Flows for Fish: Analyzing Restoration Flow releases in the San Joaquin River, CA for salmonid habitat

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Introduction

The San Joaquin River Restoration Program (SJRRP) is an interdisciplinary effort to restore a naturally reproducing and self-sustaining population of salmon and other native fish to the San Joaquin River below Friant Dam, near Fresno, California, while also reducing or avoiding adverse water supply impacts to the water users served by Friant Dam. Friant Dam was completed in 1942 to provide water for irrigation and municipal supply, and for flood control, with a storage capacity of 520,500 acre-feet. Two canals, with a combined length of 187 miles, serve as the primary conveyance of Friant Dam waters to water users. Upon completion of the dam, the majority of the waters of the San Joaquin River were diverted into the canals, leaving over 60 miles of river below Friant Dam dewatered. As a result of this operation, anadromous fish populations downstream of the dam were extirpated.

Following a lawsuit challenging the renewal of the long-term water service contracts between the United States and the Friant water users, the Natural Resources Defense Council and the Departments of the Interior and Commerce reached agreement on the terms and conditions of the San Joaquin River Restoration Settlement (Settlement) in October 2006. The San Joaquin River Restoration Settlement Act authorized federal implementation of the Settlement in March 2009. The Bureau of Reclamation's SJRRP Office coordinates implementation of the Settlement.

To achieve the goals of the Settlement, the SJRRP has multiple restoration objectives, including providing suitable salmonid rearing habitat and water temperatures through the release of Restoration Flows from Friant Dam. These two objectives are closely linked to channel capacity. When the Settlement was signed, portions of the San Joaquin River below Friant dam had zero channel capacity, constrained by deteriorated levee conditions and seepage impacts to adjacent agricultural fields. While the SJRRP is directed by the Settlement to build channel capacity to 4,500 cfs between Friant Dam and the Merced River confluence (Figure 1), financial constraints necessitated evaluation of an interim channel capacity that could be achieved with currently available funding. While the long-term goal of achieving 4,500 cfs capacity in the San Joaquin River remains, this analysis evaluates a range of lower channel capacities to assess a suitable interim channel capacity which will support biological objectives within the appropriated funding. To inform this selection, rearing habitat-flow and temperature-flow relationships were analyzed for flow rates between 1,000 cfs and 4,000 cfs under six different viable flow release strategies.

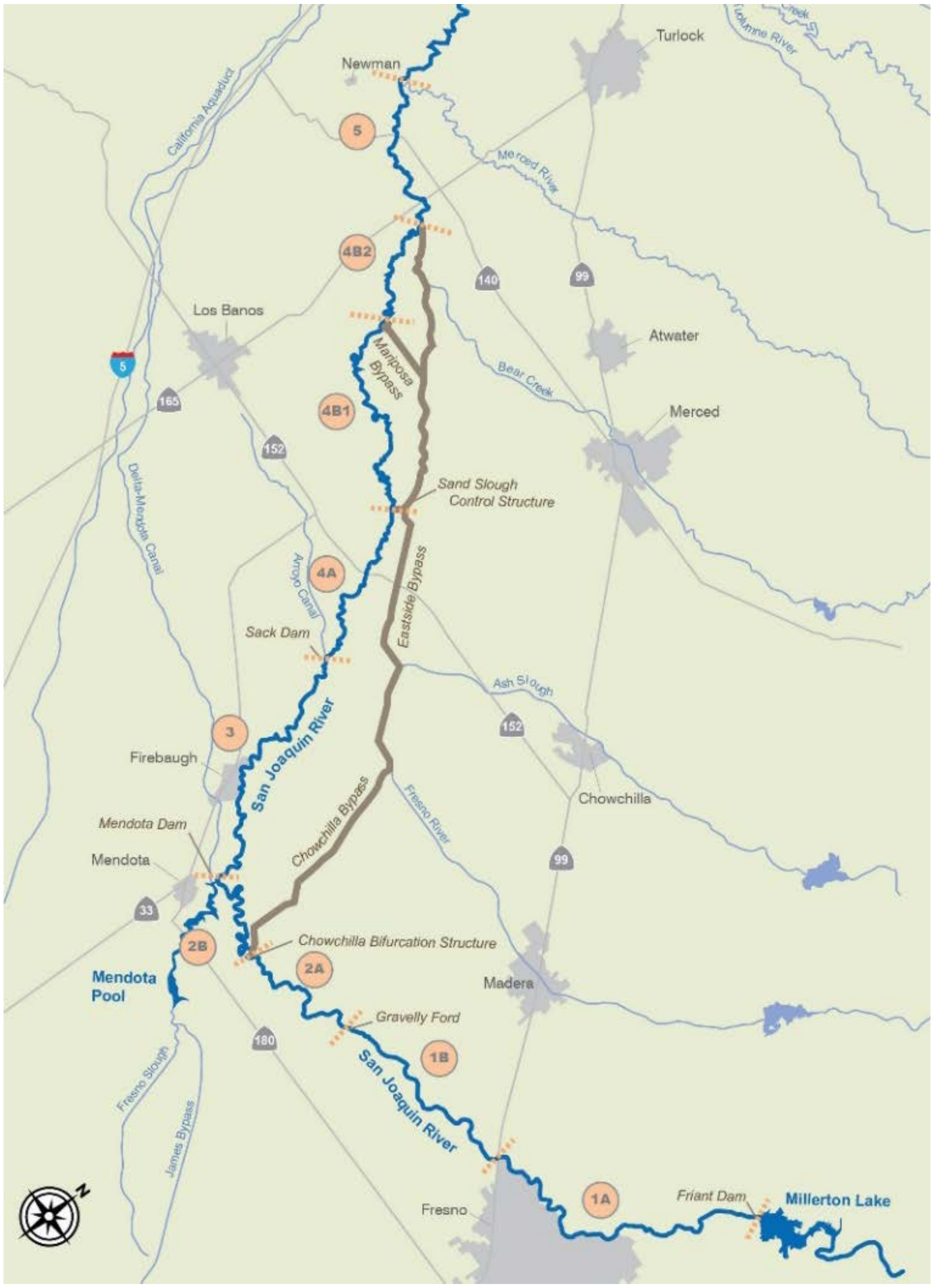

Figure 1. Map of SJRRP Restoration Area from Friant Dam to the confluence with the Merced River

Methods

To assess suitable rearing habitat at each flow rate, the two-dimensional depth averaged hydraulic model SRH-2D (Lai, 2008) was used to simulate hydraulic conditions in four reaches of the San Joaquin River. This model uses elevation data applied over a model domain and calibrated hydraulic roughness to simulate depth and velocity across the model grid cells for different boundary conditions. Models were run in 500 cfs increments from 1,000 cfs through 4,000 cfs in each reach. From each run, water depth and velocity were computed at each node. These nodes were rasterized into 5 feet by 5 feet cells, then cells were filtered by suitable juvenile rearing habitat criteria for depth and velocity. Depth and velocity habitat suitability indices (HSI) were determined from previous floodplain habitat work on the San Joaquin River (Reclamation, 2012a). Note that unlike previous work, this analysis did not filter by vegetation cover, and instead clipped the low flow channel from the suitable area to remove any in-channel cells with suitable depths and velocities that were unlikely to have vegetation cover present.

Temperature output from the Programmatic EIS/R SJR HEC-5Q model (Reclamation, 2012b; Resource Management Associates, 2007) was also analyzed in support of evaluating flow scenarios. The temperature model extends from January 1980 to September 2003 and determines temperature and flow data per node on a diurnal time scale by superimposing the SJRRP's Restoration Flow hydrographs from the Settlement over historical flow data. Water temperature data were smoothed into 7-day, daily running averages to align with known temperature tolerances for salmonid life stages. The objective was to determine when critical and lethal temperatures for salmonids were exceeded at key locations in the Restoration Area. Analysis of each day provided an estimate of temperature per day of the water year given trends of a selected flow range. This provided a relationship between flow and temperature to evaluate the flow scenarios.

Results

Findings from SRH-2D, filtered by the HSI criteria, suggest that rearing habitat is present in all reaches analyzed at flows as low as 1,000 cfs. However, at low flow rates, rearing habitat is limited to channel margins; floodplains and side channels are not inundated until flows in excess of 1,000 cfs (Figure 2). The relationship between flow and suitable habitat is not linear, and varies by reach due to the diversity of floodplain configurations found along the San Joaquin River. Additionally, as flow rate increases and inundates more floodplain, the channel margin habitat becomes unsuitable due to increasing water depth and velocity. Thus, there is not a demarcation where suitable habitat increases sharply with increasing flow, and there is a variety of rearing habitat available at flow rates far lower than the maximum 4,000 cfs flow envisioned in the Settlement.

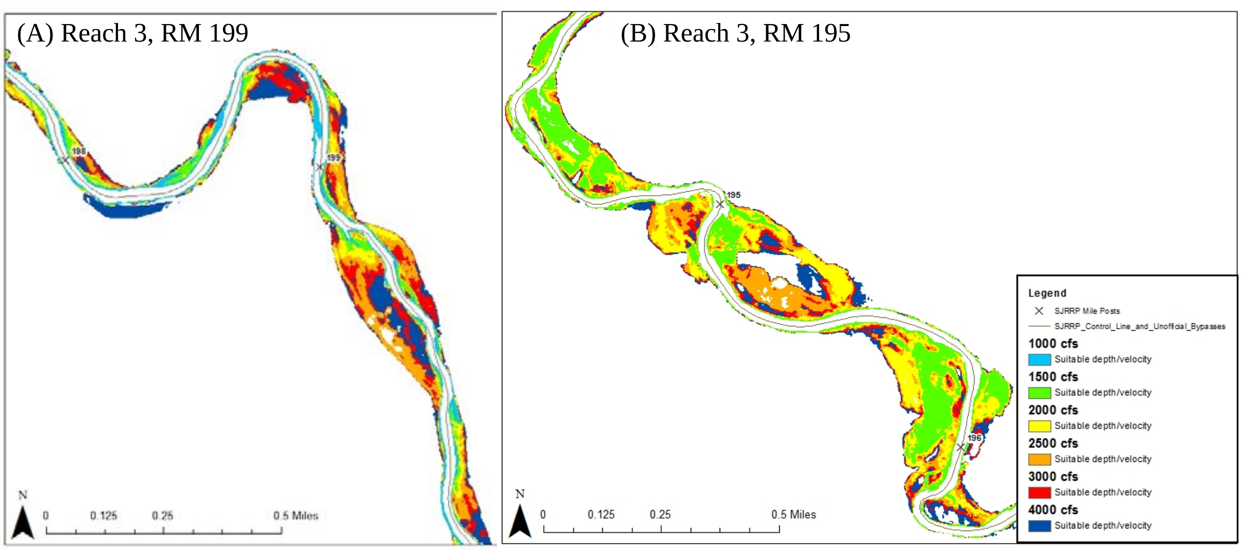

Figure 2. Inundated Area at a Series of Flow Rates in a Sample Section of Reach 3 of the San Joaquin River, Near (A) River Mile 199 and (B) River Mile 195

A comparison of hydraulically suitable rearing habitat by reach shows a general increase in rearing habitat with increased flow rate in all reaches; however, this increase plateaus near 2,500 to 3,000 cfs in three of the four reaches analyzed (Figure 3). The outlier, Reach 2B, shows increasing hydraulically suitable area with larger flows throughout almost all flow rates analyzed. This reach is the site of a planned large-scale levee setback and floodplain regrading project, and has been designed to maximize floodplain habitat. While this project has not yet been constructed, the topography used in this analysis reflects the designed grading, and is therefore the most favorable reach for suitable rearing habitat.

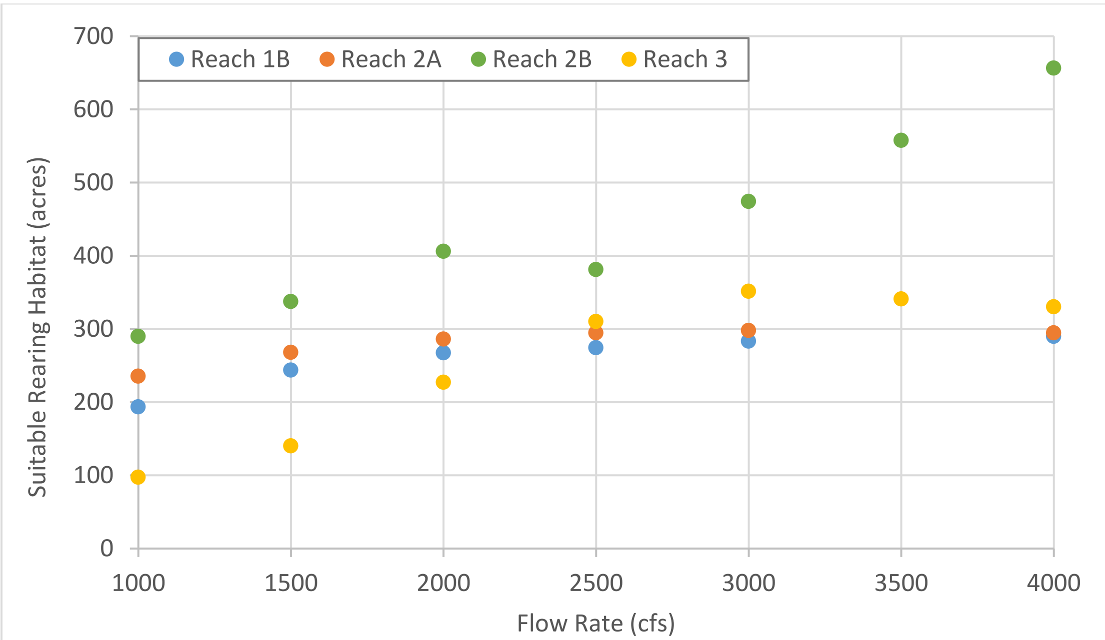

Figure 3. Hydraulically Suitable Rearing Habitat (acres) vs. Flow Rate (cfs) for Reach 1B through Reach 3 of the San Joaquin River

Results from the temperature analysis indicate that beyond mid to late April, the flow rate required to maintain water temperatures below the 68 °F lethal threshold for adult salmonids in critical migration reaches becomes difficult to attain (Figure 4). Adult salmonid upstream migration typically occurs from March through June, and juvenile salmonid downstream emigration typically occurs from November through June. These results indicate that temperature limits the optimal window for adult salmonid upstream migration, however temperatures would be suitable for at least part of the spring migration period. For emigrating juveniles, maintaining water temperatures below the 75 °F lethal threshold in all reaches can be accomplished through the end of May with flows at or below the range of channel capacities considered. Reach 5 is expected to be constraining with the highest temperatures in the system because it is furthest downstream. Even if the channel capacity existed to convey flows for managing temperature later into the summer months, there would not likely be volume available for such flows (and the requisite ramp-down after high flows to prevent fish stranding) unless other objectives such as floodplain rearing were sacrificed for temperature control.

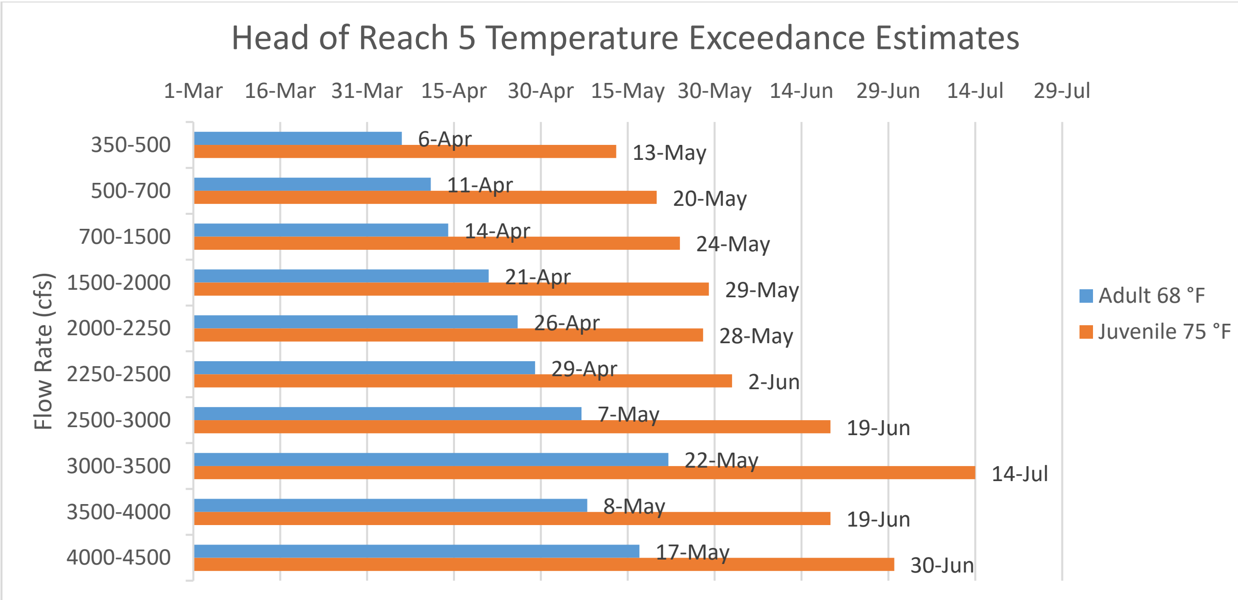

Figure 4. Estimated Dates of Temperature Exceedance at the Head of Reach 5 across different Restoration Flow rates, per Salmon Life Stage

Conclusions

While suitable rearing habitat area generally increases with higher flow rates, some rearing habitat is present at flow rates as low as 1,000 cfs. Less significant rearing habitat gain is made by increasing flow rates higher than 3,000 cfs in the unmodified reaches of the San Joaquin River. This analysis suggests that an interim channel capacity range of 2,500 cfs to 3,000 cfs will provide similar rearing habitat area as the ultimate 4,000 cfs channel capacity in the unmodified river reaches, and is likely to meet near-term rearing habitat objectives.

Adequate springtime water temperatures are most constrained in Reach 5, the lowermost section of the Restoration Area. The lethal threshold for adult Chinook salmon of 68 °F during upstream migration is expected to be more of a constraint than the lethal threshold for juvenile Chinook salmon of 75 °F during downstream emigration. There is a fair amount of uncertainty in the accuracy of the temperature model; however, the model is still valuable for comparing different flow scenarios and understanding the relationship between flow and water temperature. Temperature monitoring will be necessary to verify modeled results with in-situ data, as will an evaluation of reservoir management strategies to optimize releases for temperature control.

This analysis allowed the SJRRP to compare rearing habitat area and temperature across flow rates, ultimately leading to a selection of a 2,500 cfs interim channel capacity. Further description of this analysis is available in an SJRRP Technical Memorandum, Analysis of Physical Flow Characteristics Supportive of Chinook Salmon to Inform Channel Capacity Selection in the Funding Constrained Framework (SJRRP, 2018).

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References

Lai, Y. 2008. SRH-2D version 2: Theory and User's Manual, Sedimentation and River Hydraulics – Two-dimensional River Flow Modeling. U.S. Bureau of Reclamation, Technical Service Center, Denver, CO.

Resource Management Associates, Inc. and Reclamation. 2007. San-Joaquin Basin Water Temperature Modeling and Analysis. Mid-Pacific Region, U.S. Bureau of Reclamation, Sacramento, CA.

Reclamation. 2012a. Minimum Floodplain Habitat Area: for Spring and Fall-Run Chinook Salmon, Technical Report. San Joaquin River Restoration Program, Mid-Pacific Region, U.S. Bureau of Reclamation, Sacramento, CA.

Reclamation. 2012b. San Joaquin River Restoration Program Programmatic EIS/EIR. U.S. Bureau of Reclamation.

SJRRP. 2018. Analysis of Physical Flow Characteristics Supportive of Chinook Salmon to Inform Channel Capacity Selection in the Funding Constrained Framework. U.S. Bureau of Reclamation, Sacramento, CA. http://www.restoresjr.net/?wpfb_dl=2159