State of Oregon
Department of Environmental Quality

Snake River Temperature Total Maximum Daily Load Technical Support Document

Appendix D: Surrogate measure regression

Date: Aug. 25, 2026 - Public Comment Review Draft

Document information

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Front cover: Snake River at mile 220 downstream of Kirkwood Creek. Picture credit: Ryan Michie.

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1 Introduction

The purpose of this appendix is to document the development of the regression equation that estimates no dam temperatures at Hells Canyon Dam. No dam temperatures are the temperatures assuming a free-flowing Snake River absent the Hells Canyon Complex dams and reservoirs. The regression was developed to support implementation of the TMDL surrogate measure temperature target by providing a simple method to calculate no dam temperatures on a daily basis, accounting for warming or cooling through the reservoir reaches, using daily Snake River temperature and stream discharge data monitored upstream of Brownlee Reservoir. The final regression equation, presented in the TMDL section 9.4 as Equation 9-4, is reproduced below.

$$\begin{aligned} tmax_{RM247} = & -5.2987 \\ & + (0.5964 * tmean_{RM345}) \\ & + (0.4703 * tmax_{RM345}) \\ & + (0.4215 * log\_qmean_{RM345}) \end{aligned} \qquad \text{TMDL Equation 9-4}$$

where,

$tmax_{RM247} =$ The estimated no dam daily maximum temperature (^{o}C) at Hells Canyon Dam, Snake River mile 247.

$tmean_{RM345}$= The daily mean temperature (^{o}C) at Snake River mile 345. e.g. IPC monitoring station *Snake_River_345.2_LB.*

$tmax_{RM345}$= The daily maximum temperature (^{o}C) at Snake River mile 345. e.g. IPC monitoring station *Snake_River_345.2_LB.*

$log\_qmean_{RM345} =$ The log of the daily mean flow rate (cfs) at USGS gage 13269000, Snake River at Weiser ID.

2 Methods

Data used for the regression response variable (t_max_RM247) were derived from segment 2 of the Hells Canyon to Washington (HC-WA) No Dam CE-QUAL-W2 model scenario. See TSD Appendix C for details on No Dam model scenario. Daily maximum temperatures were calculated from the model output timeseries for the model period spanning 5 years from 2014 through the end of 2018.

The explanatory variables used in the candidate regressions (summarized in Table 2-1) were obtained from Idaho Power Company’s ‘Snake_River_345.2_LB’ temperature monitoring site, located upstream of Brownlee Reservoir at Snake River mile 345. Daily mean flow rate data were obtained from USGS gage 13269000 located on the Snake River at Weiser, ID. These monitoring sites were chosen because they represent the inflow conditions to Brownlee

Reservoir and have long-term monitoring records with observations available for the entire model period with very few missing days.

Only data from Apil 1 through November 30 were used to develop regressions. This period corresponds to the TMDL critical period and when the TMDL allocations apply to the Hells Canyon Complex. 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 1220 total daily observations available for the five-year period.

Table 2-1: Explanatory variables used in the candidate regression models.

Candidate explanatory variable	Candidate explanatory variable description
t_max_Snake_River_345.2_LB	Daily maximum temperature (°C) at IPC monitoring station Snake_River_345.2_LB.
t_mean_Snake_River_345.2_LB	Daily mean temperature (°C) at IPC monitoring station Snake_River_345.2_LB.
t_range_Snake_River_345.2_LB	Daily temperature diel range (°C) calculated as the daily maximum minus daily minimum at IPC monitoring station Snake_River_345.2_LB.
q_mean_log_13269000	The natural log of the daily mean flow rate (cfs) at USGS 13269000 Snake River at Weiser, ID.

Seven candidate linear regression models were developed using combinations of the explanatory variables (Table 2-2). The simplest of which was a model using only the daily maximum temperatures at river mile 345 (model 1) and more complex models using multiple temperature metrics in addition to flow.

Table 2-2: Summary of candidate regression models.

Model #	Response variable	Candidate regression formula
1	t_max_RM247	t_max_Snake_River_345.2_LB
2	t_max_RM247	t_mean_Snake_River_345.2_LB
3	t_max_RM247	t_max_Snake_River_345.2_LB + q_mean_log_13269000
4	t_max_RM247	t_mean_Snake_River_345.2_LB + q_mean_log_13269000
5	t_max_RM247	t_max_Snake_River_345.2_LB + t_range_Snake_River_345.2_LB + q_mean_log_13269000
6	t_max_RM247	t_mean_Snake_River_345.2_LB + t_range_Snake_River_345.2_LB + q_mean_log_13269000
7	t_max_RM247	t_mean_Snake_River_345.2_LB + t_max_Snake_River_345.2_LB + q_mean_log_13269000

Candidate models were fit using ordinary least squares regression. The R statistical program (R Core Team, 2026) was used for all calculations. Models were compared using the second-order Akaike information criterion (AICc) (Sugiura, 1978; Hurvich and Tsai, 1989, 1991). AICc values, Delta AICc, and the Akaike weights were computed using the AICcmodavg package (Mazerolle, 2023). The model with the lowest AICc was selected for further assessment. Goodness of fit statistics and regression coefficients were then calculated for the selected model.

3 Results

The seven candidate models produced a range of AICc values. Model 7 was the highest ranked model with the lowest AICc and largest Akaike Weights (Table 3-1). Model 1 using only the daily maximum temperature at river mile 345 had the lowest rank. Model 7 included the daily mean and daily maximum temperatures at river mile 345, and the natural log of flow rates at Weiser. All variables in model 7 had statistically significant regression coefficients (Table 3-2) and was selected as the final model

Table 3-1: Candidate models ranked based on AICc with the top model having the lowest AICc.

Model #	K	AICc	Delta AICc	Akaike Weights
7	5	2581.18	0.00	0.81
6	5	2584.24	3.06	0.18
5	5	2589.65	8.47	0.01
4	4	2644.64	63.46	0.00
3	4	2678.32	97.14	0.00
2	3	2718.72	137.54	0.00
1	3	2785.58	204.41	0.00

Table 3-2: Selected model regression coefficients.

Explanatory Variable	Coefficient	Standard Error	t statistic	p-value
Intercept	-5.2987	0.4246	-12.48	< 0.001
t_mean_Snake_River_345.2_LB	0.5964	0.0588	10.15	< 0.001
t_max_Snake_River_345.2_LB	0.4703	0.0574	8.19	< 0.001
q_mean_log_13269000	0.4215	0.0421	10.02	< 0.001

The final selected model was statistically significant ($F(3, 1216) = 33{,}396.32$, $p < 0.001$) and explained approximately 99% of the variation in the response variable daily maximum temperatures ($R^2 = 0.99$; adjusted $R^2 = 0.99$). Prediction errors were low, with a mean absolute error (MAE) of 0.54 and a root mean squared error (RMSE) of 0.69. The mean bias error (MBE) was effectively zero (2.49E-14), indicating no bias in the model predictions. Figure 3-1 presents the regression results compared to the CE-QUAL-W2 no dam model results.

Table 3-3: Final selected model goodness of fit statistics.

Model #	MBE	MAE	RMSE
7	2.49E-14	0.54	0.69

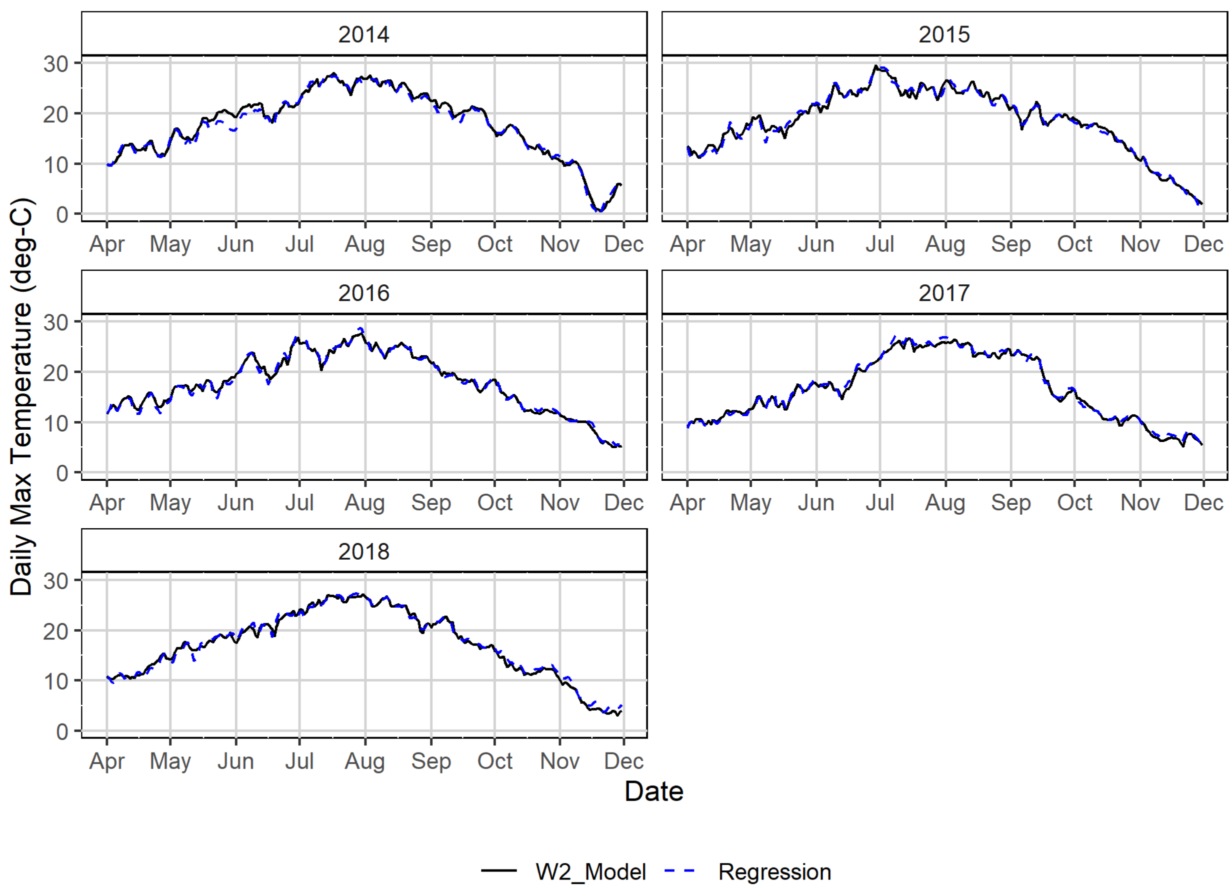

Figure 3-1: Final regression output compared to No Dam CE-QUAL-W2 model scenario daily maximum temperatures at Hells Canyon Dam (segment 2, HC-WA model).

4 References

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