Report

Reducing Spring Water Temperatures Below Sack Dam

2014 Mid-Year Technical Report

SAN JOAQUIN RIVER RESTORATION PROGRAM

July 2014

Table of Contents

Figures

Abbreviations and Acronyms

SJRRP	San Joaquin River Restoration Program

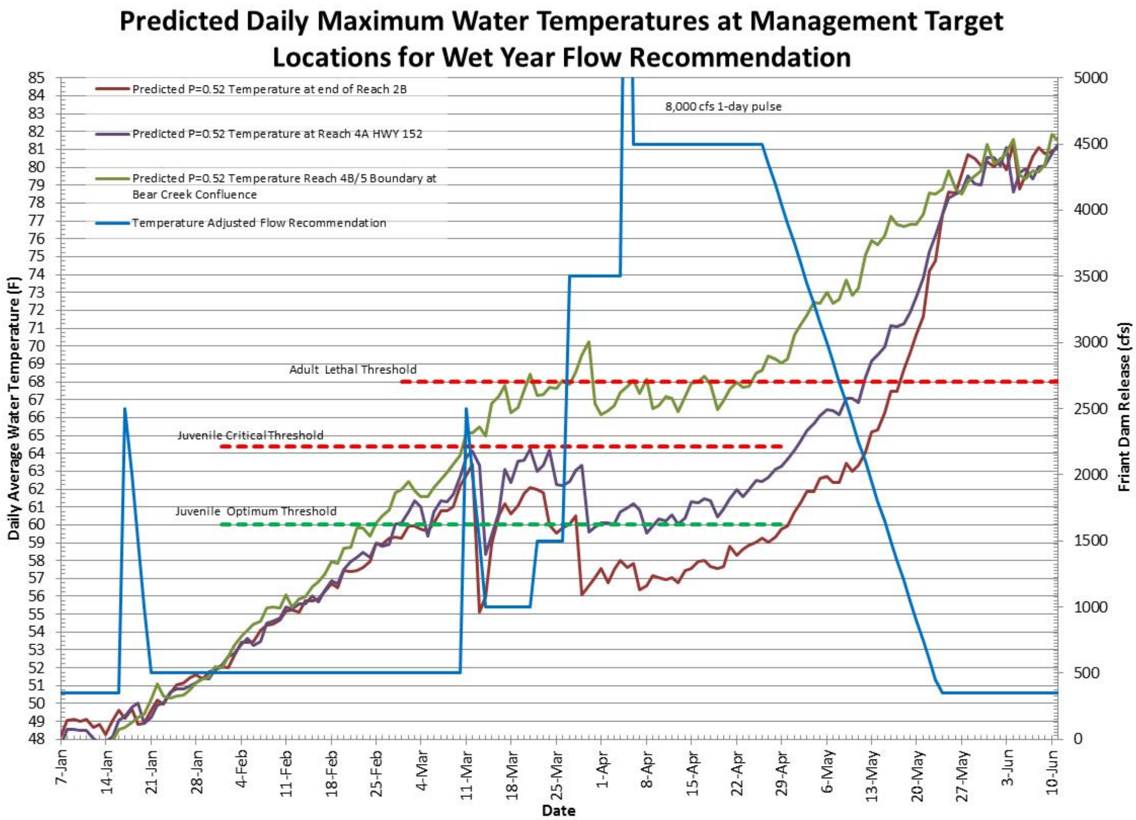
This page left blank intentionally.

1.0 Reducing Spring Water Temperatures Below Sack Dam

1.1 Background

Predictions from the initial HEC-5Q water temperature model (SJRRP 2008a) suggest that the daily maximum water temperatures in reaches 4B and 5 will exceed the lethal threshold for adult spring-run Chinook salmon at a Friant release of 4,500 cfs by April 24 during median (P = 0.52 exceedance) meteorological conditions (Figure 1). When the model was recalibrated with 2009-2010 interim flow data, the lethal threshold was exceeded by April 28 (SJRRP 2012). If the recalibrated model reflects current conditions, then only up to 30% of the adults may be able to migrate to Reach 1 based on migration timing data from Mill and Butte creeks (Johnson et al. 2006; Greg Blair, ICF, personal communication). During the same period, juveniles would also experience critical temperatures and few would be expected to survive (Figure 1). A consequence of using high volume pulse flows in April and May for adults is the inability to release prolonged pulse flows earlier in the year to benefit juvenile salmon. If no more than 30% of the adults can successfully migrate to Reach 1 where they could spawn and flow for juvenile passage must be limited to brief pulses, restoration actions to cool temperatures may be needed to reach the population viability target.

Previous water temperature model analyses for the SJRRP Restoration Area evaluated the effects of riparian shading and channel narrowing on daily maximum water temperatures primarily upstream of Mendota Pool (SJRRP 2008b). The riparian shading study (Set 4 Sensitivity Analysis) used solar radiation measurements from a Stanislaus River site that was shaded for approximately half the day and those data were used in a conceptual analysis of the median of the maximum daily temperatures in 5-foot deep pools at four sites including: Gravelly Ford, below Chowchilla Bypass, above Mendota Pool and Sack Dam. There was uncertainty in the results due to a lack of data on the effects of shade trees on wind speed and humidity, both of which would partially negate the benefits of providing shade. The effects on wind speed and humidity were not included in the sensitivity study. The results suggested that a half day of heavy riparian shade could reduce daily maximum water temperatures by about 2^{o}F at Gravelly Ford in late spring and summer at a flow release of 1,500 cfs, assuming there were no negative effects of reduced wind speed and increased humidity. Temperature reductions due to riparian shading would likely decline as flows increase above 1,500 cfs. The results for the Sack Dam site, which was only conducted at a flow of 350 cfs, suggest that the effects of riparian shading would be less at Sack Dam than at Gravelly Ford. There are several limitations of this study. First, it does not fully address the effect of riparian shading on both banks of the river below Sack Dam. The reaches below Sack Dam are particularly important to study, because the effects of riparian shading would be less in channels flowing toward the North (Restoration Area below Mendota Pool) compared to channels flowing toward the West (Restoration Area above Mendota Pool). Second, the study does not consider the cumulative effect of providing shade throughout the Restoration Area. Presumably, water temperatures in reaches 4B and 5 are partially dependent on the temperature of the water flowing in from the upstream reaches.



Note: Possible Wet Year flow recommendation designed to maximize adult spring-run passage and two brief pulse flows for juvenile passage relative to the predicted daily maximum water temperatures (SJRRP 2008a) during average meteorological conditions from 1980 to 2005 (P = 0.52 exceedance) just upstream of Mendota Pool (Reach 2B), at Highway 41 (Reach 4A), and the confluence with Bear Creek (Reach 4B-5 boundary). The lethal threshold for adult salmon is a 7-day mean daily maximum temperature of 68°F (Table 3-1, SJRRP 2010) and so temperatures that exceed the threshold for fewer than 7 days would not be lethal. The water temperature predictions in reaches 4B and 5 in this figure may exceed actual temperatures by about 2°F in April and by 1-2°F in May (SJRRP 2012).

Figure 1. Possible Wet Year

The channel narrowing analysis (Set 5 Sensitivity Analysis, SJRRP 2008b) evaluated the effects of three channel modifications on the median of the maximum daily water temperatures in conceptual 5-foot deep pools at Gravelly Ford, below Chowchilla Bypass, and above Mendota Pool at flow releases of 350 and 700 cfs: (1) 25 percent width reduction and no change in depth, (2) 25 percent width reduction and a 33% depth increase, and (3) a 50 percent reduction in width and depth. The results suggest that 50 percent reductions in channel width and depth might reduce May daily maximum temperatures by about 6°F at a flow of 700 cfs at Gravelly Ford. Flow magnitude had no effect on the temperature reduction as long as flows remained in the low flow channel (≤ 700 cfs). Temperature reduction due to channel narrowing and deepening was diminished at the Below Chowchilla and Above Mendota Pool sites compared to the Gravelly Ford site, presumably because the existing channel was wider at these sites than at Gravelly Ford. No analysis was done for the reaches below Mendota Pool where shading may affect daily maximum water temperatures in the northerly flowing channel differently from those modeled at Gravelly Ford and above Mendota Pool which flow toward the West.

The overall objective of this study and a companion Riparian Microclimate study is to determine the effect of restoring a wide riparian forest on daily maximum water temperatures in Reaches 4B and 5 during the spring. Wide riparian canopies reduce air temperatures at the river and reduced air temperatures may reduce water temperatures (Moore et al. 2005). Studies in upper watersheds in northern California indicated that a 30-meter wide riparian tree canopy reduced above stream air temperatures by 8.6°F compared to sites without riparian trees (Moore et al. 2005). The rate of decline in air temperature due to riparian tree canopies is highest up to a tree canopy width of 30 meters and only 0.36°F for each additional 10 meters of width. The initial objective of this study is to use the SJRRP HEC-5Q model to simulate the restoration of a wide riparian tree canopy in the Restoration Area using estimates of air temperature reduction, increases in humidity, and reduction in wind speed provided by Moore et al. (2005). After the companion Riparian Microclimate study has quantified the effects of a wide riparian forest on the microclimate in the Restoration Area, the HEC-5Q analysis will be revised using the microclimate data from the Restoration Area.

1.2 Methods

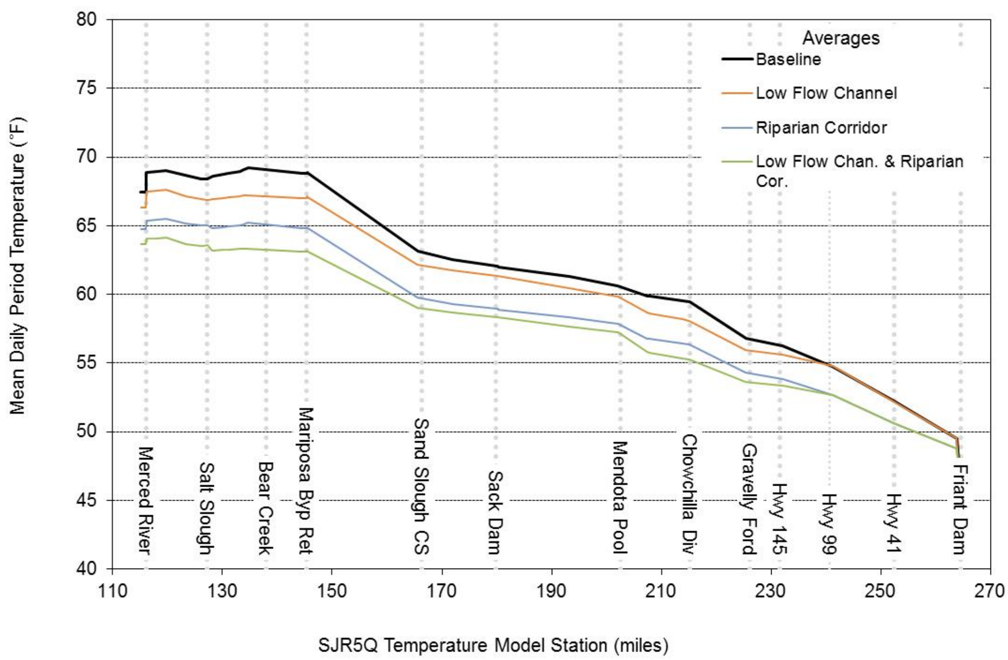
The SJRRP HEC-5Q model (SJRRP 2008a) was used to estimate the likely change in water temperature as a result of channel narrowing and restoration of a wide riparian forest. The potential effect of channel narrowing was analyzed by assuming a minimum low flow channel would be implemented from State Highway 99 to the confluence of the Merced River. To minimize the potential top width of the low flow channel, it was designed to be a trapezoidal channel with very steep side slopes, too steep to be actually constructed, and a constant hydraulic gradient. A HEC-RAS based model of this reach of the San Joaquin River was used to design the channel and verify its hydraulic performance. The resulting modified cross sections, including the new low flow channel, were then exported and used in the SJRRP HEC-5Q model to simulate the potential temperature impacts (William Smith, Principal Engineer, MWH Americas, Inc.).

Restoring a mature riparian forest from levee toe to levee toe was analyzed by assuming that daily maximum air temperatures would be reduced by 8.6°F, wind speed would be reduced by 15%, and relative humidity would be increased by 12.5% based on upper watershed studies in northern California reported by Moore et al. (2005). The HEC-5Q input data was modified to reflect the expected changes in the microclimate due to the restoration of a riparian forest by Resource Management Associates, Fairfield, California. Two different levels of restoration were evaluated: (1) a forest would be restored only in Reaches 2B and 4B and (2) a forest would be restored from Friant Dam to the confluence with the Merced River. The HEC-5Q model generated water temperature estimates in 6-hour intervals based on the Riverware daily flow estimates for the SJRRP Flow

Alternative A and the climate conditions that occurred from 1978 to 2003 (SJRRP 2008a). It was assumed that the water temperature estimates for 6 PM were equivalent to the daily maximum temperature. Both alternatives assumed that up to 4,500 cfs of the Restoration flows would be conveyed through Reach 4B.

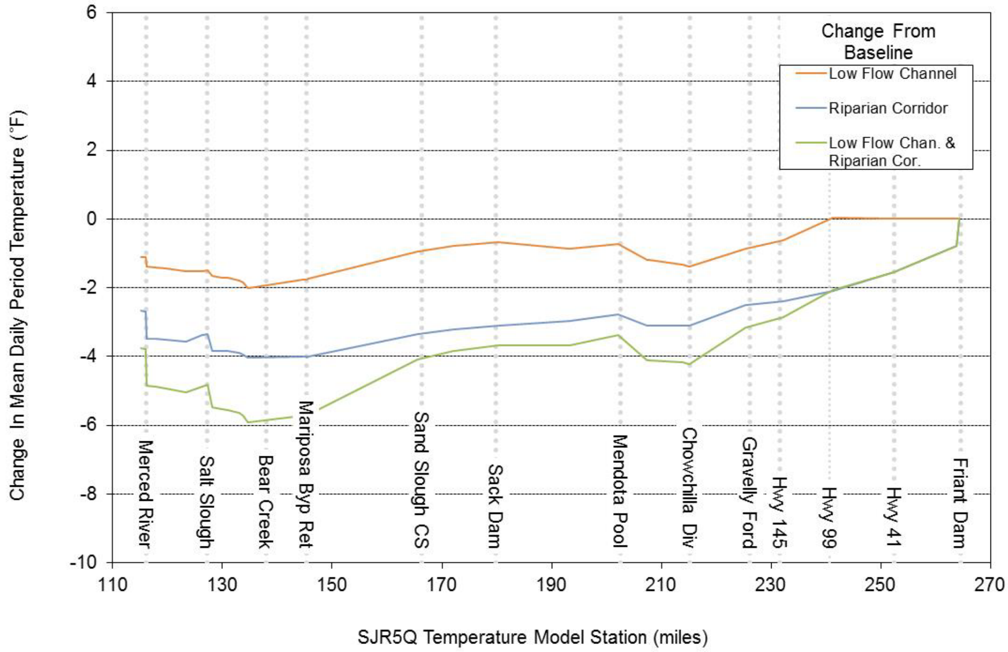
1.3 Preliminary Results

The preliminary results indicate that minimizing channel width from State Highway 99 and the confluence with the Merced River and restoring a riparian tree canopy throughout the Restoration Area may reduce daily maximum water temperatures in Reach 4B (rivermile 140) by about 6°F in early-April (Figures 2 and 3), 5°F in late-April (Figures 4 and 5), and 4.5°F in mid-May (Figures 6 and 7). The temperature reduction due to the riparian tree canopy alone ranged from 66% of the total reduction in early-April (Figure 3) to 75% in mid-May, whereas there was relatively little benefit from narrowing the channel width (Figure 7). If both the riparian tree canopy is restored and the channel width minimized, then the mean daily maximum water temperature would be maintained below 68°F, which is the upper threshold for migration and survival for adult Chinook salmon (Table 3-1, SJRRP 2010), until April 29 to May 5 under average climate conditions (Figure 4). This is a substantial improvement compared to existing conditions which maintain the mean daily maximum water temperature below 68°F until about April 8 under during average conditions (Figure 2).



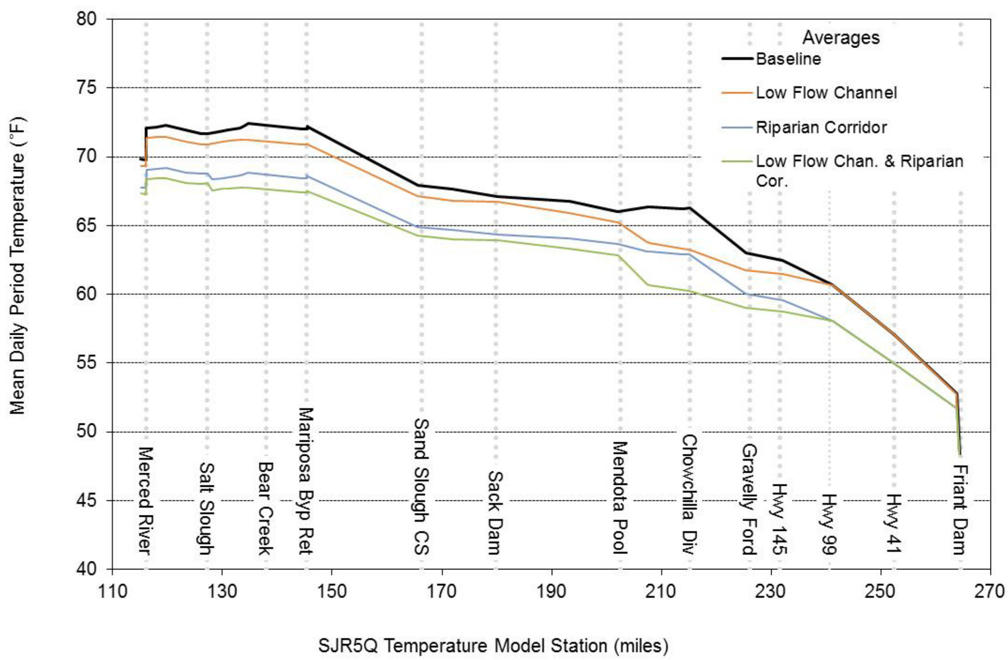
Note: HEC-5Q mean daily maximum water temperature predictions for April 8 to 14 from 1978 to 2003 for the SJRRP Restoration Area for (a) existing conditions (Baseline), (b) minimizing the width of the low-flow channel (Low Flow Channel); (b) restoring a mature riparian forest (Riparian Corridor); and (c) implementing both actions (Low Flow Chan. & Riparian Cor.).

Figure 2. HEC-5Q Mean Daily Maximum Water Temperature Predictions



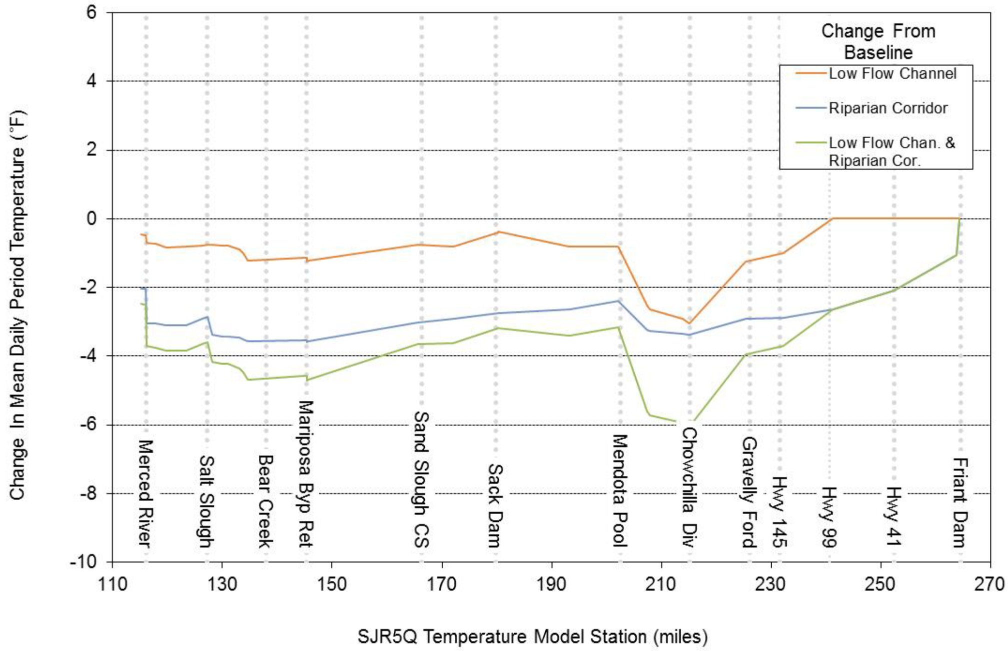
Note: The expected change in mean daily maximum water temperatures for April 8 to 14 from 1978 to 2003 for the SJRRP Restoration Area if the width of the low-flow channel was minimized (Low Flow Channel); a mature riparian forest was restored throughout the Restoration Area (Riparian Corridor); or both actions were implemented.

Figure 3. Expected Change in Mean Daily Maximum Water Temperatures



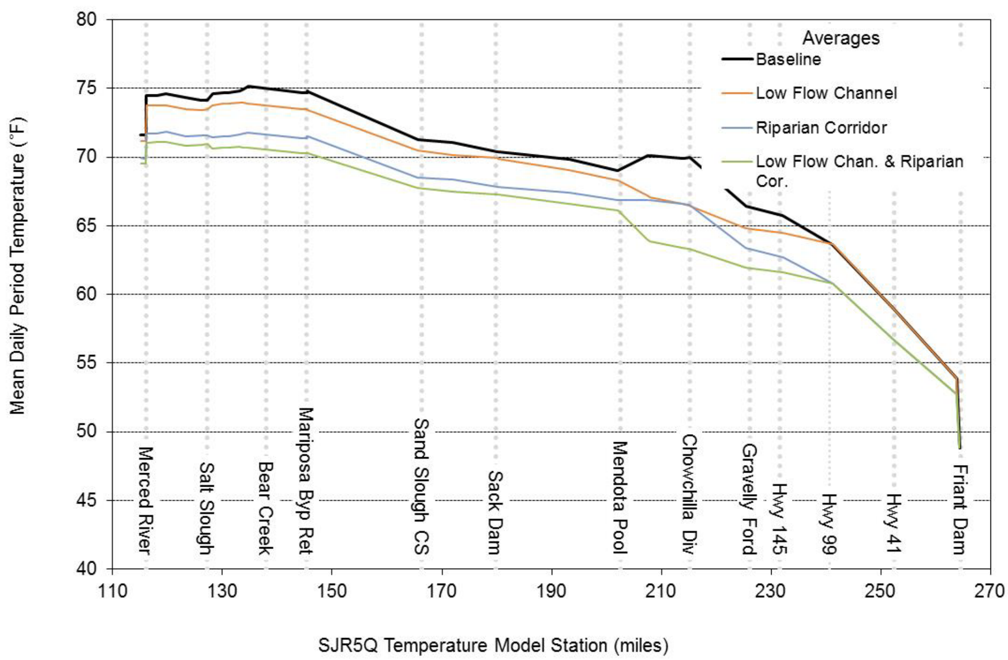
Note: HEC-5Q mean daily maximum water temperature predictions for April 29 to May 5 from 1978 to 2003 for the SJRRP Restoration Area for (a) existing conditions (Baseline), (b) minimizing the width of the low-flow channel (Low Flow Channel); (b) restoring a mature riparian forest (Riparian Corridor); and (c) implementing both actions (Low Flow Chan. & Riparian Cor.).

Figure 4. HEC-5Q Mean Daily Maximum Water Temperature Predictions



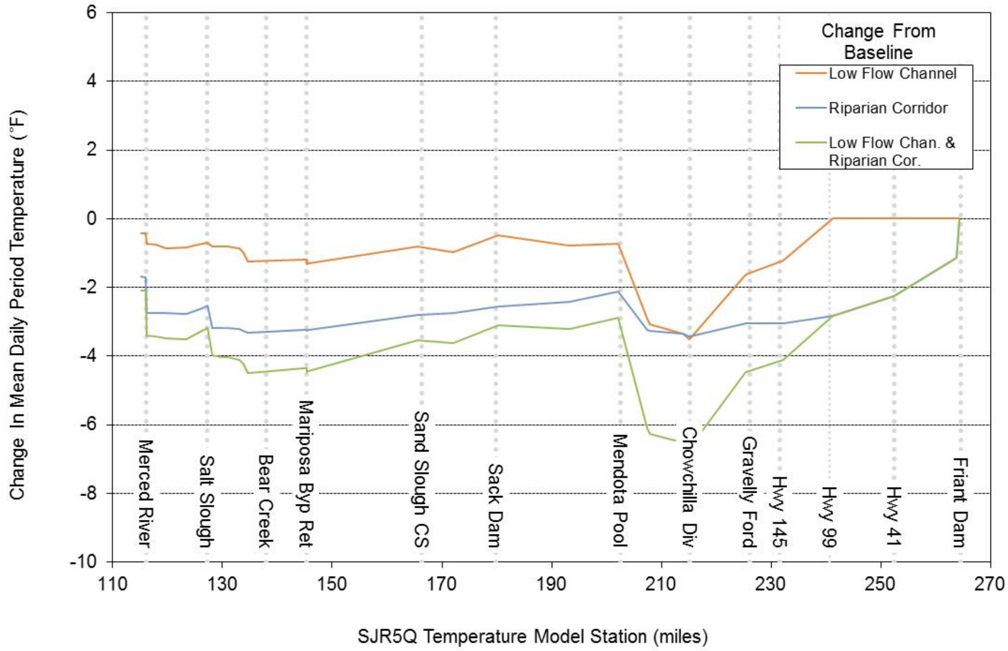
Note: The expected change in mean daily maximum water temperatures for April 29 to May 5 from 1978 to 2003 for the SJRRP Restoration Area if the width of the low-flow channel was minimized (Low Flow Channel); a mature riparian forest was restored throughout the Restoration Area (Riparian Corridor); or both actions were implemented.

Figure 5. Expected Change in Mean Daily Maximum Water Temperatures



Note: HEC-5Q mean daily maximum water temperature predictions for May 13 to 19 from 1978 to 2003 for the SJRRP Restoration Area for (a) existing conditions (Baseline), (b) minimizing the width of the low-flow channel (Low Flow Channel); (b) restoring a mature riparian forest (Riparian Corridor); and (c) implementing both actions (Low Flow Chan. & Riparian Cor.).

Figure 6. HEC-5Q Mean Daily Maximum Water Temperature Predictions



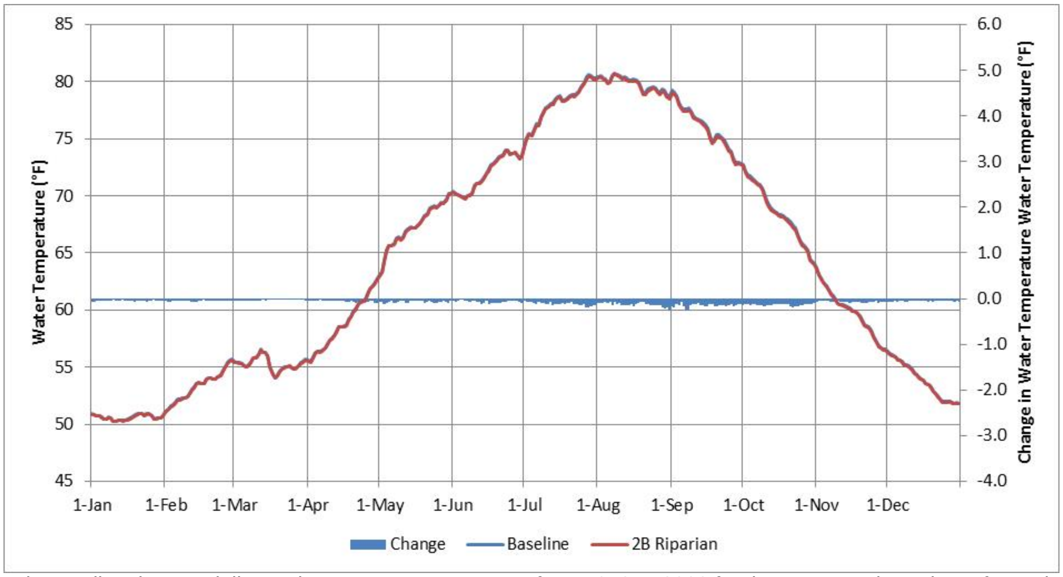
Note: The expected change in mean daily maximum water temperature s for May 13 to 19 from 1978 to 2003 for the SJRRP Restoration Area if the width of the low-flow channel was minimized (Low Flow Channel); a mature riparian forest was restored throughout the Restoration Area (Riparian Corridor); or both actions were implemented.

Figure 7. Expected Change in Mean Daily Maximum Water Temperatures

If a riparian tree canopy was restored only in Reach 2B, there would be no more than a 0.2°F reduction in the mean daily maximum water temperatures at the upstream boundary of Reach 2B (Figure 8), no more than a 1.6°F reduction in the mean daily maximum water temperatures at the downstream boundary of Reach 2B (Figure 9), and no more than a 0.3°F reduction in the mean daily maximum water temperatures at the upstream boundary of Reach 4B (Figure 10). If a riparian tree canopy was restored in both Reach 2B and Reach 4B, the mean daily maximum water temperature would be reduced by up to 2.8°F at the downstream boundary of Reach 4B (Figure 11). Almost none of the water temperature reduction in Reach 4B would be due to the restoration of a riparian forest in Reach 2B.

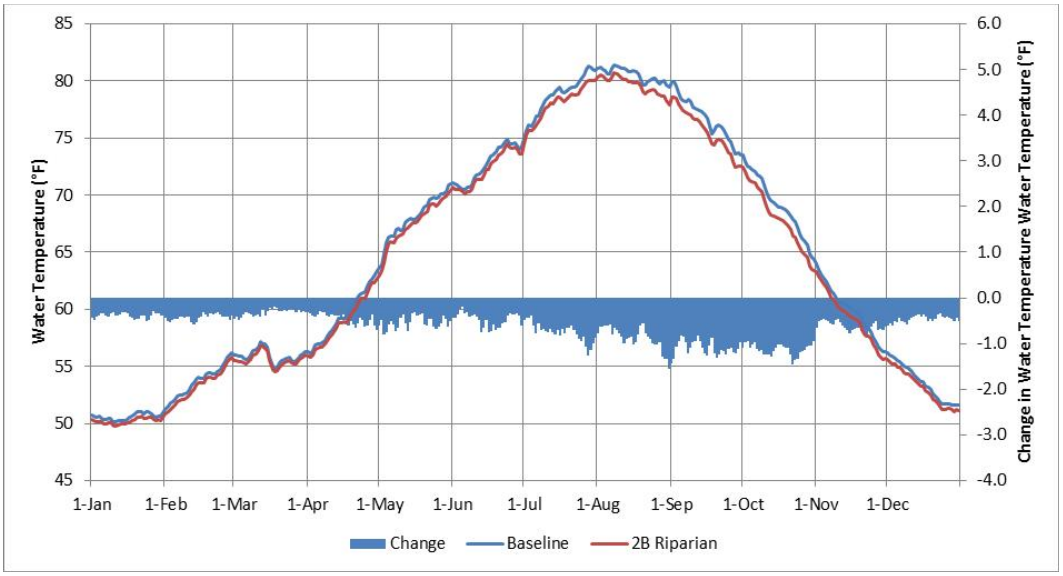
The preliminary results suggest that the greater the length of the restored riparian forest, the greater will be the reduction in water temperatures in Reach 4B. If a forest was restored in only reaches 2B and 4B, then the predicted reduction in mean daily maximum water temperatures at the tail of Reach 4B would range from 2.8°F in early April to 2.3°F in mid-May (Figure 11). In comparison, restoring a continuous riparian forest from State Highway 99 to the confluence of the Merced River would reduce the mean daily maximum water temperatures at the tail of Reach 4B by about 4°F in early April (Figure 3) to 3.33°F in mid-May (Figure 7). These results also suggest that riparian forest microclimate effects are gradual and so reducing daily maximum water temperatures at Sack Dam will require the restoration of a riparian forest in Reach 2B and possibly further upstream.

The validity of these preliminary results is dependent on the assumption that the northern California upper watershed microclimate data (Moore et al. 2005) are applicable to the Restoration Area. Therefore, no conclusions should be made until riparian forest microclimate data have been collected in the Restoration Area and greater San Joaquin basin and analyzed. It is likely that the collection of these data will not be completed until summer 2015.



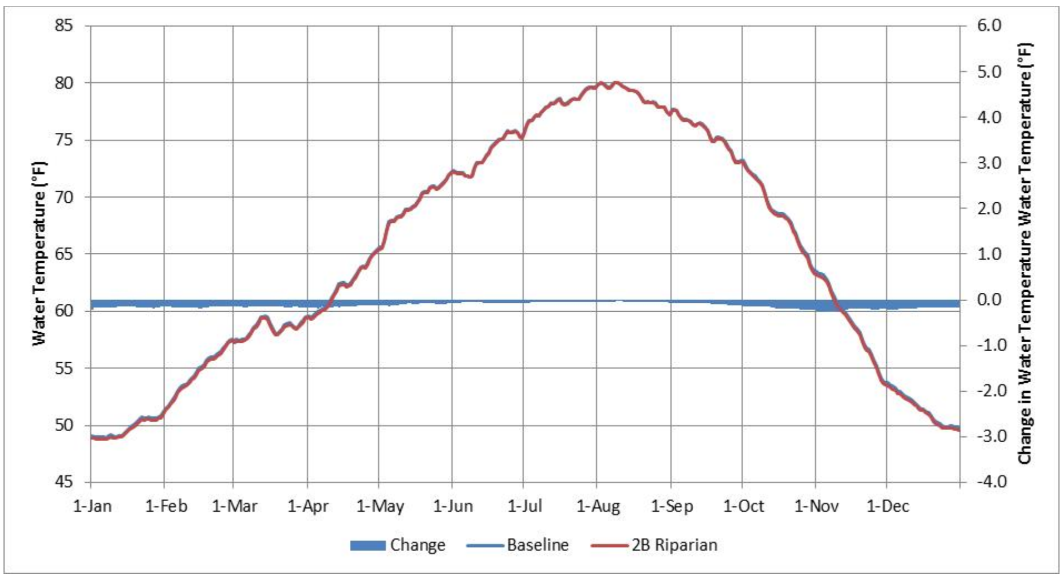
Note: The predicted mean daily maximum water temperature from 1978 to 2003 for the upstream boundary of Reach 2B if a mature riparian forest would be restored only in Reach 2B compared to existing baseline conditions.

Figure 8. Predicted Mean Daily Maximum Water Temperature



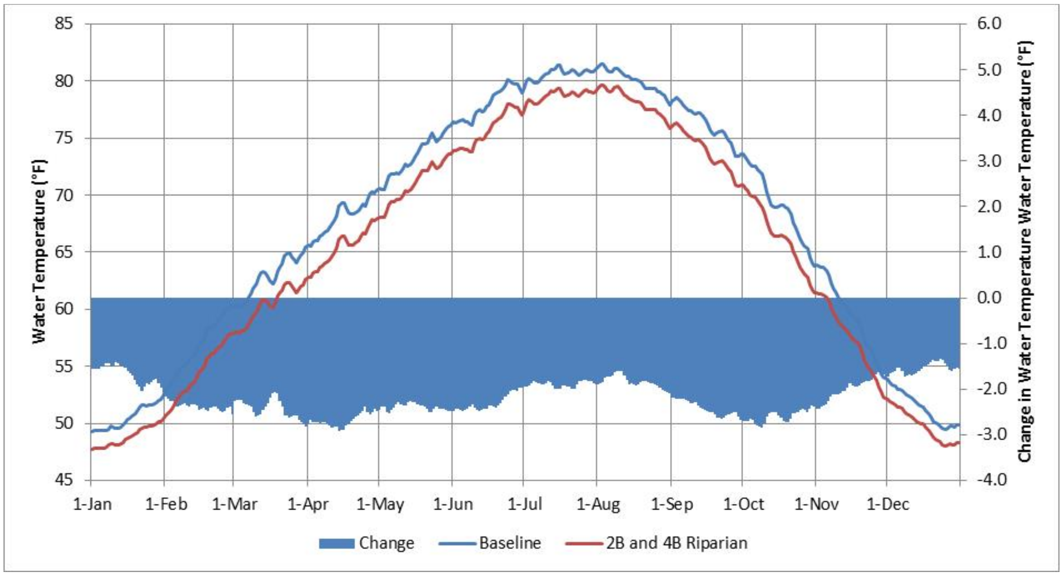
Note: The predicted mean daily maximum water temperature from 1978 to 2003 for the downstream boundary of Reach 2B if a mature riparian forest would be restored only in Reach 2B compared to existing baseline conditions.

Figure 9. Predicted Mean Daily Maximum Water Temperature



Note: The predicted mean daily maximum water temperature from 1978 to 2003 for the upstream boundary of Reach 4B if a mature riparian forest would be restored only in Reach 2B compared to existing baseline conditions.

Figure 10. Predicted Mean Daily Maximum Water Temperature



Note: The predicted mean daily maximum water temperature from 1978 to 2003 for the downstream boundary of Reach 4B if a mature riparian forest would be restored only in Reach 2B and Reach 4B compared to existing baseline conditions.
Figure 11. Predicted Mean Daily Maximum Water Temperature

1.4 References

Johnson, P., B. Nass, D. Degan. J. Dawson, M. Johnson, B. Olson, C. Harvey-Arrison. 2006. Assessing Chinook salmon escapement in Mill Creek using Acoustic Technologies in 2006. Report submitted to the U.S. Fish and Wildlife Service Anadromous Fish Restoration Program, U.S. Department of the Interior. LGL Limited, Environmental Research Associates, North Bonneville, Washington. November 2006.

Moore, R.D., D.L. Spittlehouse, A. Story. 2005. Riparian microclimate and stream temperature response to forest harvesting: a review. Journal of the American Water Resources Association, 41(4): 813-834.

SJRRP. 2008a. Temperature Model Sensitivity Analyses Sets 1 & 2. Draft Technical Memorandum, February 2008.

SJRRP. 2008b. Temperature Model Sensitivity Analyses Sets 4 & 5. Draft Technical Memorandum, October 2008.

SJRRP. 2010. Conceptual models of stressors and limiting Factors for San Joaquin River Chinook salmon. Exhibit A in Fisheries Management Plan: A framework for adaptive management in the San Joaquin River Restoration Program. November 2010.

SJRRP. 2012. SJRRP temperature model SJR5Q Evaluation in Post-Settlement Conditions. Draft Technical Memorandum, October 2012.