Draft Temperature Total Maximum Daily Loads for the Lower Columbia-Sandy Subbasin

Technical Support Document

Appendix E: Bull Run River Surrogate Measure

January 2024

The purpose of this appendix is to document the surrogate measure model scenario and approach used to develop the regression equation (Equation 2) used to predict no dam temperatures.

The City of Portland Bull Run drinking water and hydroelectric project has been assigned 0.3 °C of the human use allowance and the equivalent load allocation on the Bull Run River. In the Sandy River, warming from the dam and reservoirs has been assigned 0.01°C of the human use allowance upstream of Troutdale WPCF, and zero downstream of Troutdale WPCF outfall.

As outlined in the TMDL section 9.1.4.2, the surrogate measure temperature target at the lamprey barrier just downstream Reservoir #2 is:

a) The estimated free flowing (no dam) 7DADM temperatures at the lamprey barrier; or
b) On days the surrogate measure calculated under item a) is cooler than the values in I and II, the surrogate 7DADM temperature may be no warmer than values in I and II.
    I. 16.3°C June 16 - August 14
    II. 13.3°C May 1 - June 15 and August 15 - November 15.

DEQ developed a regression equation (Equation 2) to predict the free flowing (no dam) daily maximum temperatures at the lamprey barrier downstream of Reservoir #2.

Two different regression approaches were evaluated. The first was to develop a regression to predict the daily maximum directly. The second regression approach is based on the concept that the daily maximum temperature can be calculated from the daily mean plus half the daily diel range as shown in Equation 1:

$$Daily\ Maximum = Daily\ Mean + \frac{Daily\ Diel\ Range}{2} \qquad \textbf{Equation 1}$$

Using this framework, a separate regression was developed for prediction of the two components of Equation 1: A regression to predict the daily mean no dam temperatures, and a regression to predict the daily no dam temperature diel range. Rounds (2010) used a similar approach to estimate no dam temperatures in the Willamette Basin.

For regression development, the response variables were derived from segment 7 of the Lower Bull Run No dam (background) CE-QUAL-W2 model for the period of 2014 to 2018. The 2014 to 2018 CE-QUAL-W2 models were developed by the City of Portland and based on the 2016 calibrated model and 2016 background scenario models used for scenarios in this TMDL. The City of Portland provided the model outputs to DEQ for processing.

The explanatory variables include:

- daily maximum temperature (t_max)
- daily mean temperature (t_mean)
- daily temperature diel range calculated as the daily maximum minus daily minimum (t_range)
- daily mean flow rate (q_mean)

Data for the explanatory variables were obtained from the following USGS gages near the Bull Run Project:

- 14138850 Bull Run River Near Multnomah Falls OR
- 14138900 North Fork Bull Run River Near Multnomah Falls OR
- 14139800 Fir Creek Near Brightwood, OR
- 14141500 Little Sandy River Near Bull Run, OR

Only data between May 1 and November 30 were used for regression development. The daily mean flow rates were transformed by taking the log of each value prior to regression development. Days with missing values were removed. There were 1070 total observations available for the five-year period.

The full set of models are described in Table 1. Model 1 and model 13 use the flow weighted daily mean temperatures or flow weighted daily max temperatures from all gages. The daily mean flow is the sum of flow from all gages.

Table 1 Summary of regression models.

Model #	Response Variable	Explanatory Variables
1	Daily Mean	t_mean + q_mean_log
2	Daily Mean	t_mean_14138850 + q_mean_14138850_log
3	Daily Mean	t_mean_14138870 + q_mean_14138870_log
4	Daily Mean	t_mean_14138900 + q_mean_14138900_log
5	Daily Mean	t_mean_14139800 + q_mean_14139800_log
6	Daily Mean	t_mean_14141500 + q_mean_14141500_log
7	Daily Range	t_range_14138850 + q_mean_14138850_log
8	Daily Range	t_range_14138870 + q_mean_log
9	Daily Range	t_range_14138870 + q_mean_14138870_log
10	Daily Range	t_range_14138900 + q_mean_14138900_log
11	Daily Range	t_range_14139800 + q_mean_14139800_log
12	Daily Range	t_range_14141500 + q_mean_14141500_log
13	Daily Maximum	t_max + q_mean_log
14	Daily Maximum	t_max_14138850 + q_mean_14138850_log
15	Daily Maximum	t_max_14138870 + q_mean_14138870_log
16	Daily Maximum	t_max_14138900 + q_mean_14138900_log
17	Daily Maximum	t_max_14139800 + q_mean_14139800_log
18	Daily Maximum	t_max_14141500 + q_mean_14141500_log

Each set of models were evaluated using the second order Akaike information criterion (AICc) (Sugiura 1978, Hurvich and Tsai 1989, 1991) as well as the coefficient of determination (R-squared).

Table 2: Ranking models fitted to the daily mean temperature.

Model #	AICc	Delta_AICc	log-likelihood
6	1930.02	0	-960.99
1	2358.4	428.38	-1175.18
2	2472.3	542.27	-1232.13

5	2606.86	676.84	-1299.41
3	3081.72	1151.69	-1536.84
4	3628.93	1698.91	-1810.45

Table 3: Ranking models fitted to the daily diel temperature range.

Model #	AICc	Delta_AICc	log-likelihood
12	2684.02	0	-1337.99
8	2865.53	181.51	-1428.75
9	2900.73	216.71	-1446.34
10	3004.85	320.83	-1498.41
7	3015.47	331.44	-1503.71
11	3237.33	553.31	-1614.64

Table 4: Ranking models fitted to the daily maximum temperature.

Model #	AICc	Delta_AICc	log-likelihood
18	2834.19	0	-1413.08
13	3096.87	262.68	-1544.41
14	3254.42	420.23	-1623.19
17	3464.56	630.37	-1728.26
15	3828.7	994.51	-1910.33
16	3919.5	1085.31	-1955.73

The AICc results show the regression model 6 (daily mean), model 12 (daily range), and model 18 (daily max) utilizing data from the Little Sandy River gage 14141500 had the best fit based on AICc. After combining model 6 and 12 using the framework from Equation 2, the overall coefficient of determination was 0.97 and the residual standard error was 0.91. The coefficient of determination for the daily maximum model (model 18) was also 0.97 and residual standard error was 0.91. Based on these metrics both models had the same goodness of fit.

Reviewing the residuals, the range between the 1st and 3rd quartile residuals for the combined models 6 and 12 was slightly smaller (1.1541) than the range for model 18 (1.2093) implying combined models 6 and 12 had a marginally better fit for at least 50 percent of the data points. The median residual for combined models 6 and 12 was slightly positive (0.1630) where model 18 had a slightly negative residual (-0.0767) implying the combined models 6 and 12 is slightly under predicting the daily maximum temperatures. While small, the under prediction represents a margin of safety so DEQ choose to utilize combined models 6 and 12 using daily mean and daily range from the Little Sandy River as the final model for prediction of the no dam temperatures. Equation 2 represents the combined final form.

Equation 2

$$T_{Max} = 0.1405173 + 1.1572642\overline{T_{LS}} + -0.3588068 \log \overline{Q_{LS}} + \left(\frac{3.7557135 + 1.1668769 T_{dLS} + -0.5969993 \log \overline{Q_{LS}}}{2}\right)$$

Where,

$T_{Max} =$ The no dam daily maximum stream temperature at the lamprey barrier downstream of Reservoir #2. (Lower Bull Run River model segment 7)

$\overline{T_{LS}} =$ The daily mean temperature (ºC) at USGS Gage 14141500 Little Sandy River Near Bull Run.

$\overline{Q_{LS}} =$ The mean daily discharge (cfs) at USGS Gage 14141500 Little Sandy River Near Bull Run.

$T_{dLS} =$ The daily temperature range (ºC) calculated as the daily maximum minus the daily minimum at USGS Gage 14141500 Little Sandy River Near Bull Run.

Figure 1: presents a plot of the predicted daily maximum at the lamprey barrier compared to the daily maximum derived from the CE-QUAL-W2 model for years 2014 – 2018.

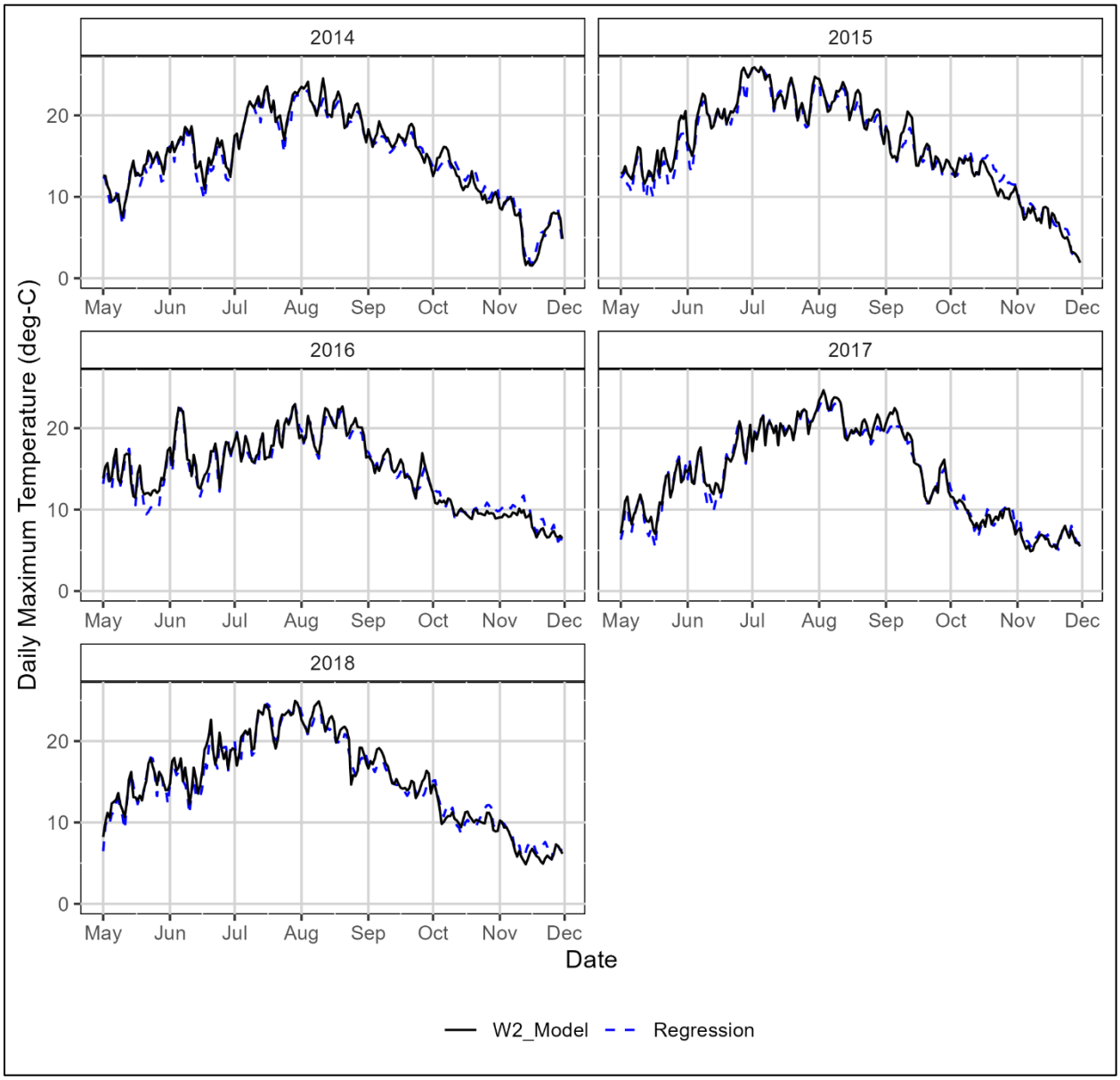

Figure 1: Comparison of daily maximum stream temperatures at the lamprey barrier calculated using Equation 2 and from the CE-QUAL-W2 model for years 2014 – 2018.

A model scenario was developed to estimate the Bull Run temperatures with the dam and reservoir release temperatures set at the surrogate measure temperature target. The surrogate measure scenario is the same as the calibrated model except the boundary condition represent the dam release temperatures (Tin_BR2.npt) and flow (Qin_BR2.npt) at segment 7 were modified. The temperatures from the dam were modified and the release flows are the same as no dam scenario.

In order to translate the target, which is expressed as a 7DADM, to hourly temperatures, the hourly no dam temperatures were increased the same amount each day such that the daily maximum temperature for that day equaled the minimum of the surrogate measure target in the previous seven days. This approach was used to ensure the targets were attained as a 7DADM. Figure 2 shows the 7DADM difference between the no dam scenario and the surrogate scenario when temperature exceeded the applicable criteria.

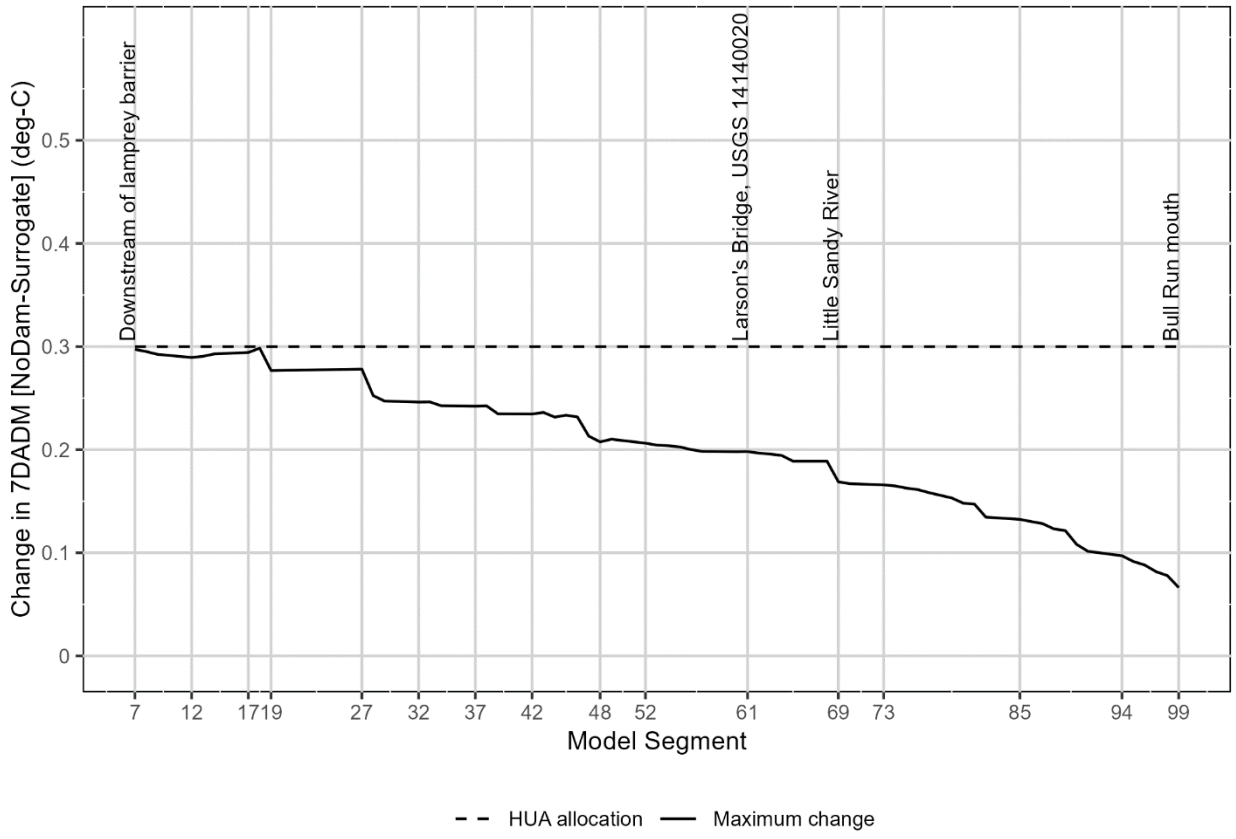

Figure 2: Bull Run River maximum 7DADM temperature change above the applicable criteria due to Bull Run River dams and reservoirs with discharges attaining the surrogate measure.

References

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