

April 24, 2018

Upper Sacramento River – April 2018 Preliminary Temperature Analysis

Summary of Temperature Results by Month (Monthly Average Temperature °F)

Initial Compliance Location (°F DAT)	ARR	MAY	JUN	JUL	AUG	SEP	OCT	Late Sep-Oct Uncertainty Estimation
April 90%-Exceedance Outlook – 10% Historical Meteorology								
Keswick Dam KWK	52.6	52.0	52.4	53.0	53.1	53.3	52.2	53 - 56
Sac. R. abv Clear Creek CCR	53.1	52.9	53.1	53.5	53.6	53.7	52.3	54 - 58
Balls Ferry BSF	55.9	57.2	56.1	55.5	55.5	55.5	53.6	55 - 58
April 90%-Exceedance Outlook – 50% Historical Meteorology								
Keswick Dam KWK	52.5	51.9	52.0	53.0	53.0	53.1	52.0	53 - 56
Sac. R. abv Clear Creek CCR	52.9	52.7	52.6	53.4	53.5	53.5	52.1	54 - 58
Balls Ferry BSF	55.5	56.6	55.5	55.3	55.3	55.2	53.2	55 - 58
April 50%-Exceedance Outlook – 10% Historical Meteorology								
Keswick Dam KWK	52.3	51.3	52.0	52.8	53.1	53.3	52.0	53 - 56
Sac. R. abv Clear Creek CCR	52.9	52.1	52.5	53.2	53.4	53.5	52.1	54 - 58
Balls Ferry BSF	55.8	56.7	55.4	55.1	55.2	55.2	53.3	55 - 58
April 50%-Exceedance Outlook – 50% Historical Meteorology								
Keswick Dam KWK	52.2	50.9	52.2	52.8	53.2	53.1	51.8	53 - 56
Sac. R. abv Clear Creek CCR	52.7	51.5	52.6	53.1	53.4	53.3	51.9	53 - 57
Balls Ferry BSF	55.3	55.8	55.3	54.9	55.1	54.9	53.0	54 - 58

* The HEC5Q model output is displayed above for the months April through October. Based on past analysis, the temperature model does not perform well in late September and October. One factor is that the modeled release temperatures are cooler than has historically been achieved when all release is through the side gates (lowest gates), especially when there's a large temperature gradient between the pressure relief gates (PRG) and the side gates. For the months of September and October, an uncertainty estimate is provided based on the Fall Temperature Index (graphics below). This is based on a historical relationship between end-of-

September Lake Shasta Volume less than 56°F and likely downstream temperature performances for the early fall months. The range represents the 90% confidence interval based on that data. Refinement of the concepts for those estimates is underway.

Temperature Model Inputs, Assumptions, Limitations and Uncertainty:

1. The latest available profiles for Shasta, Trinity, and Whiskeytown were taken on April 17, April 4, and April 3 respectively. Model results are sensitive to initial reservoir temperature conditions and the model performs best under highly stratified conditions. The April 2018 temperature profile does not yet exhibit conditions for ideal model computations (still nearly isothermal conditions although warming will initiate stratification). The model performs well after the reservoir stratifies, typically in late spring. The concern this year is assuming over or under estimations with variable hydrologic and meteorological conditions and not capturing the stratification with sufficient detail to project.
2. Guidance on forecasted flows from the creeks (e.g., Cow, Cottonwood, Battle, etc.) between Keswick Dam and Bend Bridge are not available beyond 5 days. Creek flows developed from the historical record that most closely reflects current conditions were used for all model runs. The resulting low creek flows cause significant additional warming in the upper Sacramento River during spring.
3. Operation is based on the April 2018 Operation Outlooks and DWR Bulletin 120 inflow projections (monthly flows, reservoir release, and end-of-month reservoir storage) for the 90%- and 50%-exceedances. Trinity Lake inflows are updated with the CNRFC 90% runoff exceedance for the 90% runoff exceedance studies.
4. Although mean daily flows and releases are temperature model inputs, they are based on the mean monthly values from the operation outlooks. Mean daily flow patterns are user defined and are generalized representations. It is important to note that these outlooks do not suggest a certain actual future outcome, but rather the statistical likelihood of an event occurring, including, but not limited to, projected storage and releases. Thus, the outlooks do not provide exact end of month storages or flow rates but general projections that will likely fall within the range of uncertainty based on the different hydrologic runoff conditions between the 90% and 50% runoff exceedance hydrology.
5. Cottonwood Creek flows, Keswick to Bend Bridge local flows, and ACID diversions are mean daily synthesized flows based on the available historical record for a 1922-2002 study period. Inflows were adjusted to a 95% historical exceedance for both the 90% and 50% runoff exceedance studies.
6. Meteorological inputs represent historical (1985 – 2017) monthly mean equilibrium temperature exceedance at 10% and 50% patterned after like months on a 6-hour time-step. Assumed inflow temperature remain static inputs and do not vary with the assumed meteorology.
7. Meteorology, as well as the flow volume and pattern, significantly influences reservoir inflow temperatures and downstream tributary temperatures; and consequently, the development of the cold-water pool during winter and early spring.
8. Modified model coefficients more closely represent actual Keswick Dam temperatures. As a result, temperature predictions downstream of Keswick Dam are likely to be warmer than actual. Model re-calibrations efforts are underway.

Model Run Date April 22, 2018

Temperature Analysis Results:

Modeling runs explore Sacramento River compliance performance above Clear Creek confluence and Balls Ferry locations by varying hydrology and meteorology. The temperature results for the Sacramento River between Keswick Dam and Balls Ferry are shown in Figures 1. The fall uncertainty estimation relationship between end-of-September lake volume below 56°F and a Balls Ferry compliance through fall is based on the Figures 5-7.

Model Run	End of September Cold Water Pool <56°F (TAF)	First Side Gate	Full Side Gates
90% Hydro, 10% Historical Met	682	9/1	10/8
90% Hydro, 50% Historical Met	682	9/1	10/10
50% Hydro, 10% Historical Met	690	9/1	10/9
50% Hydro, 50% Historical Met	725	9/3	10/12

Sacramento River Modeled Temperature 2018 April 90%-Exceedance Water Outlook - 10% Historical Meteorology

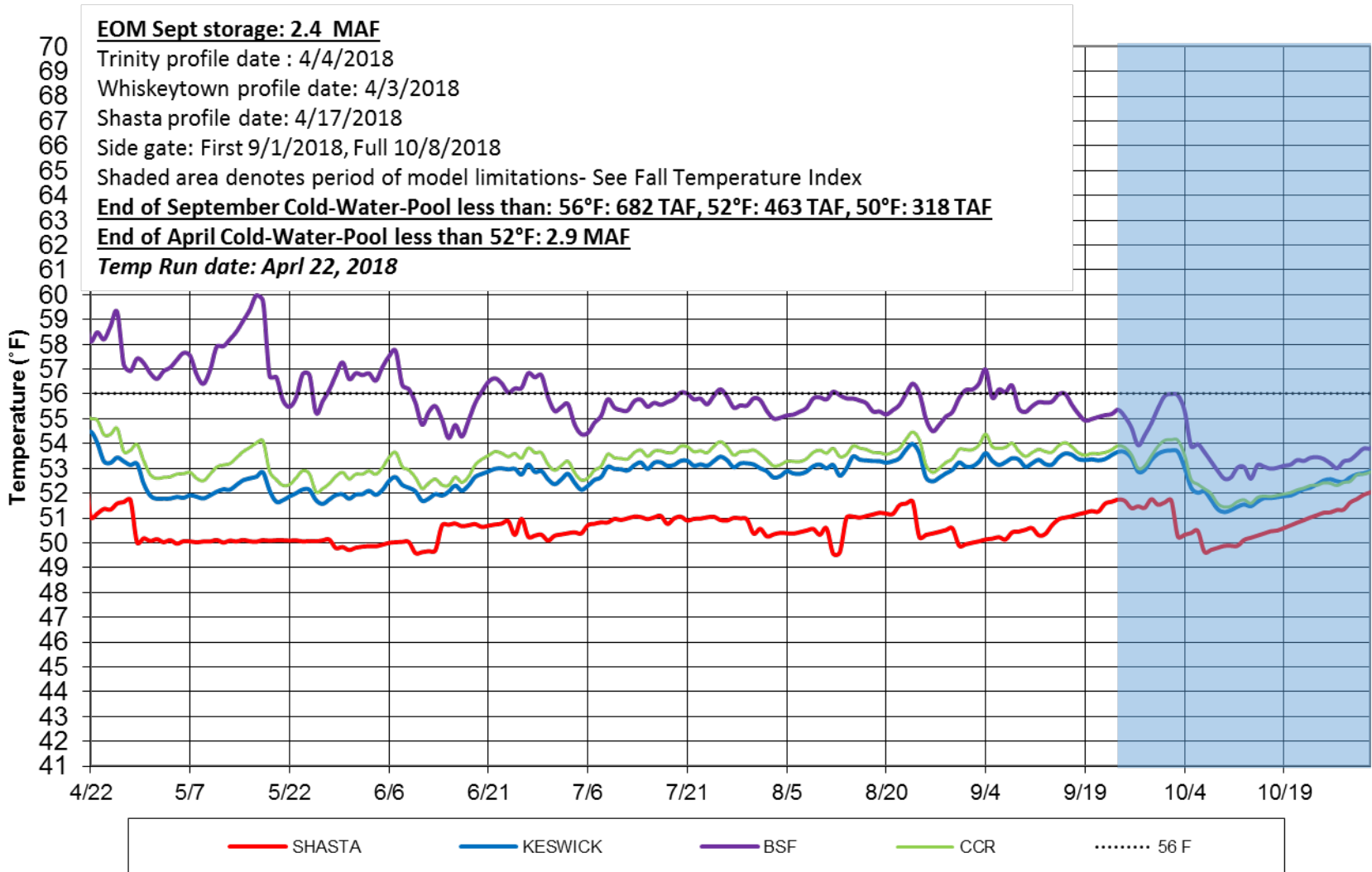


Figure 1

Sacramento River Modeled Temperature 2018 April 90%-Exceedance Water Outlook - 50% Historical Meteorology

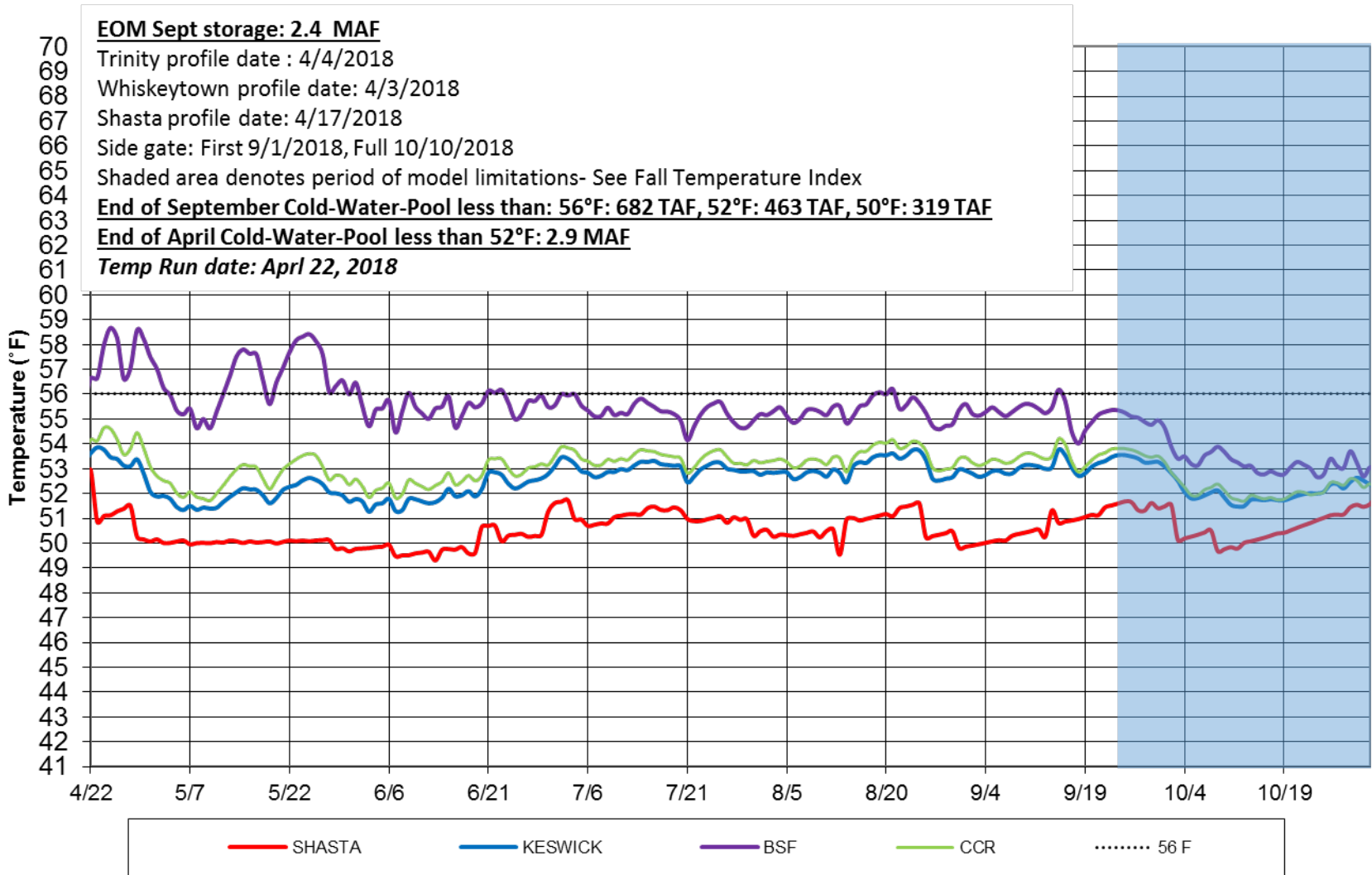


Figure 2

Sacramento River Modeled Temperature 2018 April 50%-Exceedance Water Outlook - 10% Historical Meteorology

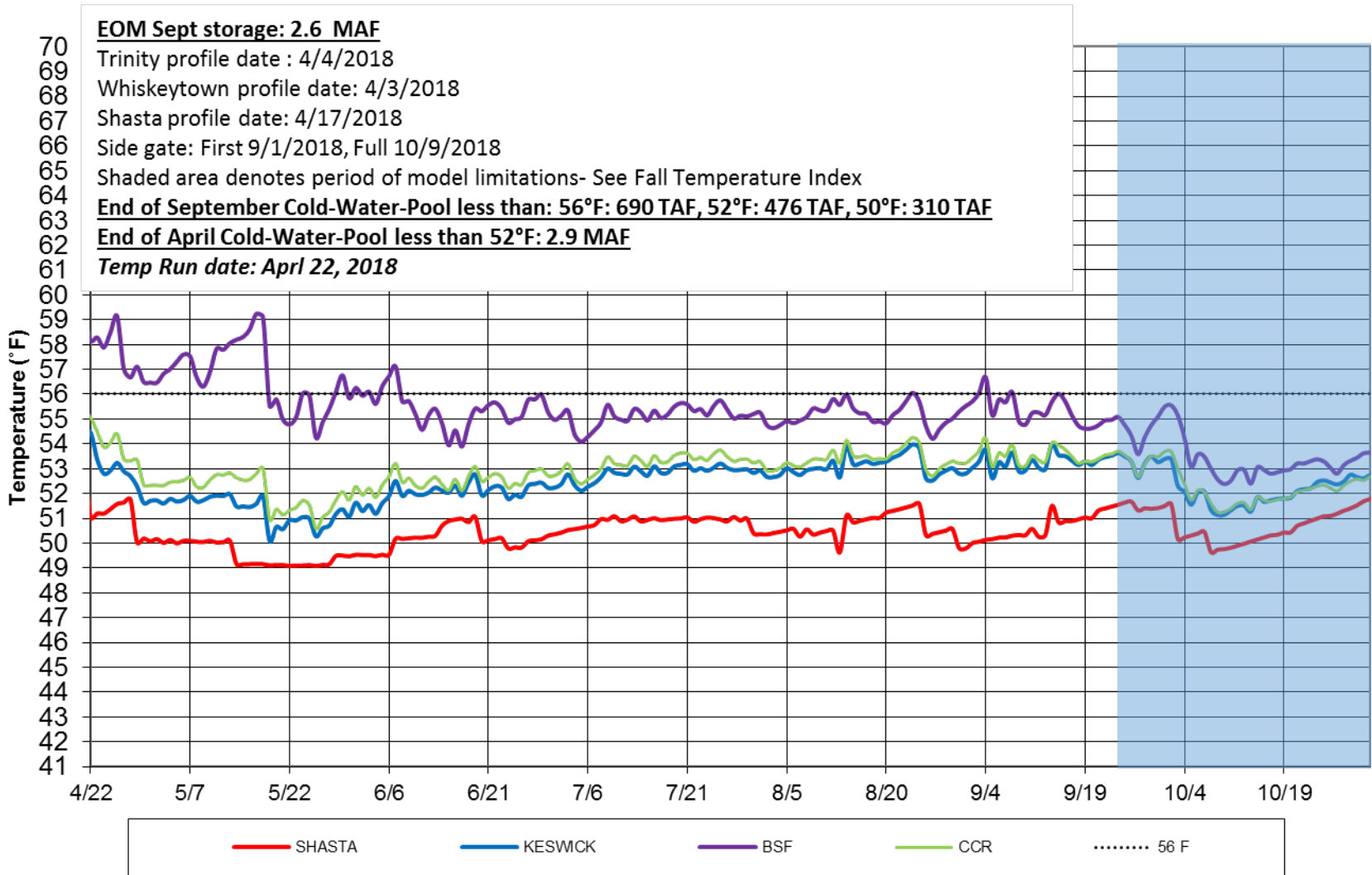


Figure 3

Sacramento River Modeled Temperature 2018 April 50%-Exceedance Water Outlook - 50% Historical Meteorology

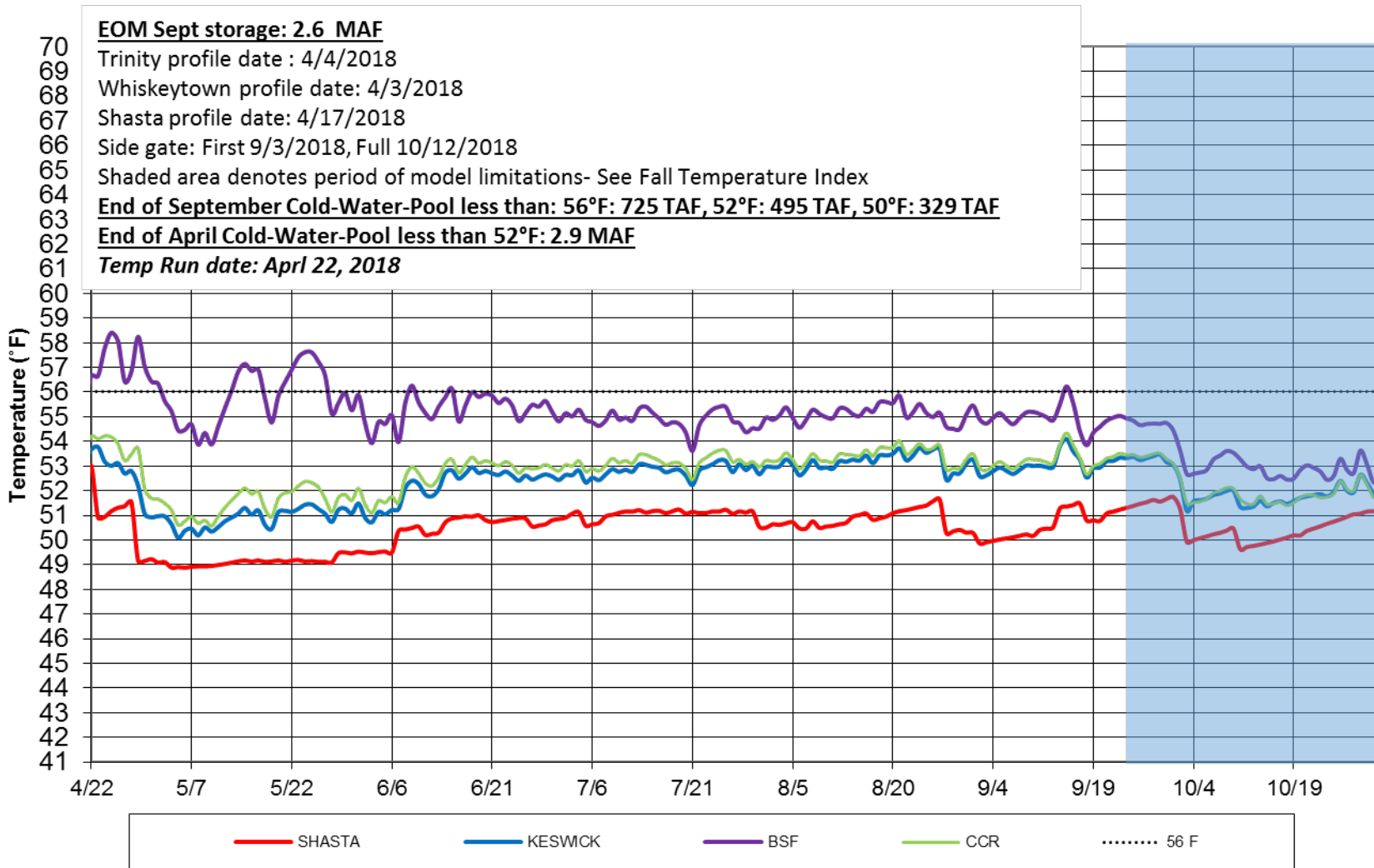


Figure 4

Figures 5-7 Model Performance and Fall Temperature Index:

1. Based on past analyses, the temperature model does not perform well in late September and October. One factor is that the modeled release temperatures are cooler than has historically been achieved when all release is through the side gates (lowest gates), especially when there's a large temperature gradient between the pressure relief gates (PRG) and the side gates.
2. Based on historical records, the end-of-September Lake Shasta volume below 56°F can be used as an indicator of fall water temperature in the river reach to Balls Ferry.
3. Based on these records and estimates, the index below illustrates a range of uncertainty in the ability to meet for river temperatures not to exceed 56 °F downstream based on the end-of-September lake volume less than 56°F; see charts below.
4. Refinement of these estimates and concepts is currently underway.

Sacramento River - Lake Shasta Early Fall Water Temperature - Keswick (KWK)

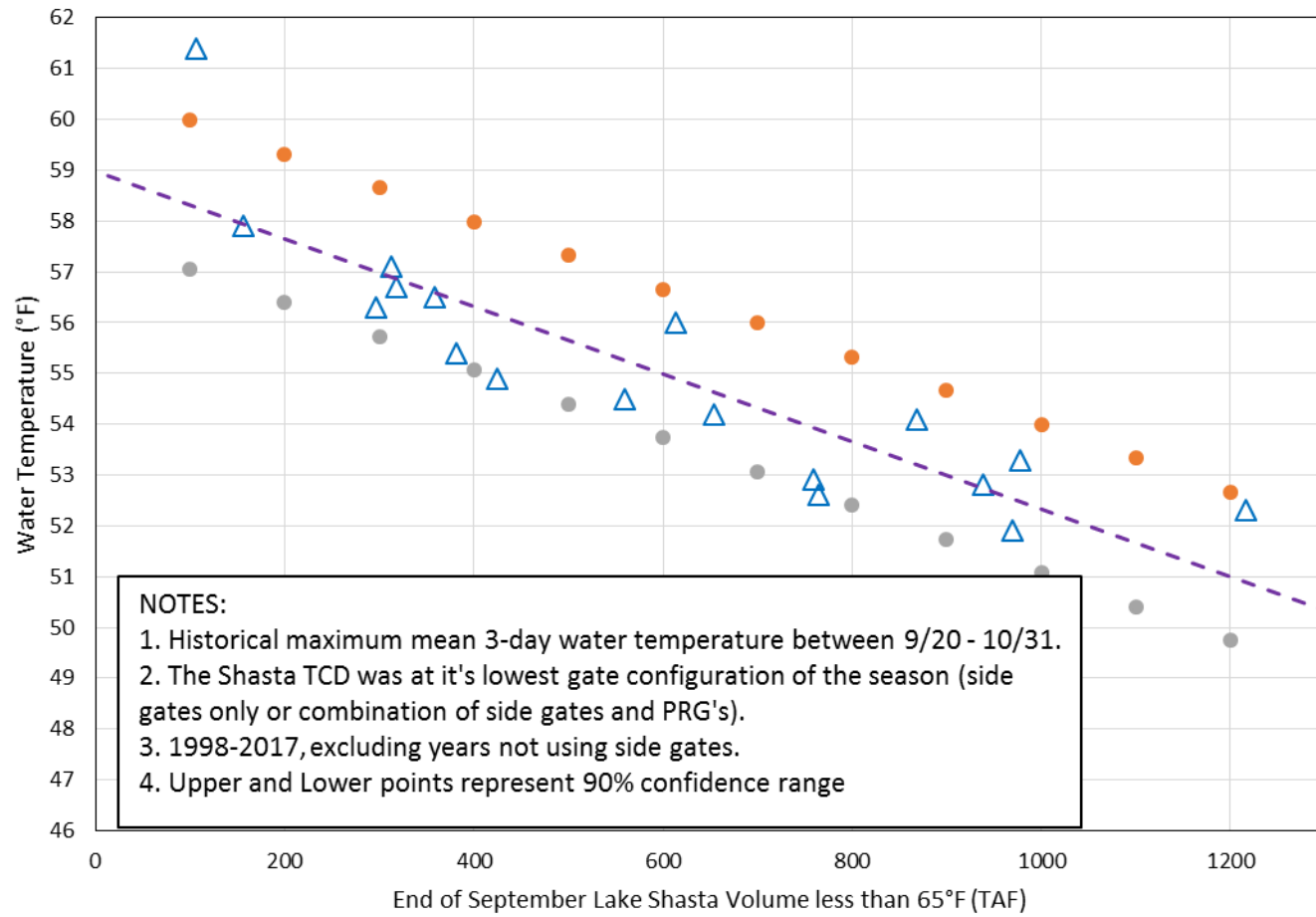


Figure 5

Sacramento River - Lake Shasta Early Fall Water Temperature - Sac River above Clear Creek (CCR)

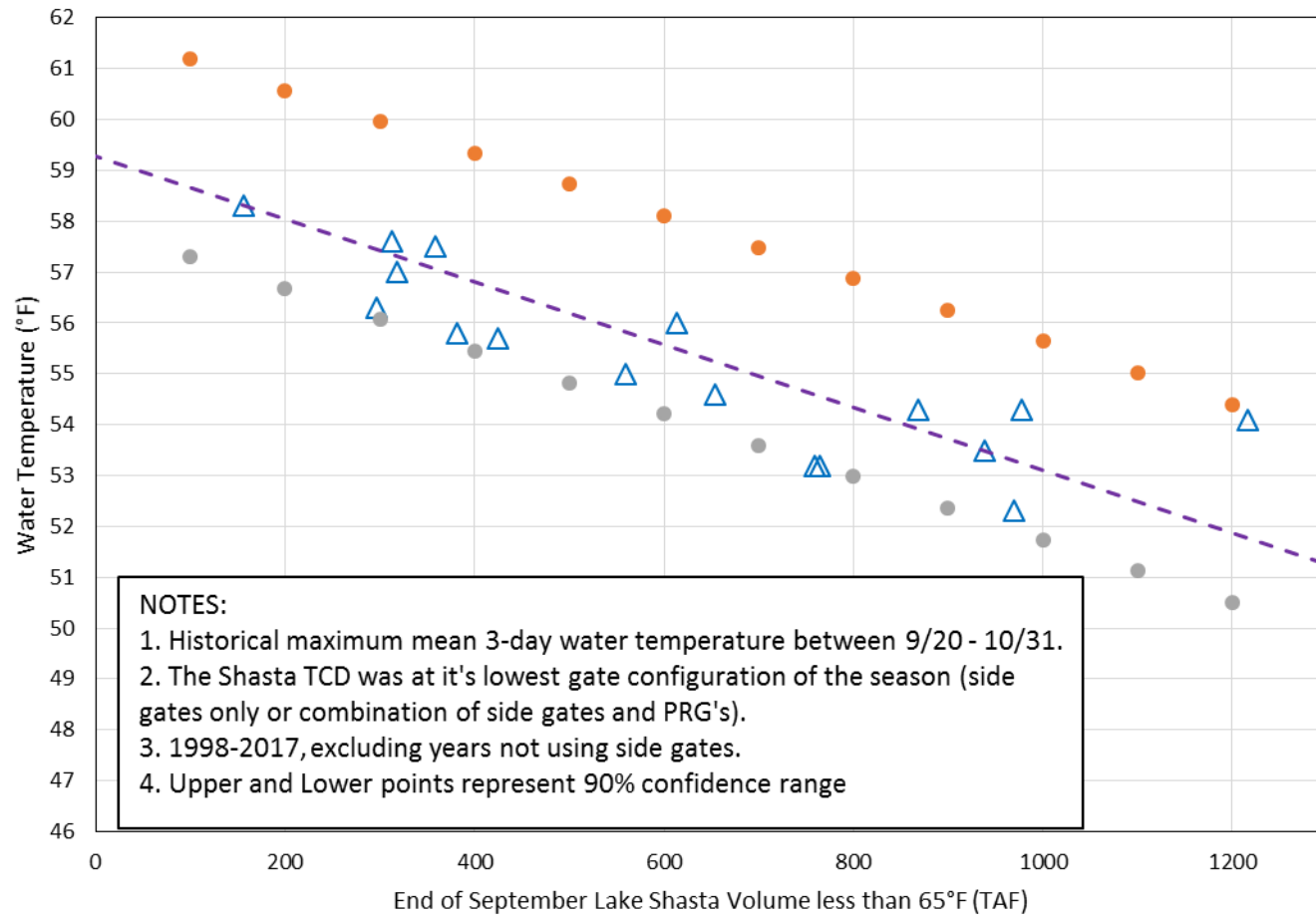


Figure 6

Sacramento River - Lake Shasta Early Fall Water Temperature - Balls Ferry (BSF)

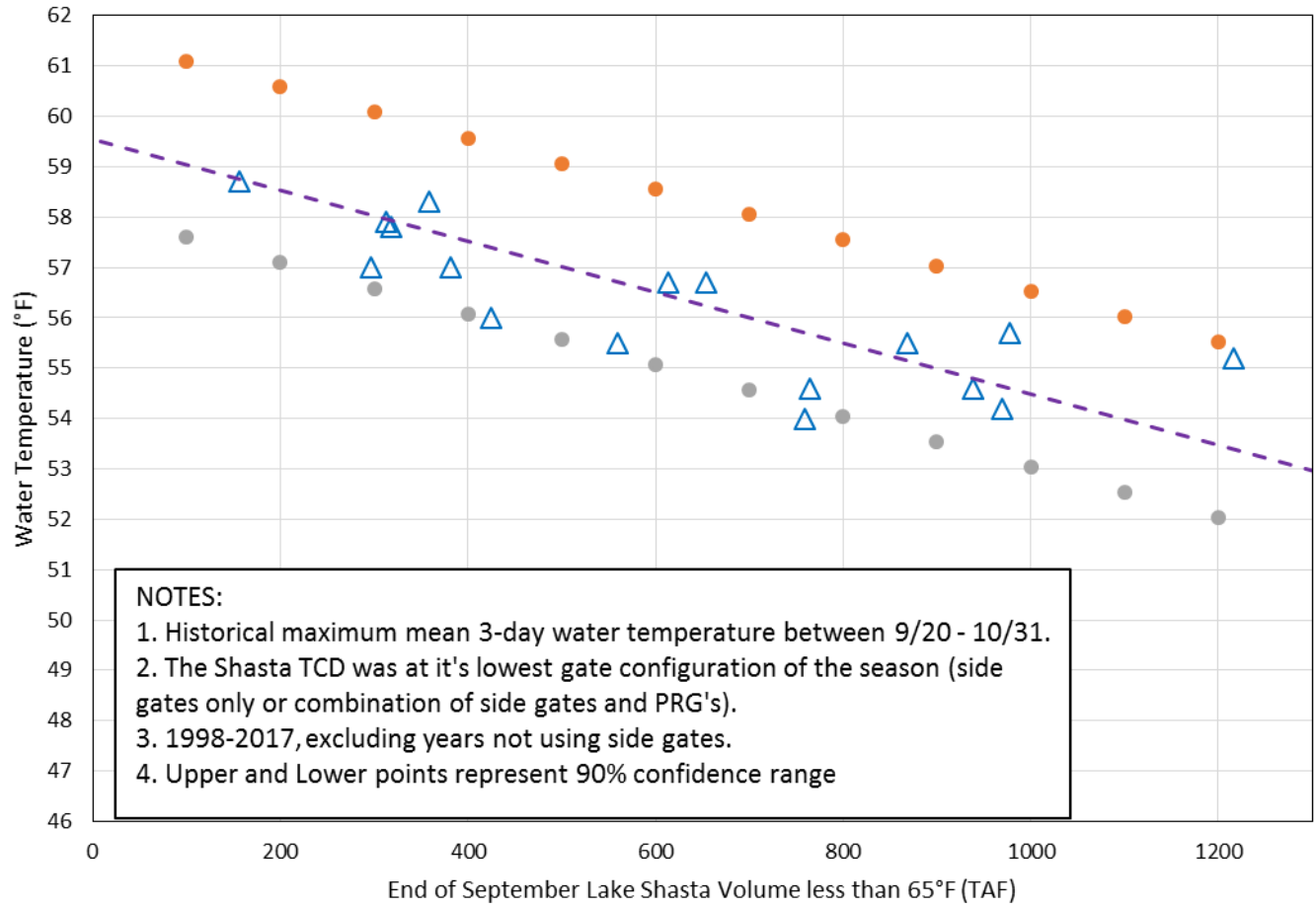


Figure 7