Quality Assurance Project Plan

Continuous Stream Temperature Monitoring by the Freshwater Monitoring Unit

by
William J. Ward

Freshwater Monitoring Unit
Environmental Monitoring & Trends Section (EMTS)
Environmental Assessment Program
Washington State Department of Ecology
PO Box 47600
Olympia, WA 98504-7710

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Approvals

Approved by:	November 28, 2005
William J. Ward, Principal Investigator, EMTS	Date
Approved by:	November 29, 2005
Rob Plotnikoff, Unit Supervisor, Freshwater Monitoring Unit, EMTS	Date
Approved by:	December 2, 2005
Bob Cusimano, Section Manager, EMTS	Date
Approved by:	December 5, 2005
Bill Kammin, Ecology Quality Assurance Officer	Date

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Abstract

The purpose of this program is to annually collect diel (24-hour) continuous temperature data every 30 minutes during the summer (July – September) at most of the Department of Ecology's statewide ambient stream monitoring stations.

The data may be used to (1) interpret a station's historical monthly temperature patterns, (2) do trend analyses, (3) support temperature Total Maximum Daily Load (TMDL) studies, and (4) determine compliance with current and proposed water quality standards.

Background

The purpose of this Quality Assurance Project Plan is to describe the objectives of the recently established[1] continuous stream temperature monitoring program conducted by the Washington State Department of Ecology (Ecology) Freshwater Monitoring Unit (FMU).

The ongoing monitoring program focuses on summer (July – September) stream temperatures at about 50 of the 82 active stations[2] within Ecology's statewide long-term ambient[3] stream sampling network. The program may also include previously sampled stations or special study request locations as resources permit.

The purpose of the program is to collect diel (24-hour) stream temperature data that may be used to expand the interpretation of a station's ambient monitoring results and to determine its compliance with Washington State water quality standards. The standard requires stream temperature to be measured on consecutive days in order to apply the criterion. The continuous temperature results are also assessed using Ecology's policy for identifying impairments under the federal Clean Water Act (Section 303(d)).

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[1] Pilot program began in 2001.
[2] Program limited to station locations where representative stream temperatures may be obtained throughout the entire monitoring period (July – September).
[3] Status and trend

Project Description

Goals

1. Collect diel continuous temperature data from most of Ecology's ambient stream monitoring stations and special study request stations as resources permit.

2. Provide these data to internal and external users: Ecology; other state, federal, and local agencies; educational institutions; the private sector; and individuals.

Objectives

1. Establish continuous temperature monitoring locations at as many of the current and past ambient stream monitoring stations as possible and at other locations based on need and available resources.

2. Follow established protocols to ensure that representative stream temperatures are obtained throughout the desired monitoring period (July – September) and to prevent equipment loss to vandalism or high streamflow.

3. Ensure the reliability of the data through pre- and post-deployment calibration checks and quality control procedures designed to locate and remove anomalous data.

4. Provide timely and high quality data to internal and external users by storing finalized results on Ecology's FMU web page, in Ecology's EIM database, and in Ecology's FMU Access® Data Logger Database.

5. Evaluate and publish the seasonal maximums and maximum 7-day average of daily maximums in our annual ambient monitoring report.

Organization and Schedule

Organization

The project organization is divided by Ecology's regional boundaries (Table 1).

Table 1. Personnel and areas of responsibility.

Personnel	Ecology Region	Phone	Duties
Bill Ward	Northwest, Southwest, and statewide	360-407-6621	Project manager, regional staff lead, methods, data accuracy, and equipment procurement.
Jim Ross	Eastern	509-329-3425	Regional staff lead.
Chris Coffin	Central	509-454-4257	Regional staff lead.
Dave Hallock	Statewide	360-407-6681	Data management, miscellaneous data analysis and reports.

Schedule

The primary focus of the program is to annually establish a minimum of 50 temperature monitoring stations to obtain summer (July – September) stream temperatures at most of Ecology's active ambient stream monitoring stations. The regional staff lead, with the assistance of volunteers, independently sets up a schedule to establish the stations within the desired monitoring period.

In some instances, stations may need to be established as early as February (before the spring runoff) to anchor the stream temperature loggers at a depth that will be submerged throughout the desired monitoring period. Temperature loggers deployed prior to the desired monitoring period are to be programmed to begin monitoring no sooner than June 1.

Some events, such as high streamflow in the fall or scheduling problems, may result in temperature logger retrieval after the September cutoff. If this occurs, the additional information will be kept but stored separately for data management and analysis.

There are a number of annual tasks that need to be addressed in order to prepare for and complete the monitoring program. The tasks are listed in Table 2.

Table 2. Schedule for ongoing annual tasks.

Date	Task
Early spring	Assess equipment needs and submit purchase orders for replacement/ additional parts.
Late spring	Do pre-deployment temperature logger calibration checks, re-test loggers that fail to meet the accuracy criteria, and reject loggers that fail both tests.
June	Pre-program temperature loggers for a delayed start and distribute them and other necessary equipment to regional staff leads.
July	Deploy temperature loggers.
Late September	Retrieve temperature loggers.
October	Download data from temperature loggers.
November	Review data, delete identified anomalies, and begin to load finalized data into database.
December	Conduct post-deployment temperature logger calibration checks.
January	Re-test loggers that fail the calibration check accuracy criteria, and adjust/reject results from the loggers that fail the re-test.

Quality Objectives

Data Quality Objectives

The Data Quality Objectives (DQOs) are needed for this project because the results may be compared to a standard or used to select between two alternative conditions. The continuous temperature data may be used for the following purposes:

1. Determining compliance with water quality standards under Section 303(d) of the federal Clean Water Act.
2. Water quality modeling needed to establish Total Maximum Daily Loads (TMDLs) studies.
3. Evaluating trends in stream temperature.

DQOs can be established to address statistical requirements for trend analysis. Linear trend analysis is a form of hypothesis testing of the model (Lettenmaier, 1977):

$Yt = \mu + \Delta\mu * t/t1 + \varepsilon t$

where,

yt = the value of the monitored water quality variable at time, t
μ = the mean at the beginning of the time period
Δμ = the change in the mean over the time period
tl = the length of the time period
t = the time elapsed since the beginning of the time period
εt = a stochastic error term

The hypothesis to be tested is:

H0 (null hypothesis): Δμ = 0 (no change in the mean value), and
Ha (alternate hypothesis): Δμ ≠ 0 (a change has occurred).

The size of trend (Δμ) that can be detected depends on the degree of confidence desired in one's conclusion, the number of independent samples collected, and the variability in the data. Power, confidence level, and sample size are related so that both α (the probability of detecting a change when one has not occurred, i.e., falsely rejecting the null hypothesis – type I error) and β (the probability of not detecting a change when one has occurred, i.e., falsely failing to reject the null hypothesis – type II error) decrease with increasing sample size. Also, when one chooses a smaller α (i.e., one assumes a stricter criterion before rejecting H0), β increases (assuming sample size stays the same). Given values for α, β, and sample size (n), one can calculate the magnitude of the trend that can be detected relative to the standard deviation of the data.

The DQO is the specified magnitude of the trend that we wish to detect. Washington's Water Quality Standards (Chapter 173-201A-200(b)(i) WAC) define the level of acceptable measurable change as 0.3ºC. However, because the ability to detect trends is related to the variance of the data, separate DQOs for trend detection may need to be determined for different streamflow gaging stations. Depending on the variance measured at a particular station, DQOs may also need to be specified for different measures of stream temperature. For example, different DQOs may be needed for trends in maximum daily temperature vs. the 7-day average of the daily maximum temperature. This project will collect quality control data to evaluate the actual error attained as compared to the DQO set for trend analysis.

Measurement Quality Objectives

The accuracy and instrument bias measurement quality objectives (MQOs) of each temperature logger is verified through both pre- and post-deployment calibration checks following the procedures described in the *Continuous Temperature Sampling Protocols for the Environmental Monitoring and Trends Section* (Ward, 2003) and in the *TFW Stream Temperature Survey Manual* (Schuett-Hames et al, 1999). The procedures require the temperature loggers be tested in controlled water temperature baths that bracket the expected monitoring range (near 0ºC and near 20ºC). The results are then compared to those obtained with a certified reference thermometer.

All temperature loggers that fail to meet the instrument accuracy (Table 3) will be checked a second time. Temperature loggers that fail a second pre-deployment check will not be used. Temperature loggers that fail a second post-deployment check (this rarely occurs) will have their data adjusted or rejected based on the following:

- If the difference between the pre- and post-deployment calibration check results for a temperature logger is at or below the instrument accuracy, then the instrument bias will be corrected by adding to the raw data the difference between the mean of the pre- and post-deployment calibration check results, and the certified reference thermometer[4].

Table 3. Summary of equipment, accuracy, and reporting limits.

Equipment	Accuracy	Reporting Limit
Certified Reference Thermometer # 61099-035, HB Instrument Co.	± 0.1 °C	0.1 °C
Field Thermometer # 1546RL, Brooklyn Thermometer Co.	± 0.2 °C	0.1 °C
Thermistor Thermometer #U-08402 Thermistor & #U-93823 Probe, Cole Parmer Co.	± 0.3 °C	0.1 °C
Temperature Logger (Water/Air) #TBI 32-05+37 StowAway TidbiT, Onset Computer Corp.	± 0.2 °C	0.1 °C
Temperature Logger (Air) #TBI 32-20+70 StowAway TidbiT, Onset Computer Corp.	± 0.4 °C	0.1 °C

[4] e.g. – The temperature logger instrument accuracy is ±0.2°C. The mean pre-deployment calibration check difference is -0.19°C (meets instrument accuracy), and the mean of post-deployment calibration check difference is -0.23°C (fails instrument accuracy). Therefore a correction factor of +0.21°C is needed to correct the data for instrument bias (-19°C + (-0.23°C)/2).

Sampling bias is minimized by following the deployment procedures described in Ward (2003). These procedures specify site selection and deployment methods designed to ensure that the temperature logger results are representative of stream conditions throughout the entire monitoring period and not biased by the effects of solar radiation or low streamflow conditions.

Sampling Design

Study Area

The continuous temperature monitoring program is mostly limited to those basin or long-term stream monitoring stations (Figure 1) that are part of Ecology's statewide ambient stream monitoring program and, to a limited extent, to special request locations based on need and available resources. In 2001, 47 continuous temperature monitoring stations were established, in 2002 there were 53, and in 2003 there were 54. Refer to Table 4 for a breakout of the stations that were monitored during those years.

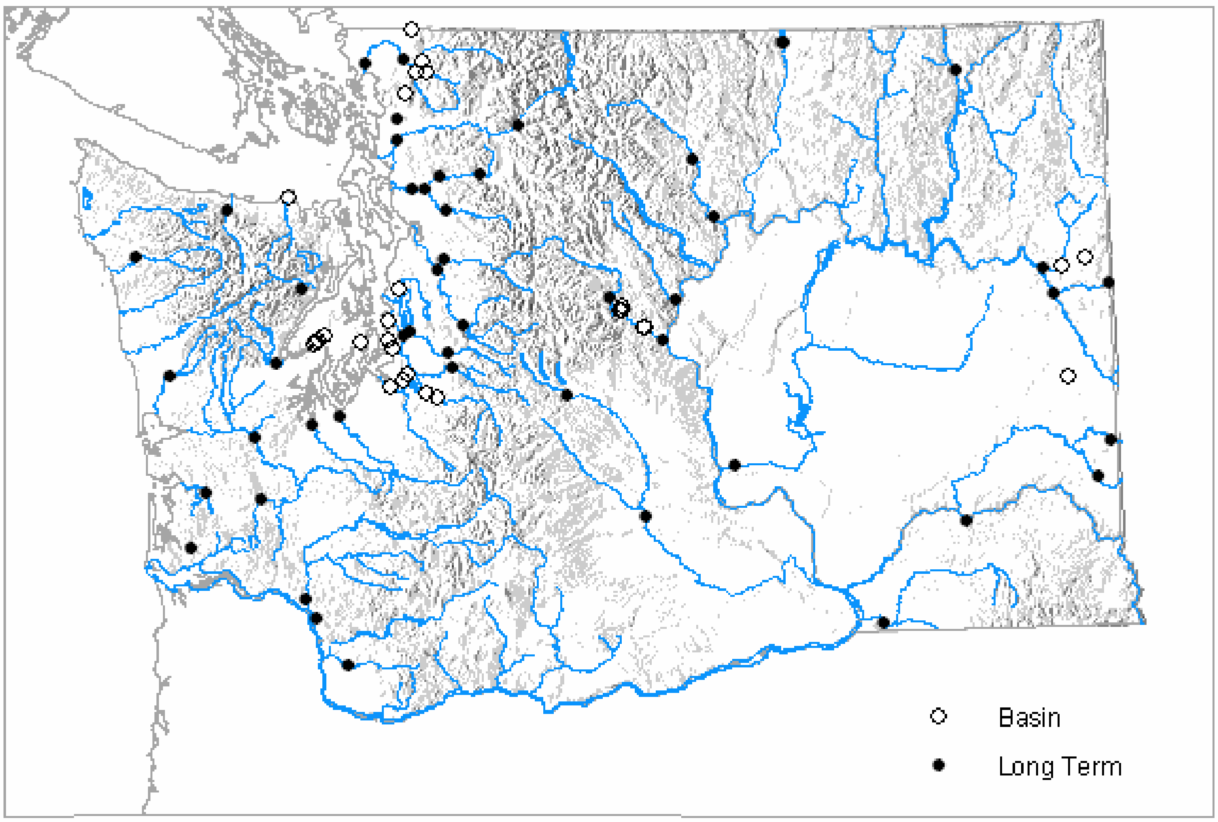

Figure 1. Continuous stream temperature monitoring stations, 2001-2004.

Table 4. Continuous stream temperature monitoring stations, 2001 – 2003.

Station	Station Name	2001	2002	2003		Station	Station Name	2001	2002	2003
01A050	Nooksack R. @ Brennan	X	X	X		18A050	Dungeness R nr mouth		X	X
01A120	Nooksack R @ No Cedarville	X	X	X		18B070	Elwha R nr Port Angeles	X	X	X
01A140	Nooksack R abv MF		X			20B070	Hoh R @ DNR Campground	X	X	X
01D080	Sumas R @ Jones Rd.		X			22A070	Humptulips R nr Humptulips	X	X	X
01F070	SF Nooksack R @ Potter Rd.		X			23A070	Chehalis R @ Porter	X	X	X
01G070	MF Nooksack R		X			23A160	Chehalis R @ Dryad	X	X	X
03B050	Samish R nr Burlington	X	X	X		24B090	Willapa R nr Willapa	X	X	
04A100	Skagit R @ Marblemount	X	X	X		24F070	Naselle R nr Naselle	X	X	X
05A070	Stillaguamish R nr Silvana	X	X	X		26B070	Cowlitz R @ Kelso	X	X	X
05A090	SF Stillaguamish R @ Arlington	X	X	X		27B070	Kalama R nr Kalama	X	X	X
05A110	SF Stillaguamish nr Granite Falls		X	X		27D090	EF Lewis R nr Dollar Corner	X	X	X
05B070	NF Stillaguamish R @ Cicero	X	X	X		32A070	Walla Walla R nr Touchet	X	X	X
05B110	NF Stillaguamish R nr Darrington	X	X	X		34A170	Palouse R @ Palouse	X	X	X
07C070	Skykomish R @ Monroe	X	X	X		34B110	SF Palouse R @ Pullman	X	X	X
07D050	Snoqualmie R nr Monroe	X	X	X		35B060	Tucannon R @ Powers	X	X	X
07D130	Snoqualmie R @ Snoqualmie	X	X	X		37A205	Yakima R @ Nob Hill	X	X	
08C070	Cedar R @ Logan St/Renton	X	X	X		39A090	Yakima R nr Cle Elum	X	X	X
08C110	Cedar R nr Landsburg	X	X	X		41A070	Crab Cr nr Beverly	X	X	X
09A090	Green R @ Tukwila		X			45A070	Wenatchee R @ Wenatchee	X		
09A190	Green R @ Kanaskat	X		X		45A110	Wenatchee R nr Leavenworth	X		
10A050	Puyallup R @ Puyallup		X	X		45C070	Chumstick Cr nr Leavenworth			X
10C085	White R nr Sumner		X			45D070	Brender Cr nr Cashmere			X
10C095	White R @ R Street		X	X		45E070	Mission Cr nr Cashmere			X
10C115	White R nr 274th Ave.		X			45Q060	Eagle Cr nr mouth			X
10C135	White R abv Rainier WWTP		X			45R050	No Name Cr nr Cashmere			X
11A070	Nisqually R @ Nisqually	X	X	X		46A070	Entiat R nr Entiat	X	X	X
13A060	Deschutes R @ E St Bridge	X	X	X		48A070	Methow R nr Pateros	X		X
15E070	Union R nr Belfair			X		48A130	Methow R nr Twisp	X	X	X
15G050	Little Mission Cr nr mouth			X		49A190	Okanogan R @ Oroville	X	X	X
15H050	Stimpson Cr @ Hwy 300			X		49B070	Similkameen R @ Oroville	X		X
15J050	Big Mission Cr @ Hwy 300			X		55B070	Little Spokane R nr mouth	X	X	X
15K070	Olalla Cr @ Forsman Rd			X		56A070	Hangman Cr @ mouth	X	X	X
16A070	Skokomish R nr Potlatch	X	X	X		57A150	Spokane R @ Stateline Br	X	X	
16C090	Duckabush R nr Brinnon	X	X	X		60A070	Kettle R nr Barstow	X	X	
							Total per Year	**46**	**53**	**54**

"X" indicates monitoring was conducted

The current design of Ecology's stream monitoring program includes 62 long-term stations, and 20 basin or regional stations.

Long-term stations were chosen to provide trend analysis and to immediately characterize water quality conditions (see the *Project Description* section). These stations were selected to:

- Monitor most major rivers in the state.
- Determine the water quality of the major rivers that enter the state.
- Detect trends of the effects of urban centers or land use activities.
- Describe natural occurring water quality conditions from the upper reaches of major rivers.

Basin stations were chosen to characterize water quality and to address specific needs for monitoring data. These stations were selected to:

- Support planned TMDL activities.
- Confirm suspected water quality problems.
- Determine sources of water quality degradation.
- Characterize water quality where not previously monitored.
- Support the waste discharge permitting process.

Stream stations must meet the following criteria before qualifying for temperature monitoring:

- Be located in a well-mixed location, as close to the thalweg as possible, where representative stream temperature data may also be obtained during the late summer low-flow period.
- Be unaffected by groundwater or tributary sources and about six inches off the streambed.
- Be well hidden to prevent loss to vandalism or damage.
- Be safe to access.

Representativeness

The data quality objective (DQO) for representativeness is to annually monitor as many of the statewide stream monitoring network stations and special request stations as feasible. Feasible stations are those that can be safely monitored following established protocols: *Continuous Temperature Sampling Protocols for the Environmental Monitoring and Trends Section* (Ward, 2003) and in the *TFW Stream Temperature Survey Manual* (Schuett-Hames et al, 1999).

The continuous temperature data collected may not be considered as representative of a watershed or the state as a whole, but will be considered as representative of the stream reach being sampled.

Comparability

All measurements and analytical procedures will be documented so that the data can be comparable with samples collected and analyzed in a like manner.

Completeness

The DQOs for completeness is a measure of the amount of valid data needed to meet the goals defined for the uses of the data. The goals for the collected data will be to (1) expand the interpretation of a station's monthly ambient monitoring results, (2) meet the purposes of TMDL studies, (3) determine compliance with proposed and current water quality standards, and (4) conduct trend analyses.

The use of continuous stream temperature data for TMDLs and water quality standards compliance is based on the ability to evaluate the temperature criteria defined by Washington's Water Quality Standards (Chapter 173-201A-200(1)(c) WAC). The temperature criteria established for protection of aquatic life is measured by the 7-day average of the daily maximum temperatures (7-DADMax). Assessing compliance with this standard may require that the 7-DADMax be calculated using the 7-day period that contains the maximum annual stream temperature.

The stream water temperature data may have periods of time with data gaps caused by instrument malfunction or from the probe being exposed to air when flows drop below the deployment location. If these data gaps exist, the continuous air temperature data collected from the station or a nearby one will be used to determine if the data gap occurred during the hottest time of the year. If the data gap spans the hottest time period, then the entire stream temperature data set may not be used for assessing standards compliance. However, if there are other periods of the year that also exceed the 7-DADMax, then the data set may be used for compliance assessment.

The assumption is that the highest annual stream temperature will coincide with the highest air temperature. This situation may also preclude use of the data set to determine that standards were met.

Sampling Procedures

The sampling protocols will follow the procedures described in the *Continuous Temperature Sampling Protocols for the Environmental Monitoring and Trends Section* (Ward, 2003) and in *the TFW Stream Temperature Survey Manual* (Schuett-Hames et al, 1999).

Water and air temperature loggers will be deployed in locations where representative temperature data may be obtained throughout the entire monitoring period. All loggers will be deployed inside a 2-2½ piece of 1½ inch camouflage-painted PVC pipe to shade them from sunlight and to prevent them from being found and vandalized. In addition, each deployment location will be photographed and have site-specific survey information documented on a standardized form.

Further, mid-deployment checks of the water temperature logger locations will rely heavily on the temperature and stream height results obtained by staff during ambient monitoring runs. The periodic checks may result in a temperature logger re-location to a greater depth.

Quality Control Procedures

The accuracy and instrument bias of each temperature logger is verified through both pre- and post-deployment calibration checks following the procedures described in Ward (2003) and in the Schuett-Hames et al. (1999).

If a recently retrieved temperature logger has a consistent bias of more than ± 0.2ºC, then the raw data may be adjusted or flagged with an appropriate data qualifier. If the pre- and post-deployment biases are not consistent, then the data may be adjusted or rejected.

Finalized station data will be validated by deleting the pre-deployment, post-deployment, and anomalous[5] data from the raw data set.

[5] An example is when dropping water levels expose a temperature logger. This is identified by reviewing a plot of the water and air temperature results. The pattern for water temperature will be erratic and will track the air results without a lag time.

Data Management Procedures

Data will be reviewed and entered into Ecology's FMU Access® Data Logger Database where results may be exported in Excel® files, text (.txt) files, and plots. The database also enables the exportation of annual station daily maximum, minimum, and mean data summaries into Ecology's Environmental Information Management (EIM) Database.

In addition, data summaries, 2-hour plots, and downloadable text files will be put on Ecology's Stream Monitoring Web page, www.ecy.wa.gov/programs/eap/fw_riv/rv_main.html.

Reports

A summary of the temperature logger results, methods, and data quality will be published in our Annual River and Stream Water Quality Report (e.g., Hallock, 2004).

Data Verification and Validation

The data will be verified and validated by following the procedures described in the *Continuous Temperature Sampling Protocols for the Environmental Monitoring and Trends Section* (Ward, 2003) and in the *TFW Stream Temperature Survey Manual* (Schuett-Hames et al, 1999). These procedures are summarized below:

- Calibration checks and field procedures will be documented on appropriate forms.
- Data will be checked for entry errors and completeness.
- Pre- and post-calibration check results and field measurements will be reviewed to ensure the data quality objectives were met.
- Results will be checked for reasonableness using data plots, field measurements, and stream height/flow information (if available).
- Detected data errors will be corrected, flagged with data qualifiers, or deleted.

Data Quality (Usability) Assessment

Stream temperature data that have met specified MQOs and passed data validation will be available to internal and external users. The data will be summarized and stored on Ecology's FMU web page, in Ecology's EIM database, and in Ecology's FMU Access® Data Logger Database. The data will also be summarized and compared to state water quality standards in our annual River and Stream Water Quality Reports (e.g., Hallock, 2004).

References

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