Appendix J Shasta Temperature Operations

J.1 Introduction

Temperature regulations downstream of Shasta Dam led to the construction of the Temperature Control Device (TCD), a selective withdrawal system which allows the extraction of water from four different depths. This grants access to colder water at lower depths and the opportunity to blend water extracted from different depths. Blending allows operators to meet temperature regulations while conserving cold water pool for future use.

The HEC-5Q temperature model features a Fortran implementation of the TCD in its simulations of Shasta Dam operations (Reclamation, 2008). The model requires a time series input of target Shasta Dam outlet temperatures, which it then meets as closely as possible using blending between different elevations. For comparative analysis purposes in the Reinitiation of Consultation on Long-term Operations of the Central Valley Project (CVP) and State Water Project (SWP) Biological Assessment (ROC on LTO BA), Proposed Action (PA) temperature operations were developed at a monthly scale (Reclamation, 2019). Although monthly scale temperature targeting managed Shasta outflow temperature with perfect foresight, sub-monthly influences (e.g. heat waves) were not observed.

To better understand real-time operations under the PA, daily-scale temperature targeting was performed for specific years of interest, which are those designated under the PA as falling into the "Tier 3" temperature management operation. Because daily-scale temperature targeting adjusts to available cold water pool, Shasta inflows, and meteorology, it manages temperature in a manner similar to actual operations. It should be noted that daily-scale temperature targets were developed with perfect foresight. Temperature compliance of daily-scale temperature targeting was measured with modeled Sacramento River temperature. Impacts of Sacramento River temperature were then assessed with Winter run Chinook salmon egg mortality. Two proposed temperature-dependent egg mortality models were utilized, developed by Drs. Martin and Anderson.

In Tier 3 years with low cold water pool volume, daily-scale temperature targeting decreases simulated mortality. In Tier 3 years with low mortality, there is little change between daily-scale and monthly-scale temperature targeting in the simulations.

J.2 Sensitivity Analysis Details

Published PA results indicate significant temperature-based egg mortalities in Tier 3 years (End-of-April Shasta storage between 2,500 and 3,500 thousand acre-feet [TAF]). A simple spreadsheet tool was created to facilitate daily-scale temperature targeting for Tier 3 years: 1924, 1929, 1930, 1935, 1990, and 1992. For each year, a separate model run was created starting on January 1st, 1922, the beginning of the HEC-5Q simulation used for the ROC on LTO BA, to the end of the year of interest. All years before the year of interest were given the Shasta Dam temperature target time series from ROC on LTO BA modeling. Commencing simulations at the beginning of the planning time-period ensures that the daily-scale model experiences the exact same antecedent conditions as the monthly-scale analysis.

The spreadsheet calculates warming from Shasta Dam to Sacramento River below Clear Creek, as ROC on LTO BA temperature compliance is set to this location. To minimize the number of variables changing between iterations, the warming between the locations in the monthly-scale run was used for all iterations. Daily-scale Shasta Dam tailwater targets were back-calculated using daily warming values from Shasta release to Sacramento River below Clear Creek.

Late-season violations typically resulted from depleted cold water pool. Monthly-scale temperature targeting attempted to address this issue by setting warmer temperature targets (while still maintaining 56 or 53.5 degrees Fahrenheit) at the beginning of the season. Theoretically, warmer early-season temperature targets preserves cold water pool volume, reducing major violations later in the season. Daily-scale temperature targeting employed this same technique at a more refined scale.

For each year, daily-scale temperature targeting results were processed through the Martin and Anderson temperature-dependent egg mortality models. Results from these runs were compared with results from the original monthly-scale runs. Timeseries plots of Shasta storage, Shasta outflow (by extraction location), Shasta release temperature, and Sacramento River below Clear Creek temperature for each year and HEC-5Q simulation are presented in Attachment 1.

J.3 Conclusions

Mortality results for all six Tier 3 years can be subdivided into two halves, good and bad years. The bad years - 1924, 1990 and 1992 - have mortalities above 35%, while mortalities in good years - 1929, 1930 and 1935 - never exceed 13%. Daily-scale temperature targeting achieved reductions in bad year mortalities by as much as 16%, but reductions were not found for the good years, in which the monthly-scale method already achieved low mortality. Mortality results, summarized by year, are presented in Table 1.

Table 1. Annual Winter-Run Chinook Salmon Temperature-Based Egg Mortality by HEC 5Q Simulation, Mortality Model and Year

HEC 5Q Run	1924		1929		1930		1935		1990		1992	
	Anderson	Martin	Anderson	Martin	Anderson	Martin	Anderson	Martin	Anderson	Martin	Anderson	Martin
Monthly-scale	46%	66%	8%	13%	7%	6%	5%	6%	35%	36%	66%	77%
Daily-scale	30%	57%	11%	23%	8%	10%	7%	17%	30%	36%	57%	70%

Mortality reduction in bad years is roughly consistent between the Martin and Anderson mortality models, although the Anderson model typically predicts lower mortality than the Martin model. This is because the Anderson model uses only the temperatures of the five days before hatching to estimate mortality, while the Martin model uses all days between fertilization and emergence. Because the PA attempts to meet a lower target toward the middle of the temperature management period, when the largest number of redds are constructed and reach hatching stage, the Anderson model will tend to favor the PA. This does not affect comparisons between different implementations of the PA.

These results indicate that daily-scale temperature targeting reduces simulated temperature-dependent Winter run Chinook salmon egg mortality in Tier 3 years with low initial cold water pool volumes. As daily-scale temperature targeting better represents real-time operations, temperature-based egg mortalities are likely to be lower than what is suggested in the ROC on LTO BA in Tier 3 years.

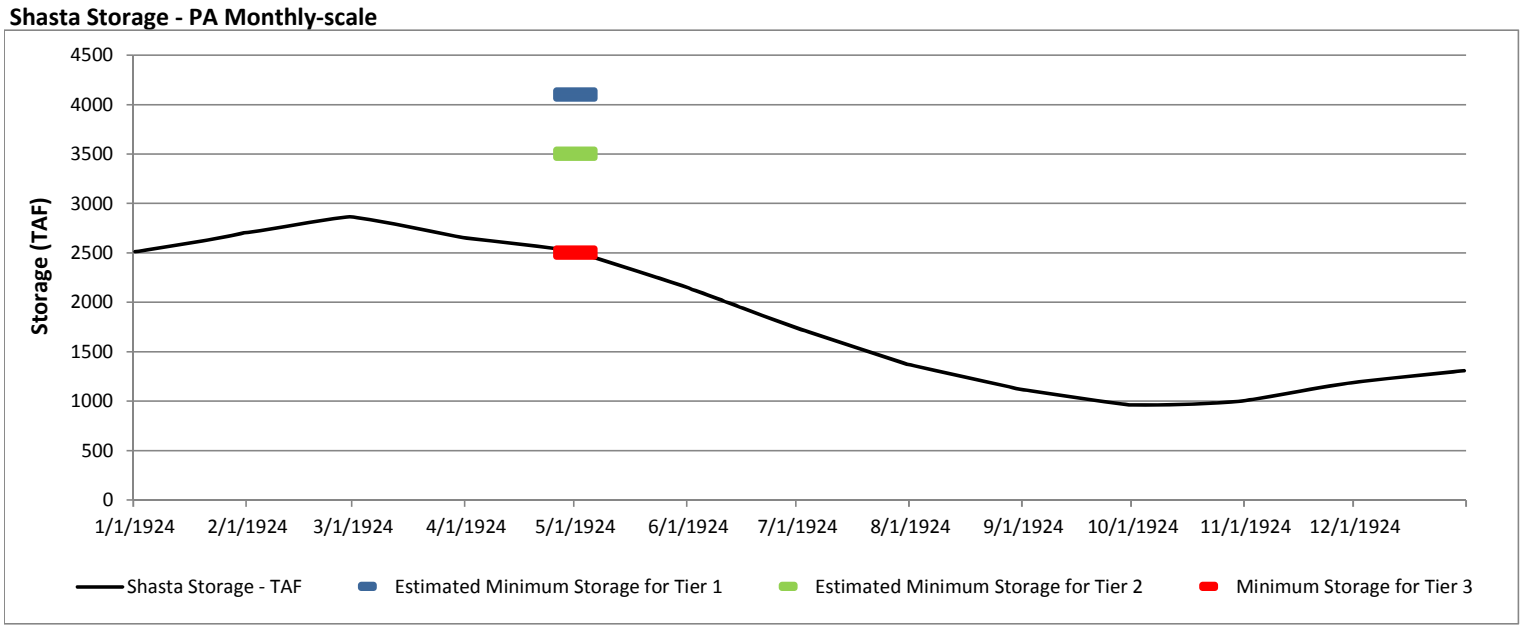
J.4 References

U.S. Bureau of Reclamation, 2008. Central Valley Project and State Water Project Operations Criteria and Plan Biological Assessment, Appendix H Reclamation Temperature Model and SRWQM Temperature Model, August 2008.

U.S. Bureau of Reclamation, 2019. Reinitiation of Consultation on the Coordinated Long-Term Operation of the Central Valley Project and State Water Project: Final Biological Assessment, January 2019.

Reinitiation of Consultation on the Coordinated Long-term Operation of the Central Valley Project and State Water Project: Shasta Temperature Management Sensitivity Analysis - Attachment 1

Shasta Storage - PA Monthly-scale



Select Year:

1924

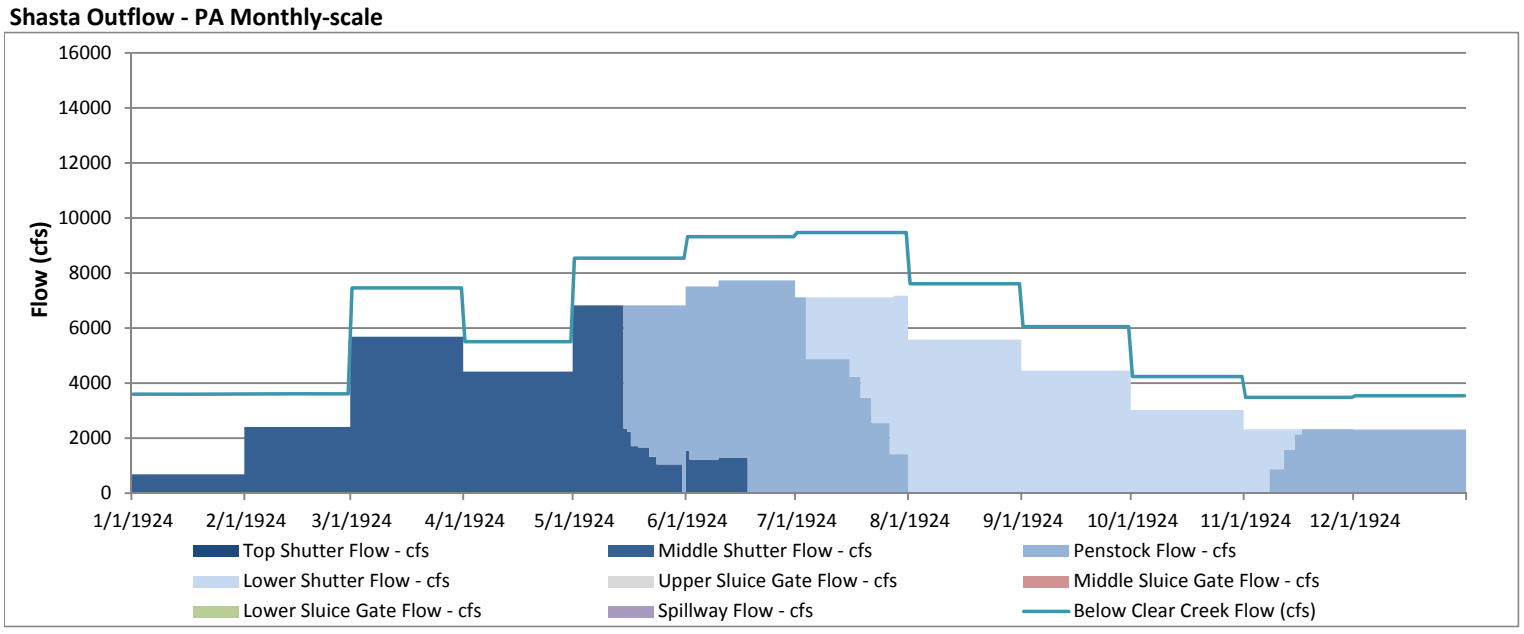
Temperature Tier:

Tier 3

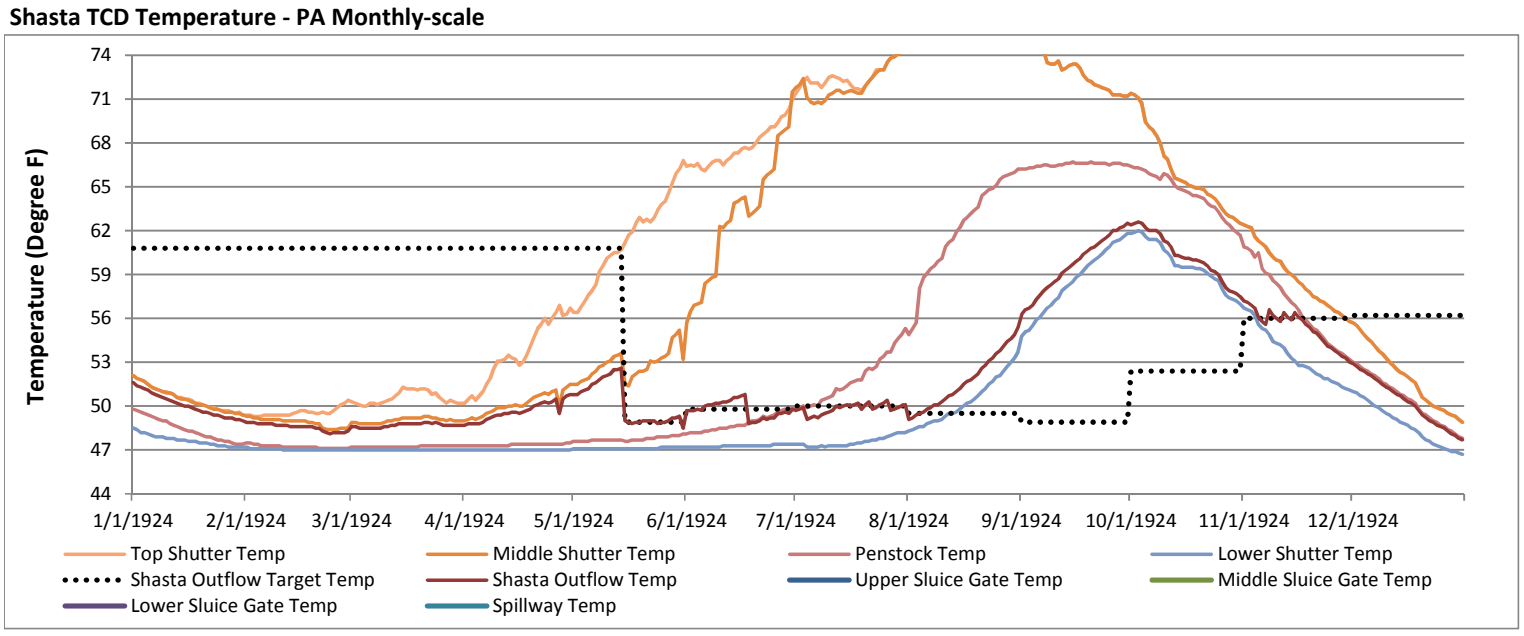
Annual Mortalities:

Anderson	46%
Martin	66%

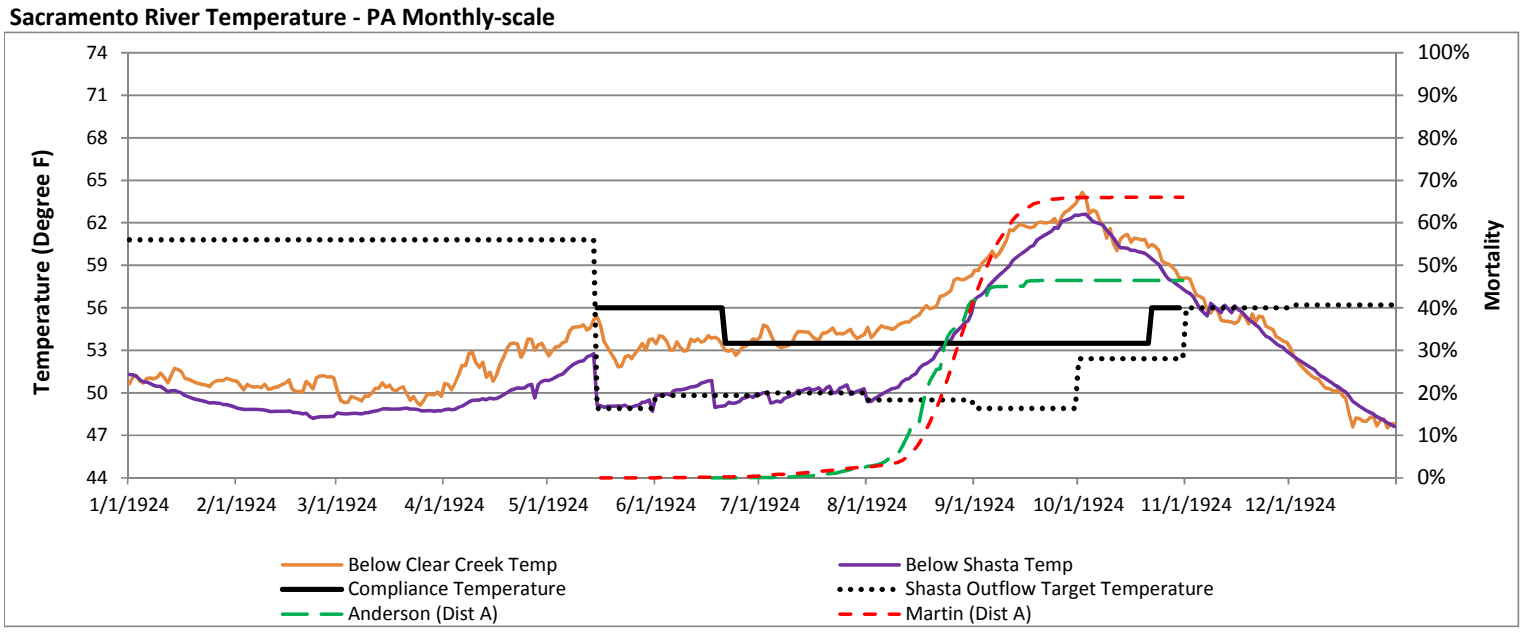
Shasta Outflow - PA Monthly-scale



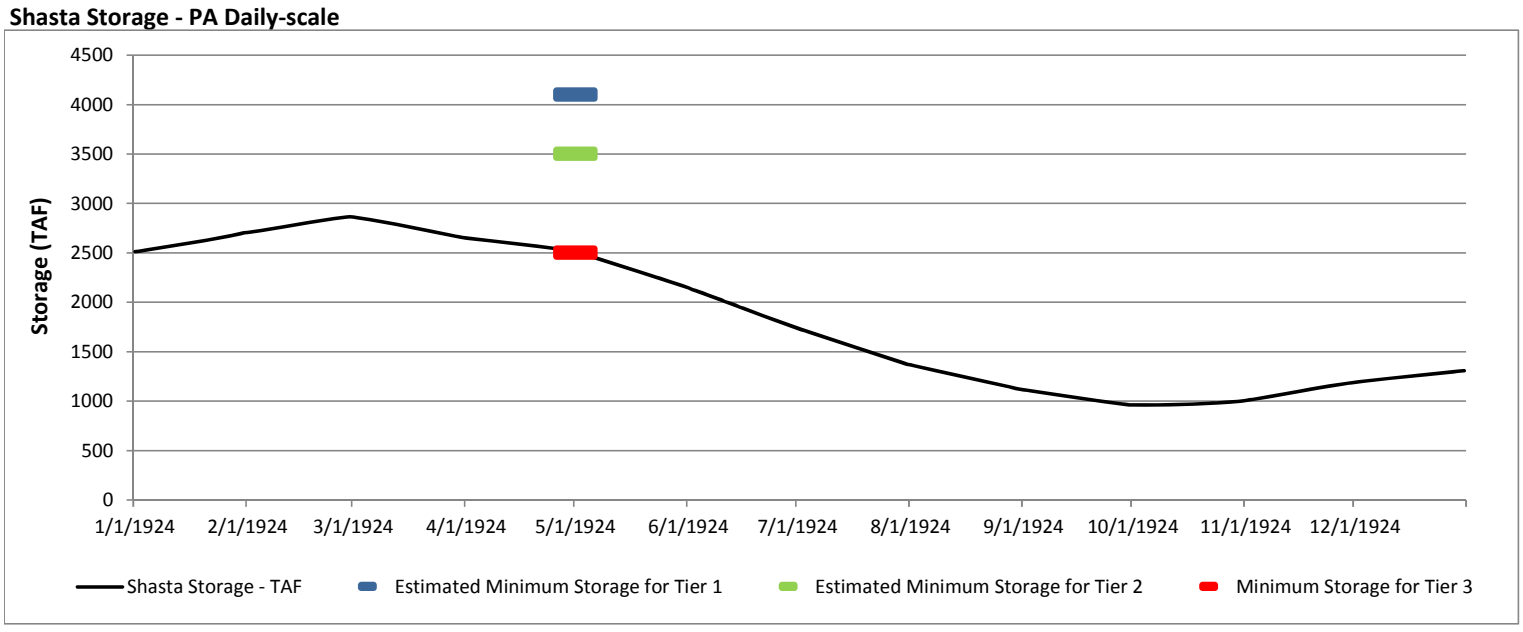
Shasta TCD Temperature - PA Monthly-scale



Sacramento River Temperature - PA Monthly-scale



Shasta Storage - PA Daily-scale



Select Year:

1924

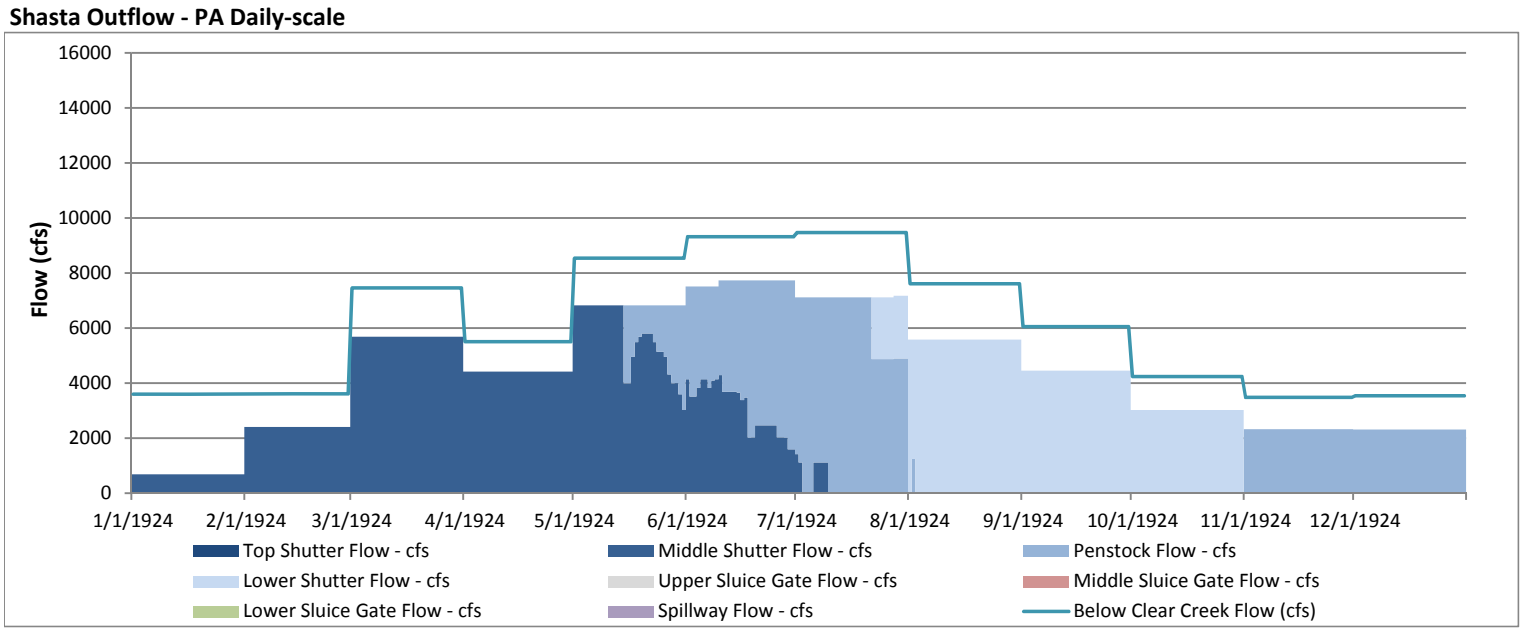
Temperature Tier:

Tier 3

Annual Mortalities:

Anderson	30%
Martin	57%

Shasta Outflow - PA Daily-scale



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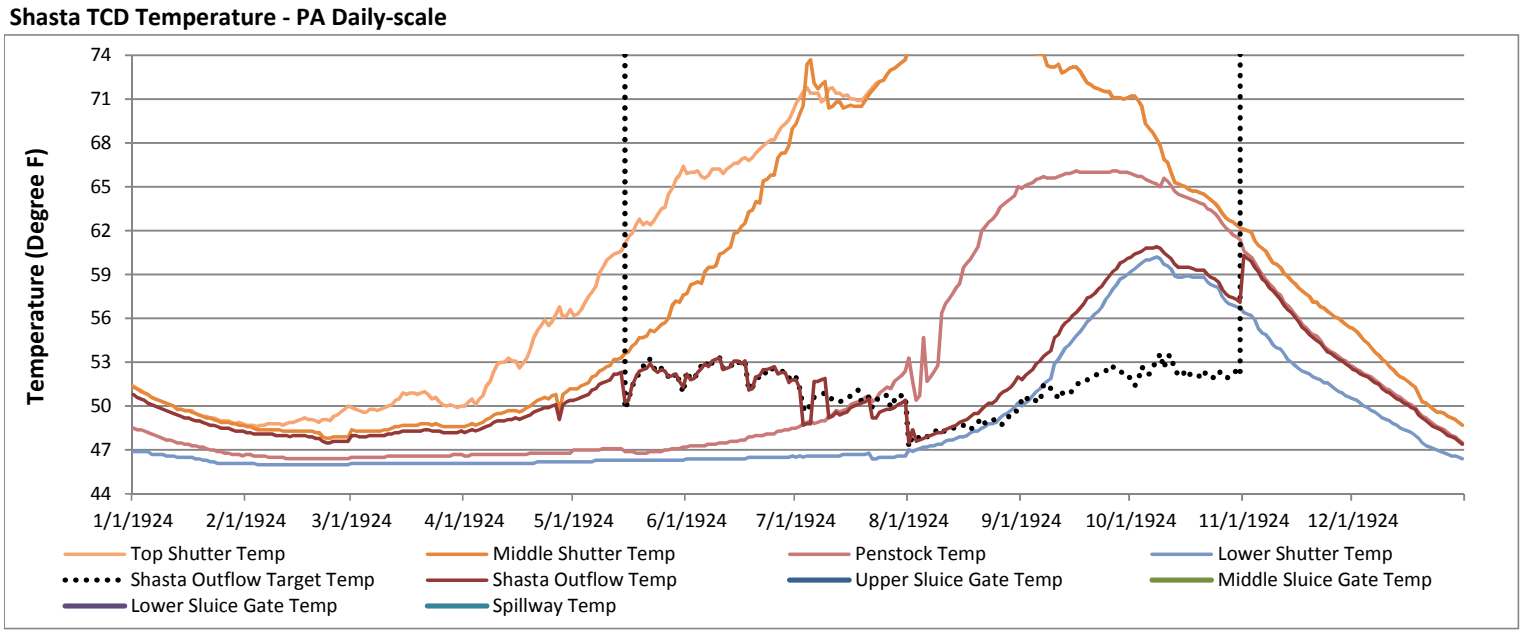
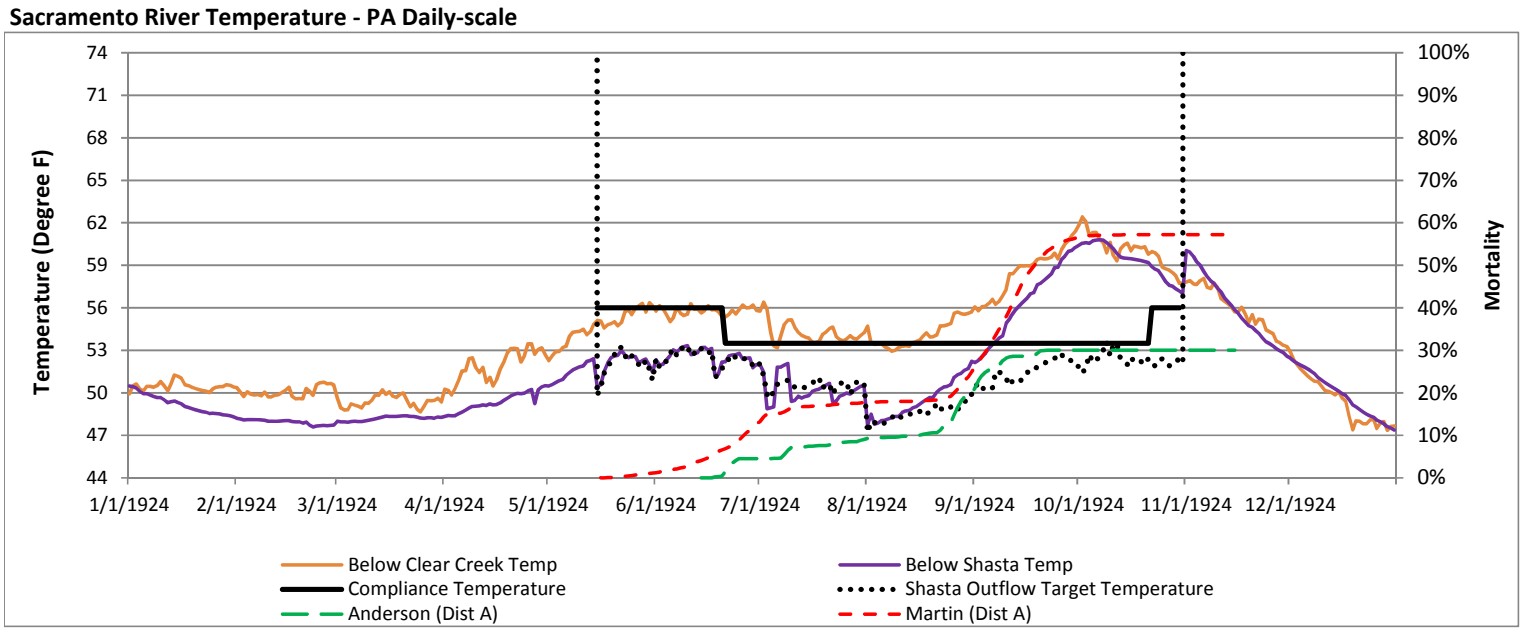
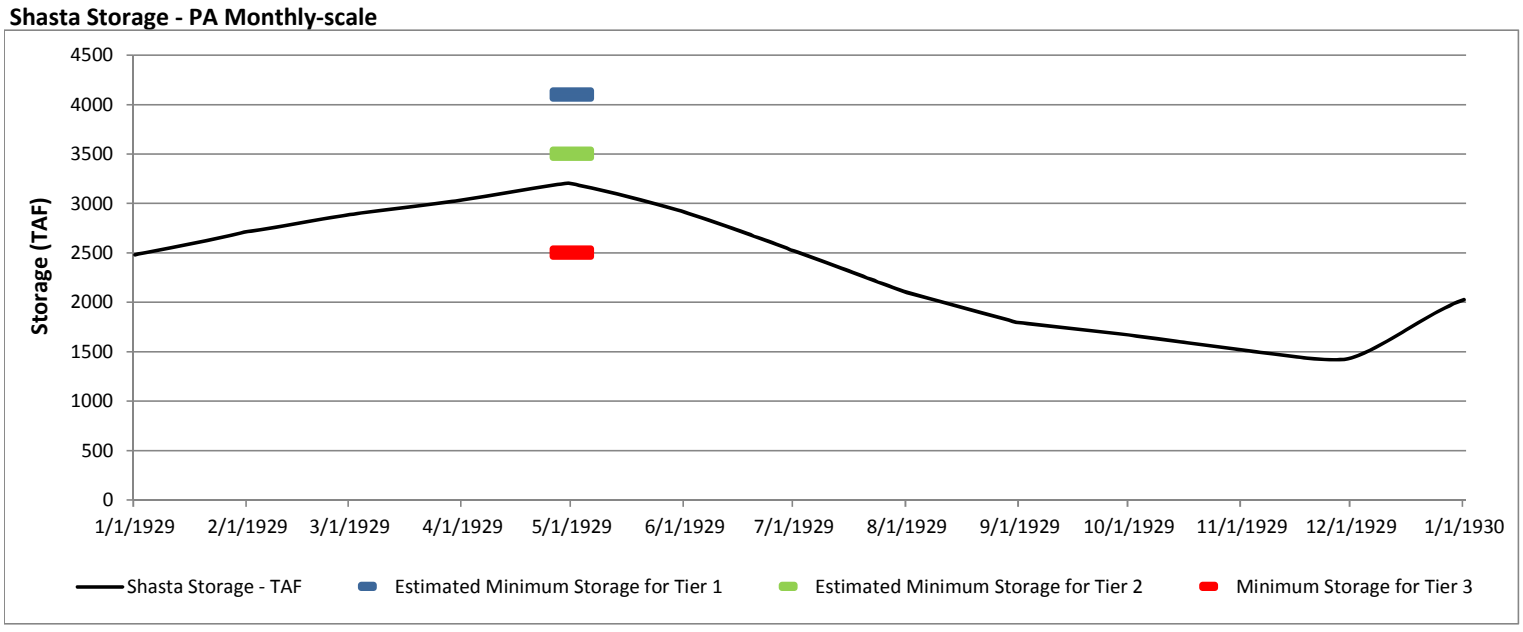


Sacramento River Temperature - PA Daily-scale



Shasta Storage - PA Monthly-scale



Select Year:

1929

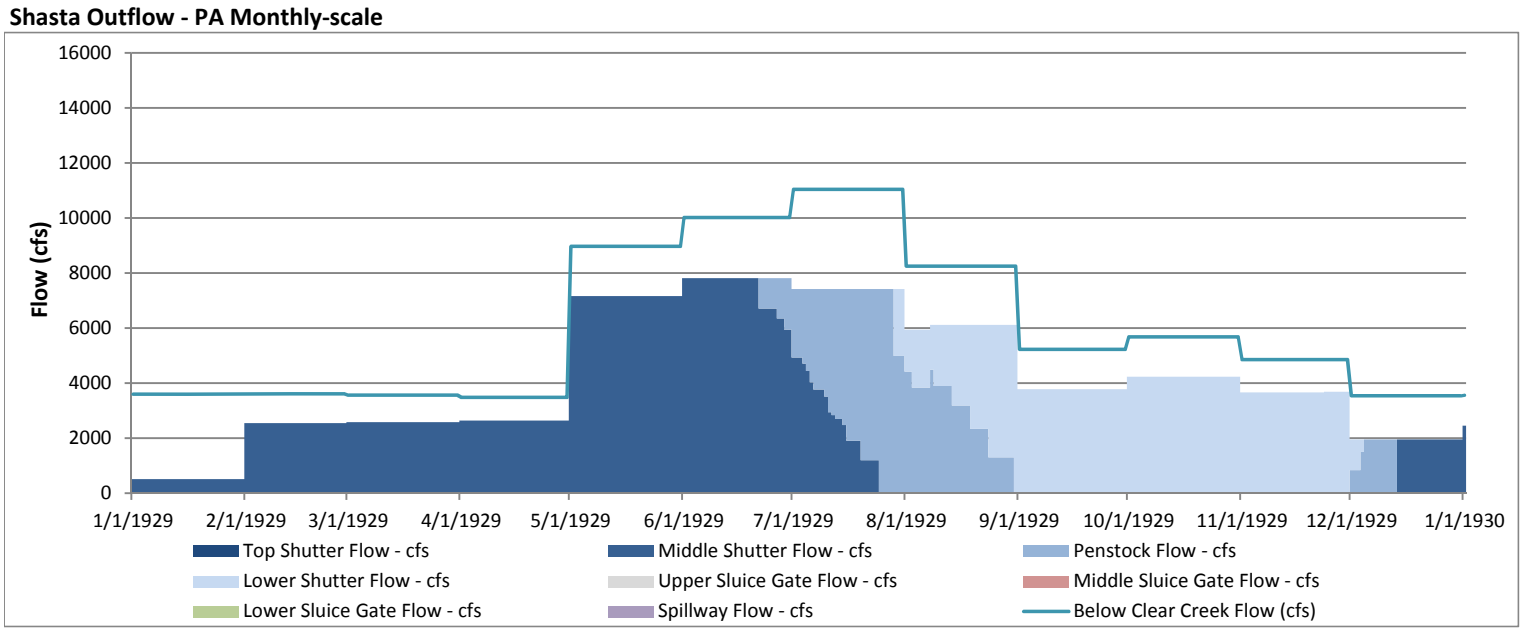
Temperature Tier:

Tier 3

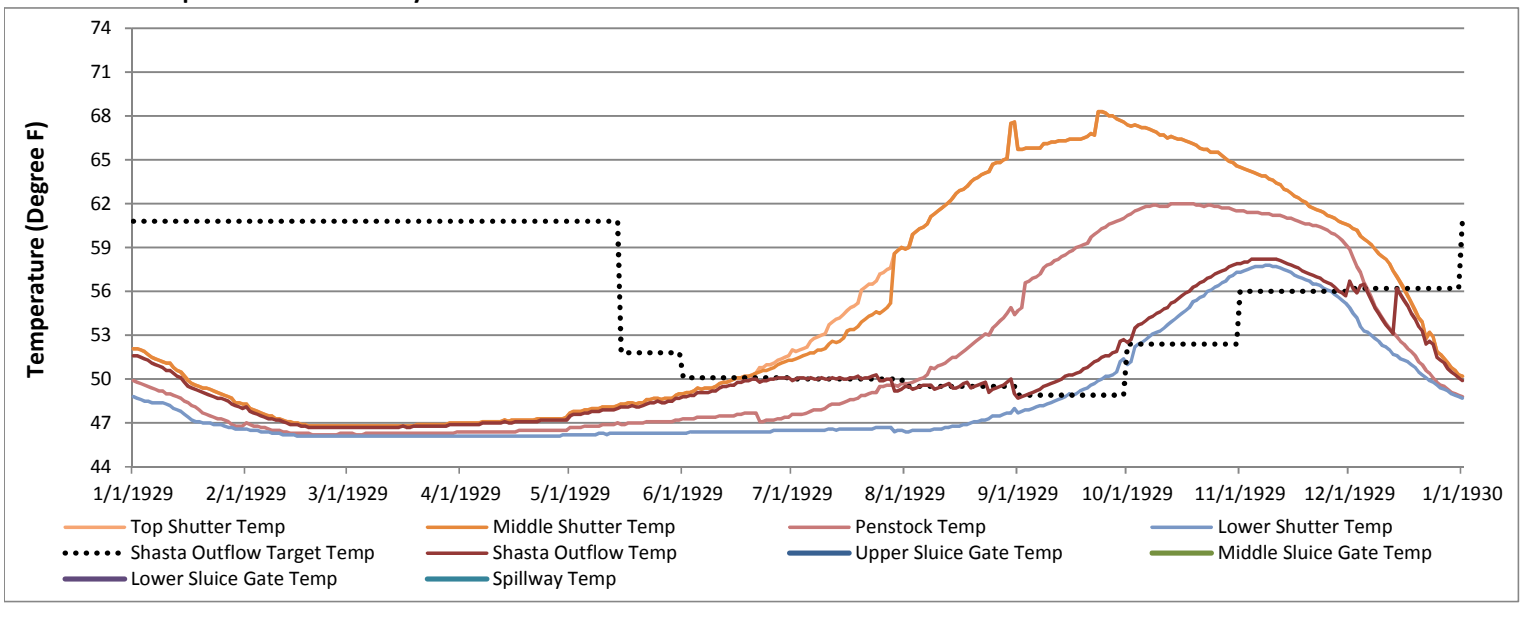
Annual Mortalities:

Anderson	8%
Martin	13%

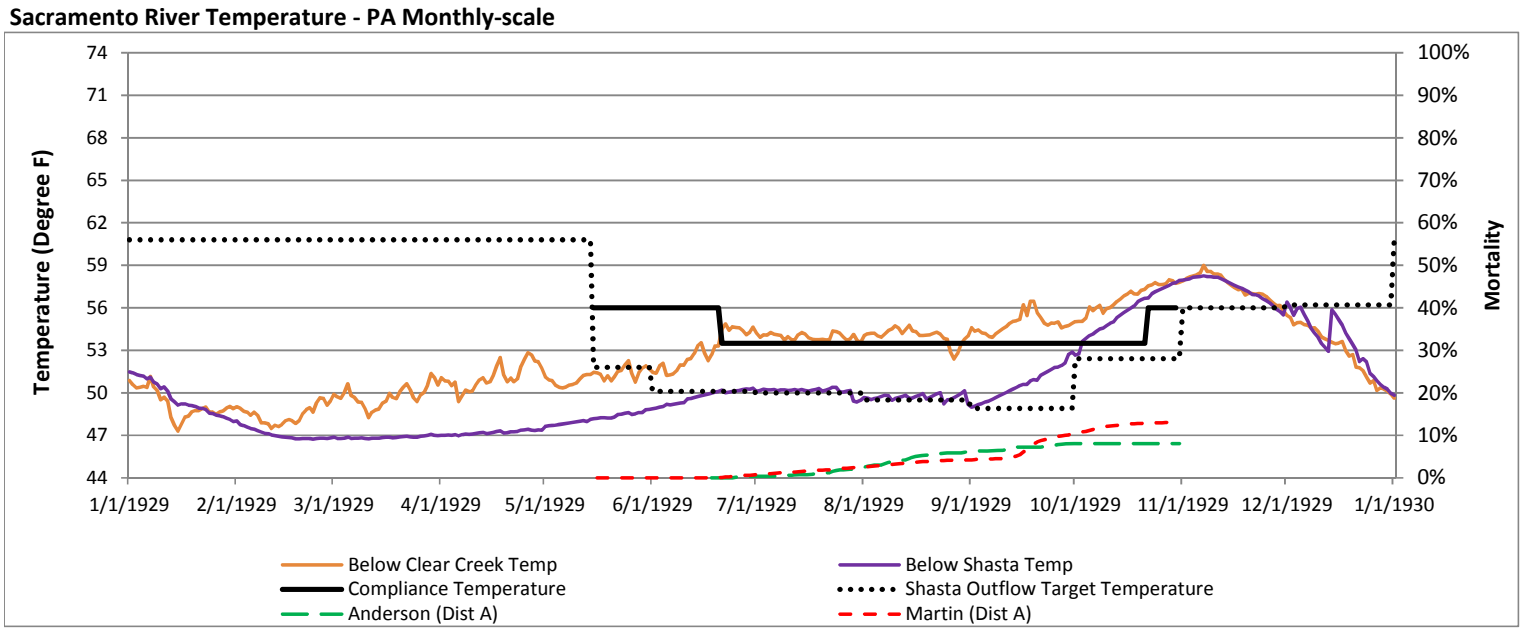
Shasta Outflow - PA Monthly-scale



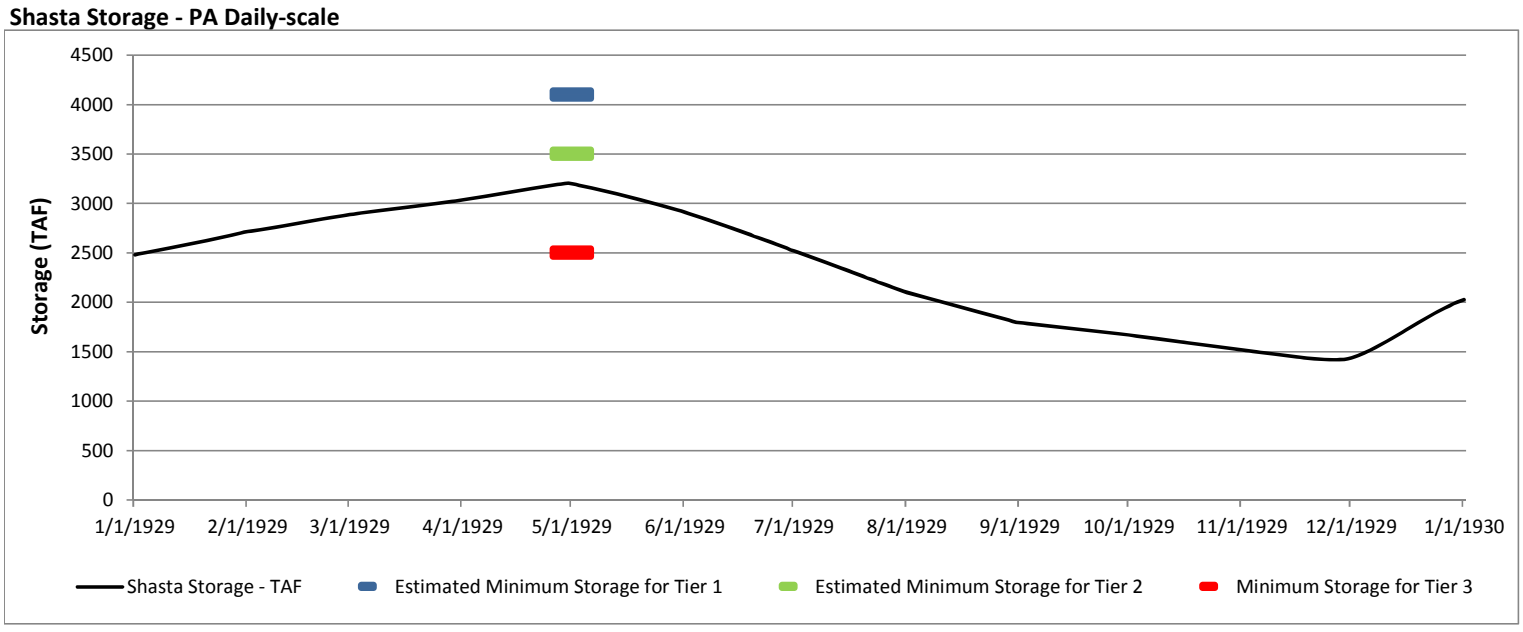
Shasta TCD Temperature - PA Monthly-scale



Sacramento River Temperature - PA Monthly-scale



Shasta Storage - PA Daily-scale



Select Year:

1929

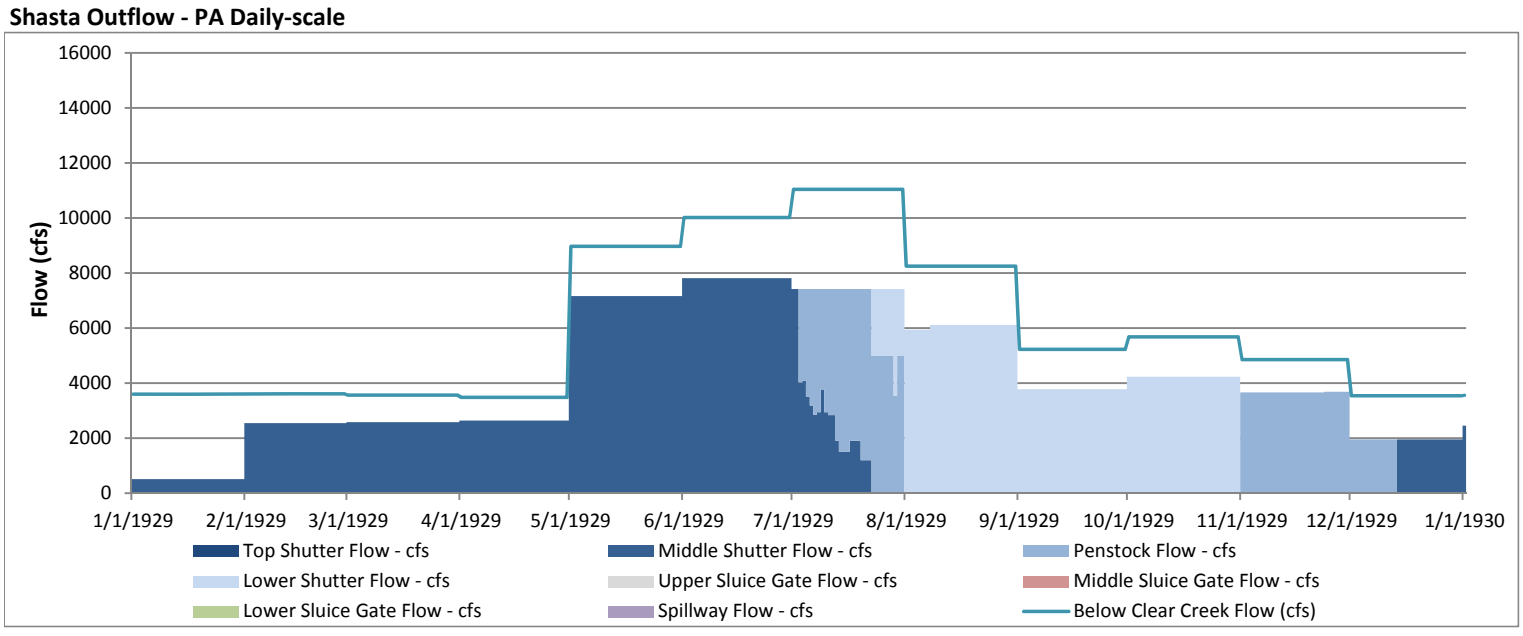
Temperature Tier:

Tier 3

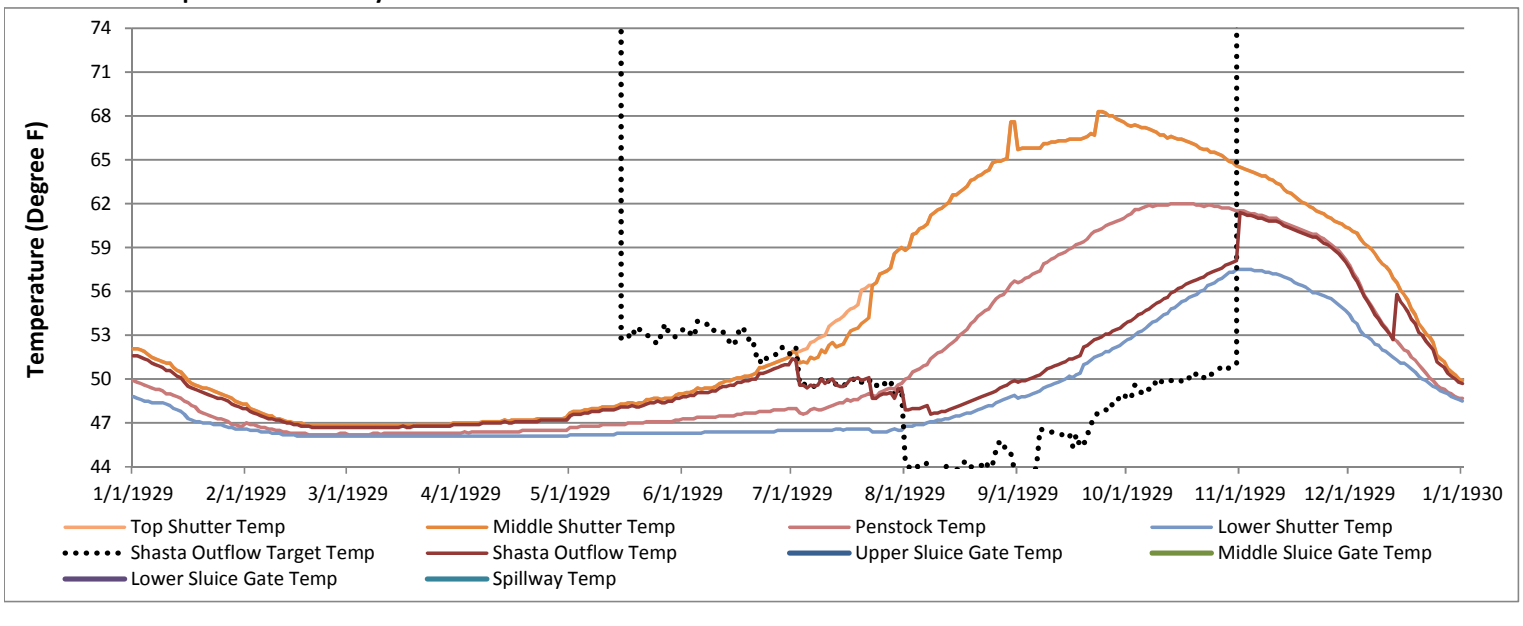
Annual Mortalities:

Anderson	11%
Martin	23%

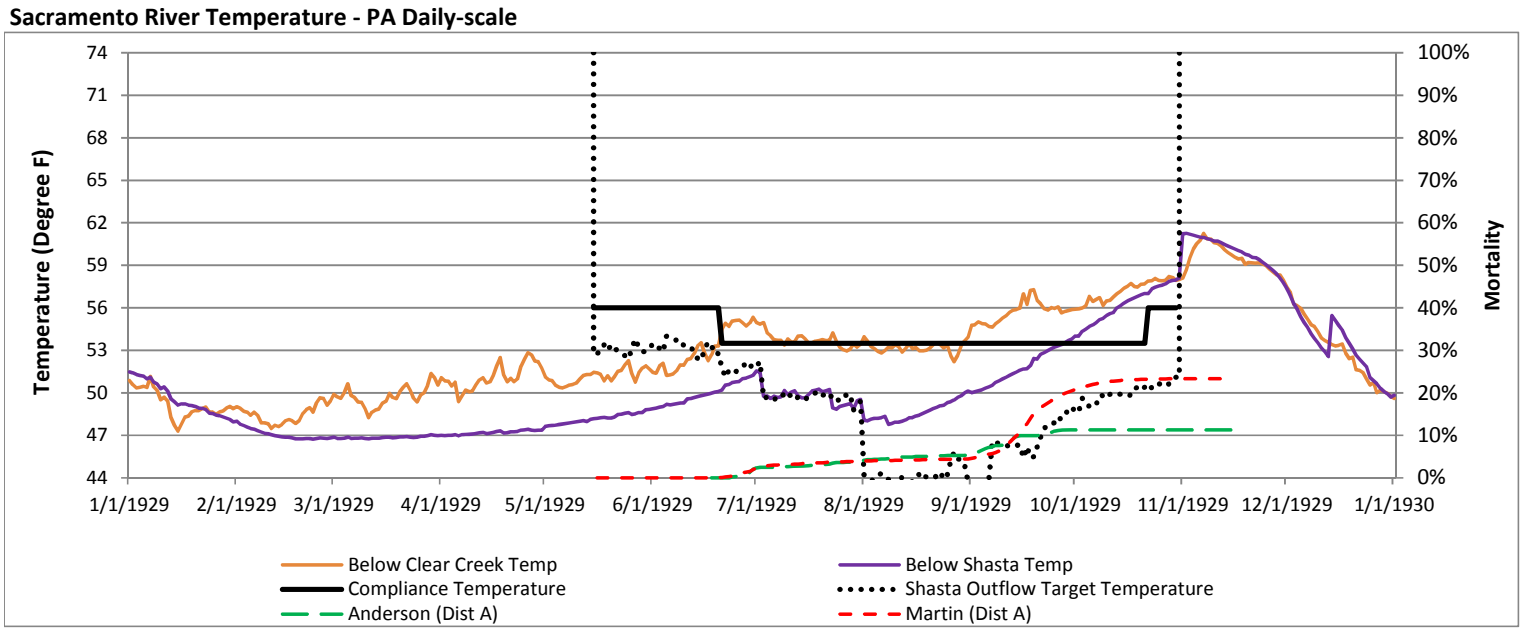
Shasta Outflow - PA Daily-scale



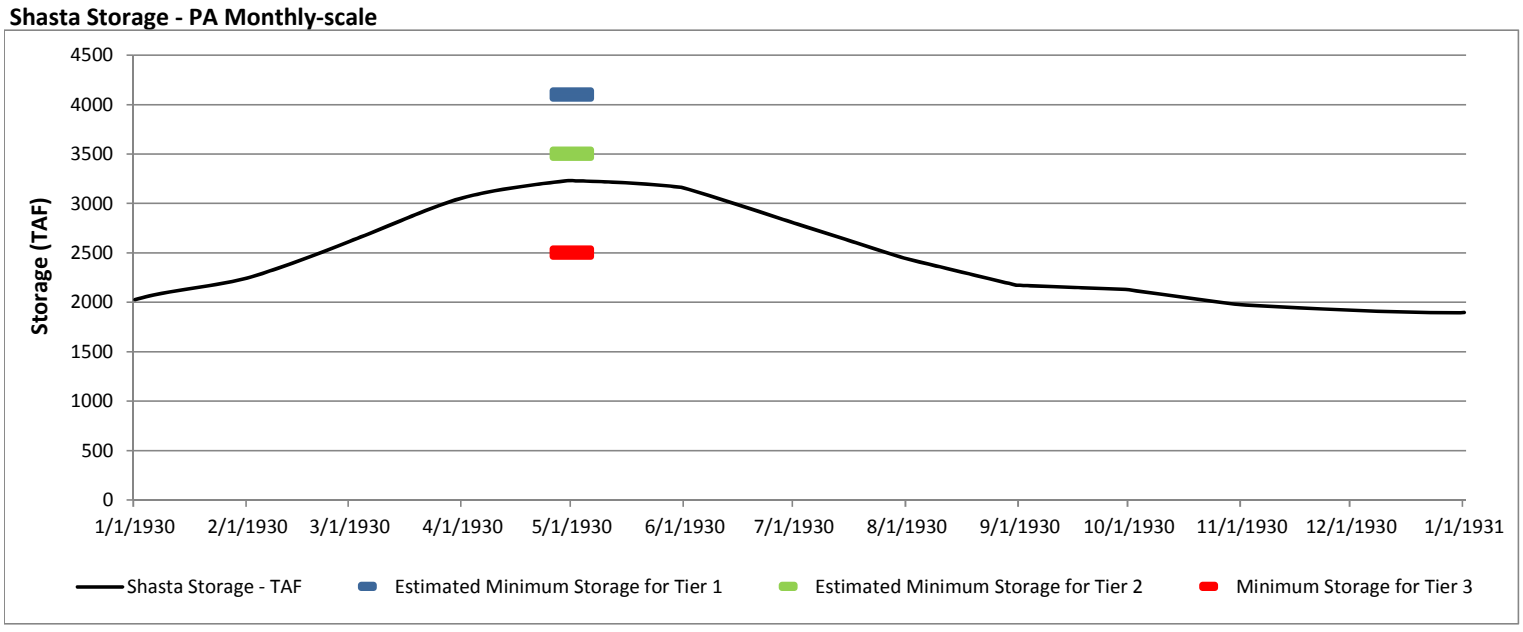
Shasta TCD Temperature - PA Daily-scale



Sacramento River Temperature - PA Daily-scale



Shasta Storage - PA Monthly-scale



Select Year:

1930

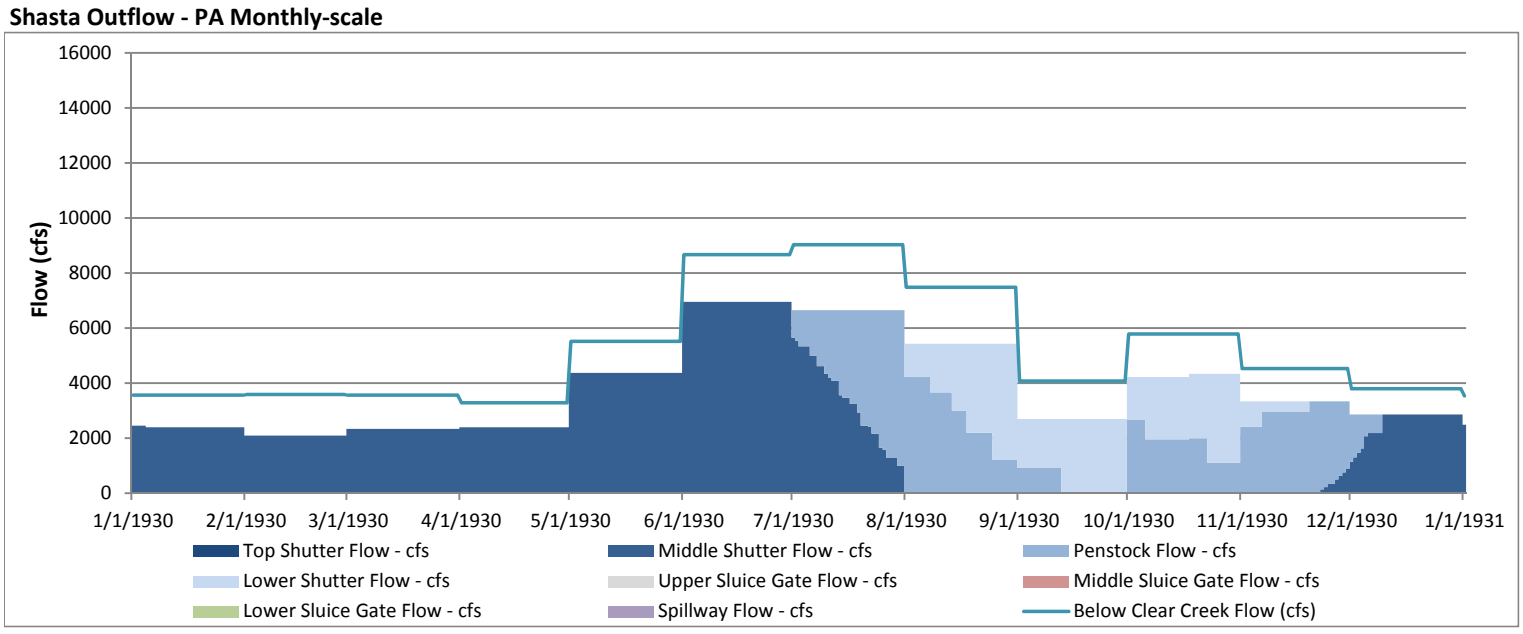
Temperature Tier:

Tier 3

Annual Mortalities:

Anderson	7%
Martin	6%

Shasta Outflow - PA Monthly-scale



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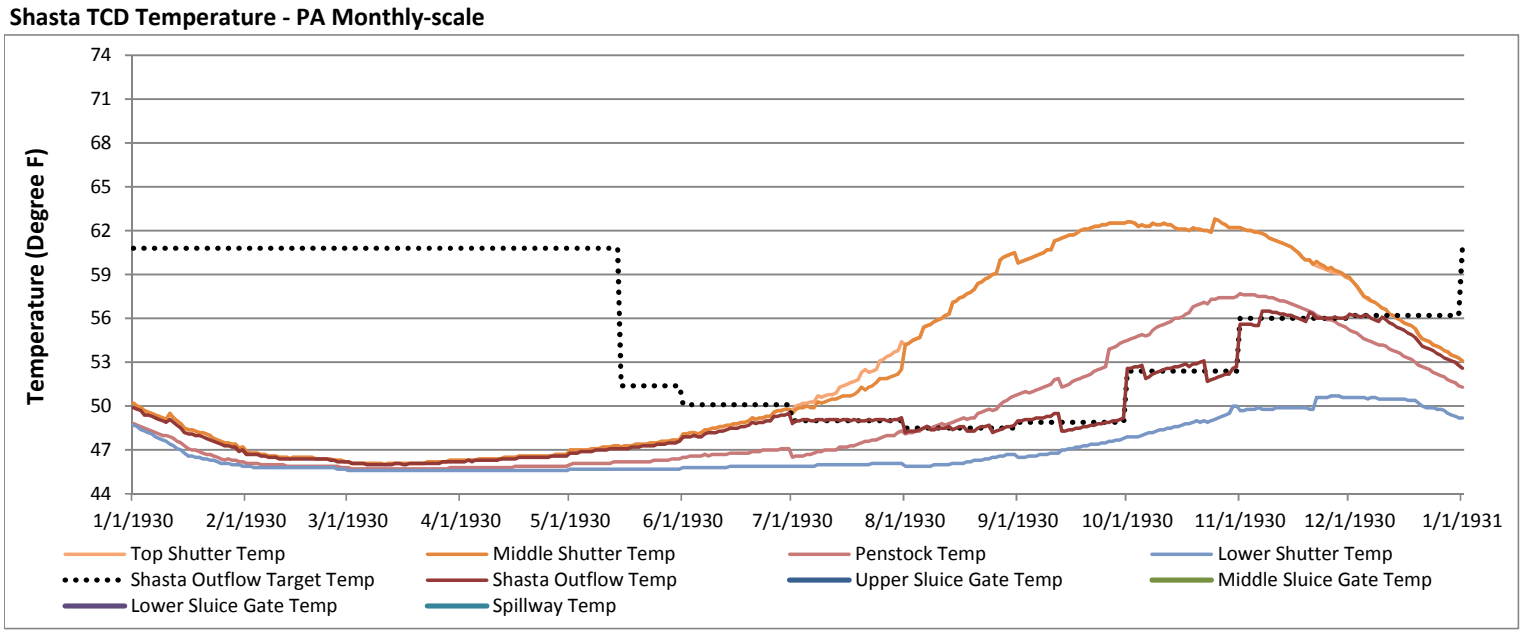
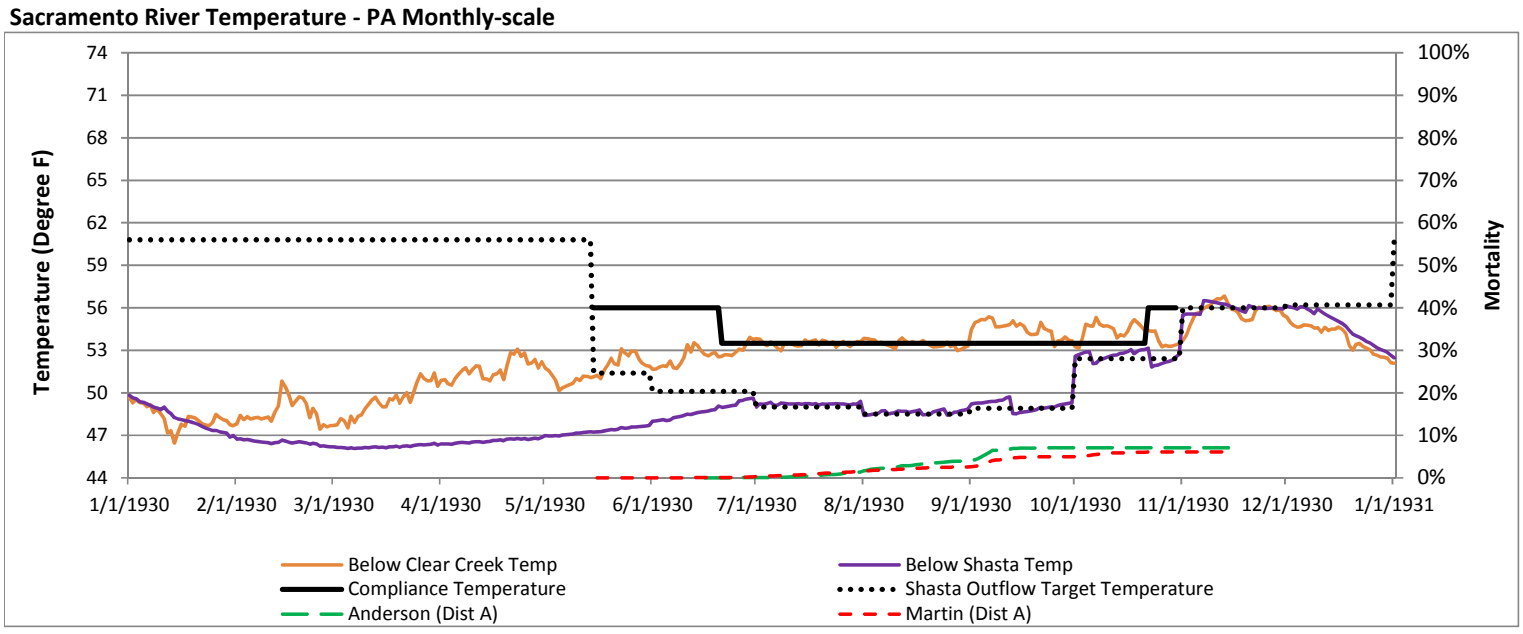
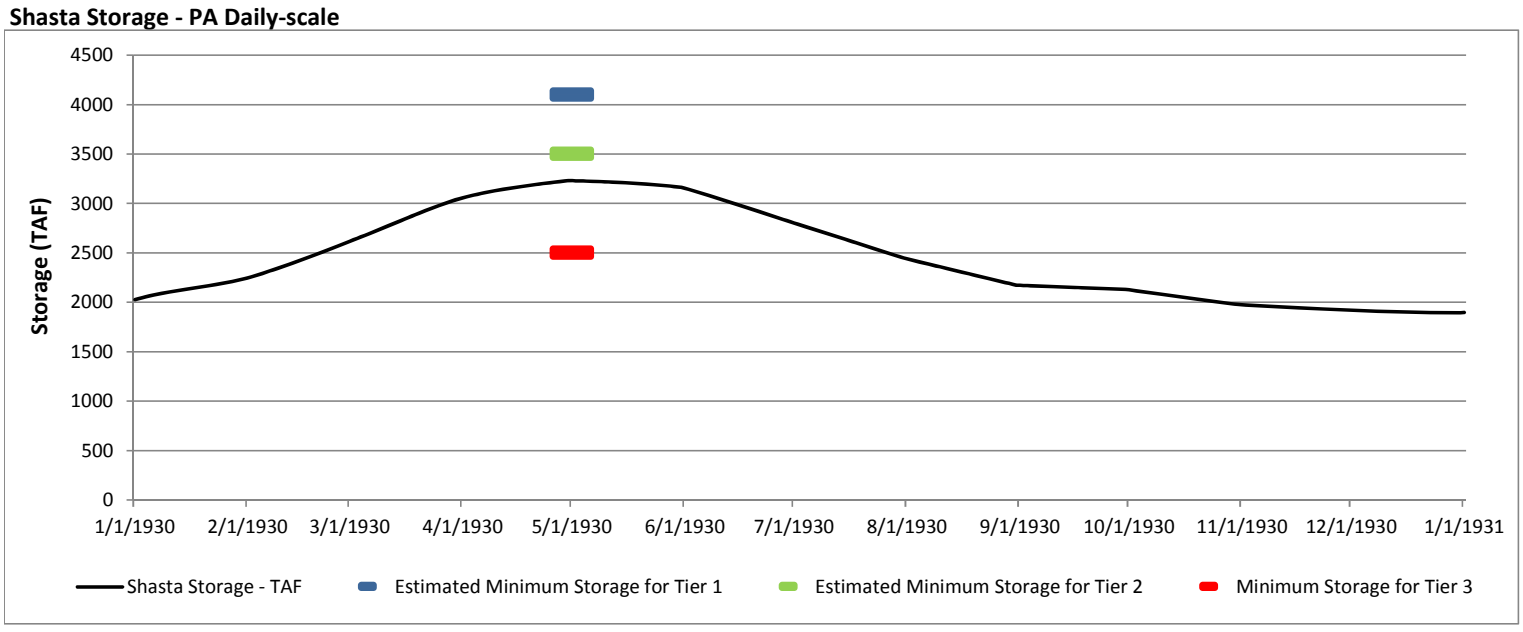


Sacramento River Temperature - PA Monthly-scale



Shasta Storage - PA Daily-scale



Select Year:

1930

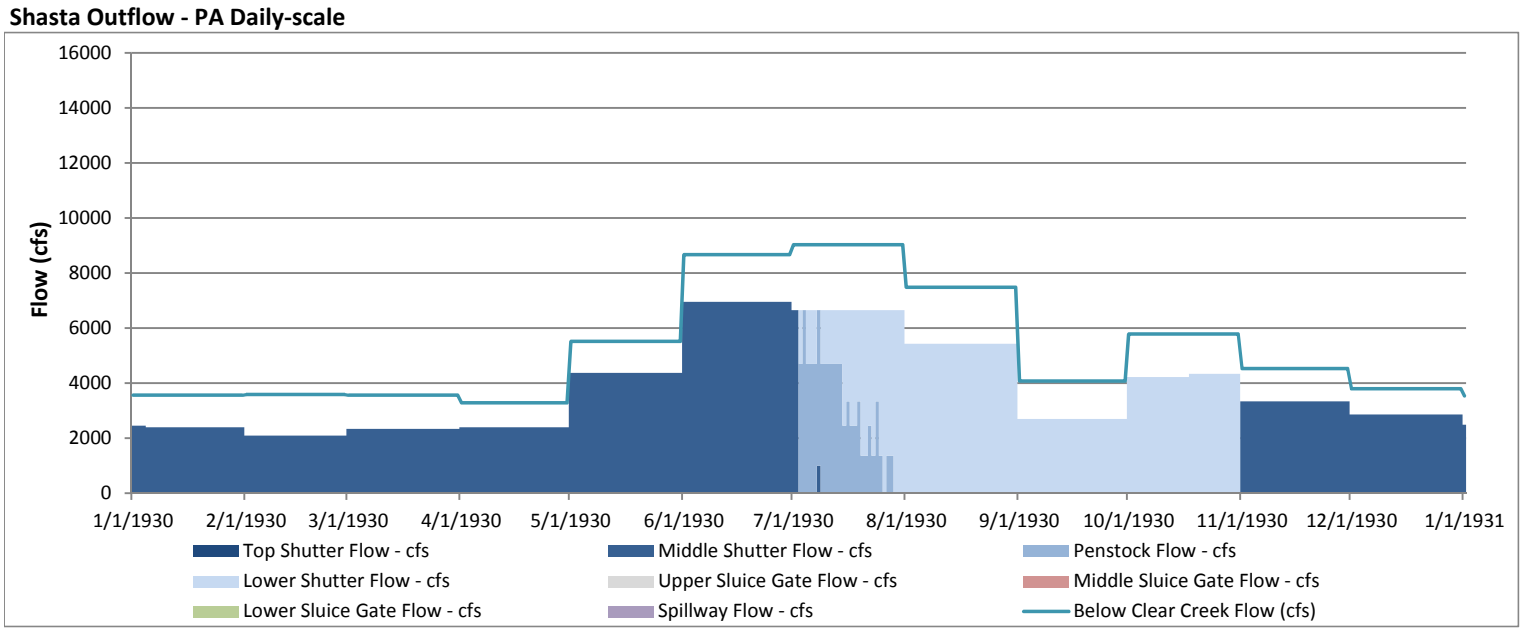
Temperature Tier:

Tier 3

Annual Mortalities:

Anderson	8%
Martin	10%

Shasta Outflow - PA Daily-scale



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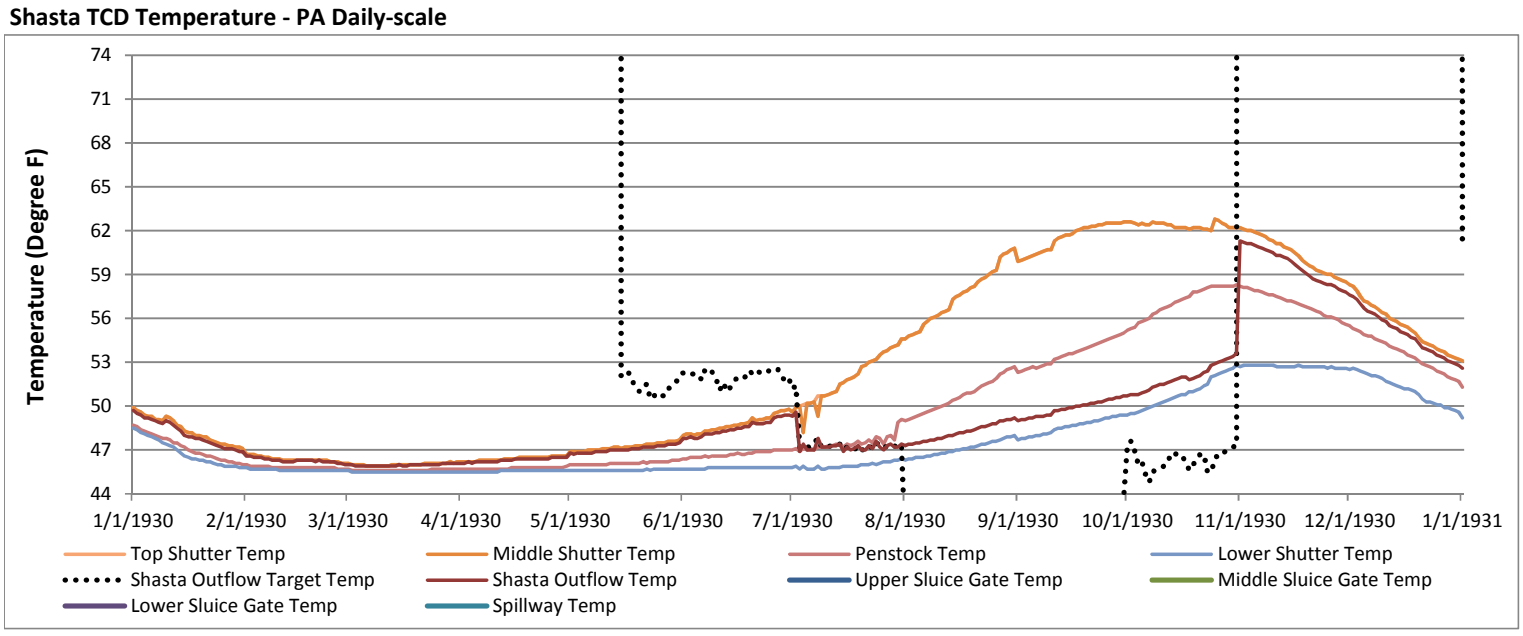
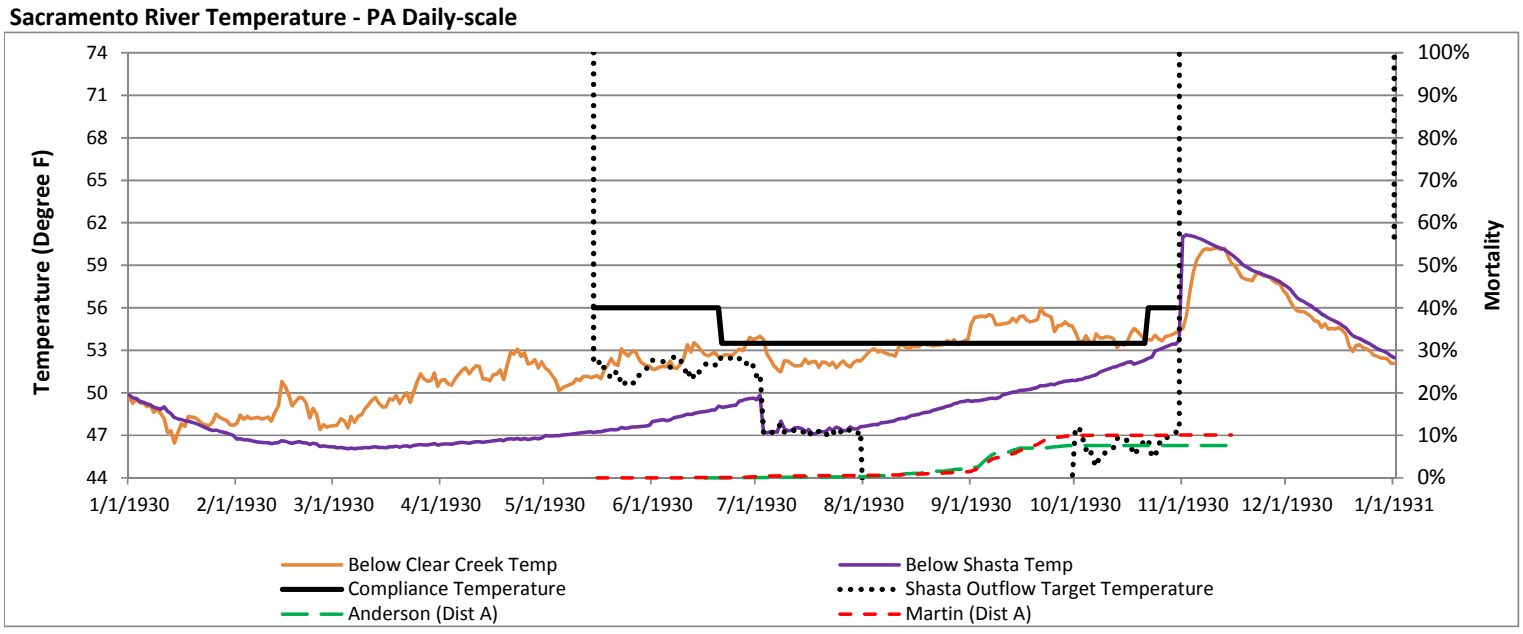
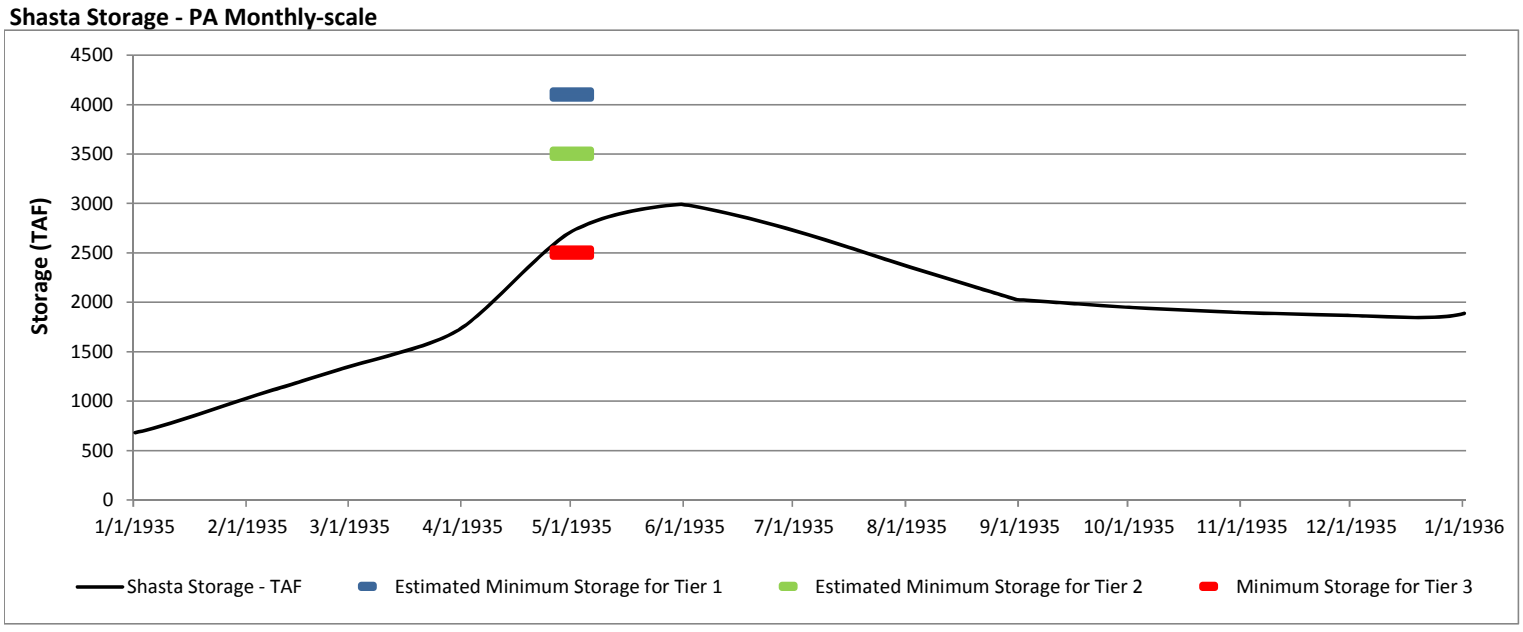


Sacramento River Temperature - PA Daily-scale



Shasta Storage - PA Monthly-scale



Select Year:

1935

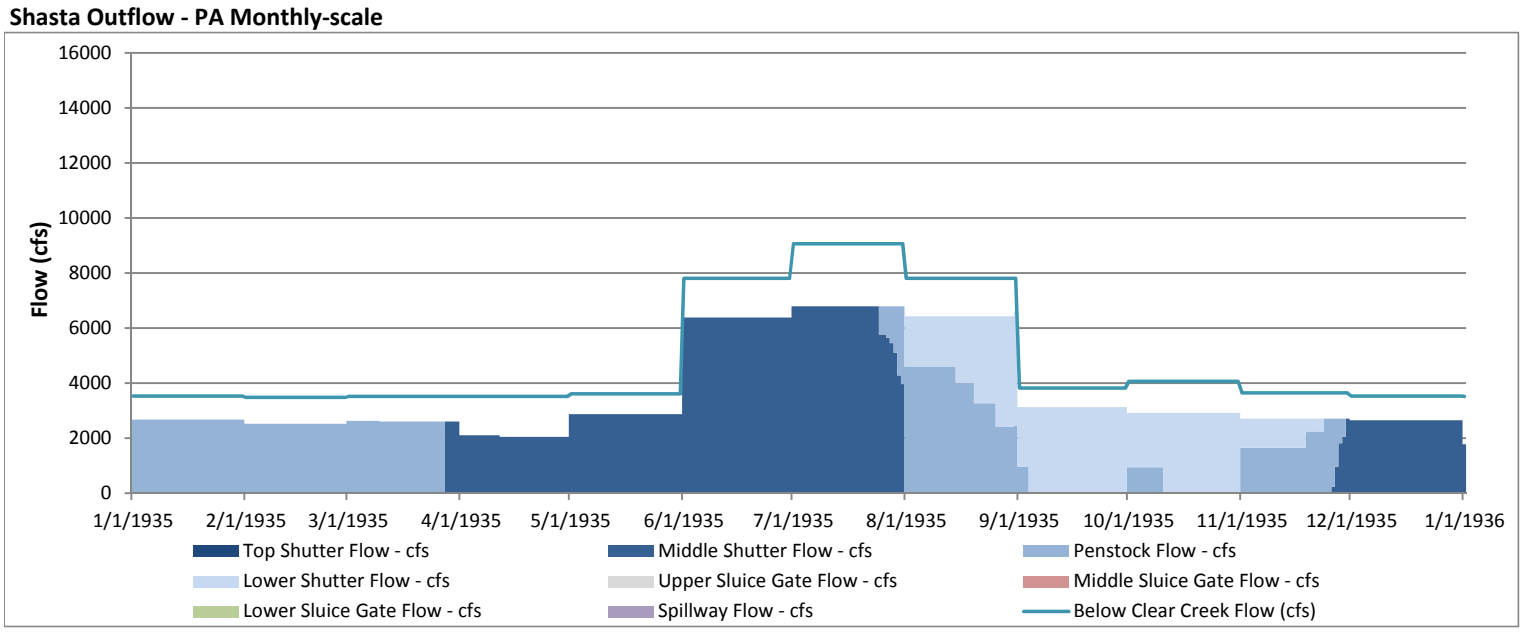
Temperature Tier:

Tier 3

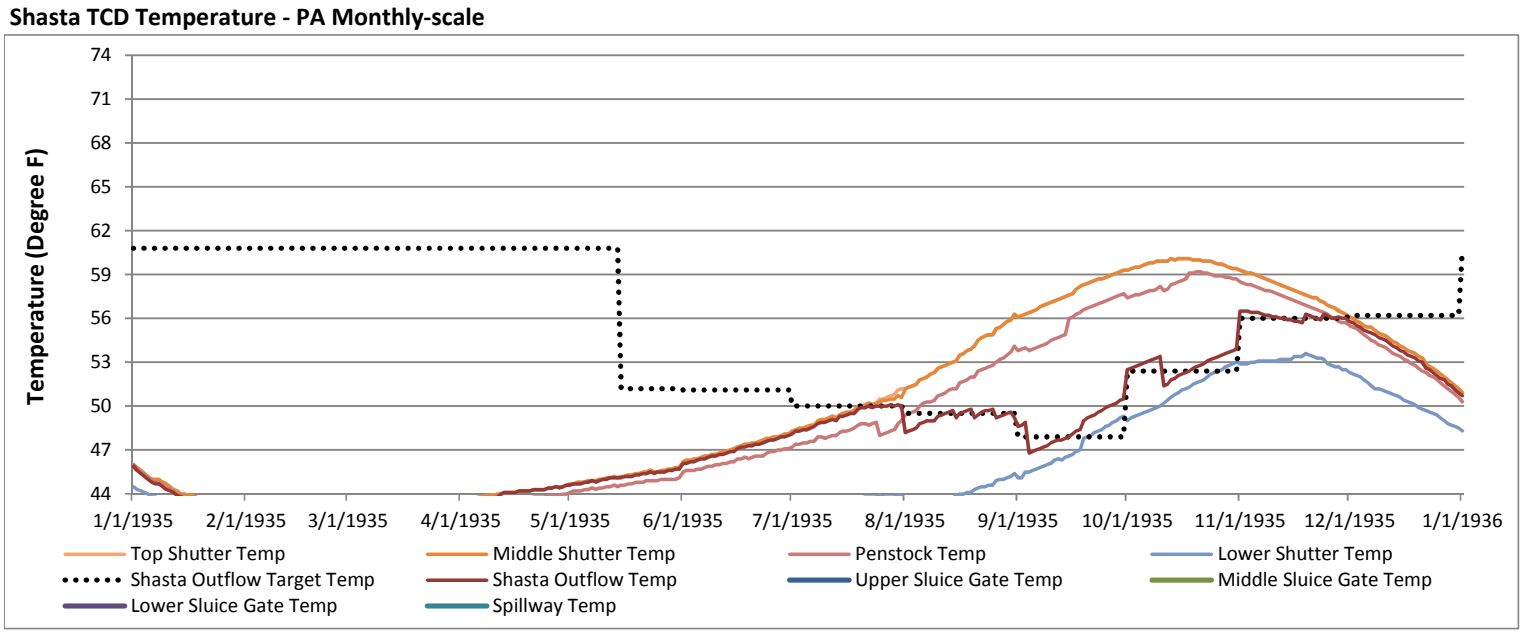
Annual Mortalities:

Anderson	5%
Martin	6%

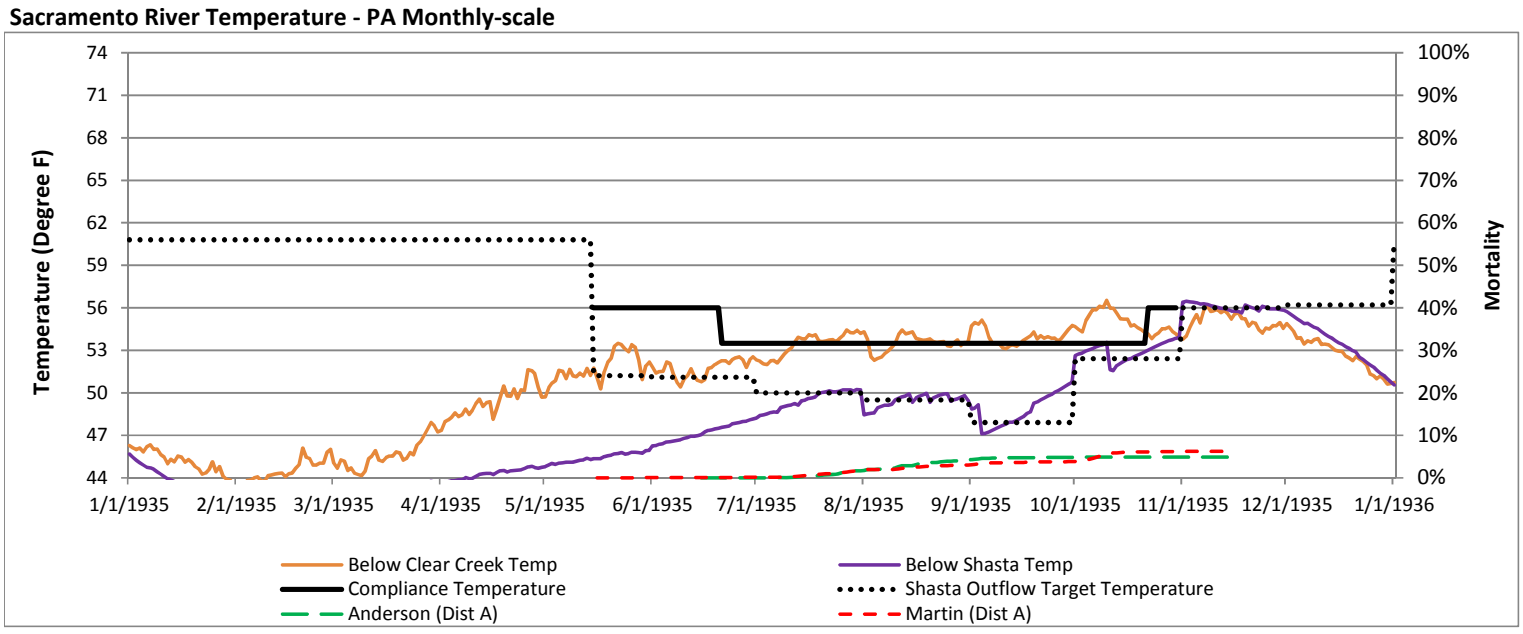
Shasta Outflow - PA Monthly-scale



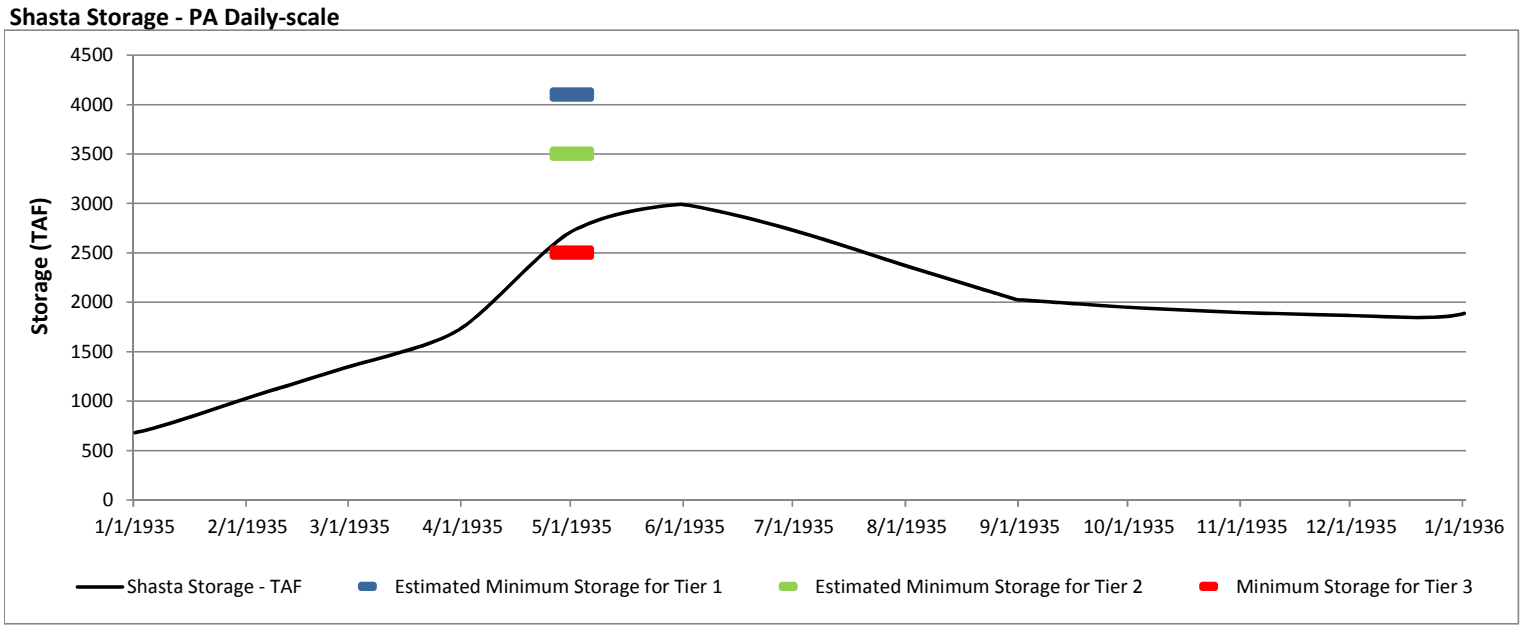
Shasta TCD Temperature - PA Monthly-scale



Sacramento River Temperature - PA Monthly-scale



Shasta Storage - PA Daily-scale



Select Year:

1935

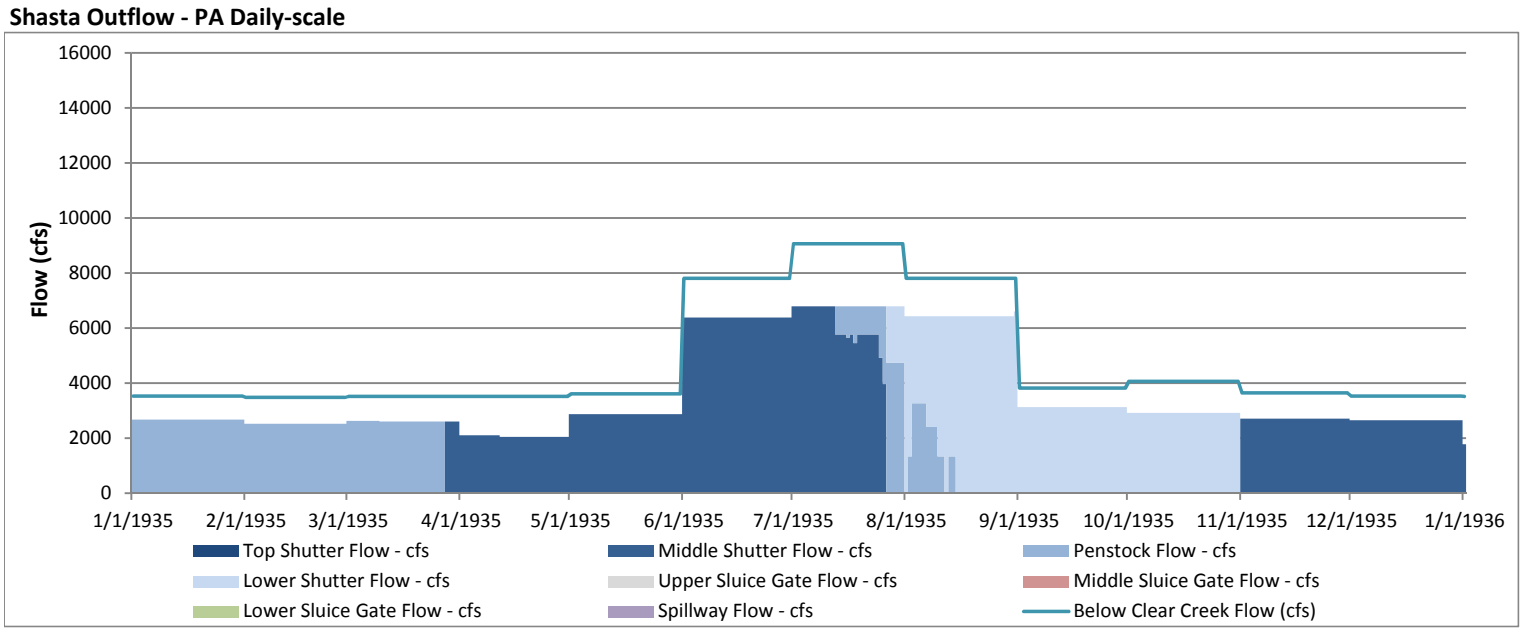
Temperature Tier:

Tier 3

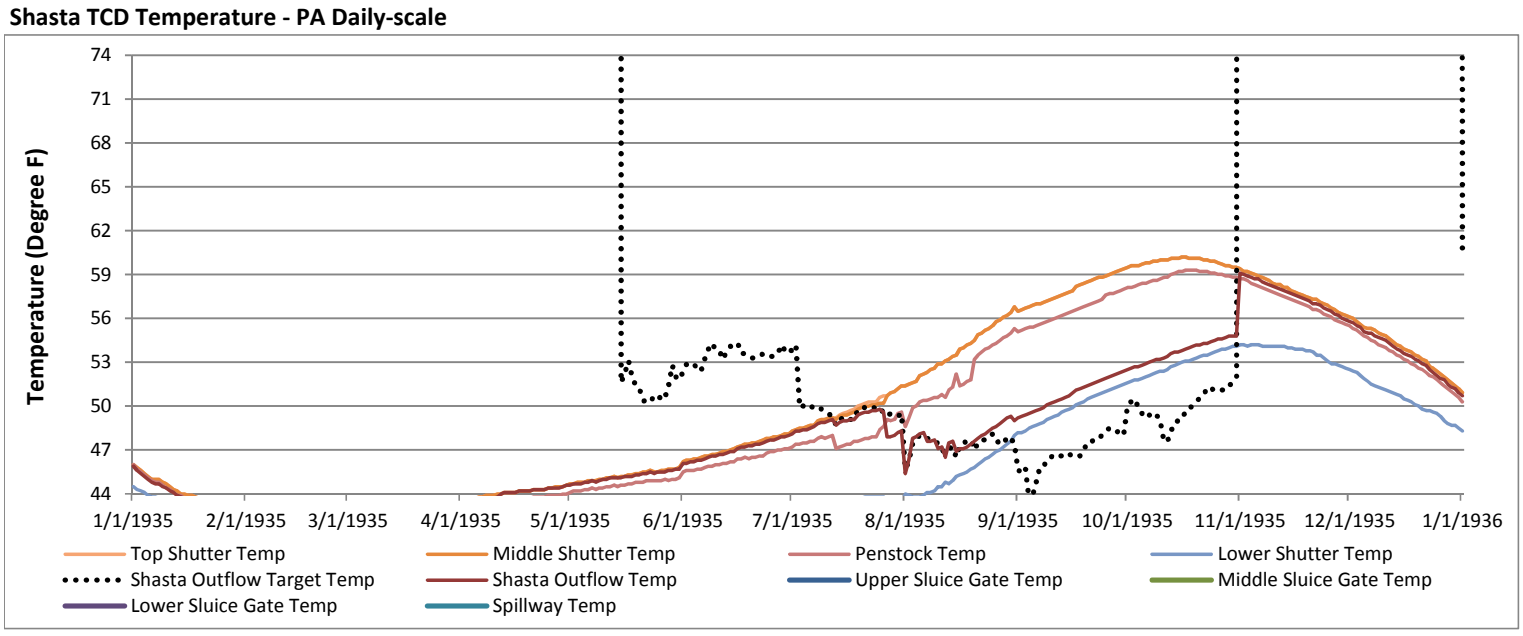
Annual Mortalities:

Anderson	7%
Martin	17%

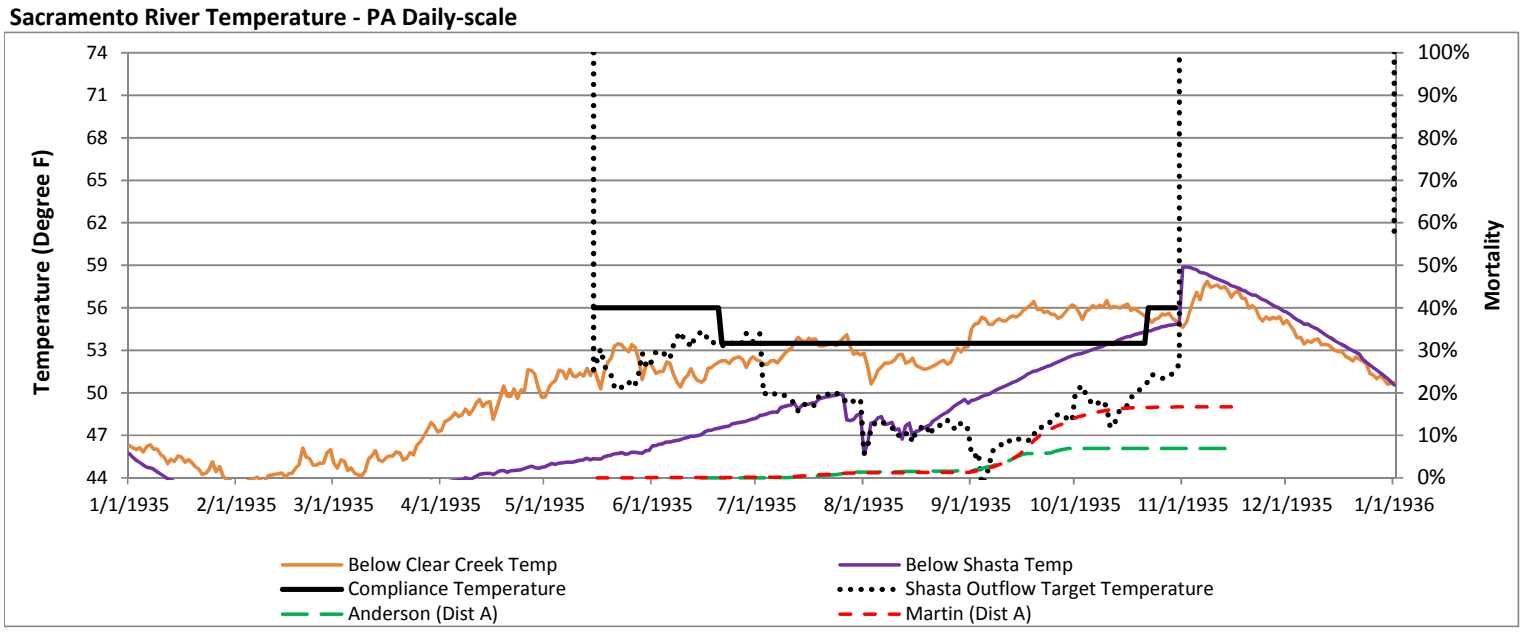
Shasta Outflow - PA Daily-scale



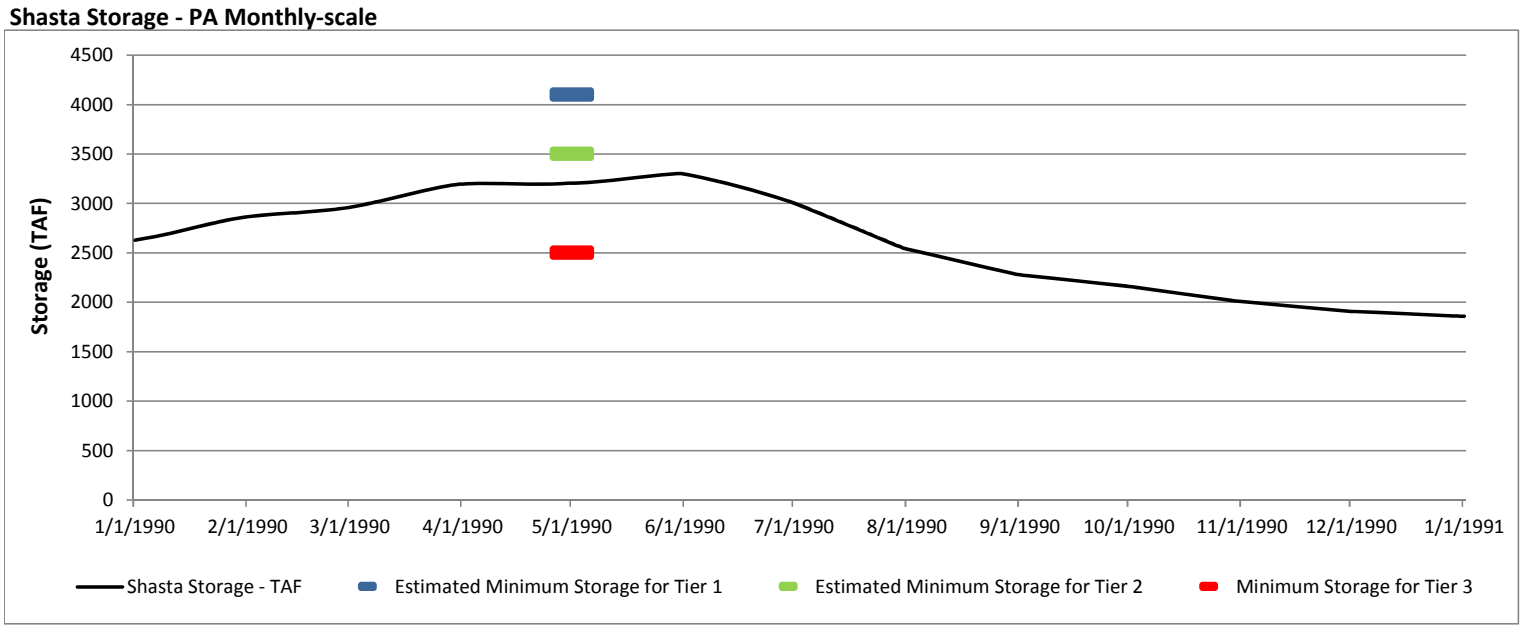
Shasta TCD Temperature - PA Daily-scale



Sacramento River Temperature - PA Daily-scale



Shasta Storage - PA Monthly-scale



Select Year:

1990

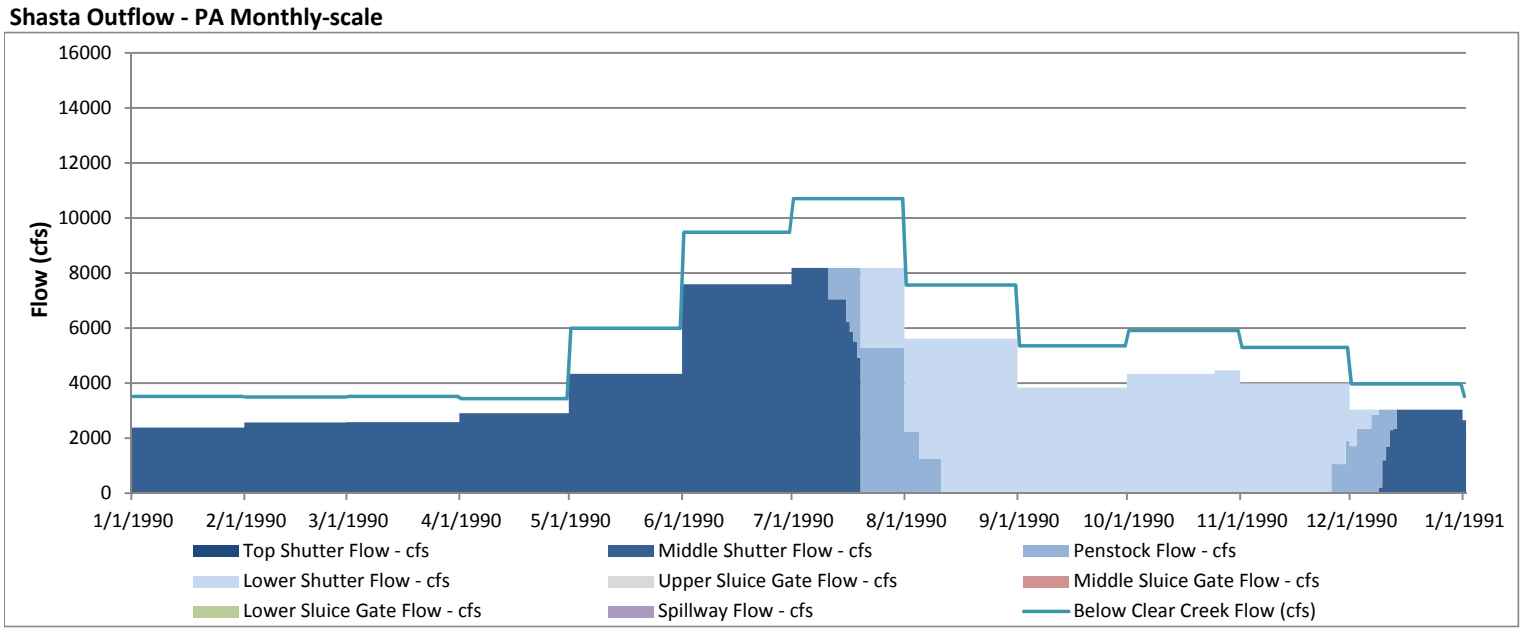
Temperature Tier:

Tier 3

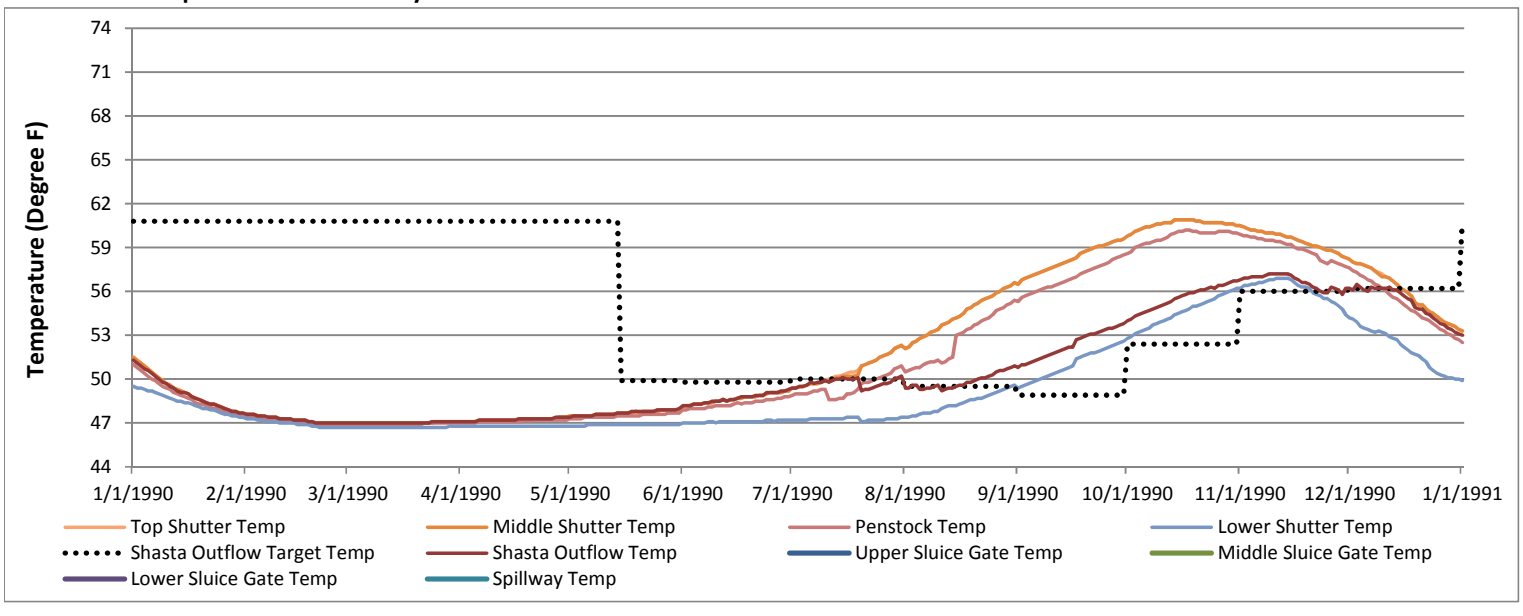
Annual Mortalities:

Anderson	35%
Martin	36%

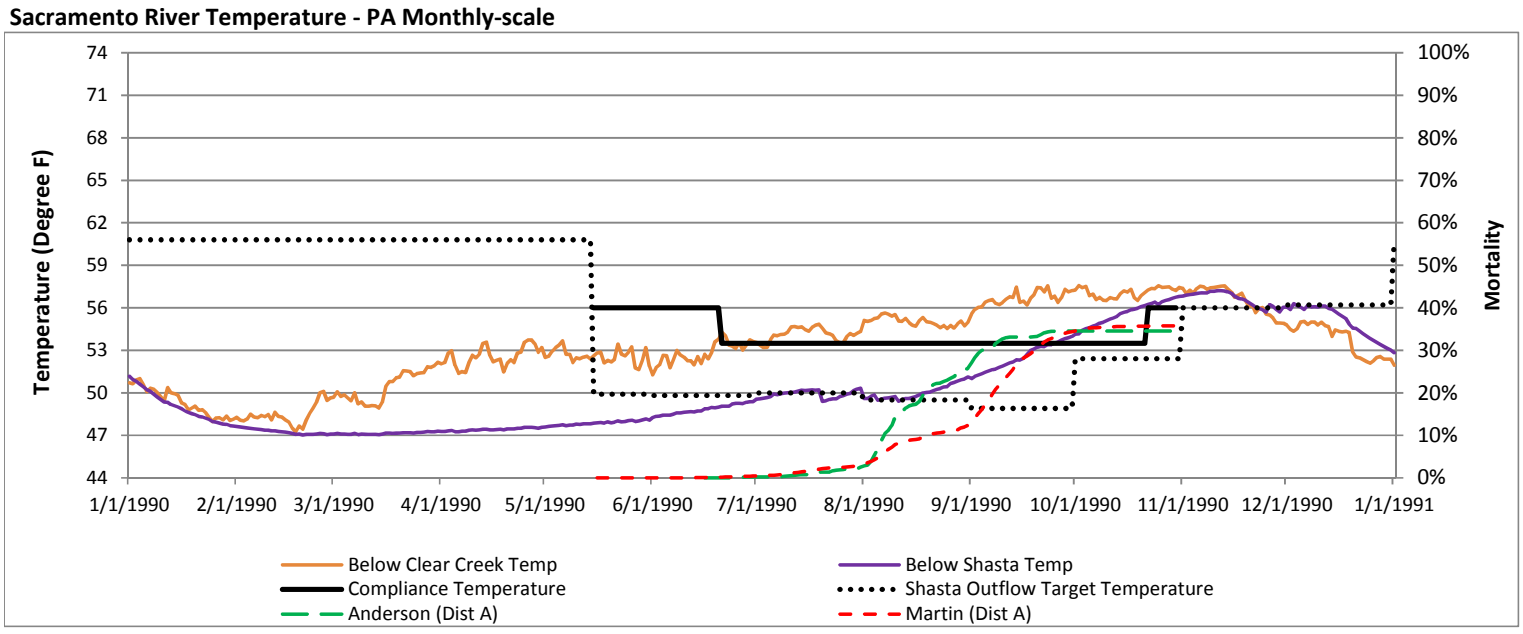
Shasta Outflow - PA Monthly-scale



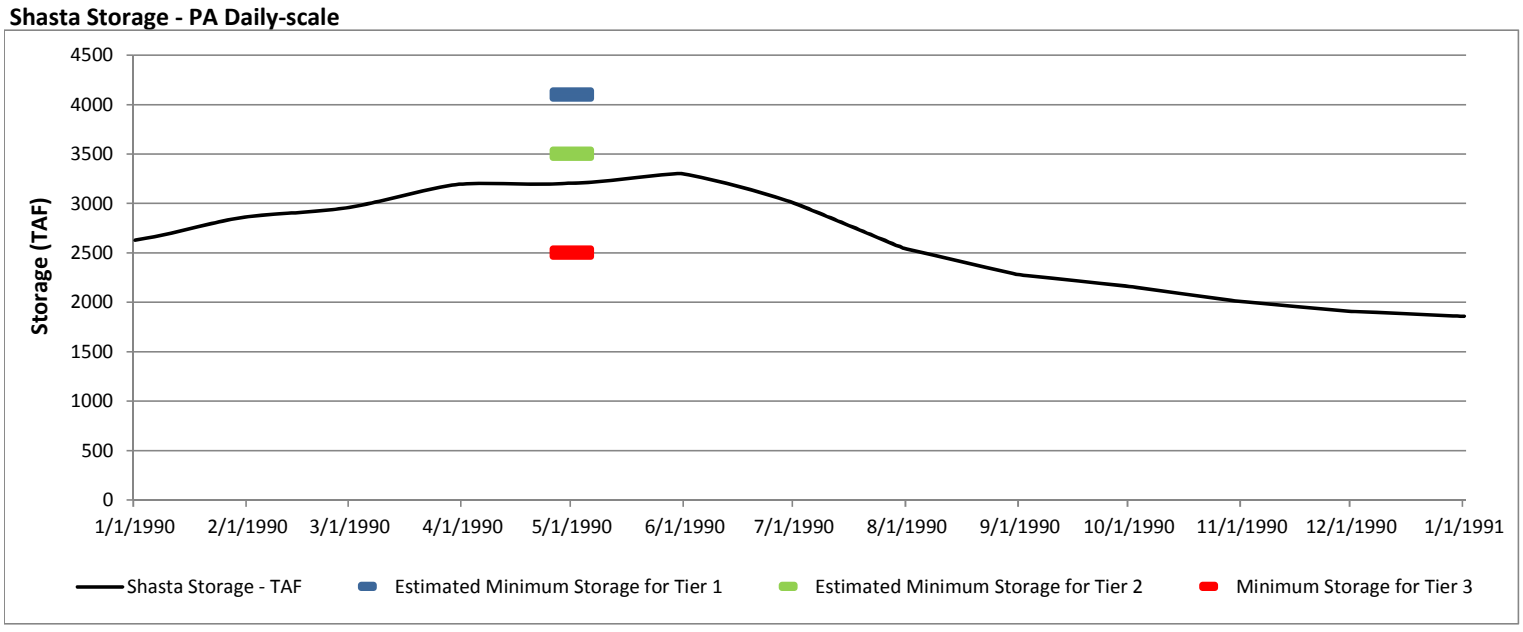
Shasta TCD Temperature - PA Monthly-scale



Sacramento River Temperature - PA Monthly-scale



Shasta Storage - PA Daily-scale



Select Year:

1990

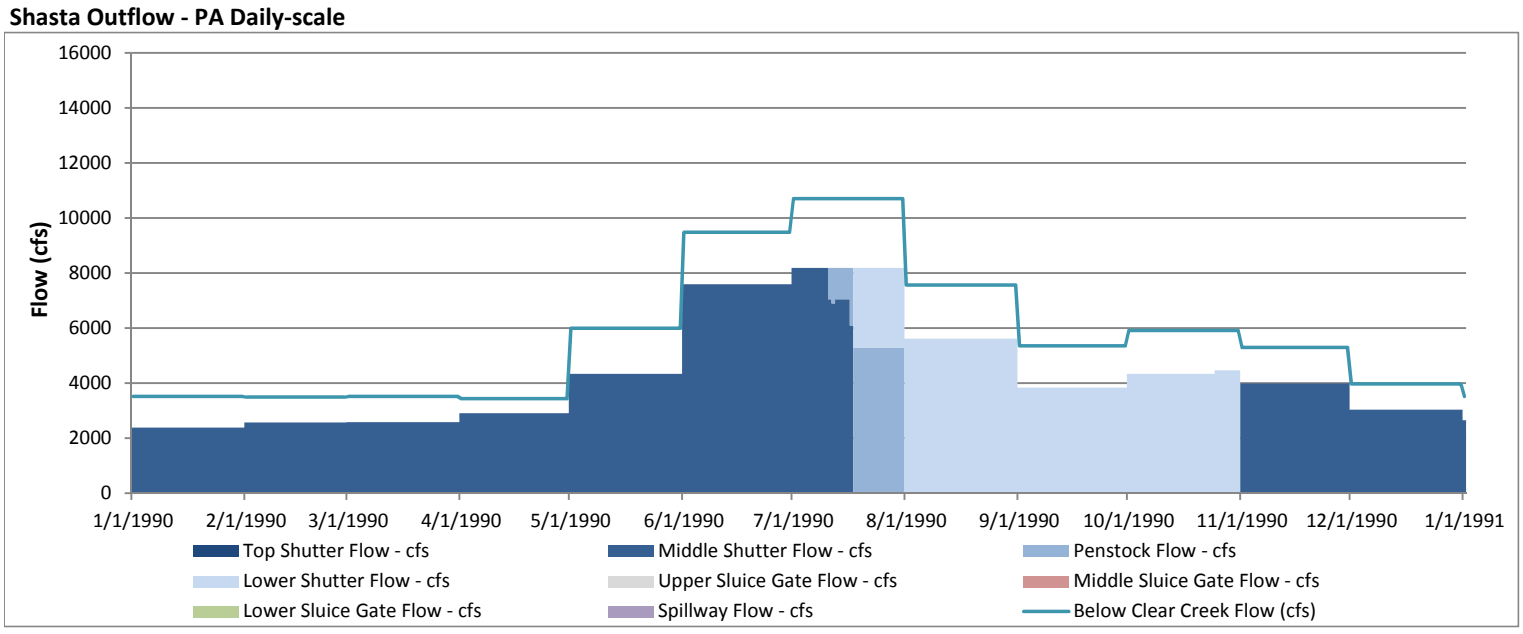
Temperature Tier:

Tier 3

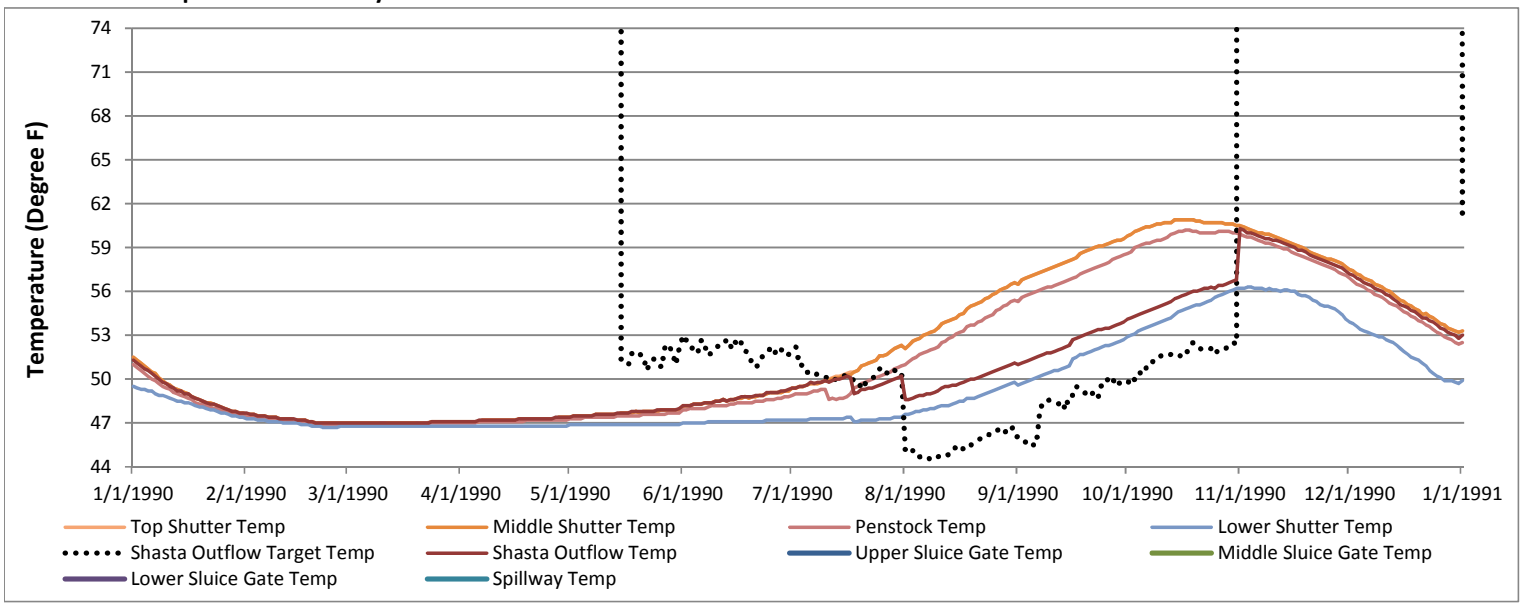
Annual Mortalities:

Anderson	30%
Martin	36%

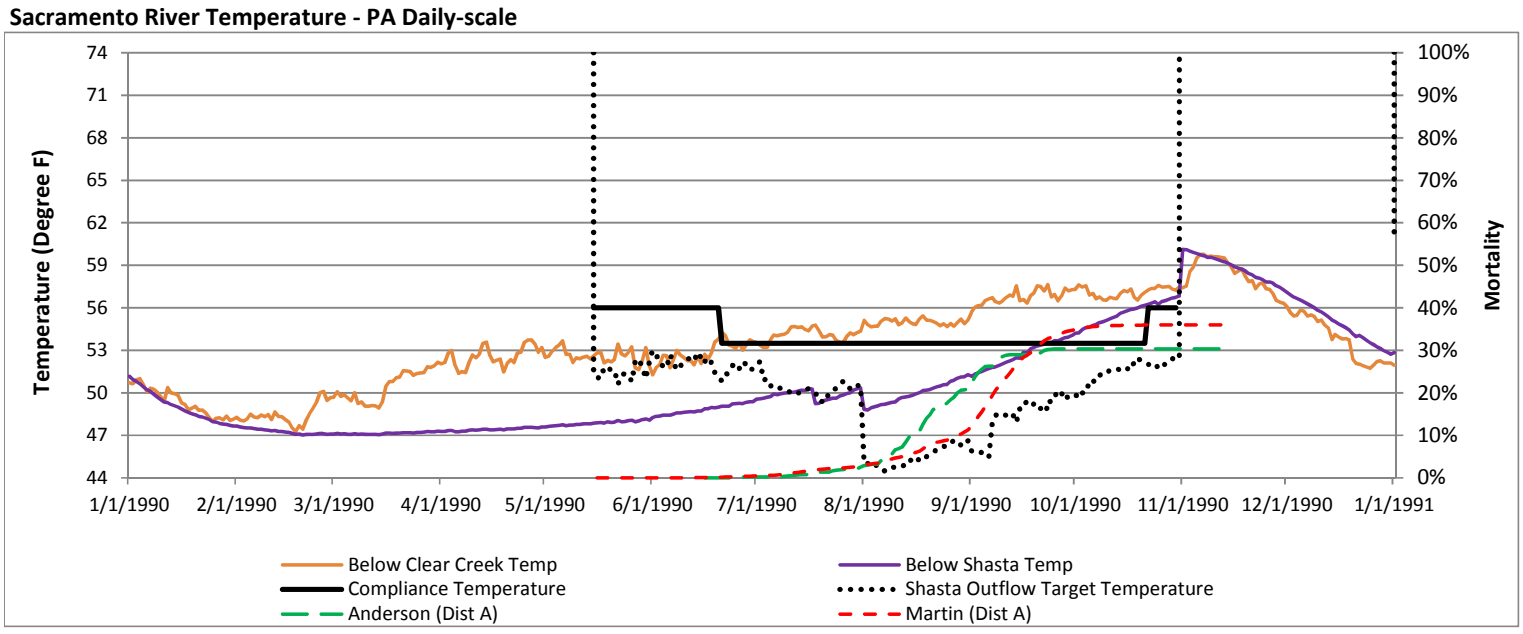
Shasta Outflow - PA Daily-scale



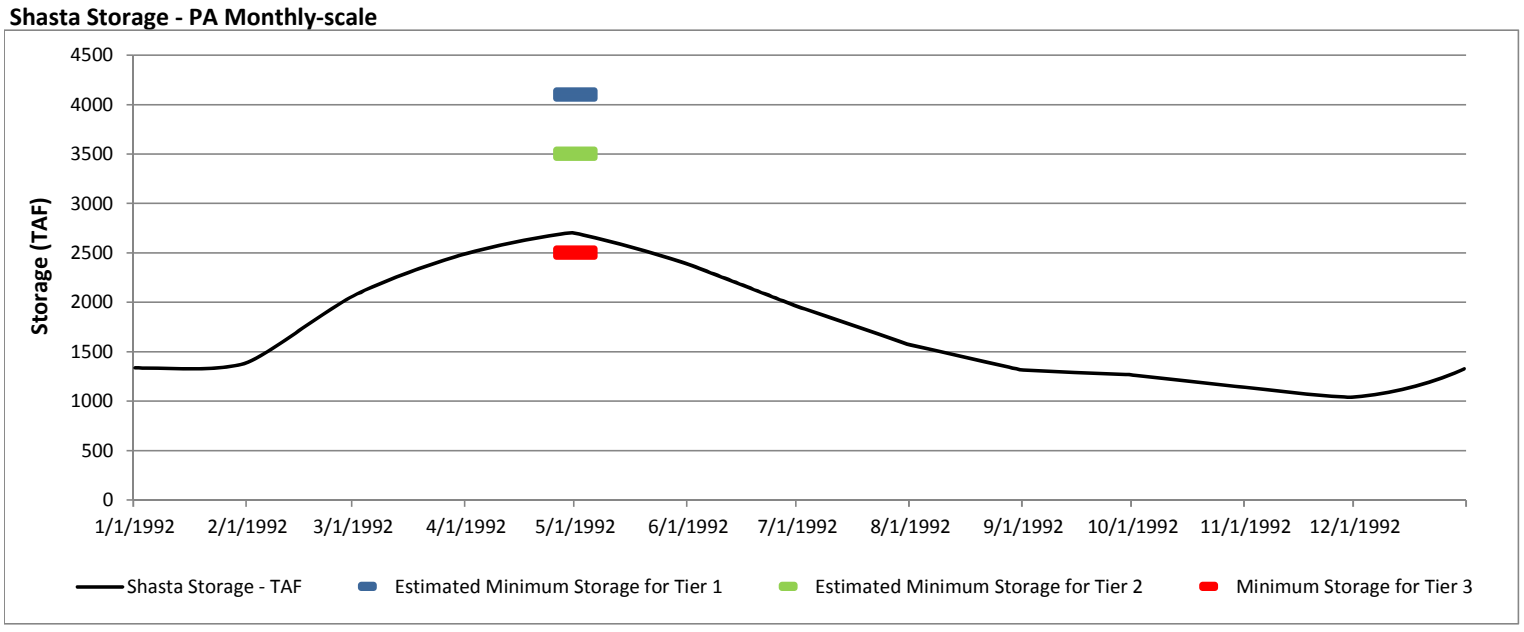
Shasta TCD Temperature - PA Daily-scale



Sacramento River Temperature - PA Daily-scale



Shasta Storage - PA Monthly-scale



Select Year:

1992

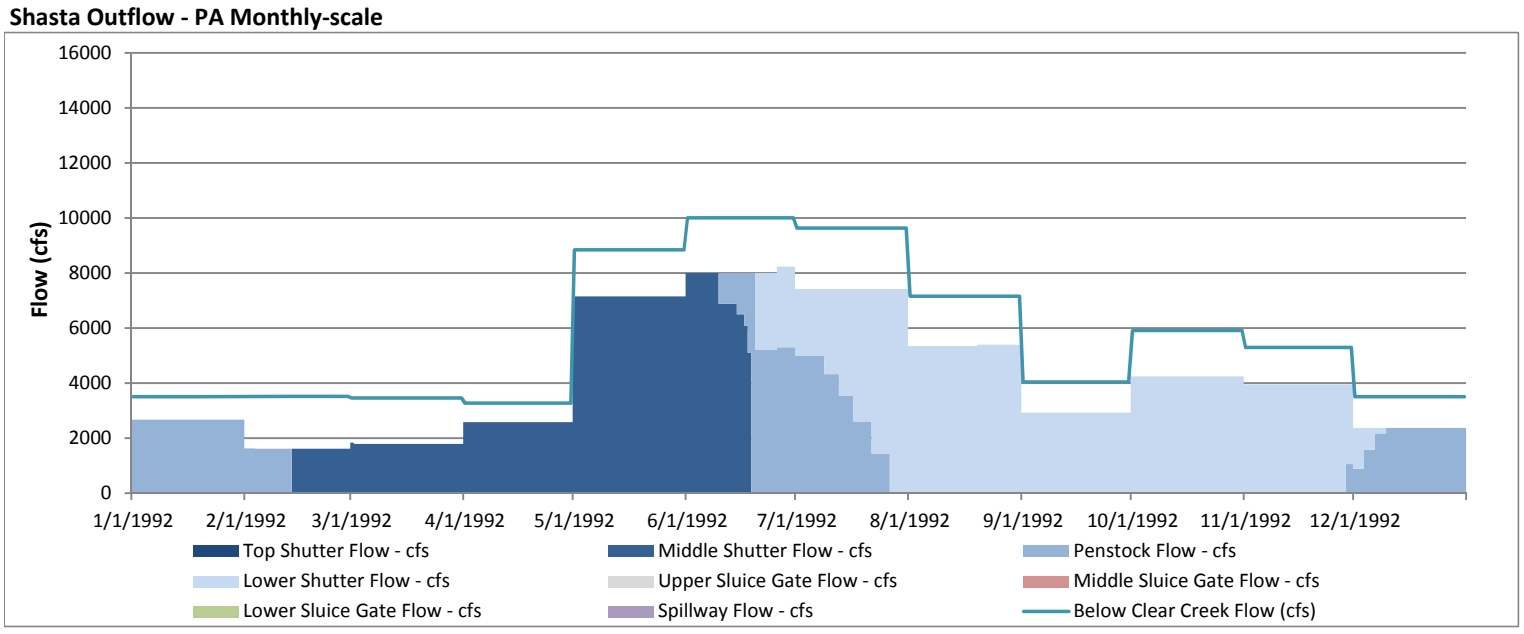
Temperature Tier:

Tier 3

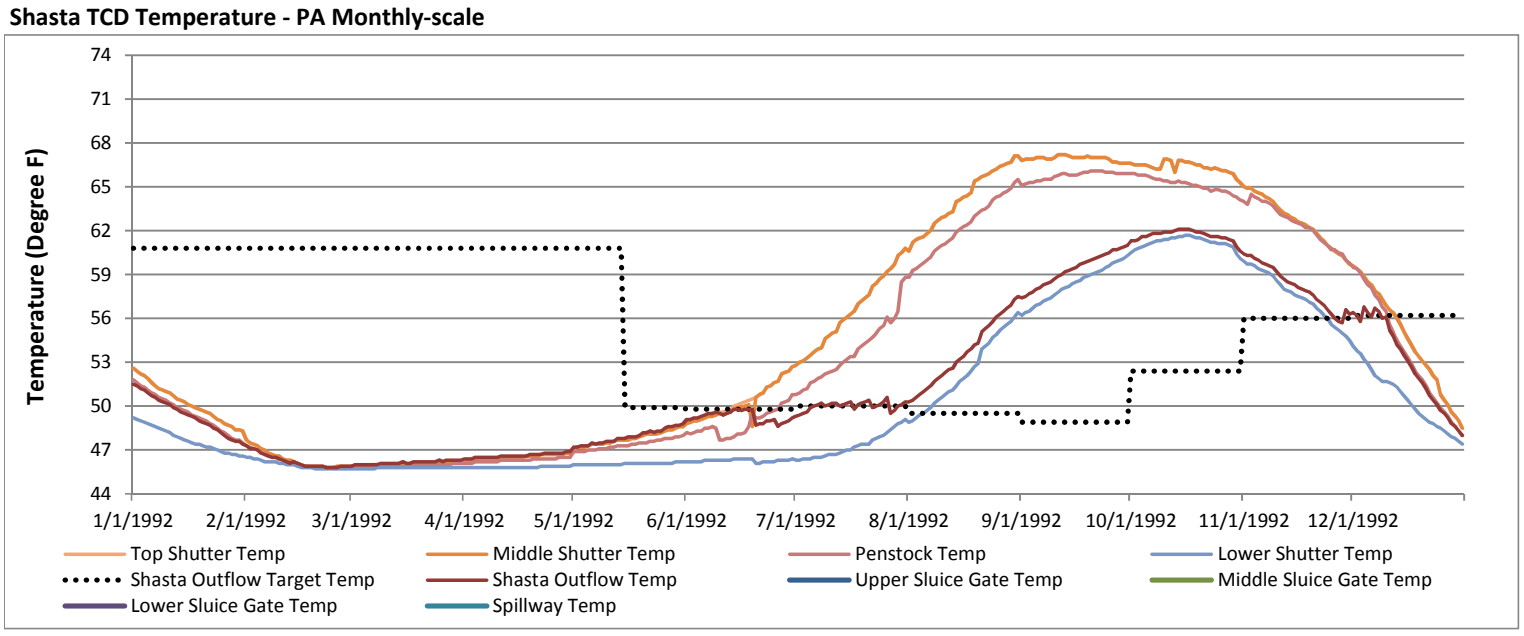
Annual Mortalities:

Anderson	66%
Martin	77%

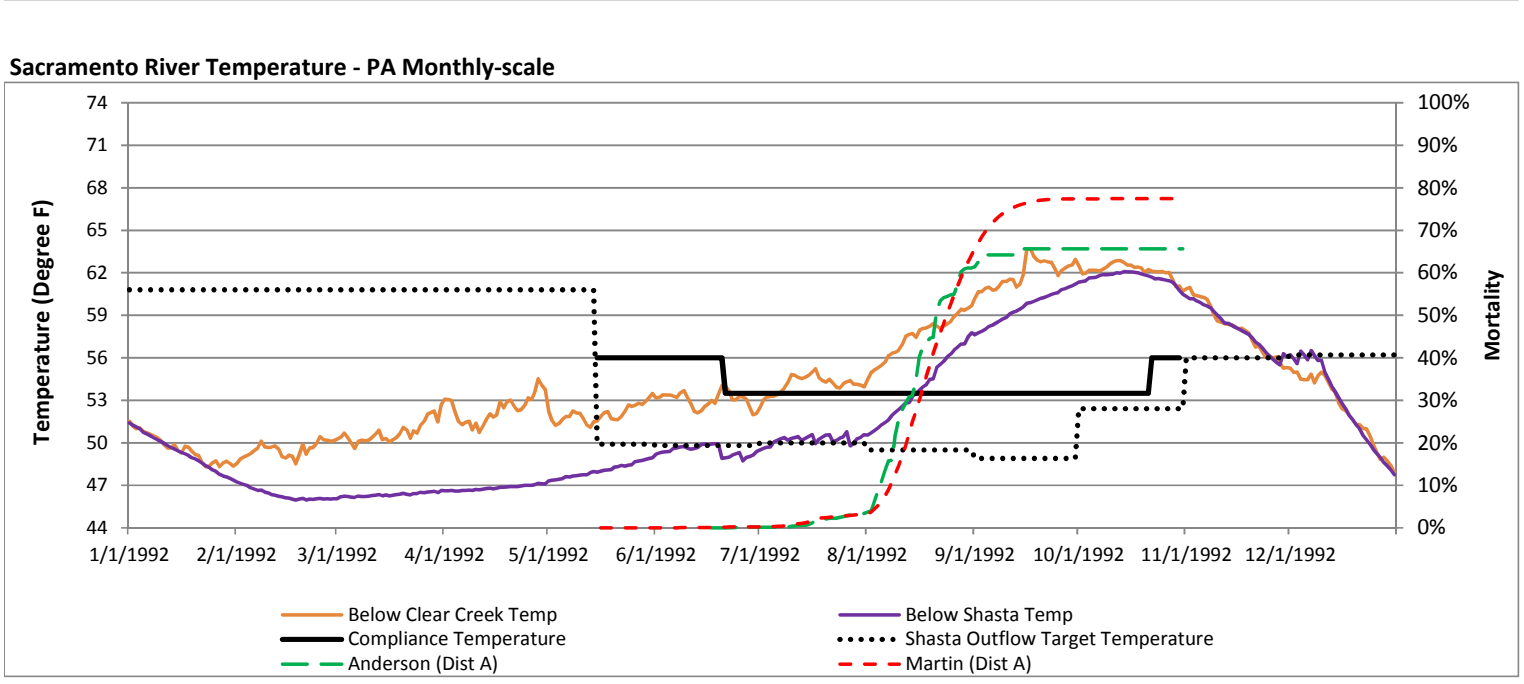
Shasta Outflow - PA Monthly-scale



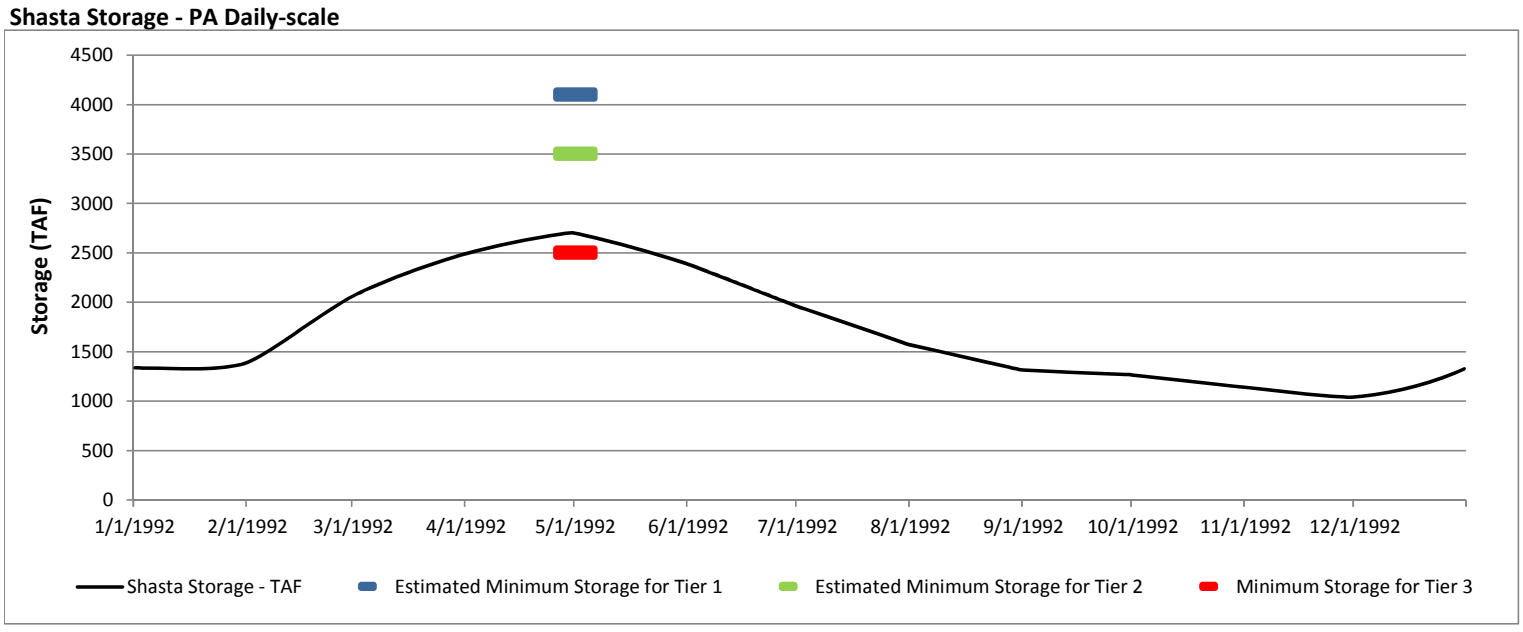
Shasta TCD Temperature - PA Monthly-scale



Sacramento River Temperature - PA Monthly-scale



Shasta Storage - PA Daily-scale



Select Year:

1992

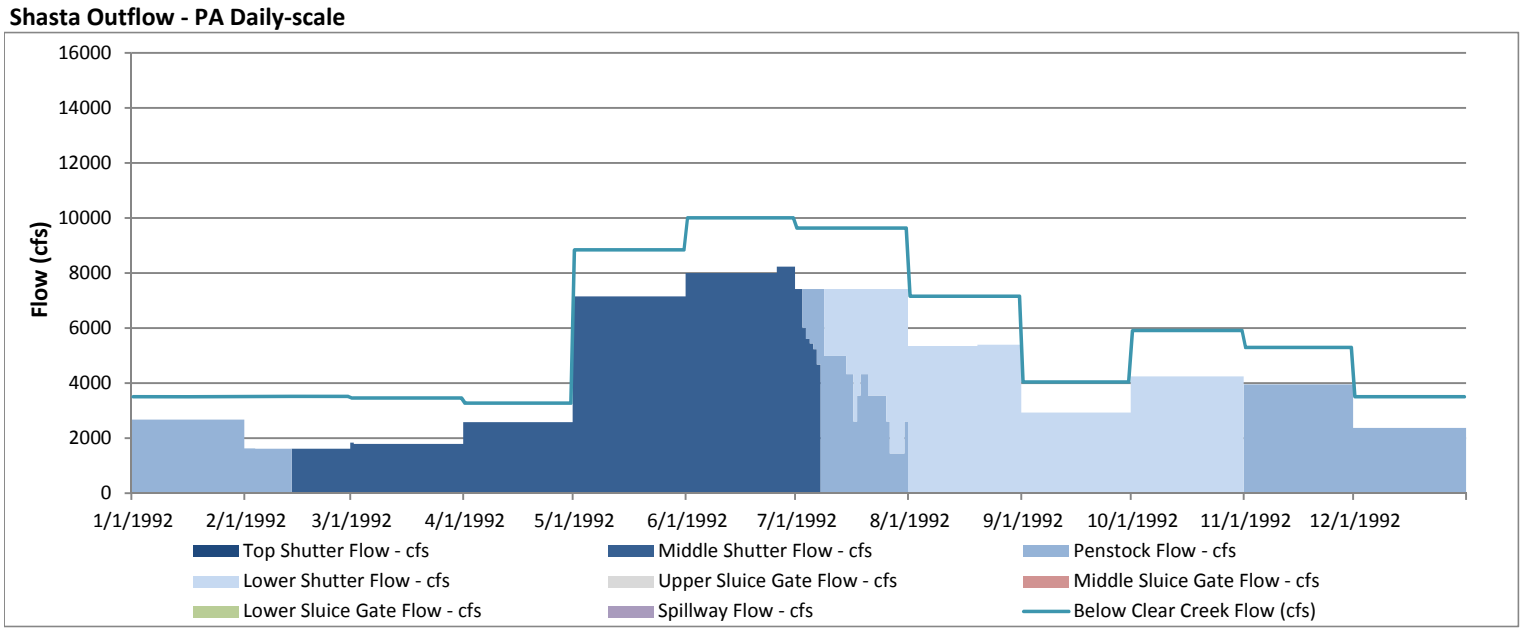
Temperature Tier:

Tier 3

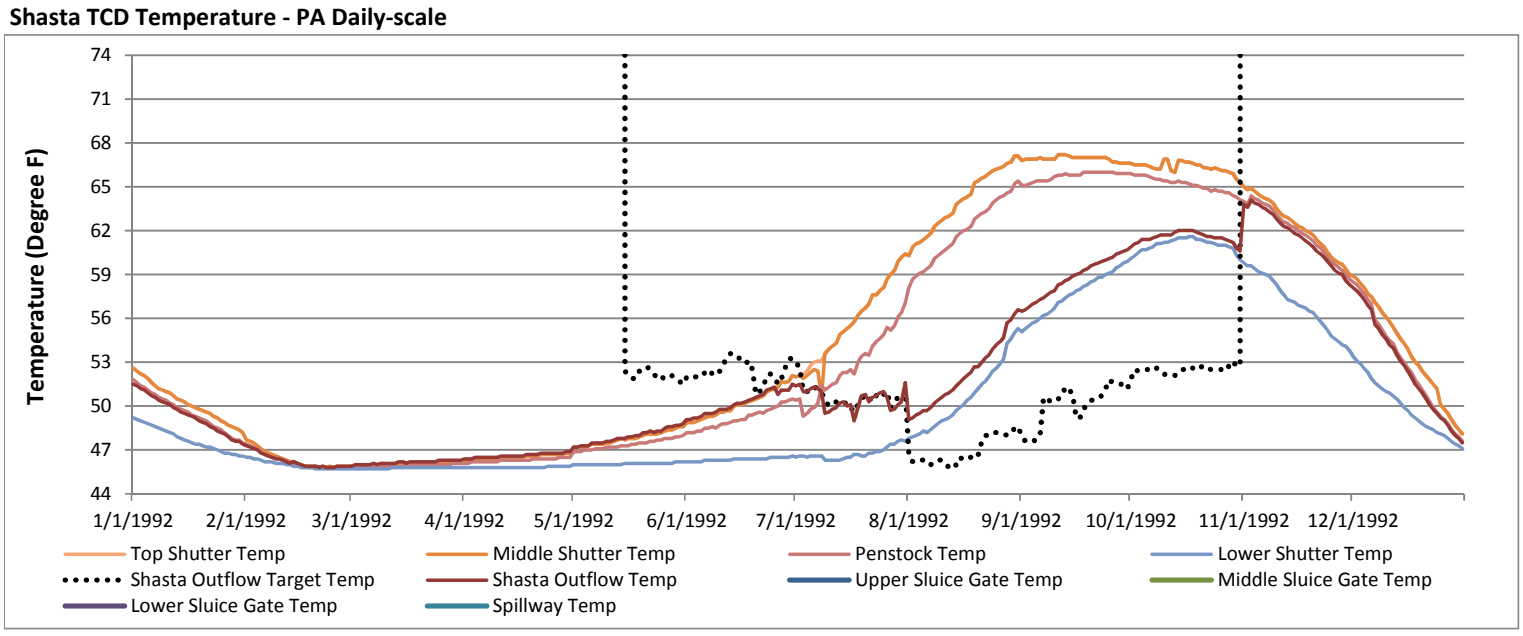
Annual Mortalities:

Anderson	57%
Martin	70%

Shasta Outflow - PA Daily-scale



Shasta TCD Temperature - PA Daily-scale



Sacramento River Temperature - PA Daily-scale