DRAFT Technical Memorandum

Temperature Model Sensitivity Analyses Sets 4 and 5

SAN JOAQUIN RIVER
RESTORATION PROGRAM

October 2008

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List of Abbreviations and Acronyms

°F	degrees Fahrenheit
CalEPA	California Environmental Protection Agency
CALFED	CALFED Bay-Delta Program
CEQA	California Environmental Quality Act
cfs	cubic feet per second
CVP	Central Valley Project
DFG	California Department of Fish and Game
DWR	California Department of Water Resources
ft msl	feet above mean sea level
FWUA	Friant Water Users Authority
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NRDC	Natural Resources Defense Council
PEIS/R	Program Environmental Impact Statement/Report
PMT	Program Management Team
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
Settlement	Stipulation of Settlement
SJR5Q	San Joaquin River HEC-5Q model
SJRRP	San Joaquin River Restoration Program
State	State of California
TAF	thousand acre-feet
TCD	temperature control device
TM	Technical Memorandum
USFWS	U.S. Fish and Wildlife Service
USACE	U.S. Army Corp of Engineers

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This Draft Technical Memorandum (TM) was prepared by the San Joaquin River Restoration Program (SJRRP) Team as a draft document in support of preparing a Program Environmental Impact Statement/Report (PEIS/R). The purpose for circulating this document at this time is to facilitate early coordination regarding initial concepts and approaches currently under consideration by the SJRRP Team with the Settling Parties, Third Parties, other stakeholders, and interested members of the public. Therefore, the content of this document may not necessarily be included in the PEIS/R.

This Draft TM does not present findings, decisions, or policy statements of any of the Implementing Agencies. Additionally, all information presented in this document is intended to be consistent with the Settlement. To the extent inconsistencies exist, the Settlement should be the controlling document, and the information in this document will be revised before its inclusion in future documents. While the SJRRP Team is not requesting formal comments on this document, all comments received will be considered in refining the concepts and approaches described herein to the greatest extent possible. Responses to comments will not be provided and this document will not be finalized; however, refinements will likely be reflected in subsequent SJRRP documents.

1.0 Introduction

In 1988, a coalition of environmental groups, led by the Natural Resources Defense Council (NRDC), filed a lawsuit challenging the renewal of long-term water service contracts between the United States and the Central Valley Project (CVP) Friant Division contractors. After more than 18 years of litigation of this lawsuit, known as *NRDC et al. v. Kirk Rodgers et al.*, a Stipulation of Settlement (Settlement) was reached. On September 13, 2006, the Settling Parties, including NRDC, Friant Water Users Authority (FWUA), and the U.S. Departments of the Interior and Commerce, agreed on the terms and conditions of the Settlement, which was subsequently approved by the U.S. Eastern District Court of California on October 23, 2006.

The San Joaquin River Restoration Program (SJRRP) will implement the San Joaquin River litigation Settlement. The Implementing Agencies responsible for managing the SJRRP are the U.S Department of the Interior, through the Bureau of Reclamation (Reclamation) and the U.S. Fish and Wildlife Service (USFWS); the U.S. Department of Commerce through the National Marine Fisheries Service (NMFS); and the State of California (State) through the California Department of Water Resources (DWR), the California Department of Fish and Game (DFG), and the California Environmental Protection Agency (CalEPA). Consistent with the Memorandum of Understanding between the Settling Parties and the State, which was signed at the same time as the Settlement, the State, through DWR, DFG, CalEPA, and the Resources Agency, will play a major, collaborative role in planning, designing, funding, and implementing the actions called for in the Settlement.

The SJRRP is a comprehensive long-term effort to restore flows in the San Joaquin River from Friant Dam to the confluence with the Merced River, ensure irrigation supplies to Friant water users, and restore a self-sustaining fishery in the river.

The Settlement has two primary goals:

- **Restoration Goal –** To restore and maintain fish populations in "good condition" in the mainstem San Joaquin River below Friant Dam to the confluence with the Merced River, including naturally reproducing and self-sustaining populations of salmon and other fish.

- **Water Management Goal –** To reduce or avoid adverse water supply impacts on all of the Friant Division long-term contractors that may result from the Interim Flows and Restoration Flows provided for in the Settlement.

Reclamation and DWR have initiated environmental compliance documentation for the SJRRP. The Implementing Agencies have organized a Program Management Team (PMT) and several Technical Work Groups to develop a plan for implementing the Settlement through a joint National Environmental Policy Act (NEPA) and California Environmental Quality Act (CEQA) process, which includes preparation of a Programmatic Environmental Impact Statement/Report (PEIS/R). Reclamation is the lead NEPA agency and DWR is the lead CEQA agency for the SJRRP.

1.1 Purpose of This Document

This Technical Memorandum (TM) is part of a series of preliminary river temperature sensitivity analyses conducted to inform the early developmental phases of a water management strategy. These three sets of sensitivity analyses aim to understand the model performance, ascertain the relationship of interactions between river temperature and ambient temperature, and examine existing and Settlement operations impacts on Millerton Reservoir and the San Joaquin River. These analyses were constructed to highlight the effects of selected factors.

Many important features of channel modification and associated fishery and water management strategies are still under development; therefore, these analyses are not intended to provide a detailed evaluation of reservoir operations and temperature management actions.

This TM documents and presents the results of the fourth and fifth sensitivity analysis performed in this series, temperature sensitivity analyses Sets 4 & 5.

2.0 Temperature Sensitivity Analyses Sets 1, 2, & 3 Summary

Temperature Sensitivity Analysis Set 1 evaluated the effects of major flow splits in Reaches 2B and 4B on temperature under existing operations. Sensitivity Analysis Set 2 evaluated the extent to which Friant Dam releases control downstream river temperatures, independent of reservoir operations. The results of Sensitivity Analysis Sets 1 & 2 were described in a separate TM (Reclamation, 2008). Sensitivity Analysis Set 3 evaluated the potential flow and temperature impacts of the Settlement flow schedules on the San Joaquin River from Friant Dam to the Chowchilla Bypass. The results of Sensitivity Analysis Set 3 were also described in a separate TM (Reclamation, 2008).

Major assumptions for the existing conditions simulation include the following:

- San Joaquin River HEC-5Q (SJR5Q) model (Reclamation, 2007) as the selected modeling tool.
- Analysis period of 1980 through 2003 with historical hydrology (inflow flows to Millerton Reservoir and the San Joaquin River, estimated depletions).
- Monthly canal diversion (Friant-Kern and Madera canals) and minimum reservoir releases based on preproject (existing conditions) model results, provided using daily average flows taken from the monthly Settlement spreadsheet model.
- Channel flow constraints by physical outlet limitations and minimum pool assumptions.
- All releases to the river made through the low-level outlet, except spillway flows when the river outlet capacity is exceeded.

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3.0 Sensitivity Analysis Set 4 Riparian Shading Analysis

To test the hypothesis that increased riparian shading along the San Joaquin River would reduce the heating taking place in the river and improve water temperatures, several temperature model simulations of the San Joaquin River were performed under various assumed levels of riparian shading.

3.1 Analysis Assumptions

For the analysis a constant Friant release temperature of 50 degrees Fahrenheit (°F) was assumed. This temperature is consistent with other temperature sensitivity simulations, and provides a consistent basis of comparison for this sensitivity analysis. Three constant Friant release rates of 350, 700, and 1,500 cfs were selected. These cover the lower portion of the range of flows expected under the Settlement where the temperature are the highest and where the impacts of the increased riparian shading would be the greatest.

Riparian shading was assumed to occur at three levels:

- Existing – Values in calibrated model
- Moderate – Midway between existing and heavy
- Heavy – Values adjusted to maximum potential based on experience on other rivers

The SJR5Q temperature model uses an equilibrium temperature concept to estimate river water temperatures. This equilibrium temperature can be thought of as the water temperature a 5-foot pool of water would reach under the given meteorological conditions. These equilibrium temperatures are computed outside the SJR5Q model for the expected meteorological conditions.

For this analyses the effects of riparian shading on water temperature were estimated by representing shading effects as increased cloud cover. This approach was developed using solar radiation measurements from a temporary weather station located adjacent to the Stanislaus River that was subject to shading during approximately half of the day. It must be stressed that this is an approximation and may not represent the type of riparian corridor conditions envisioned by the SJRRP Team. The scaling factor applied to the hourly average cloud cover (cloud cover is computed from observed solar radiation) is a function of the following input parameters.

1. Total riparian tree cover fraction above the horizon (used to compute longwave back radiation)
2. Riparian shading fraction at noon

3. Fraction of daylight hours corresponding to #3
4. Riparian shading fraction below the tree horizon
5. Fraction of daylight hours corresponding to #5

A seasonal factor was applied to the above input parameters to account for sun angle and deciduous condition changes throughout the year.

Scaling factors used for the two riparian shading conditions are as shown in Table 3-1.

Table 3-1.Riparian Scaling Factors

Factor	Heavy Riparian Condition	Moderate Riparian Conditions
1	0.6	0.5
2	0.5	0.3
3	0.2	0.3
4	0.8	0.7
5	0.6	0.6

Seasonal factors were as shown in Table 3-2.

Table 3-2. Riparian Season Adjustment Factors

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	0.5	0.75	0.9	0.8	0.7	0.7	0.8	0.9	1.0	0.75	0.5
Deciduous		New leaves & lower sun angle			Highest sun angle		Lower sun angle followed by leaf loss				

Riparian conditions also impact wind speed and humidity. Wind speed tends to decrease while humidity tends to increase as tree density increases. These tendencies generally result in increased water temperatures. For the riparian shading sensitivity analyses, wind speed and humidity did not change; therefore the predicted impact on the San Joaquin River should be considered optimistic from a river temperature reduction perspective.

Figure 3-1 is a plot of the computed water temperature of a 5-foot pool of water under typical July meteorological conditions under several riparian conditions.

- Red – no riparian shading
- Black – moderate riparian cover
- Green – heavy riparian cover
- Blue - heavy riparian cover with wind speed decreased by 25%

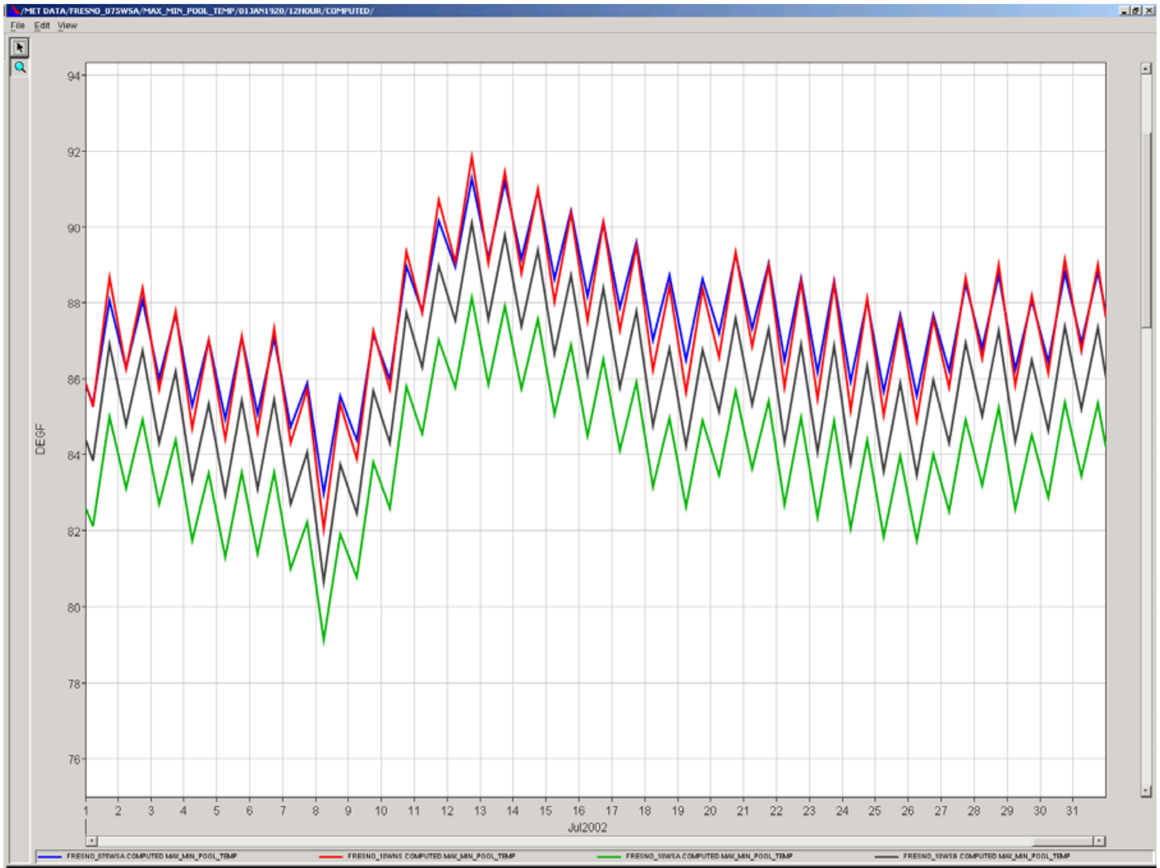

Figure 3-1.
Computed water temperature of a 5-foot pool of water under typical July meteorological conditions under several riparian conditions.

As one can see, the heating due to decrease in wind speed counters the cooling effects of riparian shading.

3.2 Analysis Results

Figure 3-2 shows the median of the maximum daily temperatures each day of the year for the 1980 – 2005 period of record SJR5Q temperature simulation at a Friant release of 350 cfs. This is the release throughout the hottest period of the year under all conditions. The start date of this release under the settlement varies from April 1 in dry years to Jul1 in wet years. The figure also includes the maximum and minimum of the maximum daily values for each day of the year to show the variation in the maximum daily temperature from year to year.

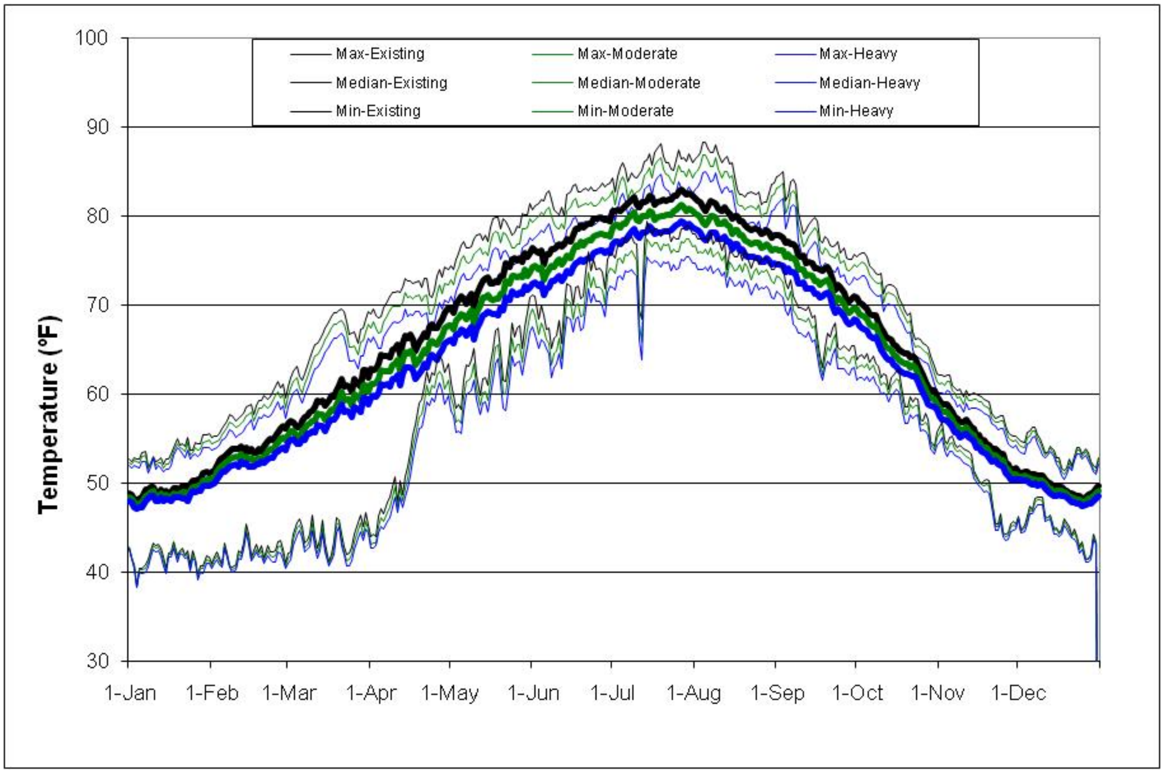

Figure 3-2.
San Joaquin River at Gravelly Ford Maximum Daily Temperatures for Friant Release of 350 cfs

Figure 3-2 shows a potential reduction of about 1.5 ºF (82 ºF to 80.5 ºF) with moderate riparian cover and about 3 ºF (80.5 ºF to 79 ºF with heavy riparian cover during the hottest portion of the year. Of potentially more interest from a fishery perspective the beginning of temperatures above 70 ºF is delayed approximately 1 to 2 weeks from mid March to early April. During this time interval the Friant release specified under the Settlement agreement is higher than the 350 cfs values and the spring delay in temperature increase my not be a reliable conclusion.

Figure 3-3 and 3-4 show the median of the maximum daily temperatures each day of the year for the 1980 – 2005 period of record SJR5Q temperature simulations at Friant releases of 700 and 1500 CFS. These releases are more typical of the anticipated Friant releases during this time period under the Settlement.

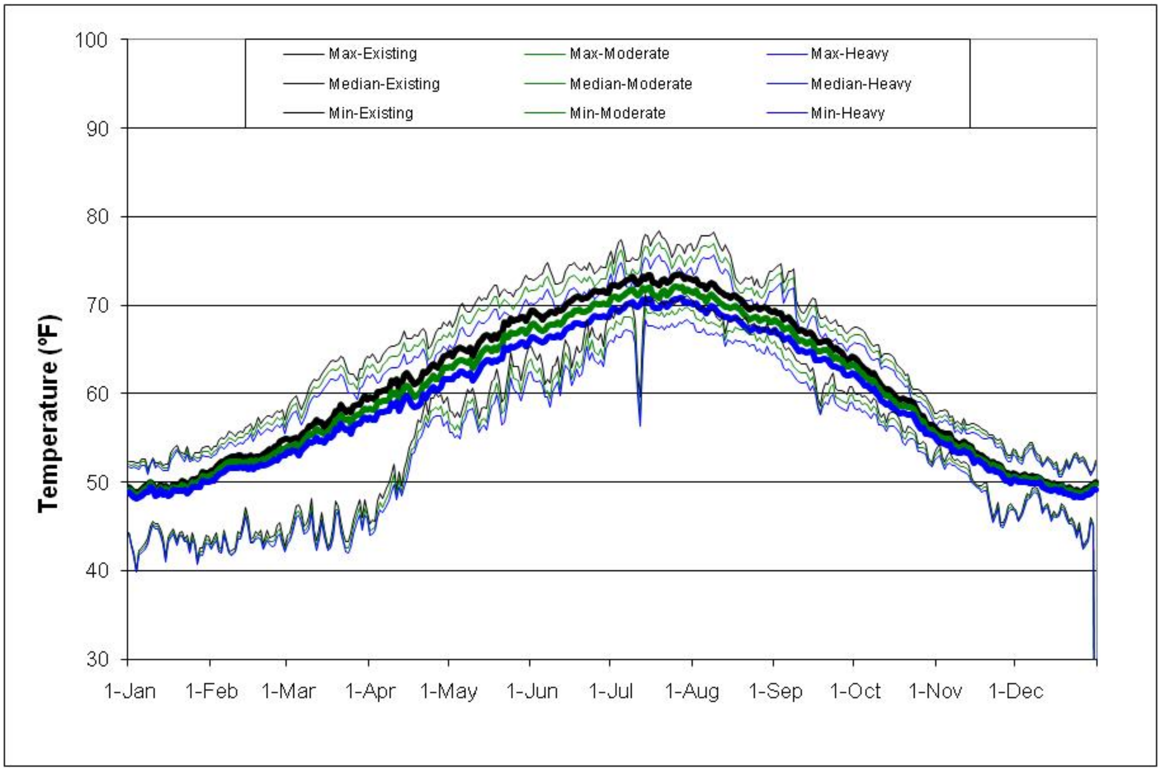

Figure 3-3.
SJR at Gravelly Ford Maximum Daily Temperatures at Friant Release of 700 CFS

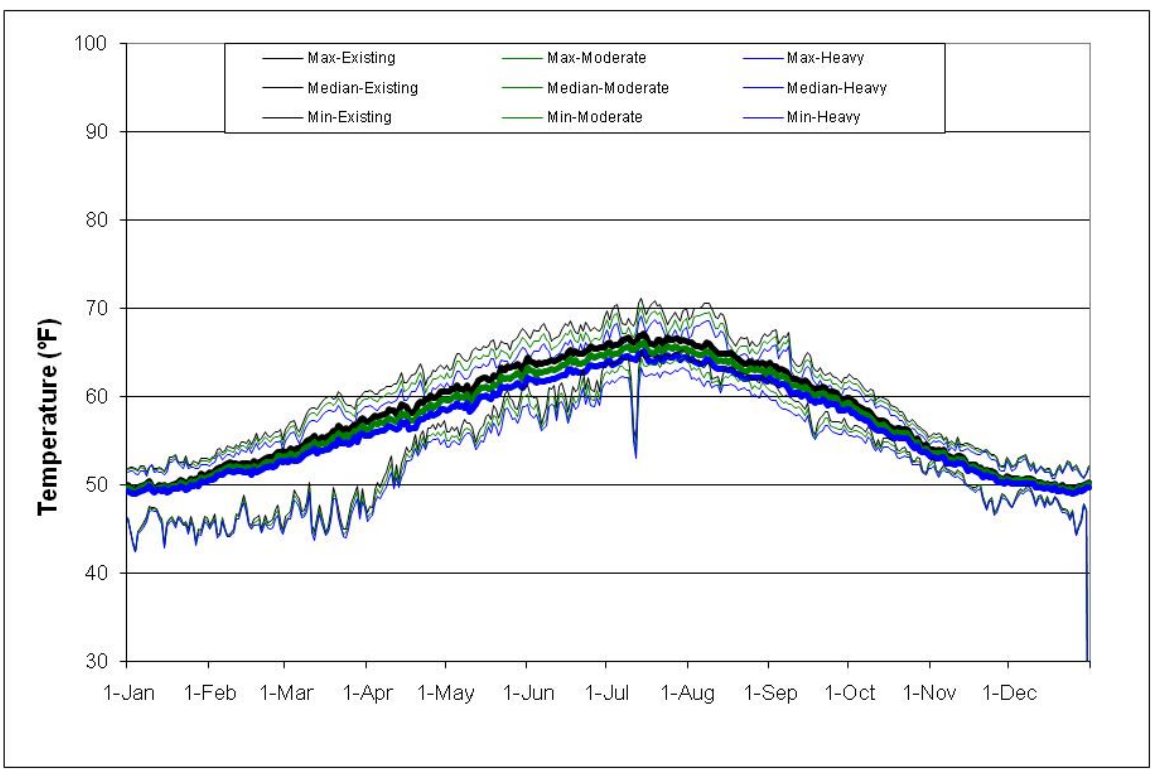

Figure 3-4.
SJR at Gravelly Ford Maximum Daily Temperatures at Friant Release of 1500 CFS

These figures better represent the anticipated flows during the spring period. In both figures the beginning of temperatures above 70 ºF is delayed 1 to 2 weeks compared to the existing condition.

As the SJR flow increases the temperature reduction due to increased riparian shading decreases. Because of this higher release rates were not included in the sensitivity analysis.

Figures 3-5, 3-6 and 3-7 show simulation results at the Chowchilla Bypass, just upstream of Mendota Pool and at the Sack Dam.

Figures 3-5, 3-6 and 3-7 show that as you move downstream from Gravelly Ford the potential impact of increased riparian is about the same at each location. This is because the changes in the riparian shading are actually defining a new, lower, equilibrium temperature for the SJR under the same meteorological conditions. Once the SJR reaches this new equilibrium condition there is little or no additional impact to the temperature in the river. This also implies that if the riparian shading is increased at the upstream end of the SJR (reach 1 and 2) that the downstream end would revert to the old equilibrium condition and the temperatures would be unchanged in the lower reaches (3, 4 and 5).

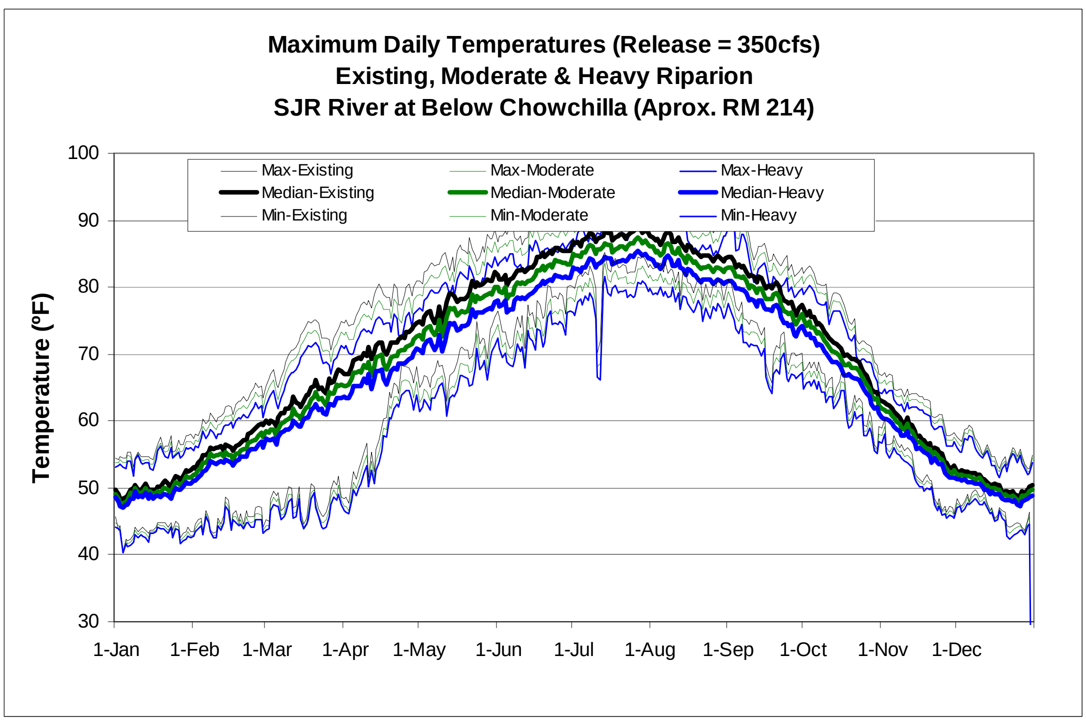

Figure 3-5.
SJR Below Chowchilla Bypass Maximum Daily Temperatures at Friant Release of 350 CFS

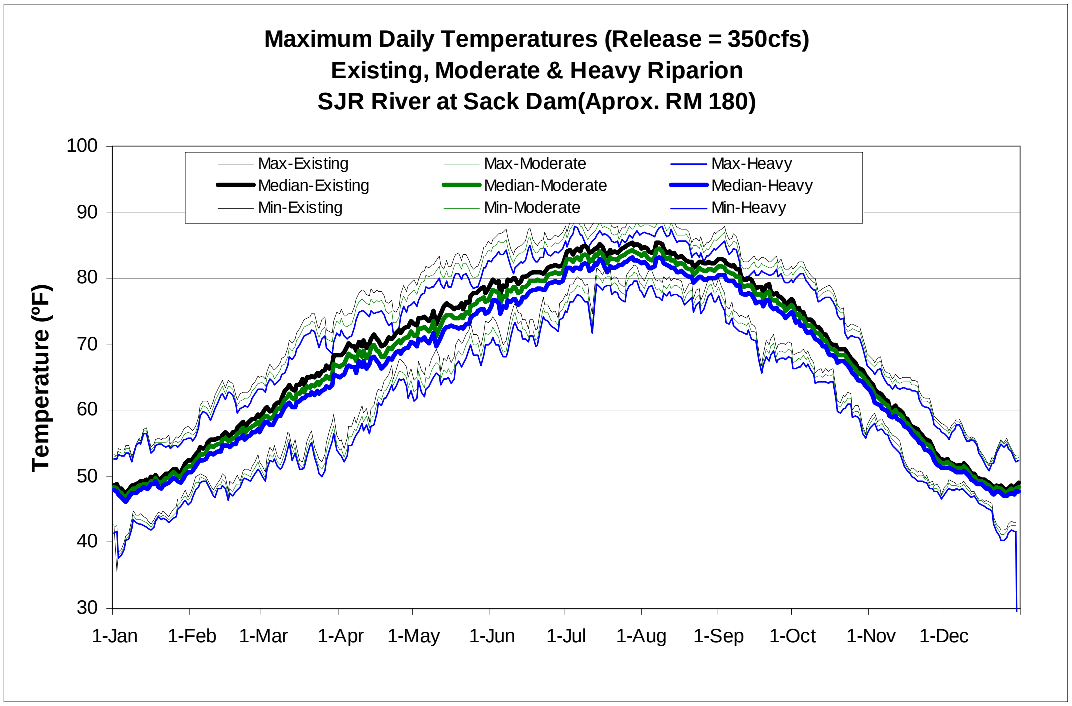

Figure 3-6.
SJR Above Mendota Pool Maximum Daily Temperatures at Friant Release of 350 CFS

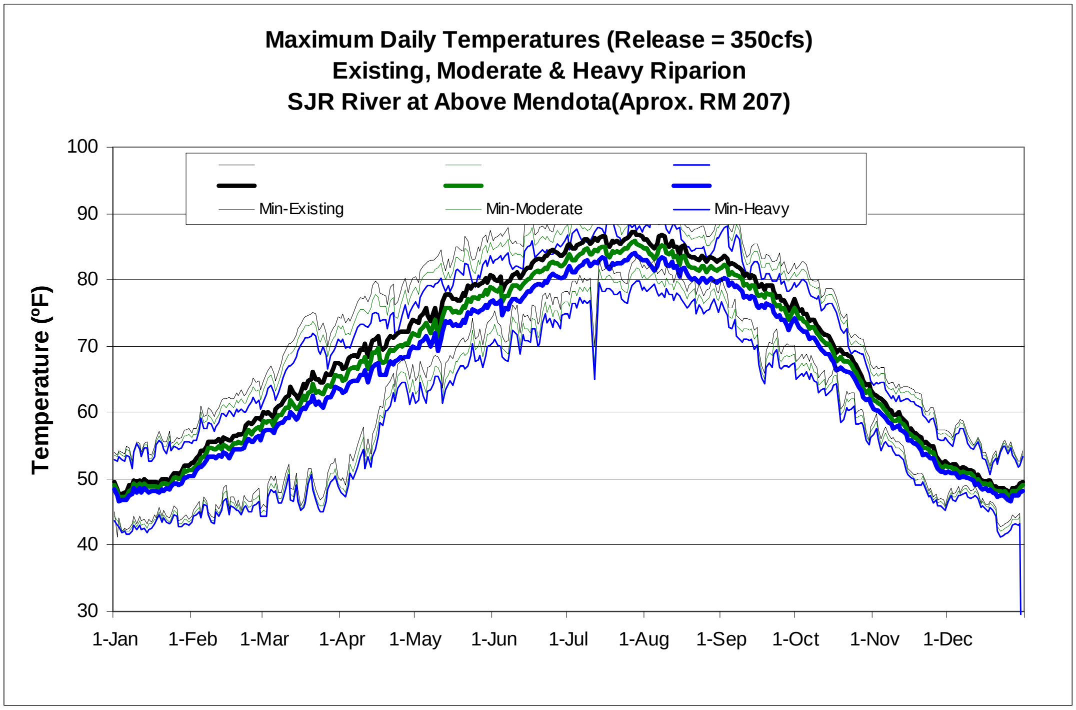

Figure 3-7.
SJR at Sack Dam Maximum Daily Temperatures at Friant Release of 350 CFS

3.3 Results summary

The analysis shows that increasing the riparian shading along the SJR has the potential to:

- Impact is greater at low flows than high flows.
- Reduce peak summer temperatures that range from the low to high 80's by 3 to 5 ^{o}F.
- Delay time of year when temperatures are above 70 F by 1 to 3 weeks.

The sensitivity analysis may overstate the magnitude of the potential temperature impact somewhat because the wind speed and humidity were not adjusted to account for the increased riparian shading.

Due to the uncertainty associated with the impacts on stream temperatures associated with the riparian conditions, additional field studies should be performed prior to embarking on any riparian corridor restoration scheme.

4.0 Temperature Sensitivity Analysis Set 5 – Channel Modification Analysis

In order to test the hypothesis that modifications to the SJR river channel could reduce the heating taking place in the river and improve water temperatures, several temperature model simulations of the San Joaquin River were performed under various assumed levels of modifications to the SJR low flow channel from Friant Dam downstream to Mendota Pool. The analysis does not consider the hydraulic, habitat, cost, or geomorphic feasibility or impacts of making channel modifications of this magnitude.

4.1 Analysis Assumptions

For the analysis a constant Friant release temperature of 50 °F was assumed. This temperature is consistent with other temperature sensitivity simulations and provides a consistent basis of comparison within this sensitivity analysis.

Since the channel modification are limited to the low-flow portion of the channel flow rates of 250, 350 and 700 CFS were selected for use in the analysis as representative of the potential flows in the low flow channel.

An assumption was made that channel modifications would not be made to the SJR downstream of Mendota Pool. The channel modifications for this analysis were limited to the reach of the SJR from Friant to just upstream of Mendota Pool. This reach is approximately 60 miles long.

The analysis was structured to look at two possible channel modifications,

- Reduce the width to increase velocity and reduce the air/water temperature interaction area
- Increase the depth to increase the "insulation" factor of the upper portion of the river profile

Three levels of channel modification were selected for analysis:

Table 4-1.
Channel Cross Section Modification Factors

Condition		Width Reduction	Depth Increase
Condition 1	(W25-D0%)	25%	0%
Condition 2	(W25-D33%)	25%	33%
Condition 3	(W50-D50%)	50%	50%

The existing channel cross sections were developed from cross section data from the USCE Comprehensive Flood Study (reference). These were modified by applying a scaling factor in the SJR5Q model to reduce the width and/or increase the depth of all cross sections from Friant Dam to Mendota Pool. The SJR5Q model includes channel cross sections approximately every 0.5 miles.

4.2 Analysis assumptions

Figure 4-1 shows the median of the maximum daily temperatures each day of the year for the 1980 – 2005 period of record SJR5Q temperature simulation at a Friant release of 350 CFS. This is the predominant release throughout the hottest period of the virtually all years under the Settlement Agreement. The figure also includes the maximum and minimum of the maximum daily values for each day of the year to give an idea of the variation in the maximum daily temperature from year to year.

Figure 4-1 shows peak temperature reductions of about 3 to 8 °F during the hottest portion of the year depending on the level of channel modification. Of potentially more interest from a fishery perspective the beginning of temperatures above 70 F is delayed approximately 2 to 5 weeks in the W25-D33% and W50-D50% alternatives respectively.

Figure 4-1 also shows that the impact of the W25-D0% and W25-D33% are very similar. This implies that the change in width is much more important to temperatures than the change in depth. Because of this the W25-D33% alternative was not included in any other simulations for this sensitivity analysis.

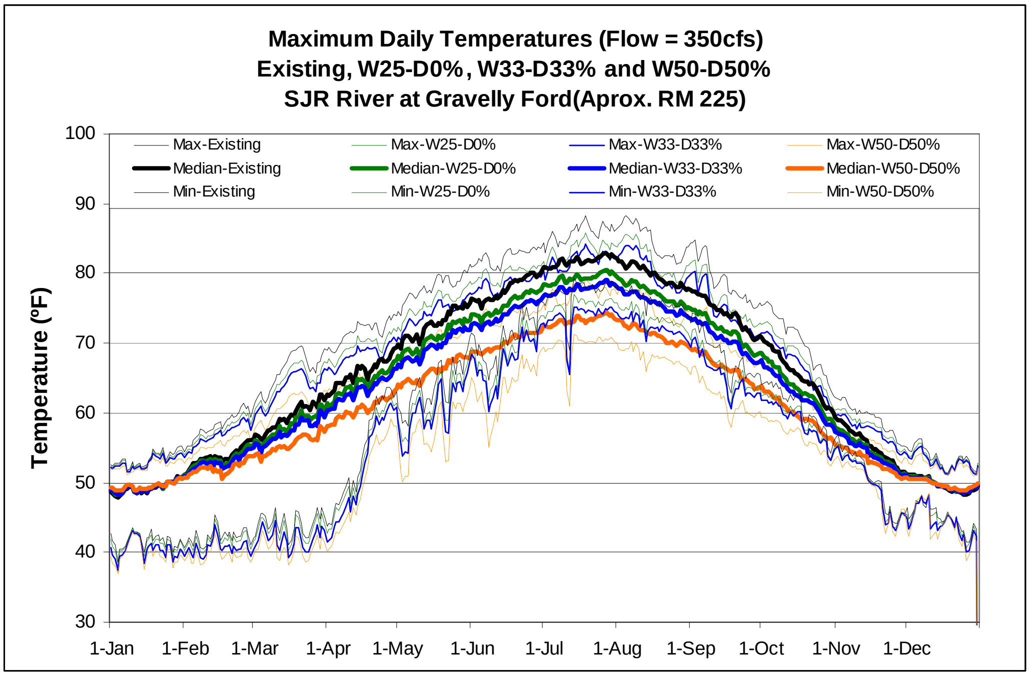

Figure 4-1.
SJR at Gravelly Ford Maximum Daily Temperatures w/wo Channel Modifications at Friant Release of 350 CFS

Figures 4-2 and 4-3 show the median of the maximum daily temperatures each day of the year for the 1980 – 2005 period of record for the SJR5Q temperature simulations at Friant releases of 250 and 700 CFS. The lower flow of 250 was included as the settlement does specify flows at this level in critical years.

Figures 4-2 and 4-3 show about the same level of temperature reduction as at the 350 CFS flow level, even though the absolute temperature values are different. This may be because the major controlling factor is the top width and as long as the flow remains in the low flow channel the top width remains relatively stable. At higher flow rates where the flow leaves the low flow channel the modifications may be less effective; however at these higher flow rates the SJR temperature tend to be lower and less temperature reduction may still yield similar absolute temperatures.

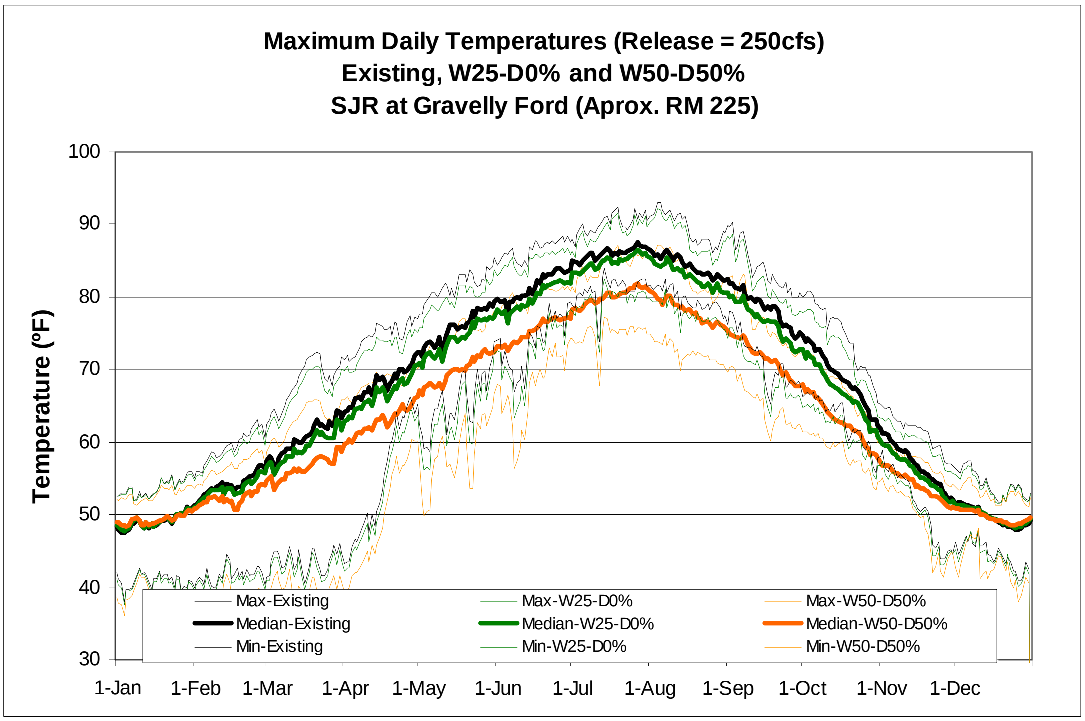

Figure 4-2.
SJR at Gravelly Ford Maximum Daily Temperatures w/wo Channel Modifications at Friant Release of 250 CFS

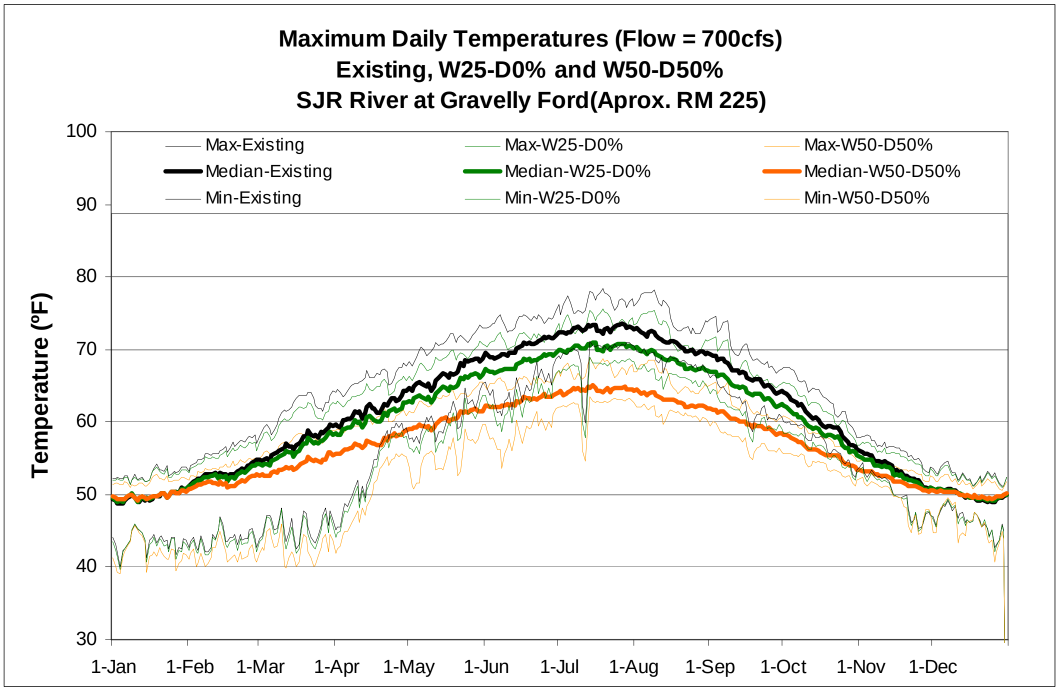

Figure 4-3.
SJR at Gravelly Ford Maximum Daily Temperatures w/wo Channel Modifications at Friant Release of 700 CFS

Figures 4-4 and 4-5 show simulation results at the Chowchilla Bypass and just upstream of Mendota Pool.

Figures 4-4 and 4-5 show that as you move downstream from Gravelly Ford the magnitude of the potential temperature reduction appears slightly smaller but follows the same general trends as at Gravelly Ford. This is expected since the original channel geometry has an impact on the potential temperature change to new channel geometry. For example a channel that is already very narrow and would not see as much improvement as a relatively wide channel.

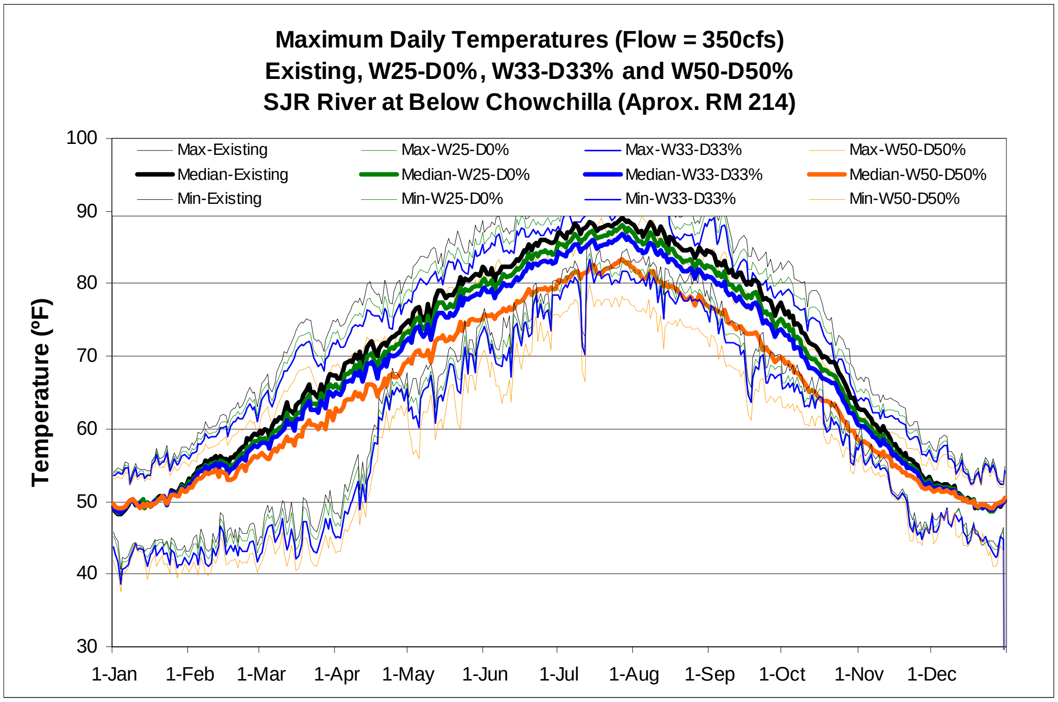

Figure 4-4.
SJR at Below Chowchilla Maximum Daily Temperatures w/wo Channel Modifications at Friant Release of 350 CFS

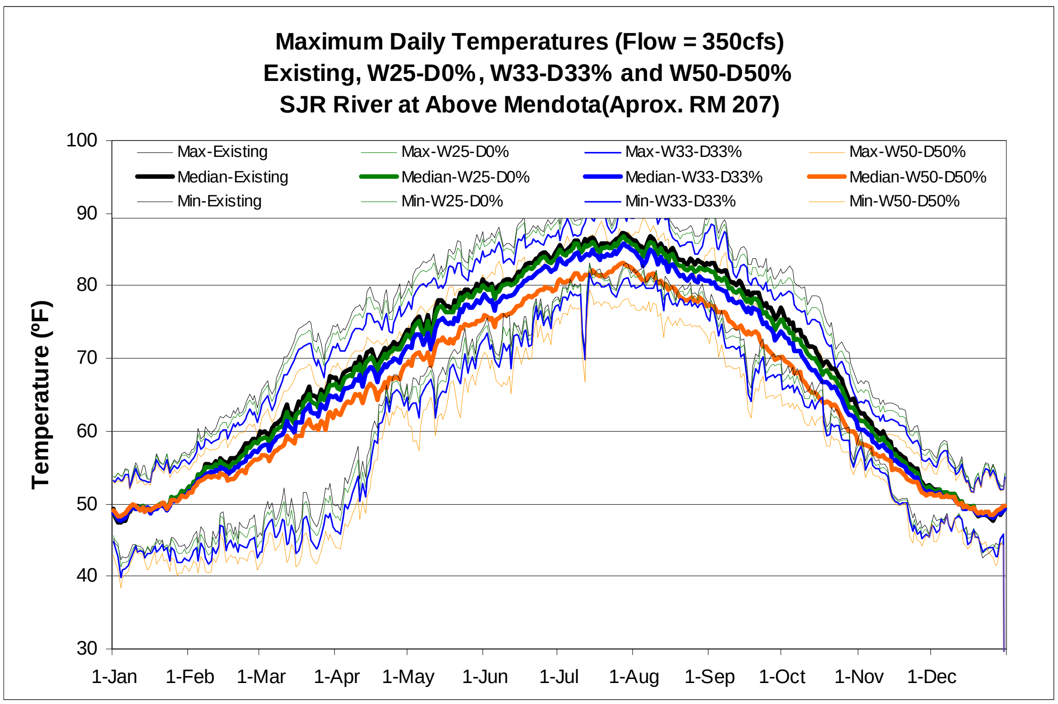

Figure 4-5.
SJR at Above Mendota Pool Maximum Daily Temperatures w/wo Channel Modifications at Friant Release of 350 CFS

4.3 Results Summary

The analysis shows that channel modifications to the low flow channel of the SJR has the potential to:

- Reduce peak summer temperatures that range from the low to high 80's by 3ºF – 9ºF
- Delay the time of year when temperatures are above 70ºF by 2 to 6 weeks.

The sensitivity analysis may overstate the magnitude of the potential temperature impact somewhat as it assumes that the entire low flow channel is modified, the SJR5Q model does not include local channel conditions but rather generalized conditions for specific reaches. The analysis also does not include consideration of the geomorphic feasibility, or of the potential environmental impacts of channel modifications of this magnitude.

~~4.0~~5.0 References

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Personal Communication, Don Smith, RMA, 10/2/2008

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