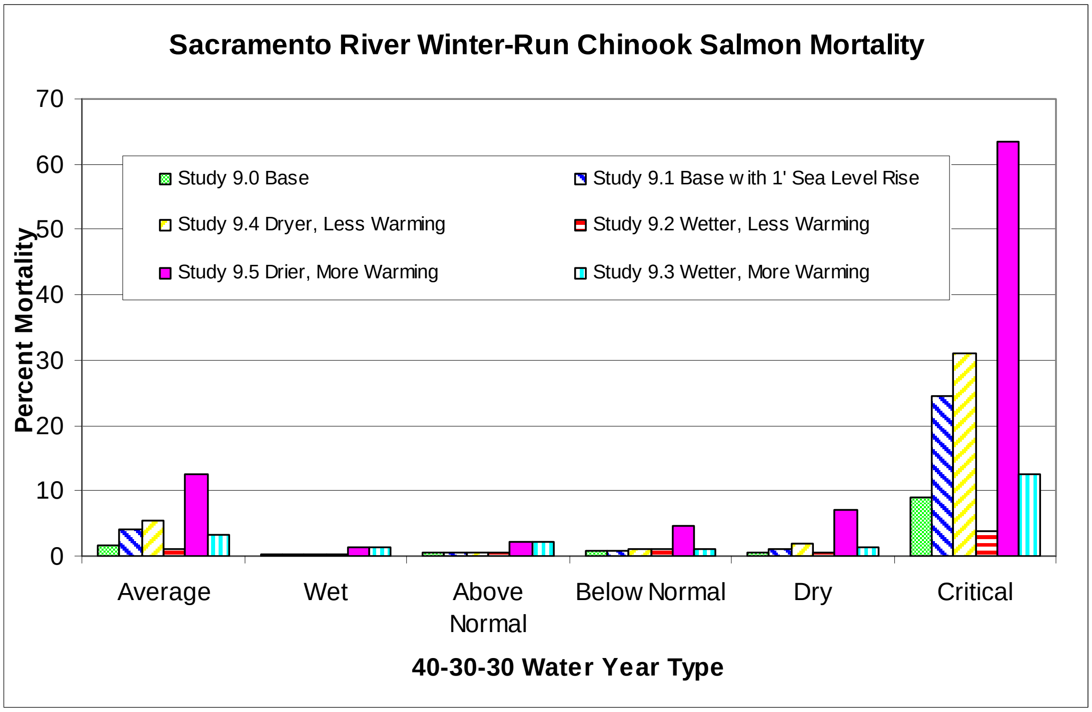

Figure 11-78. Sacramento River winter-run Chinook egg mortality with climate change scenarios from Reclamation egg mortality model. All studies except 9.0 include 1’ sea level rise. Study 9.0 is future conditions with D-1641.

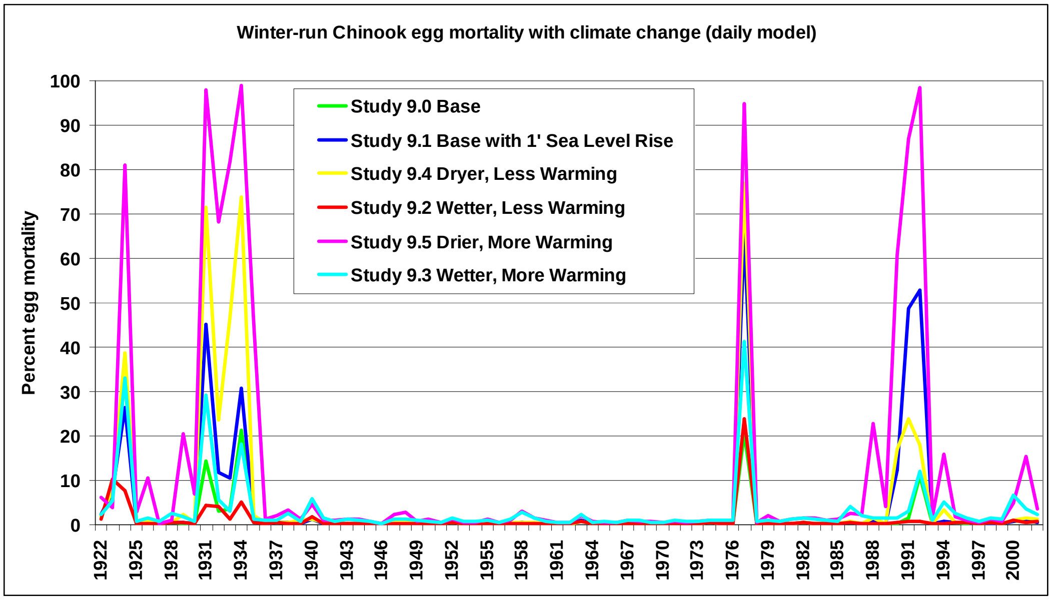

Figure 11-79. Sacramento River Winter-run Chinook egg mortality with climate change scenarios from Reclamation egg mortality model. All studies except 9.0 include 1' sea level rise. Study 9.0 is future conditions with D-1641.

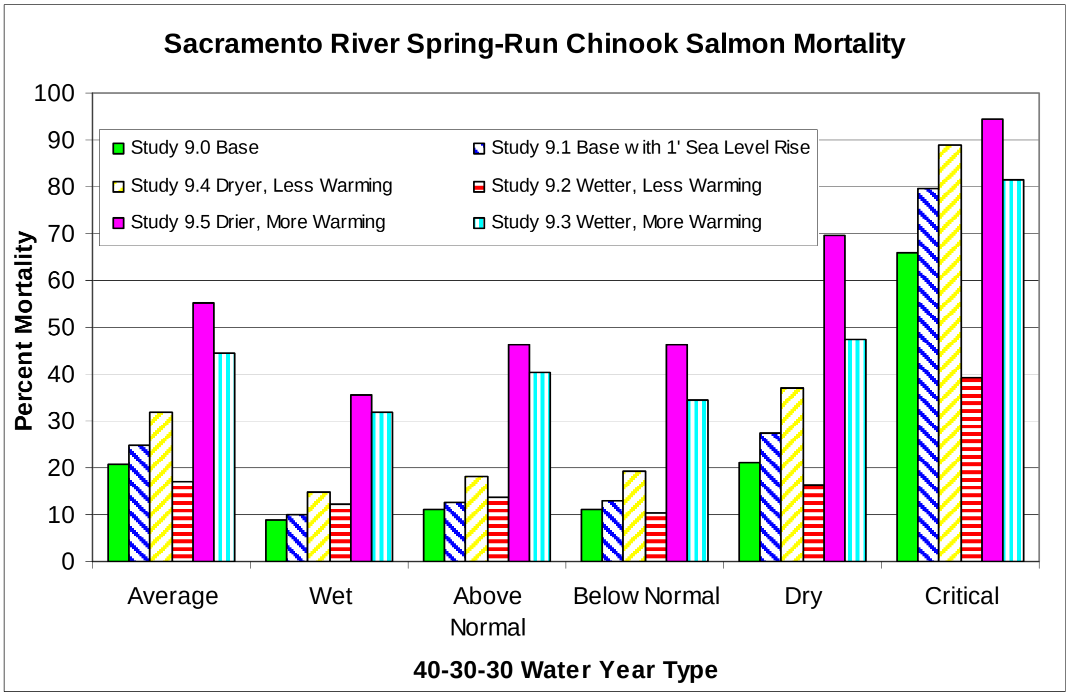

Figure 11-80. Sacramento River spring-run Chinook egg mortality with climate change scenarios from Reclamation salmon egg mortality model. All studies except 9.0 include 1' sea level rise. Study 9.0 is future conditions with D-1641.

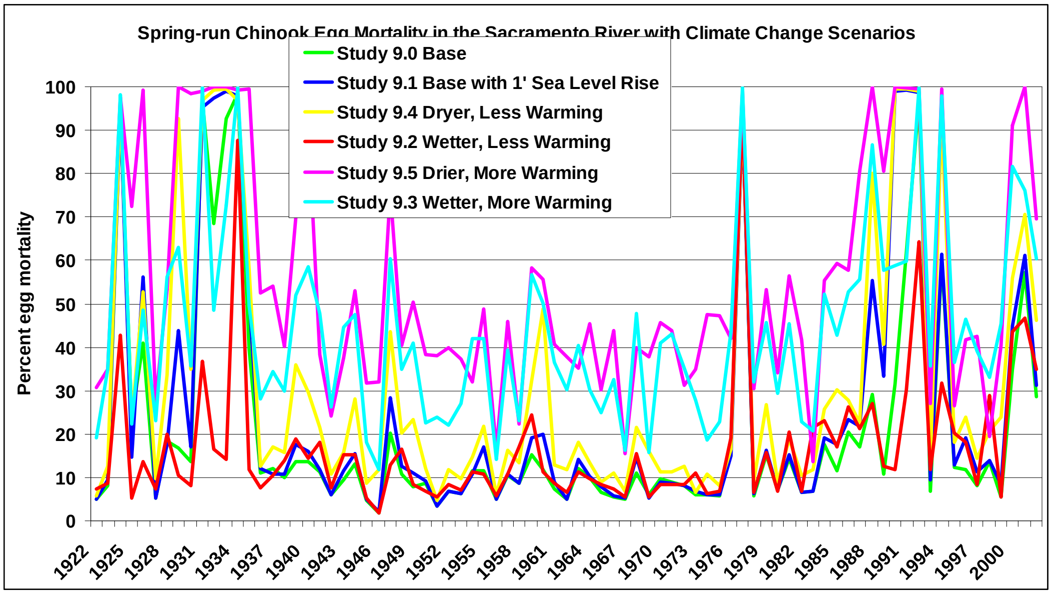

Figure 11-81. Sacramento River spring-run Chinook egg mortality with climate change scenarios record from Reclamation egg mortality model. All studies except 9.0 include 1’ sea level rise. Study 9.0 is future conditions with D-1641.

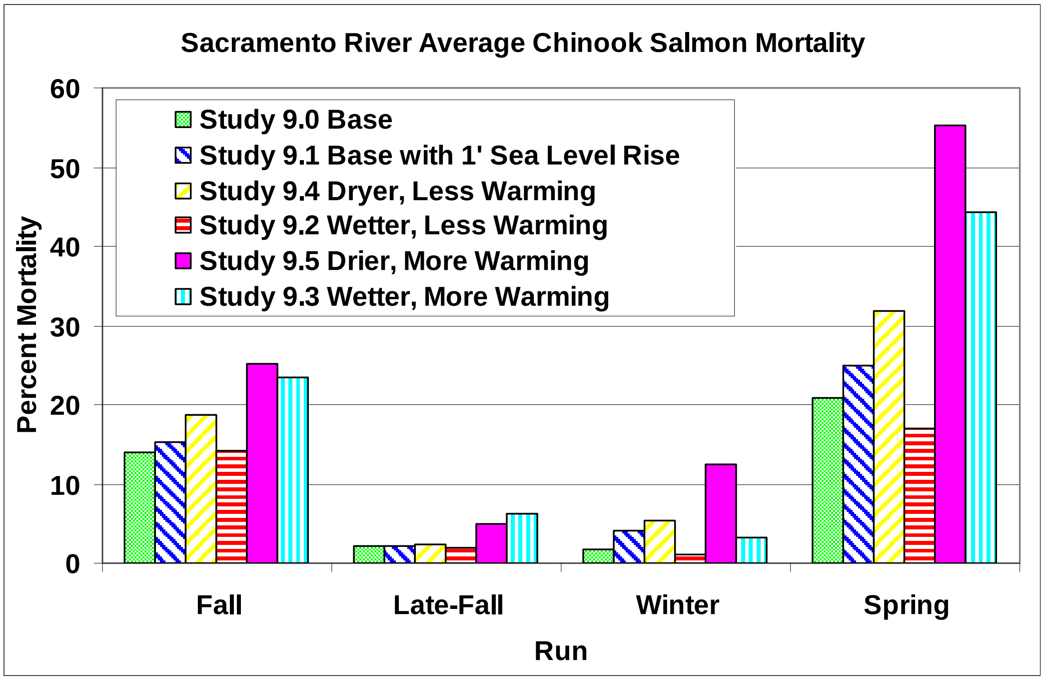

Figure 11-82. Sacramento River average Chinook salmon mortality by run and climate change scenario from Reclamation salmon egg mortality model. All studies except 9.0 include 1’ sea level rise. Study 9.0 is future conditions with D-1641.

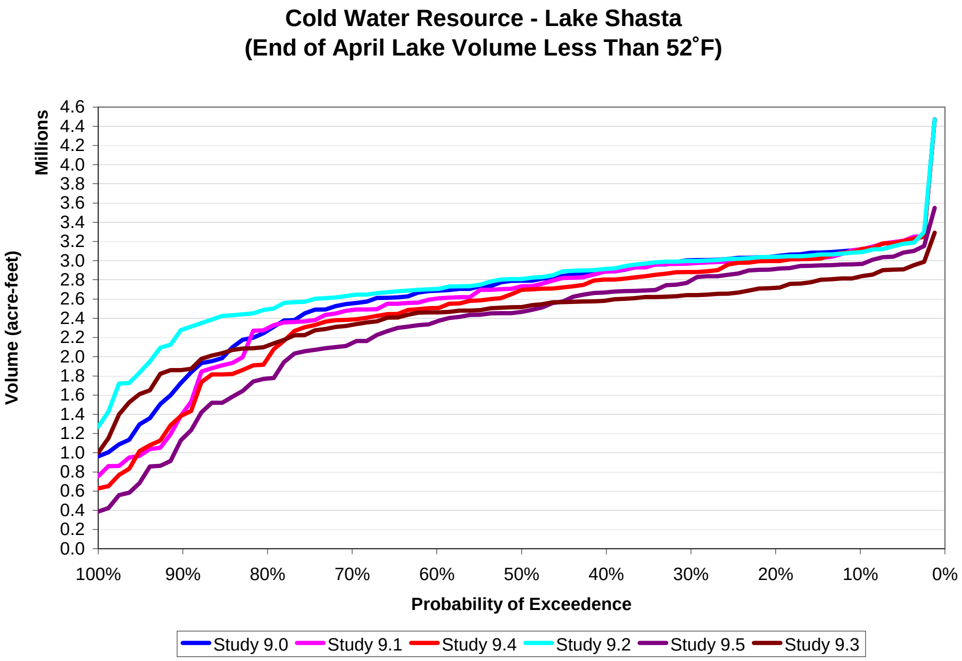

Figure 11-83.Shasta Lake coldwater pool volume at end of April with climate change scenarios. All studies except 9.0 include 1' sea level rise. Study 9.0 is future conditions with D-1641.

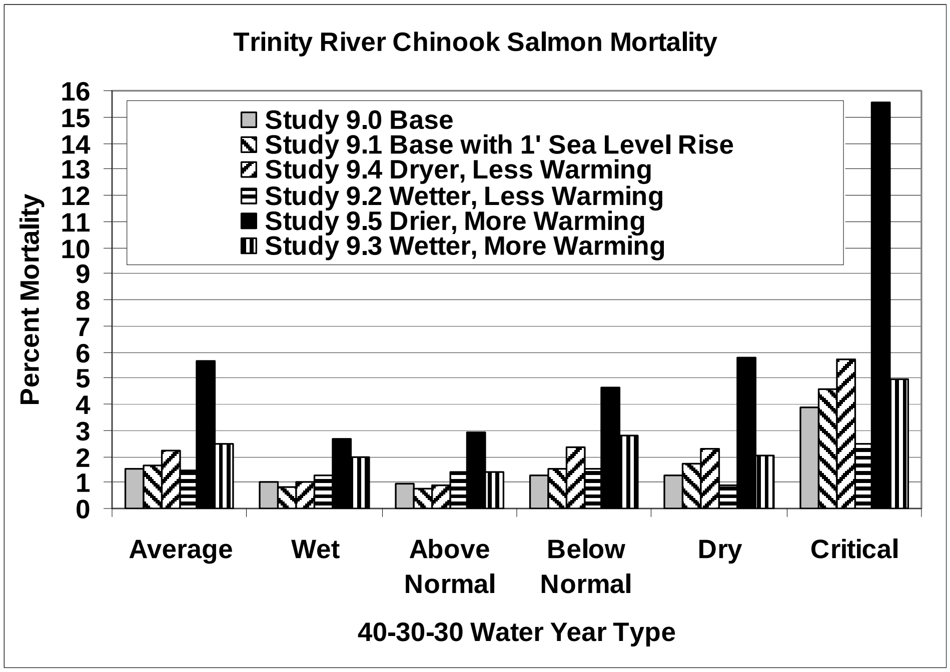

Figure 11-84. Trinity River fall-run Chinook egg mortality with climate change scenarios from Reclamation salmon egg mortality model. All studies except 9.0 include 1' sea level rise. Study 9.0 is future conditions with D-1641.

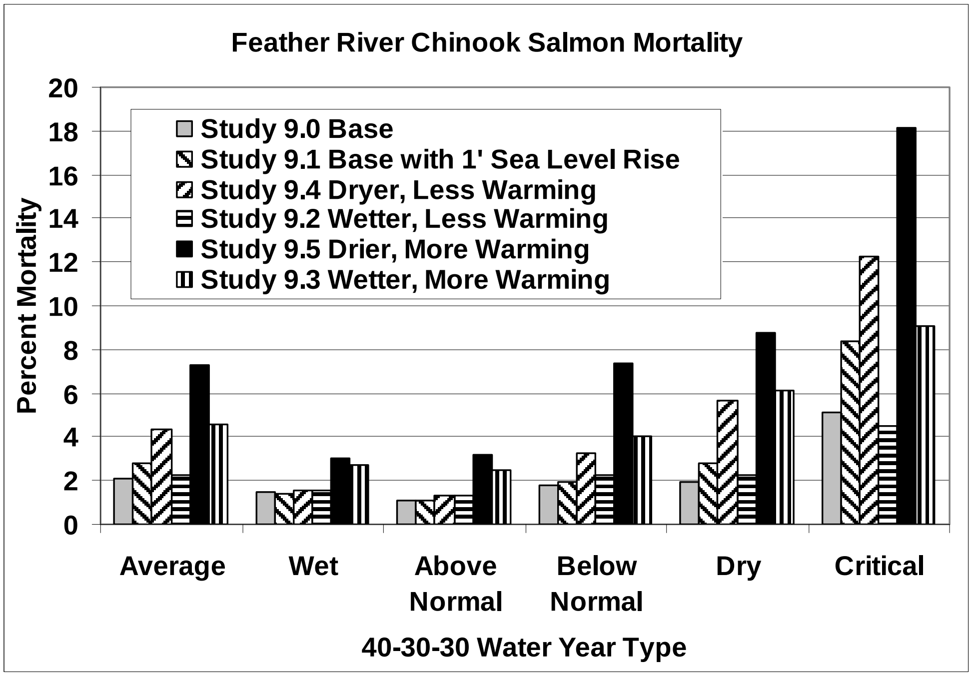

Figure 11-85. Feather River fall-run Chinook egg mortality with climate change scenarios from Reclamation egg mortality model. All studies except 9.0 include 1' sea level rise. Study 9.0 is future conditions with D-1641.

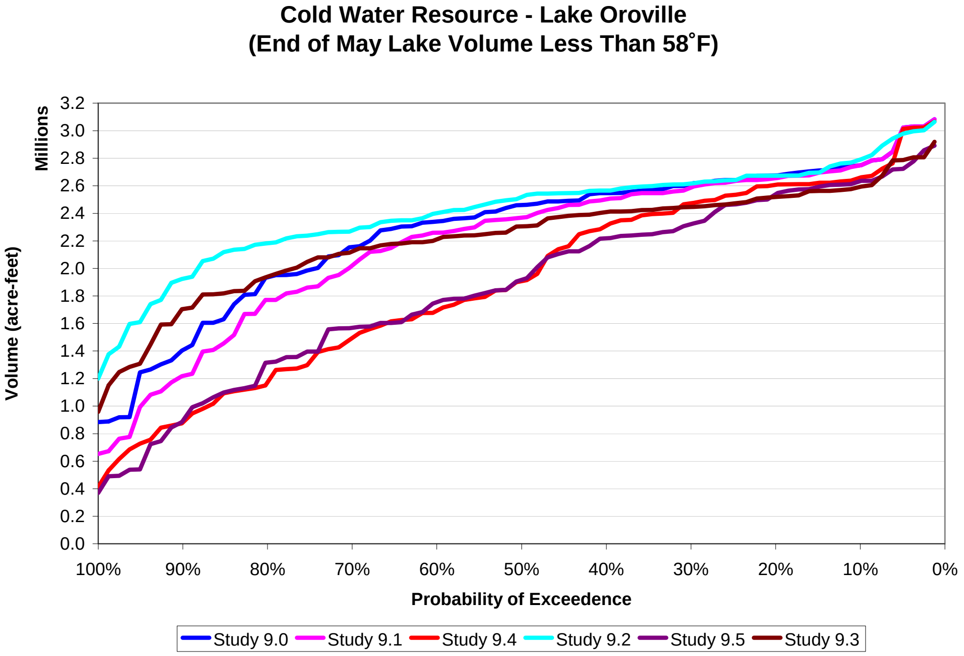

Figure 11-86. Oroville Lake coldwater pool volume at end of April with climate change scenarios. All studies except 9.0 include 1' sea level rise. Study 9.0 is future conditions with D-1641.

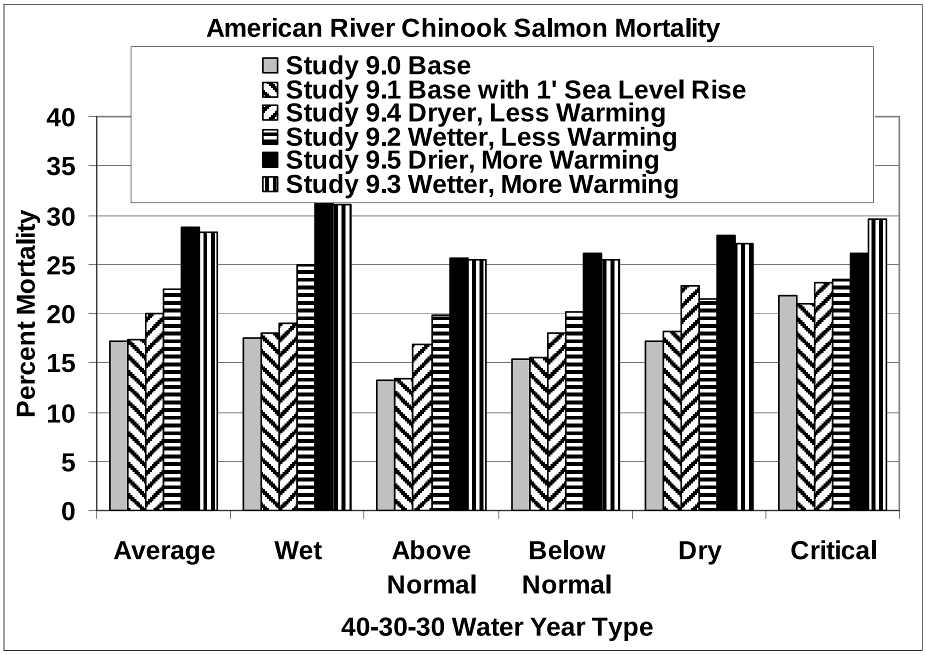

Figure 11-87. American River fall-run Chinook egg mortality with climate change scenarios from Reclamation salmon egg mortality model. All studies except 9.0 include 1' sea level rise. Study 9.0 is future conditions with D-1641.

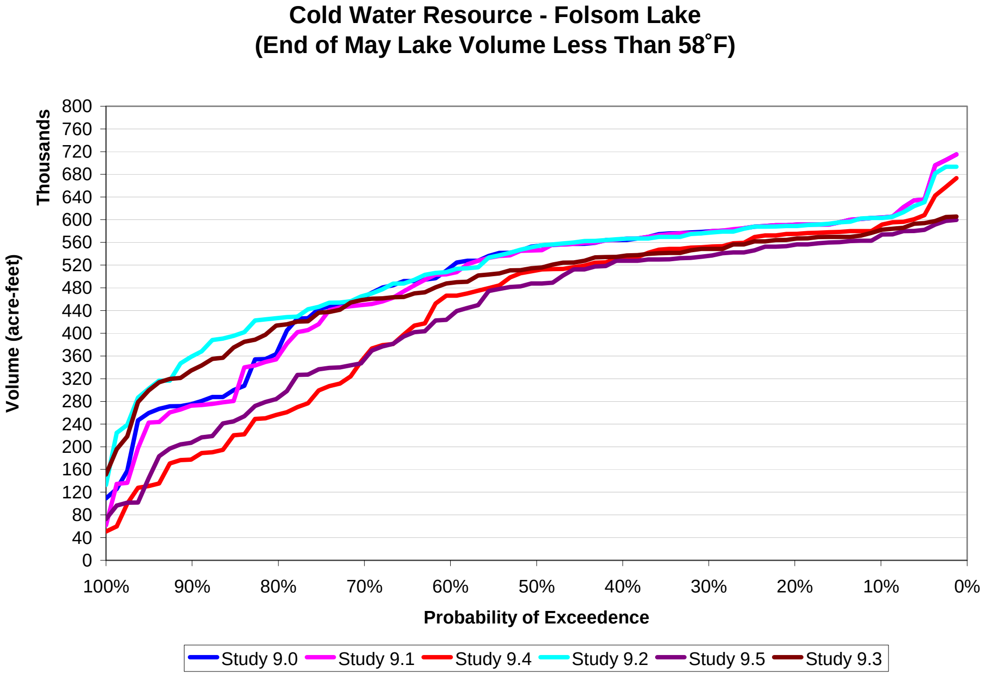

Figure 11-88. Folsom Lake end of May coldwater pool with climate change scenarios. All studies except 9.0 include 1' sea level rise. Study 9.0 is future conditions with D-1641.

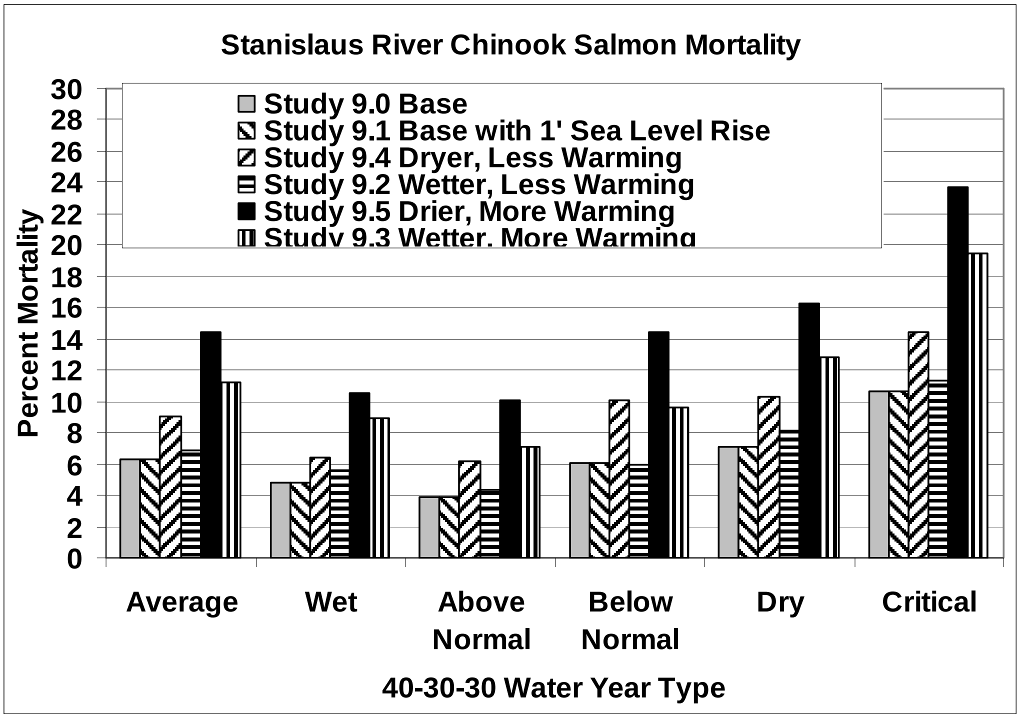

Figure 11-89. Stanislaus River fall-run Chinook egg mortality with climate change scenarios from Reclamation salmon egg mortality model. All studies except 9.0 include 1’ sea level rise. Study 9.0 is future conditions with D-1641.

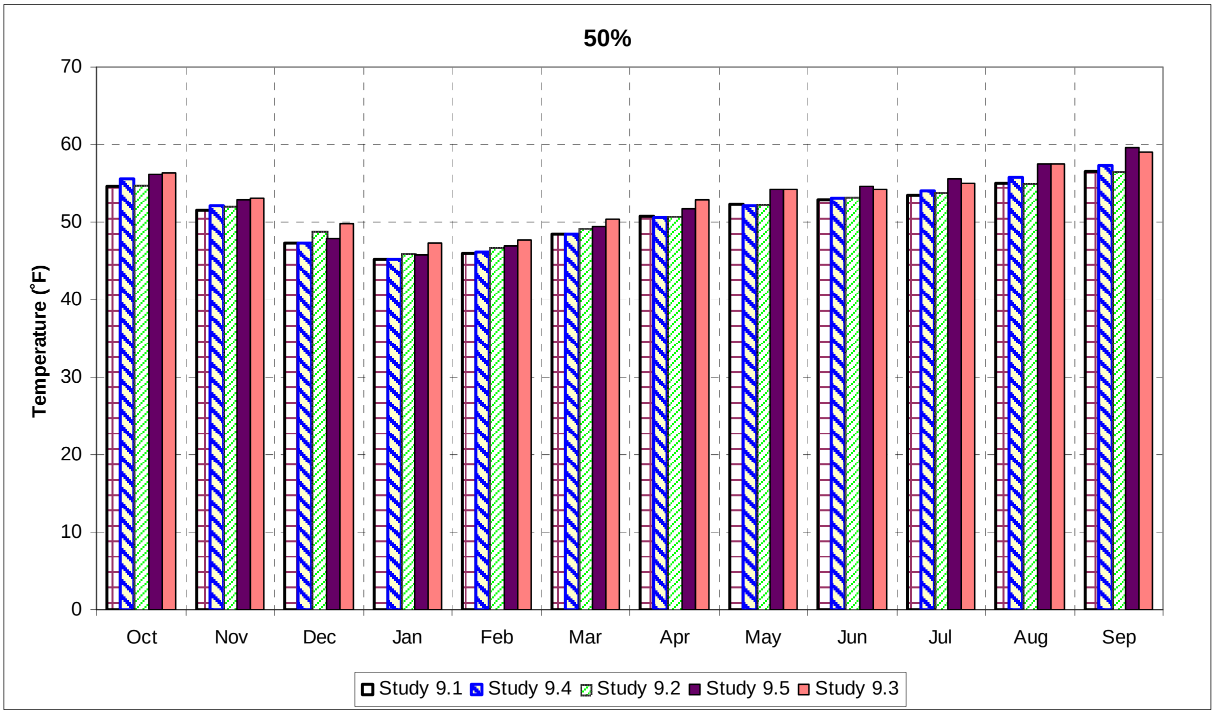

Figure 11-90. Water temperature in the Sacramento River at Balls Ferry under climate change scenarios at the 50% exceedence level.

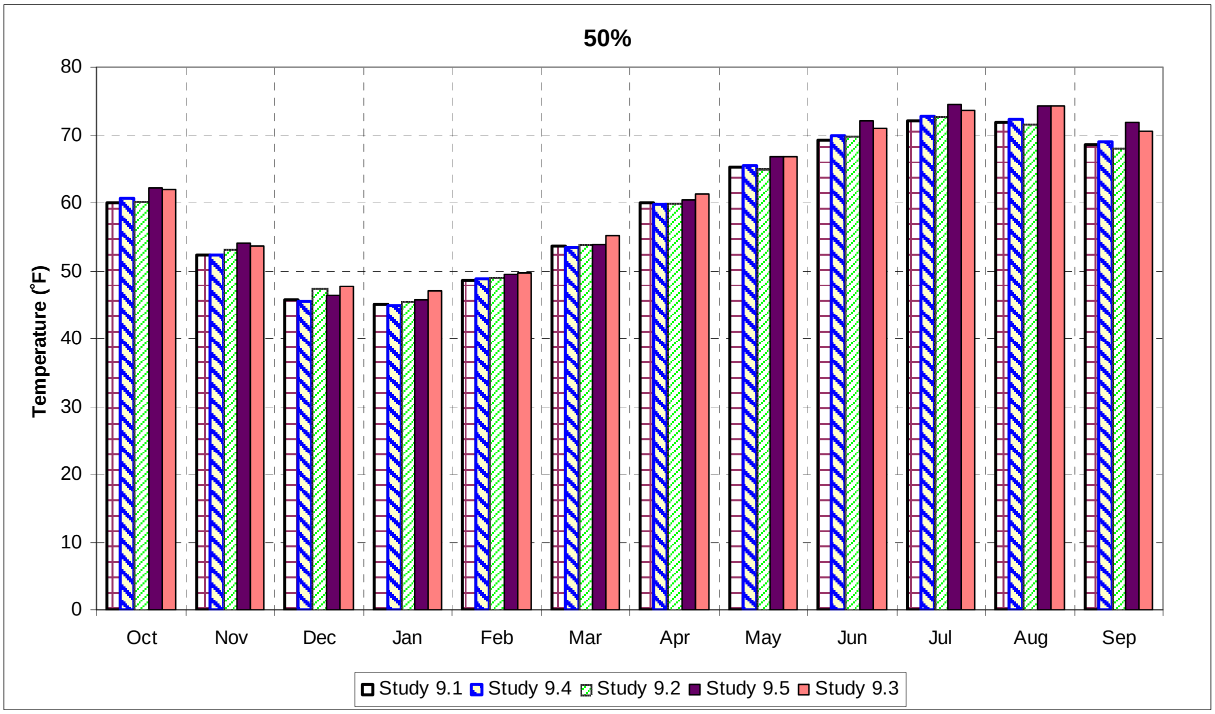

Figure 11-91. Water temperature in the Sacramento River at Freeport under climate change scenarios at the 50% exceedence level.

A mechanism exists whereby global greenhouse warning could, by intensifying the alongshore wind stress on the ocean surface (due to increased temperature gradient between land and water), lead to acceleration of coastal upwelling. Evidence from several different regions suggests that the major coastal upwelling systems of the world have been growing in upwelling intensity as greenhouse gases have accumulated in the earth's atmosphere. Effects of enhanced upwelling on the marine ecosystem are uncertain but potentially dramatic (Bakun 1990). Focusing on the California Current, Diffenbaugh et al (2003) show that biophysical land-cover–atmosphere feedbacks induced by CO_2 radiative forcing enhance the radiative effects of CO_2 on land–sea thermal contrast, resulting in changes in eastern boundary current total seasonal upwelling and upwelling seasonality. Specifically, relative to CO_2 radiative forcing, land-cover–atmosphere feedbacks lead to a stronger increase in peak- and late-season near-shore upwelling in the northern limb of the California Current and a stronger decrease in peak- and late-season near-shore upwelling in the southern limb. Barth et al (2007) show how a 1-month delay in the 2005 spring transition to upwelling-favorable wind stress in the northern California Current Large Marine Ecosystem resulted in numerous anomalies: warm water, low nutrient levels, low primary productivity, and an unprecedented low recruitment of rocky intertidal organisms. Early in the upwelling season (May–July) off Oregon, the cumulative upwelling-favorable wind stress was the lowest in 20 years, nearshore surface waters averaged 2°C warmer than normal, surf-zone chlorophyll-*a* and nutrients were 50% and 30% less than normal, respectively. Delayed early-season upwelling and stronger late-season upwelling are consistent with predictions of the influence of global warming on coastal upwelling regions.

Implications for salmonids are that if coastal upwelling does indeed increase but occur later under warming scenarios then, although uncertain, food supplies for salmonids in the ocean could increase and provide favorable foraging conditions and high ocean survival.

Consideration of Variable Ocean Conditions

Salmon and steelhead spend the majority of their lives in the ocean. Therefore, conditions in the ocean exert a major influence on the growth and survival of these fish from the time they leave freshwater until they return as adults to reproduce. Mantua et al (1997) described a recurring pattern of ocean-atmosphere climate variability centered over the mid-latitude North Pacific basin. Over the past century, the amplitude of this climate pattern has varied irregularly at interannual-to-interdecadal time scales. This pattern is referred to as the Pacific Decadal Oscillation (PDO). Major changes in northeast Pacific marine ecosystems have been correlated with phase changes in the PDO; warm eras have seen enhanced coastal ocean biological productivity in Alaska and inhibited productivity off the west coast of the contiguous United States, while cold PDO eras have seen the opposite north-south pattern of marine ecosystem productivity.

Another pattern, called the *El Niño/Southern Oscillation (ENSO),* occurs on a shorter time scale of six to eighteen months compared to 20 to 30 years for the PDO. The same general pattern is evident with warm periods showing inhibited productivity along the Pacific coast of the southern US and enhanced ocean biological productivity in Alaska.

Sierra snowpack and streamflow are also correlated with ENSO and PDO. During the warm phases lower snowpack and streamflows occur and during cool phases above average snowpack and streamflows occur (Mantua et al, 1997).

During the cooler phases of ENSO and PDO, California salmon populations generally experience increased marine survival. In addition, higher streamflows tend to occur during the cooler phases, enhancing freshwater production and providing the opportunity for more diverse life history types of juvenile salmonids. The inverse effects on California salmonid populations tend to occur during warm cycles. These alternating patterns of productivity, which are independent of CVP and SWP water operations, can mask most changes in populations that occur due to water operations. The effects of habitat conditions resulting from water operations interact with the effects of oceanic productivity on salmon survival/production. Ocean conditions can exert a dominant effect on year-to-year productivity. Therefore, any effects need to be considered in light of variable and difficult to quantify ocean conditions and climate variability.

Returns of several West Coast Chinook and coho salmon stocks were lower than expected in 2007. In addition, low jack returns in 2007 for some stocks suggest that 2008 returns will be at least as low. Central Valley fall run Chinook escapement was estimated to have been less than 25 percent of predicted returns and below the escapement goal of 122,000 – 180,000 adults for the first time since the early 1990’s and continuing a declining trend since the recent peak abundance in 2002. For the spring and summer of 2005 (the ocean-entry year for 2004 brood fall-run Chinook and 2003 brood coho), two approaches to estimating ocean suitability for juvenile salmon both indicated very poor conditions for salmon entering the ocean, indicating poor returns for coho in 2006 and age 3 fall Chinook in 2007. Coast-wide observations showed that 2005 was an unusual year for the northern California Current, with delayed onset of upwelling, high surface temperatures, and very low zooplankton biomass. These poor ocean conditions provide a plausible explanation for the low returns of Central Valley fall Chinook in 2007 and coho in 2006 and 2007. Coho returns to Trinity River Hatchery were not reduced in 2006 but 2007 returning coho were severely reduced and would have been affected by the 2005 ocean conditions. Consistent with Central Valley fall Chinook record low jack return in 2007, the ocean indicators would predict very low fall Chinook adult returns in 2008 (Varanasi and Bartoo, 2008). As a result of predicted low returns the California commercial and recreational fishing season have been closed by the PFMC and NMFS in 2008.

According to Robert Webb (pers comm.) the timing and intensity of springtime upwelling along the west coast of the US has dramatic impacts on the productivity and structure of the California Current ecosystem with studies documenting the effects on marine mammals, coast sea birds, and marine and anadromous fish populations. Schwing et al (2006) documented the delayed onset of upwelling in the northern California Current in 2005, noting that while not unprecedented, this delay impacted dramatically organisms with life histories closely tied to the evolution of the annual cycle and dependent on the high productivity associated with the upwelling. One thing to note was the unusually warm (nutrient depleted) water that penetrated north as far as Oregon.

The wind-driven California Current System (CCS) plays a critical role as it advects cold water southward along the western coast, thus contributing to a significant land-sea temperature and pressure difference in spring-summer when the land warms. This pressure difference results in northerly coastal winds that drive coastal upwelling, bringing nutrient rich water to the surface. The California Current is also linked to the large-scale wind forcing and ocean circulation. For example, the second EOF of SST and sea surface height over the North Pacific is characterized by a dipole-like structure with a nodal line along 40°N, close to the axis of the eastward flowing

North Pacific Current. Variations of this mode primarily correspond to a strengthening and weakening of the north Pacific gyre circulation. North of Cape Mendocino (~40°N) upwelling starts in spring and lasts until fall, while south of Cape Mendocino upwelling occurs year-round. The seasonality of upwelling in the northern region appears to be crucial for ecosystem dynamics, especially for species whose life history is closely tied to the seasonal cycle.

Anomalous near-shore oceanographic conditions associated with delayed upwelling and anomalous water temperatures during the Springs of 2005 and 2006 are thought to have played the critical role in low juvenile fish survivorship. Schwing et al (2006) identified anomalous anomalous April–June sea level pressure over the North Pacific. Their analysis concluded that while El Niños can be linked to weaked/delayed upwelling along the west coast of the US, El Niños are not the only cause. Offshore transport, water column stability, and freshwater input were identified as other important influences on critical nutrient availability. A subsequent NWS analysis of the potential predictiblility of the suppressed spring upwelling in 2005 and 2006 along the west coast of the US (pers. comm. Dave Reynolds) suggests that the persistence of a cutoff low just off the coast is sufficient to disrupt “northwest flow and stratus by destroying the marine inversion and coast jet”.

Habitat restoration can mitigate some of the negative impacts of climate change on salmonid habitat. However, climate change will make salmon restoration more difficult.

During times of decreased ocean productivity the production of fish from freshwater can be critical to maintaining salmon runs. The abundance of hatchery fish released into the bay tends to remain constant and could result in higher mortality of the wild fish due to competition for lower than normal krill populations or other factors.

Consideration of the Risks Associated with Hatchery Raised Mitigation Salmon and Steelhead

Reclamation funds the operation of Coleman Hatchery, Livingston Stone Hatchery, Nimbus Hatchery, and Trinity River Hatchery. DWR funds the operation of the Feather River Hatchery (FRH). The USFWS operates Coleman and Livingston Stone Hatcheries and DFG operates Feather River, Nimbus, and Trinity Hatcheries. These hatcheries are all operated to mitigate for the anadromous salmonids that would have been produced by the habitat if not for the dams on each respective river. Reclamation and DWR have discretion over how the hatcheries are operated but generally leave operational decisions on how to meet mitigation goals up to the operating agency.

Most hatchery production releases from the American and Feather Rivers are released in San Pablo Bay. The bay releases have been suspected of causing increased rates of returning adults straying into tributaries other than their tributary of origin. Examination of CWT data from the American River from 2001 and 2002 shows that straying was not as high as was suspected. Out of a contribution from Nimbus Hatchery to the Central Valley escapement of nearly 80,000 Chinook in run years 2002-2004 only about 2.8 percent (2,193 fish) returned to rivers other than the American (Table 11-17). This is well within a straying rate that could be considered normal for wild fish. The highest percentage of strays from the American (0.7 percent) occurred in the Feather/Yuba River system.

Table 11-17. Contribution of Nimbus Hatchery Chinook salmon from brood years 2000 and 2001 to Central Valley rivers based on coded wire tag returns.

Contribution of Nimbus Hatchery Fish from BY 2000 and BY 2001 to Central Valley Rivers

Sum of Contribution	runyr					
sampsite	2002	2003	2004	Grand Total	Percent of total	
ABRB			142	142	0.2%	Sacramento River (abov
AMN	2,406	49,887	12,604	64,897	82.3%	American River, in-river
BUT		25	21	46	0.1%	Butte Creek
FEA	214			214	0.3%	Feather River
FRH		14	3	17	0.0%	Feather River Hatchery
GUAD		7		7	0.0%	?
LFC			90	90	0.1%	Feather Low Flow Chan
MER		76	52	128	0.2%	Merced
MOK	166	564	55	784	1.0%	Mokelumne
MRFI			65	65	0.1%	Mokelumne River hatch
MRH	116	50	22	188	0.2%	Merced Hatchery?
NFH	1,797	6,769	2,777	11,343	14.4%	Nimbus Hatchery
SAA	397			397	0.5%	Carquinez to American
STA		110	56	166	0.2%	Stanislaus
TUO	7	81	11	99	0.1%	Tuolumne
YUB	27	220		247	0.3%	Yuba
Grand Total	5,130	57,802	15,897	78,829	100.0%	

Total straying of Nimbus hatchery fish 2002-2004
(sum of contribution recovered in rivers other than American)
2,193
2.8% recovered in other rivers compared to American

Consultations for Hatchery Genetic Management Plans are underway for Nimbus, Feather River, Coleman, and Trinity River Hatcheries. These will address the effects of hatchery operations on the listed species.

Williams (2006) summarized existing knowledge on effects of hatchery production on wild populations in the Central Valley and outlined radical recommendations for protecting or rehabilitating diverse, naturally adapted populations of salmon in the Central Valley. These recommendations include abandoning production hatcheries altogether and rely on natural production, moving fall-run hatcheries to the coast to support the fall-run Chinook fishery and eliminate competition between natural and hatchery fish in the rivers, concentrating fall-run hatchery production in one river to concentrate the effects on only one river, or substantially reduce hatchery production in all hatcheries or experimentally halt production in selected hatcheries. His formal recommendations are less radical and include: thoroughly reconsider hatchery operations, mark all hatchery fish, release fish only at hatcheries or nearby, avoid overproduction, review and document hatchery practices, and look for evidence of domestication.

Feather River Spring-Run Chinook Straying and Genetic Introgression

Prior to the construction of numerous dams (including the Oroville Dam) on the Feather River, spawning spring- and fall-run Chinook salmon were temporally and spatially separated—i.e., spring-run Chinook salmon spawned earlier and in higher reaches of the watershed compared to fall-run Chinook salmon. Although data are limited, there is a general consensus that there were once genetically distinct Chinook salmon runs in the Feather River system (Lindley et al. 2004; Yoshiyama et al. 2001).

Today, the Fish Barrier Dam located on the Feather River blocks the early-returning (arriving in April through June) run of sexually immature adult Chinook salmon in the Feather River from moving upstream to historical spawning habitat (the dam blocks access). As there is overlap in the timing of spawning, this spring-run Chinook salmon now spawns in the same location as the more numerous later-returning fall-run Chinook salmon. Findings of recent genetic studies using microsatellite markers suggest that: (1) FRH produced spring-run Chinook salmon are genetically similar to fall-run Chinook salmon and (2) phenotypic in-river spring-run Chinook salmon are genetically more similar to fall-run Chinook salmon than to spring-run Chinook salmon populations in Mill, Deer, and Butte creeks (Banks et al. 2000; Hedgecock et al. 2001; DWR 2004a).

A review of available literature suggests three opportunities for genetic introgression in the Feather River:

- Introgression between spring- and fall-run Chinook salmon in the Feather River;
- Introgression between hatchery-produced and wild spring-run Chinook salmon in the Feather River; and
- Straying and introgression between Feather River spring-run Chinook salmon and spring-run Chinook salmon in other systems.

Introgression Between Spring- and Fall-Run Chinook Salmon.

Conditions will continue to promote the commingling of spring-run and early maturing fall-run Chinook salmon on common spawning grounds, leading to increased opportunities for genetic introgression (hybridization) between spring- and fall-run Chinook salmon in the Feather River. In fact, data collected over the past 5 years by DWR on spawning populations of Chinook salmon in the Feather River do not show a bimodal peak that would be expected if there were temporally distinct spawning populations (DWR 2004a). In addition, continued hatchery practices—specifically, the inability to distinguish between spring- and fall-run Chinook salmon when artificially spawning—will continue to be an additional contributor to the observed genetic introgression. Data on the returns of tagged fish suggest that there may have been considerable cross-fertilization between nominal spring- and fall-run Chinook salmon at the FRH (DWR 2004a) over the past several years, and probably since the hatchery began operation in 1967. Under the new FERC license steps would be taken to try and segregate the spring-run and fall-run Chinook salmon in the Feather River to decrease introgression

Introgression between Hatchery-Produced and Wild Spring-Run Chinook Salmon.

One of the key questions about Feather River Chinook salmon involves the genetic and phenotypic existence of a spring run, and the potential effects of the FRH on this run. The Feather River's nominal spring run is part of the spring-run ESU and is thus listed as threatened. Conversely, the hatchery population is not included in the ESU. The nominal spring- and fall-run Chinook salmon in the Feather River are genetically similar and are most closely related to CV fall-run Chinook salmon. There is a significant phenotypic spring run that arrives in the Feather River in May and June and enters the FRH when the ladder to the hatchery was opened. Observations of these early arriving Chinook salmon cast doubt on the presence of a Feather River spring-run, as opposed to a hatchery spring-run. DWR is currently preparing Hatchery Genetics Management Plans for the steelhead and Chinook salmon runs produced at the Feather River Fish Hatchery. It is anticipated that they will be completed in late 2008.

Due to the lack of pre-Oroville Facilities genetic data, the genetic identity of the historic Feather River spring-run Chinook salmon cannot be definitively ascertained. However, it appears that the early arriving, immature Chinook salmon run in the Feather River does not resemble current day spring-run populations in Mill, Deer, and Butte creeks. There are no data on the potential effects (e.g., reduced fitness) of inbreeding or outbreeding of FRH-produced Chinook salmon. In addition, there are no data indicating that spring-run timing on the Feather River is an inheritable trait and the loss of this phenotype would adversely affect the recovery of the CV spring-run Chinook salmon ESU (DWR 2004a). Nonetheless, under the No-Action Alternative, continued operation of the Oroville Facilities is anticipated to continue to contribute to the ongoing genetic introgression currently observed under existing conditions.

Straying and Introgression with Spring-Run Chinook Salmon in Other Systems.

As part of existing operations, FRH-produced Chinook salmon are transported and released into San Pablo Bay. This hatchery practice was intended to reduce/avoid the mortality associated with migrating through the Sacramento-San Joaquin Delta. However, data suggest that the practice of releasing to San Pablo Bay increased the incidence of straying of FRH-produced Chinook salmon (DWR 2004a). Straying can lead to increased competition for spawning habitat and exchange of genetic material between hatchery and naturally spawning Chinook salmon (Busack and Currens 1995).

To analyze the role that hatcheries play in influencing straying rates, DFG used mark-and-recapture data (coded wire recoveries) in the ocean fisheries to reconstruct the 1998 fall-run Chinook salmon cohort from the FRH (Palmer-Zwahlen et al. 2004). This analysis was used to determine the rate at which fish released in the estuary return to the Feather River and to other streams (the stray rate). DFG estimated that of the approximately 44,100 FRH-produced fish that returned to the Central Valley, 85 percent returned to the Feather River (including the FRH), 7 percent were caught in the lower Sacramento River sport fishery, and 8 percent strayed to streams outside the Feather River basin. If salmonids returned to the Feather River in the same proportion as observed in other river systems, the straying rate would be estimated to be approximately 10 percent (DWR 2004a). Although tags from FRH-produced fish were collected in most Central Valley streams sampled, about 96 percent of the 12,438 tags recovered during the 1997 to 2002 period were collected in the Feather River or at the FRH.

A lower percentage of in-basin releases than bay releases survived to reenter the estuary as adults (0.3 percent versus 0.9 percent); however, these fish returned to the Feather River with greater fidelity (approximately 95 percent as compared to around 90 percent for bay releases). Although the straying rate from bay releases is less than might be expected based on earlier studies, it is still higher than natural straying rates and higher than the 5 percent straying rate recommended as a maximum by NMFS. Before rendering definitive conclusions, it should be noted that there are several limitations in the existing data:

- Cohort analysis was only for one broodyear;
- Tag recovery efforts on most Central Valley streams do not provide statistically reliable estimates of the number of tagged fish in the spawning populations; and

- There is a significant inland sport fishery and, in recent years, sampling of this fishery and collecting tags has been spotty because of budget cuts.

It should be noted that based on tag return and genetic data, minimal interbreeding appears to have occurred between FRH spring-run Chinook salmon and spring-run Chinook salmon in Butte, Mill, and Deer creeks. Only a few FRH-produced Chinook salmon have been collected in the lower portions of Deer, Mill, and Butte creeks, in sections supporting fall-run spawning activity. In addition, the genetic structure of spring-run Chinook salmon in the Feather River is distinct from spring-run Chinook salmon from Deer, Mill, and Butte creeks.

Under the No-Action Alternative, operations of the FRH are anticipated to result in continued straying of FRH-produced Chinook salmon at rtes currently observed under existing conditions.

Feather River Spring-Run Chinook Susceptibility to Disease

Susceptibility to disease is related to a variety of factors, including fish species, fish densities, the presence and amounts of pathogens in the environment, and water quality conditions such as temperature, DO, and pH. Oroville Facilities operations have the potential to affect all of these factors at the FRH and in the Feather River downstream of the Oroville Facilities.

Several endemic salmonid pathogens occur in the Feather River basin, including Ceratomyxa shasta (salmonid ceratomyxosis), Flavobacterium columnare (columnaris), the infectious hematopoietic necrosis (IHN) virus, Renibacterium salmoninarum (bacterial kidney disease [BKD]), and Flavobacterium psychrophilum (cold water disease) (DWR 2003a). Of the fish pathogens occurring in the Feather River basin, those that are main contributors to fish mortality at the FRH (IHN and ceratomyxosis) are of highest concern for fisheries management in the region. Although all of these pathogens occur naturally, the Oroville Facilities have the opportunity to produce environmental conditions that are more favorable to these pathogens than under historic conditions:

- Impediments to fish migrations may have altered the timing, frequency, and duration of exposure of anadromous salmonids to certain pathogens;
- Out-of-basin transplants may have inadvertently introduced foreign diseases; and
- Water transfers, pumpback operations, and flow manipulation can result in water temperature changes, which potentially increase the risk of disease.

The transmission of disease from hatchery fish to wild fish populations is often cited as a concern in fish stocking programs. There is, however, little evidence of disease transmission between hatchery fish and wild fish (Perry 1995). Further, the FRH has implemented disease control procedures (e.g., disinfecting procedures) that are intended to minimize both the outbreak of disease in the hatchery and the possibility of disease transmission to wild fish populations.

Field surveys indicated that IHN was not present in juvenile salmonids or other fish in the Feather River watershed (DWR 2004a). Eighteen percent of the adults returning to the Feather River watershed were infected with IHN, but there were no clinical signs of disease in these fish. The hypothesis advanced by DFG pathologists for the cause of the recent IHN epizootics at the FRH is that planting Chinook salmon in Lake Oroville (in the hatchery water supply) resulted in the virus entering the hatchery. Hatchery conditions can then lead to stress and the infections can rapidly escalate to clinical disease, as evidenced by high mortality. No additional epizootics have been observed since the plantings of Chinook salmon in the reservoir were brought to an end. Whether the cessation of stocking Chinook salmon will prevent future IHN outbreaks at the FRH is uncertain, as the cause of specific disease outbreaks in Oroville Facilities waters is poorly understood (DWR 2004a).

Under the No-Action Alternative, continued operations of the Oroville Facilities are anticipated to result in potential exposures to pathogens similar to that currently observed under existing conditions.

Steelhead Straying and Genetic Introgression

The lack of distinction between San Joaquin and Sacramento steelhead populations suggests either a common origin or genetic exchange between the basins. Findings of a recent genetic study on CV steelhead populations (Nielson et al. 2003) indicate that:

- Feather River steelhead populations (natural and FRH-produced populations) are more similar to populations from streams in the same general geographic location—i.e., Clear Creek, Battle Creek, upper Sacramento River, Coleman National Fish Hatchery, and Cottonwood, Mill, Deer, and Antelope creeks.
- Feather River steelhead populations are not closely linked to Nimbus Hatchery and American River populations.
- Feather River steelhead population’s closest relative is the FRH-produced steelhead and both are distinct from other Central Valley steelhead populations.
- There are no data on the potential effects (e.g., reduced fitness) of inbreeding or outbreeding of FRH-produced steelhead.

These data suggest that there appears to be considerable genetic diversity within the CV steelhead populations and that, although fish from the San Joaquin and Sacramento River basins cannot be distinguished genetically, there is still significant local genetic structure to CV steelhead populations (Figure 3-2). For example, Feather River and FRH-produced steelhead are closely related, as are American River and Nimbus Hatchery fish.

Estimates of straying rates only exist for Chinook salmon produced at the FRH. However, based on available genetic data, the effects of hatcheries that rear steelhead appear to be restricted to the population on hatchery streams (DWR 2004a). These findings suggest that, although ongoing operations may impact the genetic composition of the naturally spawning steelhead population in these rivers, hatchery effects appear to be localized. It should be noted that genetic data for steelhead are limited (DWR 2004a).

There appears to be little mixing of hatchery and wild gene pools in the FRH. This conclusion is based on study findings that show that only adipose clipped steelhead (hatchery-produced, presumably mostly from the FRH) ever reach the FRH. Spawned steelhead are released back to the river—there are no data to determine how many of these fish survive to spawn again.

Nevertheless, the commingling of spawning adults due to the blockage of fish to historical spawning and rearing habitat in headwater streams presumably provides an opportunity of mixing between FRH-produced and wild steelhead. Homogenization of the wild Feather River steelhead genetic structure cannot be ascertained as there are no data to show if the river spawners are of direct hatchery origin or the progeny of previous natural spawners. Moreover, as there are no pre-Oroville Facilities genetic data, it is not possible to characterize the distinctness of historical steelhead in the Feather River. However, the existing data suggest that some of the original genetic attributes remain in the current steelhead populations in the Feather River.

Given available genetic data, under the No-Action Alternative, straying of FRH-produced steelhead is anticipated to have a negligible effect on the genetic integrity of CV steelhead populations as observed under existing conditions and continued operation of the Oroville Facilities is anticipated to continue to provide potential opportunities for the genetic introgression currently observed under existing conditions in the Feather River.

Critical Habitat

The primary constituent elements (PCEs) of critical habitat include sites essential to support one or more life stages of the ESU (sites for spawning, rearing, migration, and foraging). The specific PCEs include:

1. Freshwater spawning sites
2. Freshwater rearing sites
3. Freshwater migration corridors
4. Estuarine areas
5. Nearshore marine areas
6. Offshore marine areas

Water operations can affect habitat conditions in the first four of the PCEs. These four PCEs are present in the action area. The critical habitat areas are delineated and some critical habitat effects are detailed in Chapters 3 and 5.

Spawning Sites

Sufficient spawning habitat would be maintained for all the listed salmonids in the affected rivers by maintaining coolwater releases from the reservoirs. A slight reduction in available coldwater for spawning habitat could occur in critically dry water years in the future as detailed above. This could result in fish spawning further upstream closer to the terminal dams. Spawning habitat has not been identified as a limiting factor to the listed species in any of the rivers at the current densities of spawners. When populations are higher with improved ocean conditions numbers of returning spawners could fully utilize the spawning habitat within the area of suitable water temperature. Spawning gravel additions would continue to occur to replace the deficits created by the loss of recruitment from upstream. These additions should maintain spawning habitat in the areas of the rivers near the dams with the coolest temperatures for egg incubation. High flows during flood control operations would provide needed gravel movement to keep spawning areas clean with freshly redeposited gravel.

Freshwater Rearing Sites

The project operations would not change rearing habitat availability. Habitat features such as meso and micro habitat sites, woody debris, aquatic vegetation and varied substrates would continue to be present in a similar configuration. These habitats would continue to produce food needed by the salmonids. Salmonid habitat improvement projects will continue to be funded by Central Valley Project Improvement Act funds received from water deliveries. Temperatures could be degraded somewhat through future climate change scenarios and decreased coldwater pool volume as detailed above. These scenarios would affect steelhead rearing habitat the most in rivers such as the American and Stanislaus.

Freshwater Migration Corridors

Freshwater migration corridors would not change through the project. Red Bluff Diversion Dam operations would remain the same in the near future but would allow for improved passage conditions when a pumping plant is constructed. Delta Cross Channel gates would be operated the same. Flows would be suitable for passage in all river reaches. Changes in flows and their effects on the critical habitat in the rivers and the delta are detailed above and in Chapters 10 and 12.

Estuarine Areas

Conditions in the estuary would remain about the same for salmonids through future operations. Salmonids would continue to use nearshore areas in the estuary as rearing habitat as they migrate and grow on their way to the ocean. Delta pumping operations and take of listed species will continue to be monitored so that adjustments can be made when take levels increase.

Evaluation of Viable Salmonid Population (VSP) Parameters

According to McElhany et al. (2000) the key parameters used to determine whether a population is likely to experience long-term viability are 1) abundance, 2) population growth rate, 3) population spatial structure, and 4) diversity. The following is a discussion of the effects of the project on VSP parameters.

Winter-run Chinook Salmon

Population Size

Winter-run Chinook have experienced recent population size increases followed by the most recent year drop in numbers experienced throughout southern Chinook and coho salmon populations. The population size increases encompassed two generations with three year average population sizes of around 7,000 to 12,000 individuals making up the escapement. The current three year running average population size appears to have sufficient numbers of individuals to have a high probability of surviving environmental variation of hydrological and ocean conditions experienced through the historical record. Depensatory processes are not likely to be important at current population levels since the population is limited to a specific area of the Sacramento River, ie. the fish are all present in the same area of the river at the same time. Genetic diversity should be maintained at these population levels. The winter-run population overlaps habitat use with other runs and all together they provide needed ecological functions such as cycling of spawning gravels and providing nutrients from carcasses. Current monitoring programs provide a high level of confidence in the winter-run population numbers and spatial distribution.

Population Growth Rate

The winter-run Chinook population has been consistently growing through all cohorts since the low levels of the early 1990's. The recent decline in 2007 and expected in 2008 is an exception. Even with the recent decline the population exhibited the ability to increase under current operational scenarios with suitable ocean conditions. The IOS model, with the assumptions used, indicates that under future operational scenarios the growth rate may decrease in comparison with the current condition due to the effects that could occur in critically dry water years. The current poor ocean conditions produced a population about one third of the three year prior escapement. This decrease in productivity was less than what has occurred for fall-run Chinook. The fall-run Chinook adult returns are dominated by returns from large numbers of hatchery Chinook released into San Pablo Bay. These hatchery fish do not experience the in-river conditions during their juvenile lifestage and the number released is relatively constant from year to year. The fact that winter-run Chinook returns did not decrease as much as occurred for fall-run Chinook indicates that juvenile winter-run production surviving to the ocean was probably high for the cohort and was supported by good in-river conditions. This means that for the current population, during years that are not critically dry, the freshwater productivity can compensate somewhat for poor ocean conditions and the population should remain viable. During successive dry water years winter-run would not fare as well.

Spatial Structure

Winter-run Chinook are restricted to the Sacramento River. This limits the spatial structure of the population compared to most salmonid runs which utilize multiple tributaries. Habitat patches are being maintained through water temperature management, reduction in impediments to migration (RBDD, ACID, and DCC gate), and habitat improvements (spawning gravel replacement). Battle Creek is being improved to potentially support winter-run Chinook in the future and increase spatial structure. No natural source subpopulations are currently available, although Livingston Stone Hatchery could be considered a subpopulation.

Diversity

Chinook salmon in the Central Valley exhibit a high diversity in run timing such that depending on the specific tributary there are Chinook salmon returning and spawning during virtually all months of the year. This allows the species to take advantage of the environmental conditions unique to individual tributaries. Blockage of many upstream habitats has reduced diversity and spatial structure somewhat however. Winter-run Chinook exhibit a diversity of age at return from fish that return from two to five years of age. The predominant trait is three year fish but the diversity in ages allows for overlap in case a year class experiences a large drop in abundance. Natural disturbance regimes such as high flows that redistribute the bed occur and provide some diversity in habitat. Gene flow between winter-run and other runs is likely negligible because their spawning timing is well separated from runs in the Sacramento and all other rivers. The project should maintain the existing diversity and run size will continue to fluctuate with year to year changes in precipitation and ocean conditions.

Spring-run Chinook Salmon

Population Size

The core spring-run population reproduces primarily in non-project streams. Spring-run experienced recent increases in population, similar to winter-run and currently are experiencing a positive growth rate. The component of the population in the Sacramento River is at a low level, however. The Clear Creek component has been steadily increasing and the Feather River component has been relatively stable. Depensatory processes could occur in the Sacramento River but this river is not considered a core spring-run habitat area for spring-run spawning. Spring-run, when combined with the other runs, provide needed ecological functions such as cycling of spawning gravels, and providing nutrients from carcasses. Spring-run population size is monitored relatively well and trends can be detected. The project is not expected to significantly affect the spring-run population size. For some reason spring run in the Sacramento River have not rebounded from population lows as they have in the Sacramento River tributary streams. Red Bluff Diversion Dam affects spring-run adult migrations in the Sacramento River more than any of the other runs. The ten month gates out operations in the future may allow upstream populations to increase, but it remains unknown whether the blockage of a portion of the run is what is currently limiting upstream population increases. For example spring run escapement in Clear Creek has increased under the current gate operations. Conditions downstream of RBDD are generally suitable for spring-run to hold for long periods during the summer. There are risks to the spring-run population from climate change scenarios, but these are not caused specifically by the project.

Population Growth Rate

The spring-run Chinook population has recently maintained cohort replacement rates of 1.0 or greater in most years. The recent year decline in returning fall-run and winter-run escapement will likely be seen in spring-run as well. The Feather River segment of the population includes a hatchery component making the natural productivity difficult to determine. The Sacramento River segment of the population is at low numbers. The necessity of managing coldwater for winter-run Chinook stresses spring-run spawners during the fall in the mainstem, especially in critically dry water years. Differences in spring-run production between current and future operational scenarios were not as apparent as for winter-run.

Spatial Structure

Spring-run Chinook are present in multiple Sacramento River tributaries. This provides a better buffer against catastrophic effects than exists for winter-run Chinook. The trait of the spring-run population holding over through the summer originally was an asset to the population because it allowed migrations to occur during high water when water temperatures were cool. It is currently a risk factor because the amount of over summer holding habitat with suitable water temperatures and habitat conditions is limited. Clear Creek may provide a good refuge for the population in dry water years with the presence of the coldwater pool in Trinity Reservoir and relatively small instream flow needs to maintain fish in Clear Creek. Battle Creek is also being made more accessible for spring-run and has shown promising numbers over two generations. The existing spatial structure should not be affected by the project. Improvements to passage at Red Bluff Diversion Dam could help upstream populations, thereby enhancing spatial structure.

Diversity

Chinook salmon in the Central Valley exhibit a high diversity in run timing such that depending on the specific tributary there are Chinook salmon returning and spawning during virtually all months of the year. This allows the species to take advantage of the environmental conditions unique to individual tributaries. Blockage of many upstream habitats has reduced diversity and spatial structure somewhat however. Spring-run Chinook exhibit a diversity of age at return from fish that return from two to five years of age. The predominant trait is three year fish but the diversity in ages allows for overlap in the event a year class experiences a large drop in abundance. Natural disturbance regimes such as high flows that redistribute the bed occur and provide some diversity in habitat. Gene flow between spring-run and fall-run Chinook can be substantial where the two runs co-exist. The two runs formerly spawned in different river reaches but the reduction in habitat is such that their spawning habitat and run timing overlap. This allows more opportunity for gene flow between the runs. Spring-run and fall-run in the Feather River probably have the greatest overlap leading to gene flow between the populations. Actions are being taken to separate the runs and reduce this effect on the Feather River.

Central Valley Steelhead

Population Size

The lack of monitoring data to effectively determine steelhead population size contributes as a risk factor for steelhead because it makes population trends difficult to detect. The best indicator of population size may be the ratio of hatchery (clipped) to unclipped steelhead in monitoring programs. This has remained relatively constant since clipping of all hatchery steelhead began in 1998. The diversity of life history types and the prevalence of resident O. mykiss in many rivers provides some insurance against low population size. It is evident that hatchery produced steelhead numbers are higher than naturally produced numbers.

Population Growth Rate

Because the population size is unknown in most tributaries the population growth rate is unknown. Based on existing monitoring programs there do not appear to be population increases occurring. No real change in population size is apparent. The streams with hatchery populations (American River, Feather River, Battle Creek) appear to have the majority of their runs made up of hatchery fish and the fish spawning in the rivers include a large hatchery produced component. Gene flow between the hatchery and naturally spawned component is substantial. The resident O.mykiss component present in rivers such as the Sacramento, Clear Creek, and Stanislaus provides a source of fish during down cycles in abundance. Water temperature can limit potential for natural populations to increase in some streams.

Spatial Structure

The spatial structure of the steelhead population provides some resiliency to the population. Steelhead and the resident form are the most widely distributed of the salmonids in the Central Valley. The spatial structure has been reduced, however, by the presence of dams on many streams eliminating access to upstream habitat. The resident form of the species still thrives in many of these upstream areas but gene flow from downstream to upstream has been eliminated. Upstream populations can provide a source of fish to anadromous reaches downstream where stocking has not replaced the natural stocks upstream. The habitat is patchily distributed during the warmwater periods of the year because the warmwater in the lower reaches of streams creates a barrier to migrations between tributaries. Project operations maintain coldwater downstream of reservoirs, maintaining resident O.mykiss.

Diversity

Steelhead (O.mykiss) exhibit a high diversity in life history forms. Numerous resident populations exist that are probably somewhat connected. Anadromous fish have been shown to produce both resident and anadromous offspring. Resident fish have also been shown to produce both resident and anadromous offspring. Steelhead provide some resiliency to the population in the case that some catastrophic event should wipe out a resident population in some stream. The resident form provides the same type of insurance in the case that the anadromous form suffers increased declines.

SONCC Coho Salmon

Population Size

The estimated coho salmon run size in the Trinity River has been above the 20-year average for seven of the last eight years. The ESU includes rivers other than the Trinity. The Trinity River Restoration Program is working to increase coho habitat and population size in the system. The Trinity River coho run has a large hatchery component with substantial gene flow with in-river spawners. Depensatory processes are unlikely to be important because the spawning population is concentrated in a small area of the river near the dam. The project should not adversely affect the coho population size and there should be benefits with the restoration program.

Population Growth Rate

The in-river spawning population is at a low level. The growth rate is difficult to determine with the substantial hatchery presence producing a steady number of fish each year. The growth rate does not appear to be large, however. The state of the population in the absence of hatchery production is unknown. Coho in the mainstem Trinity tend to congregate within a few miles downstream of the dam and hatchery. The operational scenarios should allow for population growth to occur.

Spatial Structure

Coho salmon are widespread throughout the ESU. This project should not affect spatial structure of the population as the Trinity River component will be maintained. The restoration program is working to improve habitat for coho salmon and maintain or increase habitat patches within the mainstem Trinity River.

Diversity

Coho salmon in this ESU primarily return in their third year, but a small number of males breed in their second year. There may be a few four year old fish. Natural processes are being maintained through the restoration program and its flow regime. The project should not affect diversity of the ESU.

Central California Coast Steelhead

No adverse effects of the project on Central California Coast steelhead have been identified. The portion of the project area intersecting the CCC steelhead DPS is in the north-western Delta leading to Susuin Creek. Suisun Creek was excluded from the Critical Habitat designation. Effects on this migratory corridor for CCC steelhead are expected to be minimal to water quality and of no measurable effect on VSP parameters for CCC steelhead.

Cumulative Effects

Cumulative effects include the effects of future State, tribal, local, or private actions that are reasonably certain to occur in the action area of this biological assessment. Future Federal actions that are unrelated to the proposed action are not included because they require separate ESA consultation.

Non-Federal actions that may affect the action area include State angling regulation changes, commercial fishery management changes, voluntary State or private habitat restoration, State hatchery practices, agricultural practices, water withdrawals/diversions, increased population growth, mining activities, and urbanization. State angling regulations are generally moving towards greater restrictions on sport fishing to protect listed fish species. The state closed recreational salmon fishing in California in all ocean and fresh waters except between Knights Landing and Red Bluff on the Sacramento River in the late fall. Commercial fishing regulations are designed to target the abundant fall–run Chinook and avoid fishing during times and in areas where listed species are more likely to be caught. However, during 2008 commercial salmon fishing was closed to protect the expected low numbers of Chinook salmon in the ocean.

Habitat restoration projects may have short term negative effects associated with construction work in waters but the outcome is generally a benefit to listed species. State hatchery practices (Merced, Mokelumne, American River Trout Hatchery) may have negative effects on naturally produced salmon and steelhead through genetic introgression, competition, and disease transmission from hatchery introductions. Farming activities within or near the action area may have negative effects on Sacramento and San Joaquin water quality due to runoff laden with agricultural chemicals. Essential features of critical habitat that are degraded on the Sacramento River include water, space, cover, and rearing along approximately 200 miles of mainstem river. The function of critical habitat may continue to be reduced through the cumulative loss of riparian areas along Central Valley river due to bank stabilization projects, removal of trees for levee stability, and growth and development (e.g., boat docks, marinas, sewage outfalls).

Cumulative effects include non-federal riprap projects. Depending on the scope of the action, some non-federal riprap projects carried out by State or local agencies do not require Federal permits.

These types of actions, and illegal placement of non-federal riprap are common throughout the action area. The effects of such actions result in fragmentation of existing habitat and conversion of complex nearshore aquatic habitat to simplified habitats that are less suitable for salmonids.

Cumulative effects include future non-federal water withdrawals which affect salmonids by entraining individuals into improperly screened diversions and may result in lower river flows that are needed for migration, spawning, rearing, flushing of sediment, gravel recruitment and transport of woody debris. Future temperatures in the American River are largely the result of upstream diversions impacting the coldwater pool in Folsom Reservoir. The largest diversions are screened or in planning phases with a Federal cost share. The smaller non-project diversions are largely privately owned and may have significant cumulative effects.

Cumulative effects may result from discharge of point and non-point source chemical contaminants, which include selenium and pesticides and herbicides associated with agricultural and urban activities. The proliferation of invasive species may occur from increasing water temperatures due to future level of development or climate change. Invasive species can prey on or displace native species that provide food for young fish. Contaminants may injure or kill salmonids by affecting food availability, growth rate, susceptibility to disease, or other processes necessary for survival.

Future urban growth and mining operations may adversely affect water quality, riparian function, and stream productivity. Intermittent streams used by steelhead are being impacted by urban sprawl before monitoring can detect presence/absence of the species.

Other potential cumulative effects could include: wave action in the water channel caused by boats that may degrade riparian and wetland habitat and erode banks; dumping of domestic and industrial garbage; urban land uses that result in increased discharges of pesticides, herbicides, oil, and other contaminants into the water; and non-federal dredging practices. These things also may injure or kill salmonids by affect food availability, growth rate, susceptibility to disease, or other physiological processes necessary for survival.

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