Summary Document for Relationship between Keswick Discharge Volume and Temperature and Clear Creek Gauge Water Temperature

Prepared by the Southwest Fisheries Science Center on Sept 6th, 2018

This document outlines the procedure and results of fitting of a linear relationship between clear creek gauge (CCR) water temperature and Keswick gauge (KWK) water temperature and discharge. Observed daily mean values from 1998 to 2017 were used to generate the model fit. The goal of the fitting exercise was to estimate the relationship between increasing/decreasing flow or temperature at KWK in respect to downstream water temperature at CCR. The general form of the full model is:

$$M1 = CCR_t \sim KWK_Q + KWK_t$$

Where t is channel water temperature (°F) and Q is channel discharge (cubic feet per second (cfs)).

The two reduced models are:

$$M2 = CCR_t \sim KWK_Q$$

$$M3 = CCR_t \sim KWK_t$$

To account for variation on a monthly scale, linear models were fit to daily values stratified by month, such that for the month of July over 1998-2017 there would be 620 observation points if data were successfully collected each day. Figures 1 and 2 show the results of fitting a linear model between CCR temperature and KWK discharge (Fig 1, *M2*) and temperature (Fig 2, *M3*).

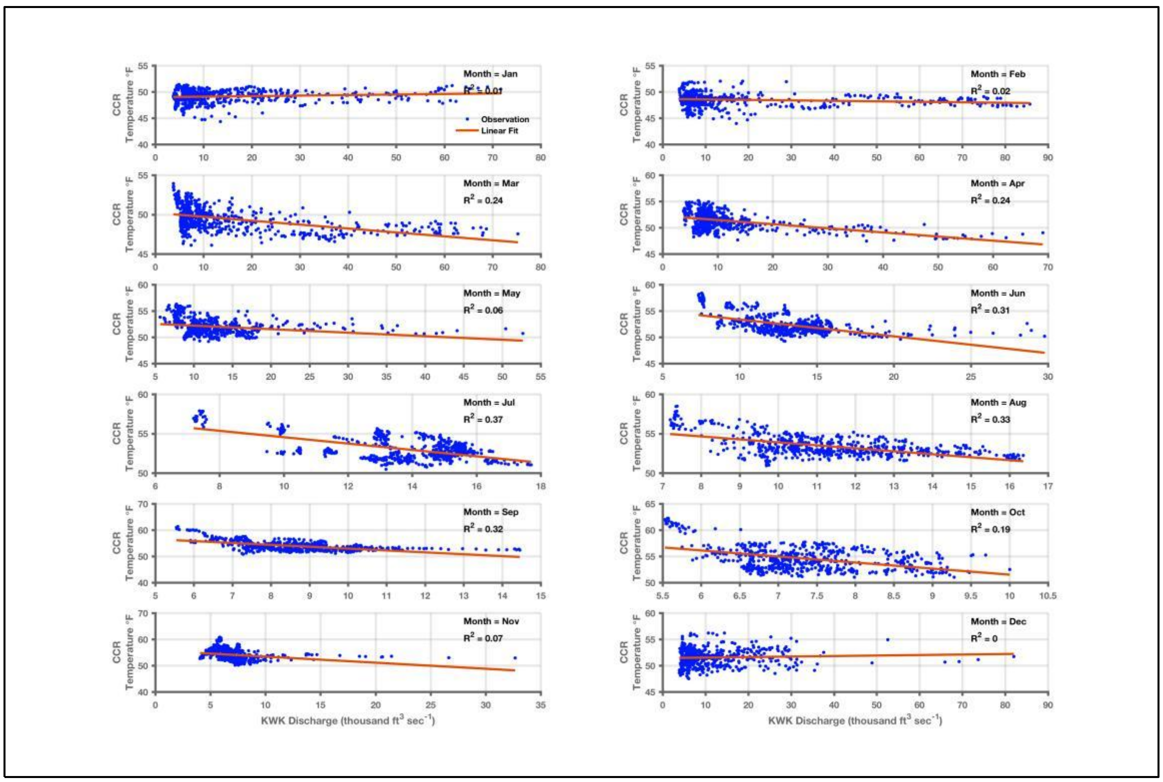

Figure 1: Linear fit (line) between observed KWK discharge volume and CCR water temperature (points) for each month with a measure of model fit (R^2) printed.

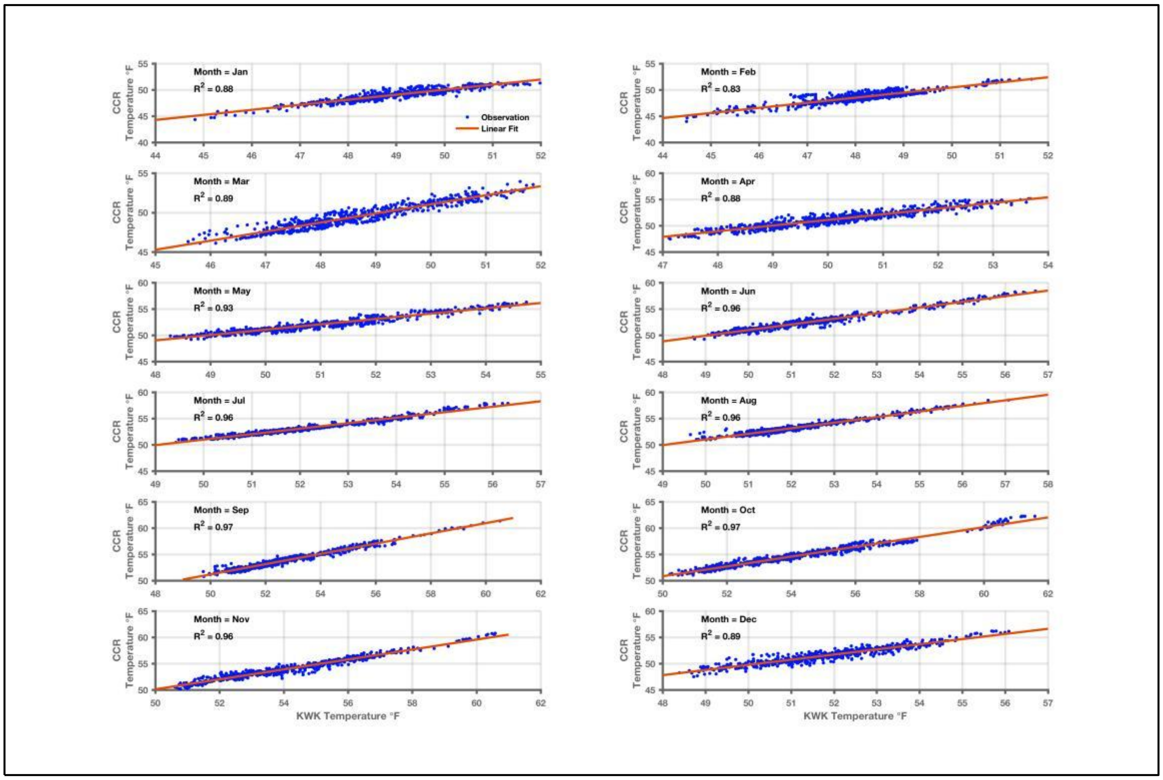

Figure 2: Linear fit (line) between observed KWK discharge temperature and CCR water temperature (points) for each month with a measure of model fit (R^2) printed.

To give a sense of the predictive capabilities of the full model (i.e. including KWK discharge and temperature), Figures 3 and 4 show observed time series of CCR temperature plotted against predicted CCR temperature for a month that typically has high discharge (July, Fig 3) and a month that typically has low discharge (Oct, Fig 4).

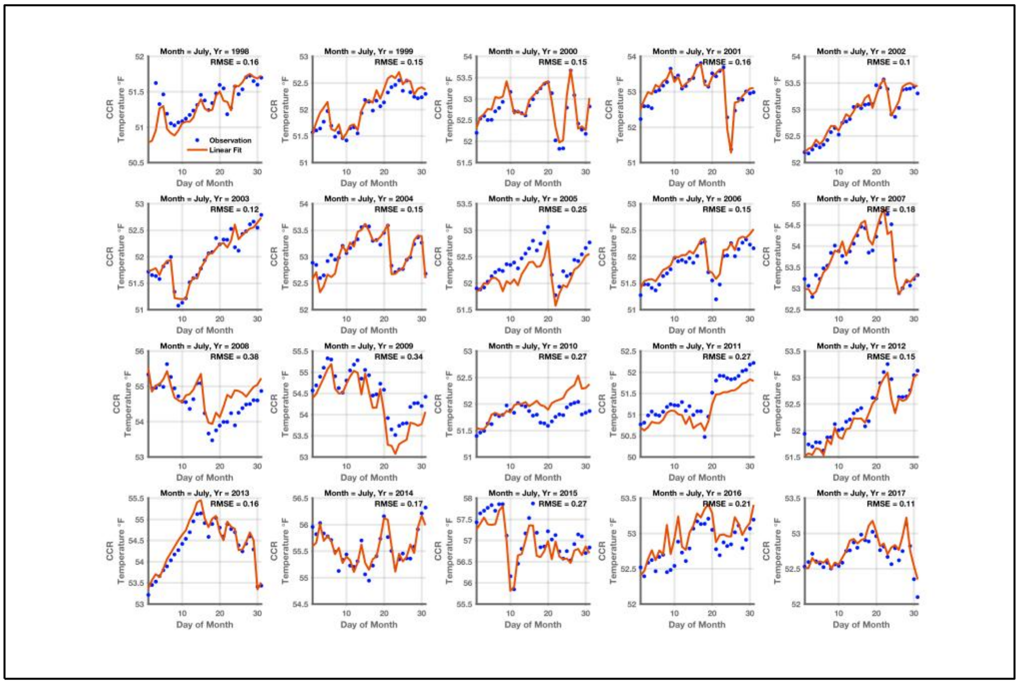

Figure 3: Daily time series of predicted (line) versus observed (points) CCR water temperature for the month of July from 1998-2017, with a measure of model error (root mean square error (RMSE)) printed for each year.

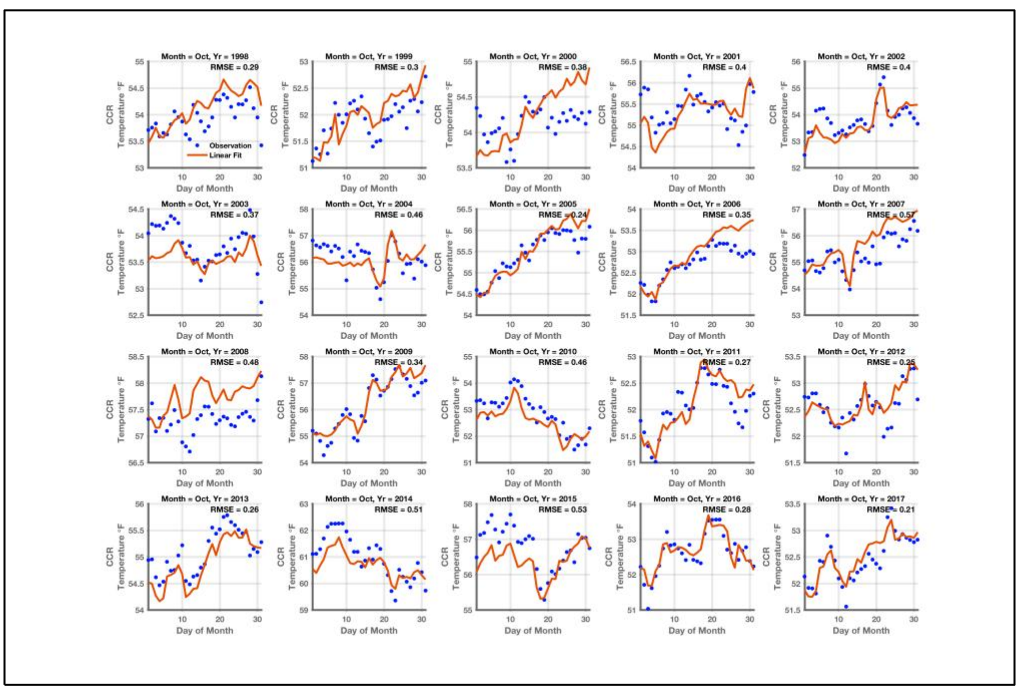

Figure 4: Daily time series of predicted (line) versus observed (points) CCR water temperature for the month of October from 1998-2017, with a measure of model error (root mean square error (RMSE)) printed for each year.

With the fitted models for each month, we can estimate the effect of increased/decreased KWK discharge volume on CCR temperature and translate this into a monthly volume of water resources used upstream from storage reservoirs, assuming constant flow for a given month. Figure 5 shows the results for a subset of months (May-Oct), which are months were active temperature management is often in place.

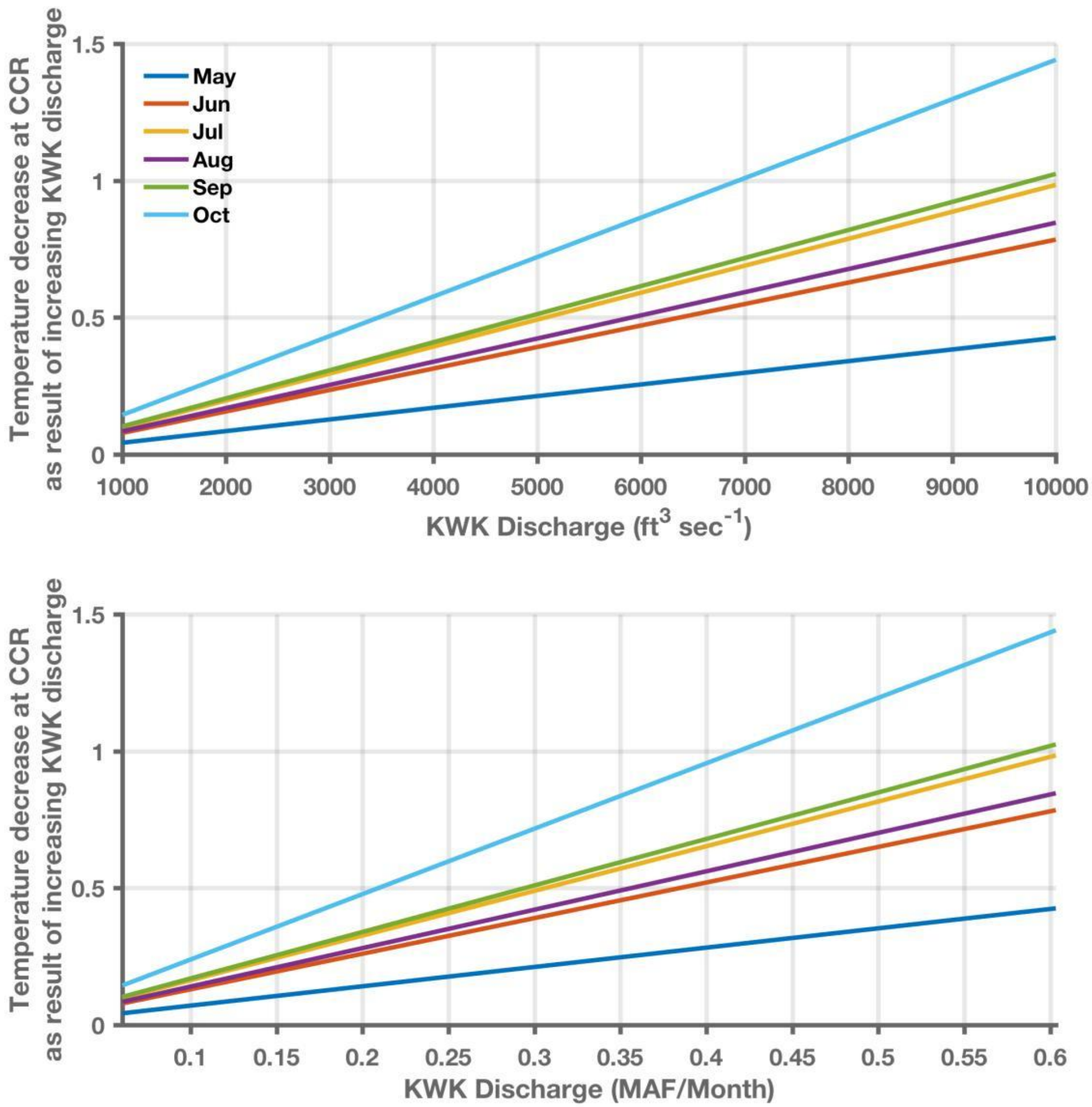

Figure 5: Estimated CCR temperature reduction as a result of increasing KWK instantaneous discharge volume (upper plot) and monthly volume (lower plot) from the fitted linear models for months from May to October. An example of interpretation from this figure is that each additional 1000 cfs from KWK is estimated to reduce CCR temperature by 0.14 °F in October, such that 7000 additional cfs would reduce CCR temperature by ~ 1 °F, which would correspond to an additional 450 thousand acre feet for that month.

Lastly, with the linear regression model, we can estimate the KWK water temperature required to achieve a given water temperature at CCR under a variety of KWK discharge scenarios. Figure 6 shows an example of this approach.

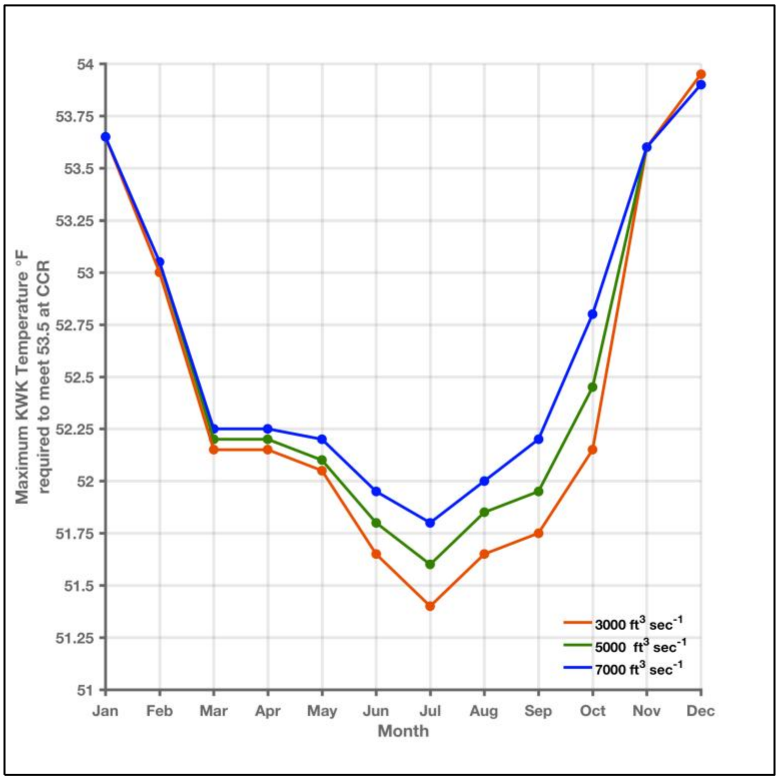

Figure 6: Estimated KWK discharge temperature required to obtain a water temperature ≤ 53.5 °F at CCR for three KWK discharge scenarios. An example of interpretation from this figure is that when KWK discharge is at 5000 cfs, the water temperature at KWK would need to be ≤ 52.5 in order for CCR water temperature to be ≤ 53.5 during the month of October.

Main Points:

- Figures 1 and 2 demonstrate that a larger fraction of the variation (as measured by R^2) in CCR temperature can be explained by *M3* compared to *M2*. This indicates KWK temperature, which ultimately is a measure of Shasta Reservoir discharge temperature is a much stronger predictor of CCR temperature. This relationship likely diminishes further downstream as other heating and cooling processes become more important.
- Figures 3 and 4 demonstrate the predictive model generally has a RMSE of < 0.5 °F in July and October indicating a well-fitting model. However, there are times when the prediction better matches the trend and magnitude of the observed data (e.g. July 2001) compared to others (e.g. October 2008).
- Figure 5 demonstrates that increasing KWK discharge will reduce CCR water temperatures. However, the effect is not constant by month, with the effect of increasing KWK discharge being weakest in May and greatest in October.
- Figure 6 demonstrates the effect of increasing or decreasing KWK discharge volume is greatest from July to October, but that October has the greatest difference in required KWK temperature between the three flow scenarios out of all months, indicating CCR temperature may be more sensitive for KWK discharge in October compared to other times of the year.