DEPARTMENT OF
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State of Washington

Addendum to
Quality Assurance Project Plan

Little Klickitat River Temperature
Total Maximum Daily Load
Steady State to
Continuous QUAL2Kw Conversion

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Addendum

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This addendum is an addition to an original Quality Assurance Project Plan. It is not a correction (errata) to the original plan.

Data for this project will be available on Ecology's Environmental Information Management (EIM) website at www.ecy.wa.gov/eim/index.htm. Search Study ID ASTO0002.

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Approved by:

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Signatures are not available on the Internet version.
EAP: Environmental Assessment Program

3.0 Background (3.0)

This study addendum develops new modeling of the original data collection for the Little Klickitat Temperature Total Maximum Daily Load (TMDL).

The original TMDL technical report (Brock and Stohr, 2002) used a steady-state version of the QUAL2K model to predict water temperature in the Little Klickitat River. The steady-state model simulated a single day that was chosen to represent a critical period.

Since publication of the TMDL technical report, Ecology published a time-varying version of the QUAL2Kw model (Pelletier et al, 2006; Pelletier and Chapra, 2008) which allows dynamic simulation of up to 365 days, rather than a single day.

This addendum provides details on applying the new time-varying version of the QUAL2Kw surface water model to predict water temperatures in the Little Klickitat River during the original TMDL study season of June through November 2000. The time-varying version of the model will use the data originally collected as part of the TMDL technical study. There will be no additional field data collection for this study.

The time-varying model version will better meet the original project objectives: "Develop a predictive computer temperature model of the Little Klickitat stream network." The new model version will allow water temperature prediction over the entire study season instead of on a single day.

The new modeling will be used to better understand the seasonal nature of the temperature wasteload allocation given to the Goldendale Public Owned Treatment Works (POTW) in the original TMDL.

This Quality Assurance project plan (QAPP) addendum builds on the previous QAPP developed for the Little Klickitat River temperature TMDL (Brock and Stohr, 2000) as well as the reported findings in the Little Klickitat River Temperature TMDL (Brock and Stohr, 2002).

3.1.4 Results of previous studies

The result from the original TMDL that applies to this new project is the maximum daily effluent temperature wasteload allocation of 18.3 degrees C given to the Goldendale POTW. There were no seasonal bounds to the wasteload allocation.

4.0 Project Description

4.1 Project goals

The goals specified in the original QAPP can be summarized as follows:

1. Characterize summer water temperature in the watershed.
2. Develop a predictive temperature model for a single day critical temperature condition in the basin.
3. Establish TMDL thermal loads for the basin.

The goal of this current project is to develop a predictive time-varying temperature model for seasonal critical temperature conditions in the basin. The seasonal model will be used to assist the Water Quality permitting group in evaluating a seasonal effluent temperature wasteload allocation for the Goldendale POTW.

4.2 Project objectives

The goal will be accomplished by the following objectives and tasks:

- A seasonal temperature model will be built and calibrated to observed flow and temperature data that was collected for the original TMDL study.
- The seasonal temperature model will be used to evaluate when seasonal limits may apply for the temperature wasteload allocation for the Goldendale POTW. Currently their temperature wasteload allocation is year-round.
- A technical memo will be written to the Water Quality client. The memo will describe the model calibration and seasonal critical condition temperature results and will include an assessment of potential seasonal limits for the effluent temperature wasteload allocation at the Goldendale POTW.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 1. Organization of project staff and responsibilities.

Staff (all are EAP except client)	Title	Responsibilities
Ian Laseke Water Quality Program Central Regional Office Phone: 509-457-7108	EAP Client	Goldendale POTW permit manager: Clarifies scope of the project. Reviews and approves final QAPP addendum and final technical memo.
Evan Newell Central Regional Office Eastern Operations Section Phone: 509-575-2825	Project Manager	Writes the QAPP addendum. Conducts QA review of data. Analyzes and models data. Writes the technical memo.
Jim Carroll Headquarters Office Eastern Operations Section Phone: 360-407-6196	Reviewer	Review QAPP addendum. Reviews model results and technical memo.
Tom Mackie Central Regional Office Eastern Operations Section Phone: 509-454-4244	Section Manager for the Project Manager and Study Area	Reviews the project scope, tracks progress, reviews and approves QAPP addendum and technical memo.
William R. Kammin Phone: 360-407-6964	Ecology Quality Assurance Officer	Reviews and approves the QAPP addendum.

EAP: Environmental Assessment Program
QAPP: Quality Assurance Project Plan

5.4 Project schedule

Table 2. Proposed schedule for completing modeling and technical memo report.

Modeling analysis work	Due date	Lead staff
Modeling analysis completed	December 2015	Evan Newell
Final technical memo		
Author lead	Evan Newell	
Schedule		
Draft due to supervisor	December 2015	
Draft due to client/peer reviewer	December 2015	
Draft due to external reviewer(s)	December 2015	
Final (all reviews done) due to publications coordinator	January 2016	
Final memo due on web	February 2016	

5.5 Limitations on schedule

This schedule is based on model development beginning in June 2015. Any time delay will require a commensurate adjustment in the planning schedule.

6.3 Model Quality Evaluation

To meet the objectives of this project, model quality results should be comparable to the original TMDL modeling for the Little Klickitat River Temperature TMDL (see section 14.2) and other models used in temperature TMDL studies. A summary of results for comparison is available in *A Synopsis of Model Quality from the Department of Ecology's Total Maximum Daily Load Technical Studies* (Sanderson and Pickett, 2014).

6.3.1 Goodness-of-fit

This study will use the following methods to assess goodness-of-fit. The methods described below will use appropriate spatial and temporal pooling of data to help provide a more comprehensive understanding of model uncertainty.

6.3.1.1 Precision

Precision is a measure of the variability in the model results relative to measured values. This study will evaluate Precision through use of the standard metrics, Root Mean Square Error (RMSE).

6.3.1.2 Bias

Bias is the average difference between modeled and observed values. This study will evaluate Bias through use of standard metrics such as the mean error or relative percent difference.

6.3.1.3 Qualitative assessment

Graphical assessment will be used to provide a qualitative assessment of the goodness-of-fit to supplement the quantitative methods.

7.0 Sampling Process Design (Experimental Design)

7.3 Assumptions underlying design

The Total Maximum Daily Load (TMDL) technical report (Brock and Stohr, 2002) used a steady-state version of the QUAL2K model to predict water temperature in the Little Klickitat River. The steady-state model simulated a single day, which was chosen to represent a critical period. For model calibration, the day represented the hottest 7 days during 2000 (July 29–August 4).

Since publication of the TMDL technical report, Ecology published a time-varying version of the QUAL2Kw model (Pelletier et al, 2006; Pelletier and Chapra, 2008) which allows dynamic simulation of up to 365 days, rather than a single day.

This addendum provides details on applying the new time-varying version of the QUAL2Kw surface water model to predict water temperatures in the Little Klickitat River during the original TMDL study season (Jun-Nov, 2000). The time-varying version of the model will use the data originally collected as part of the TMDL technical study.

The time-varying model version will better meet the original project objectives: "Develop a predictive computer temperature model of the Little Klickitat stream network". The new model version will allow water temperature prediction over the entire study season instead of on a single day.

Fewer assumptions are required for the time-varying version of QUAL2Kw, as compared to the steady-state version (summarized below).

Assumptions which are the same for both the steady-state and time-varying versions of QUAL2Kw (Pelletier and Chapra, 2008):

- One dimensional. The channel is well-mixed vertically and laterally.

Additional assumptions specific to the steady-state version (Pelletier and Chapra, 2008):

- Steady state hydraulics. Non-uniform, steady flow is simulated.

- Diel Heat budget. The heat budget and temperature are simulated as a function of meteorology on a diel time scale.
- Diel water-quality kinetics. All water quality variables are simulated on a diel time scale.
- Heat and mass inputs. Point and non-point loads and abstractions are simulated on a diel time scale.

Assumptions specific to the time-varying version (Chapra, 1997):

- Water movement (momentum) ignores the effects of local acceleration, convective acceleration, and pressure forces.

7.5 Characteristics of existing data

A summary of data inputs needed for the time-varying version of QUAL2Kw is presented in Table 3.

Table 3. Data Inputs to QUAL2Kw and Shade Models.

Data Set	Source	Year	Peer Review / QC	Approved QAPP?	Formal SOPs?	Comments
Discharge – Tributary	ECY	2000	Yes	Yes	Yes	Instantaneous
	CKCD	2000	Unk	Unk	Unk	Instantaneous
Discharge – Mainstem	ECY	2000	Yes	Yes	Yes	Continuous and instantaneous
	USGS	1985	Yes	Unk	Yes	Flow statistics
Discharge – Groundwater	ECY	2000	Yes	Yes	Yes	
Temperature – Water	ECY	2000	Yes	Yes	Yes	
	CKCD	2000	Yes	Unk	Unk	
Temperature – Air	ECY	2000	Yes	Yes	Yes	
	AgriMet	1998	Yes	Yes	Yes	For critical conditions
Vegetation Height/Density/ Overhang	ECY	2000	Yes	Yes	Yes	Site transects
Meteorological	AgriMet	2000	Yes	Yes	Yes	Goldendale airport

Unk: Unknown
QC: Quality Control
SOPs: Standard Operating Procedures

Discharge – Mainstem / Tributary / Groundwater

As part of the TMDL study, Ecology monitored flow continuously at three sites from June through November 2000 (Evans, 2001). Continuous stage height recorders (pressure transducers) and staff gages were installed, and four to six instantaneous discharge measurements were taken at all three sites. Discharge rating curves were developed for each site by relating various stage height values to their corresponding instantaneous discharge measurements. Doing so related the river stage to a corresponding instantaneous discharge measurement.

The TMDL Quality Assurance Project Plan (QAPP) (Brock and Stohr, 2000) indicates that installation and operation of the continuous flow data loggers followed standard protocols established by Ecology's Hydrology Unit (Ecology, 2000). Ecology published a technical report summarizing the flow gage results and quality assurance assessment (Evans, 2001).

During the study period, the accuracy of stage heights was addressed by linear regression of staff gage readings versus pressure transducer values. The R^2 values ranged from 0.80 to 0.99. The lower value of R^2 (0.80) may be a result of station vandalism in mid-July near the mouth, which may have caused movement of the staff gage. Two weeks of data were lost at this station. Stage was reported as stabilizing prior to the vandalism. It remained stable after the station was repaired. Flows during the missing period were estimated by linear interpolation.

During some time periods, unusual daily fluctuations in stage height readings were observed. Stage reported highest shortly after 6:00 pm and lowest at 6:00 am. The author found no explanation for the fluctuations (Evans, 2001).

Instantaneous discharge measurements by Ecology followed a modified version of the United States Geological Survey (USGS) mid-section method (Hopkins, 1999). Error due to calibration of the velocity meter was reported between 0-2%. Stream cross sections were rated between good and poor. A good cross section assumes an error of up to 5% and a poor cross-section assumes an error of up to 8%. The combination of propeller variations, poor cross-sections, and low-flow conditions contributed to the measured and predicted discharge differences ranging from less than 1% to just over 15% (Evans, 2001).

Instantaneous discharge measurements were also performed by the Central Klickitat Conservation District (CKCD). No information is currently available regarding flow measurement methods during the original TMDL study. The TMDL technical report listed CKCD discharge measurements only for station LK-8 on the mainstem Little Klickitat River (upstream of the continuous gage stations).

Groundwater discharge was calculated based on a synoptic flow survey on July 19, 2000. Flow measurements along the mainstem were combined with tributary and adjudicated water rights flows to determine gaining and losing groundwater reaches. Significant inflow/outflow was found along several reaches of the Little Klickitat. Findings were consistent with the hydrogeologic data available in the watershed (Brock and Stohr, 2002).

Temperature – Water / Air

Hourly temperature data are needed for the time-varying version of QUAL2Kw. These were obtained in 2000 using Hoboware™ tidbit temperature loggers. Ecology operated 4 water tidbits and 3 air tidbits along the mainstem from late June to mid-November 2000. Data from 6 water tidbits operated by CKCD will also be used in QUAL2Kw (one mainstem and five tributaries).

The QAPP indicates that temperature logger accuracy was assessed by comparison against several field measurements of water and air temperature (Brock and Stohr, 2000). Comparative measurements were collected at 4 locations (mouth, Olson Rd, Tom M Rd, and Hwy 97). All of the locations included tidbits operated by ECY. Two of the locations included tidbits operated by CKCD. Field thermometer accuracy was assessed against a certified reference thermometer. The TMDL technical report included graphs of these field measurements but did not include statistical comparison. A statistical comparison of the field thermometer readings and water tidbits is calculated for this addendum and presented in Table 4 below.

Table 4. Temperature Loggers vs. Field Thermometer (Mean Difference °C).

Location	ECY* Water	CKCD Water	ECY* Air
Near Mouth	+0.14	+0.14	+0.88
Olson Rd	(-0.06) #	+0.13 #	(-0.67)
Tom M Rd	+0.15 #	---	---
Hwy 97	+0.02	---	(-0.05)

* Field measurements on the day of deployment (6/22/2000) were not included in the calculation for Ecology tidbits because some temperature loggers had not stabilized at time of field measurement.

One field measurement was discarded at both the Olson Rd and Tom M Rd sites, see text below.

One field measurement was discarded at the Olson Rd site on July 19. Two tidbits at this site (ECY and CKCD) agree with each other within 0.2°C, while the field thermometer differs by approx 3.7°C from the ECY tidbit. Because of the close agreement between the ECY and CKCD tidbits, it seems likely that the field thermometer either malfunctioned or was misread.

A second field measurement was discarded at the Tom M Rd site on August 16. It differed by 3.24 °C compared to the tidbit. No other tidbits were available for comparison at Tom M Rd. However, the field thermometer readings for both discarded measurements were similar: 18.3 °C and 18.5 °C. The similarity in field thermometer values suggests that both errors might have happened in the same way.

The QAPP indicates a target temperature accuracy of water ± 0.2°C and air ± 0.4°C for temperature loggers. The above water temperature statistics meet this target; some of the air temperatures do not. Air temperature affects the convective, evaporative, and long-wave heat transfer processes in the QUAL2Kw model. As noted in the TMDL technical report, these processes introduce energy at much smaller rates than shortwave energy (Brock and Stohr, 2002).

An additional check on comparability was performed by calculating the mean difference in water temperature at two locations where ECY and CKCD both operated temperature loggers (Near-mouth and Olson Rd). No statistics for this comparison were presented in the TMDL technical report. Mean differences calculated for this addendum are: CKCD-NearMouth (0.01 °C), CKCD-OlsonRd (0.09 °C).

Air temperature data from 1998 from AgriMet (U.S. Bureau of Reclamation) at the Goldendale airport were used to develop critical conditions for the model in the TMDL technical report. AgriMet provided calibration sheets for May 10, 1998 at the Goldendale airport weather station. These sheets indicate that calibration occurred that day using an air temperature of 56°F. No estimate was available for overall accuracy of air temperature at this weather station in 1998.

Vegetation – Height/Density/Overhang

Vegetation height, density and overhang are used in the QUAL2Kw model to calculate effective shade that reduces the amount of solar radiation reaching the river.

The TMDL relied on several sources of information to document vegetation species, height, and density. These sources included a Boise Cascade watershed analysis report, field data collected by Ecology during the summer of 2000, the Washington Department of Fish and Wildlife Priority Habitat and Species Database, and vegetation documented in similar watersheds in Oregon (Raines et al., 1999; Brock and Stohr, 2002).

We used the above information to classify the areal extent of vegetation types along the river, based on GIS ortho-photos. We then used the Ttools software package to sample classified vegetation along transects perpendicular to the river. Finally, we calculated effective shade using HeatSource software obtained from Oregon Department of Environmental Quality. This software traces the path of the sun based on latitude, time of year, and time of day. It calculates the amount of shade provided to the river from both vegetation and topography.

Calculated values for effective shade were then compared to Ecology's field measurements (Table 5). Field measurements were made at ten transects (spaced 100 ft apart) at monitoring sites. A concave densiometer was used to measure canopy closure. Species and tree heights along each bank were noted.

Table 5. Comparison of calculated and measured effective shade (mainstem).

Station/ Tributary	Distance downstream from headwater (km)	Calculated Effective Shade (%) (excluding topography)	Measured Effective Shade (%) (vegetation only)
Rimrock	14.1	58.6	49.0
Tom Miller	19.1	46.4	35.0
Olson	27.2	30.0	38.1
Mouth	42.9	45.2	45.2

Meteorological

Other model inputs include solar radiation, dew point and wind speed. These were obtained for the Goldendale airport weather station operated by AgriMet (U.S. Bureau of Reclamation). Calibration sheets from 1998-2000 for this weather station were obtained by request, to identify any potential equipment problems. No problems were noted in either the May-2000 or May-2001 calibrations. Station air temperatures were within 0.6°C of air temperature benchmarks. Solar radiation standard error was within 0.3%. Wind speed rpm met all standards. Relative humidity was within 2% of benchmarks.

14.0 Data Quality (Usability) Assessment

14.2 Data analysis and presentation methods

The time-varying version of QUAL2Kw will be used to predict water temperatures based on observed conditions during the TMDL study season (late June to mid-November 2000). Water temperature predictions will also be made for critical conditions similar to those used in the original TMDL report, across a similar season (June to November). The values for vegetation height/density/overhang used in the original TMDL will be used to calculate effective shade across this season to account for changes in the sun's path.

The TMDL technical report assessed uncertainty in predicted temperatures by calculating the root mean squared error (RMSE) and average difference (Δavg) of the minimum and maximum predicted versus observed temperatures. These statistics for the Little Klickitat River are presented in Table 6.

Table 6. Calibration and verification statistics.

	Calibration (7/29-8/4)		Validation (8/21-8/27)	
	RMSE (°C)	Δavg (°C)	RMSE (°C)	Δavg (°C)
Maximum Temp	0.85	0.69	1.23	0.96
Minimum Temp	1.32	1.1	0.78	0.66
Overall Temp	1.11	---	1.03	---

Uncertainty in time-varying QUAL2Kw predicted temperatures will be assessed in a similar way, except that these statistics will be reported on a monthly basis. Target RMSE for maximum/ minimum temperatures for each month will be less than or equal to 1 Celsius degree. Average temperature difference for each month will also be less than or equal to 1 Celsius degree. These statistics will include all observed temperatures along the modeled length of river.

15.0 References

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Appendix - Acronyms

CKCD	Central Klickitat Conservation District
ECY	Washington State Department of Ecology
Ecology	Washington State Department of Ecology
POTW	Public Owned Treatment Works
QAPP	Quality Assurance Project Plan
QUAL2K	Surface water quality modeling software (earlier version)
QUAL2Kw	Surface water quality modeling software (later version)
RMSE	Root mean squared error
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey