Quality Assurance Project Plan

Lower White River Temperature Study

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Introduction

The purpose of the Lower White River Temperature Study is to collect sufficient data for potential use in a predictive temperature model of the study area. If used, the model would help distinguish between temperature exceedences that occur naturally and those that occur due to various human activities. The temperature study will investigate current temperature conditions in and just upstream of the White River bypass reach and in its main tributary, Boise Creek, and evaluate the sources of heat.

The White River, located in the Puget Sound basin in western Washington, originates from glaciers on Mt. Rainier and empties into the Puyallup River to the west near Sumner, Washington. The study area extends approximately from river mile 25 to river mile 4 (Figure 1). The lower White River flows through lands of both the State of Washington and the Muckleshoot Indian Reservation, and it is on the list of impaired water bodies under section 303(d) of the federal Clean Water Act.

High temperature values, exceeding the water quality criterion of 18ºC, were measured in the lower White River in 1996 at multiple stations and sampling dates during the "Assimilative Capacity Study for Nutrient Loading in the Lower White River" (Erickson, 1999). In 2001, temperature excursions were recorded by Dept. of Ecology (Ecology) at the White River at R Street ambient monitoring station, 10C095, as well by the University of Washington (Stuart, 2002), Puget Sound Energy (2002) and the Puyallup Tribe of Indians (Ladley 2001).

State water quality standards for the White River apply to waters under the jurisdiction of the state of Washington. Waters within Muckleshoot Indian Reservation boundaries are not under the state's jurisdiction. The Muckleshoot Tribe is eligible to adopt tribal water quality standards; but they have not been established to date. The Puyallup Tribe has a treaty fishery on the White River, and the White River affects water quality downstream, within the Puyallup Reservation.

If surface water temperatures exceed state standards due to controllable anthropogenic factors, Ecology, the U.S. Environmental Protection Agency (EPA), the Muckleshoot Indian Tribe and the Puyallup Tribe of Indians will determine whether a Water Cleanup Plan is appropriate. Water Cleanup Plans, also known as Total Maximum Daily Loads (TMDLs) are required by the Clean Water Act when water quality does not meet standards after the application of technology-based controls (i.e., after pollutant sources have implemented the best available pollutant-control technology). TMDLs set limits for the pollutant that is causing water quality standards to be violated. A Water Cleanup Plan includes an implementation plan with recommended pollutant controls. Interested and affected parties have the opportunity to participate in development of the plan.

In addition to the data collected in this study, temperature is one of the parameters to be measured continuously by the U.S. Geological Survey, the Puyallup Tribe and Ecology Aug.-Oct. 2002 in a dissolved oxygen study of the lower White River (see http://www.ecy.wa.gov/programs/wq/tmdl/watershed/puyallup/index.html). Ecology also measures temperature once a month in the White River at R Street near Auburn (http://www.ecy.wa.gov/apps/watersheds/riv/station.asp?sta=10C095). Puget Sound Energy collects continuous water temperature data on the White River year-round (see Historical Data Review section on page 8). The Muckleshoot Indian Tribe plans to conduct its own temperature study on the White River in the summer of 2002 at sites not monitored by Ecology.

In a separate effort, the U.S. Forest Service, Ecology and the U.S. Environmental Protection Agency have been examining water quality and habitat conditions in the upper White River watershed. Ecology, the Puyallup Tribe, the U.S. Forest Service, Weyerhaeuser Company, the Muckleshoot Tribe, U.S. Geological Survey, Tahoma Audubon, and the Washington Dept. of Fish and Wildlife are cooperatively monitoring conditions there (see http://www.ecy.wa.gov/programs/wq/tmdl/watershed/whitervr.html).

Project Description

Study Area

The White River drains a 494 square-mile basin with a total length of 68 miles. Streamflow during the summer months is turbid due to the river's glacial origin, which accounts for the river's namesake color. Land use in the study area is mixed urban/residential (near Auburn, Sumner, Enumclaw, Buckley, highway corridors and surrounding Lake Tapps), agricultural (on the remaining uplands of the Enumclaw plateau), and forested (tree cover on the valley floor, upstream from Auburn, and throughout the upper watershed upstream of the study area). The area is experiencing rapid residential growth, generally into areas that were previously agricultural. The Muckleshoot Indian Reservation, shown in Figure 1, is located along the White River between river miles 16 and 9. (River miles used in this report are based on the catalog of Washington streams by the Department of Fisheries (Washington Department of Fisheries, 1975). The river miles are used as benchmarks for reference purposes, and may differ from other river mile measurements due to river channel changes, scale effects, and other factors.)

At river mile 24.3, Puget Sound Energy diverts a majority of the river flow to Lake Tapps for power generation, leaving a minimum flow of at least 250 cfs (June-Aug., below Boise Creek) in the mainstem until the water is returned at mile 3.5 (Figure 1). This stretch of the river is known as the "bypass reach." However, during a three week period in August 2002, the diversion will be shut down for flume maintenance, and the bypass reach will receive natural flows (usually closer to 850 cfs). The elevation at river mile 25 is about 700 feet and at river mile 3.5 it's approximately 50 feet.

The climate is typically maritime with cool dry summers and mild wet winters. During June-September, precipitation at Buckley averages 8.6 inches and temperature averages 61ºC. (Western Regional Climate Center *http://www.wrcc.dri.edu/index.html*). The valley broadens from 1/2 mile to 1 mile wide in the bypass reach as the river moves downstream, with steep forested hills rising 100 feet above the valley floor. The forests are dominated by deciduous trees (Washington Department of Fisheries, 1975).

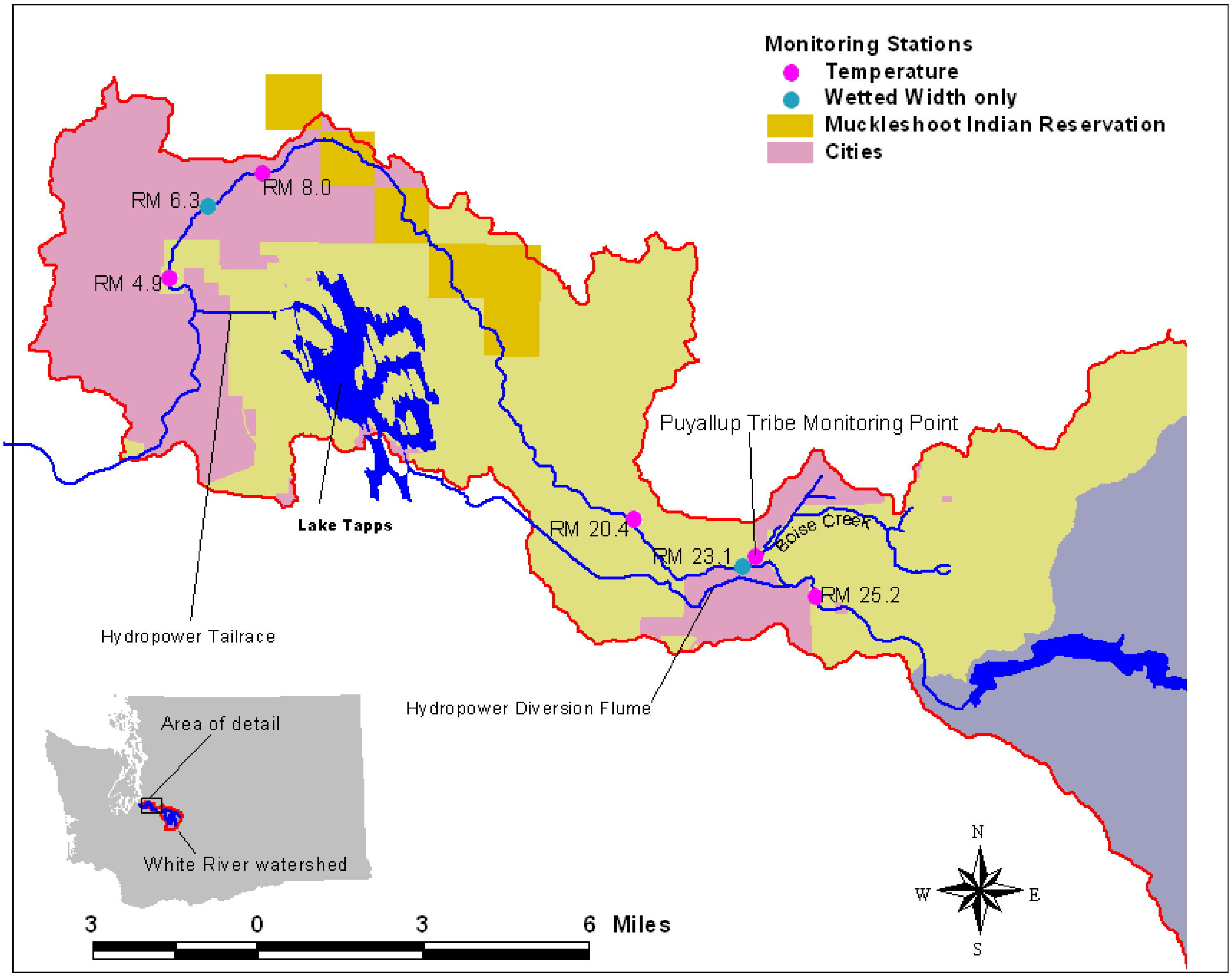

Figure 1. White River Temperature Study Area (modified from Stuart 2002)

Project Objectives

The project objectives are to:

1. Characterize summer water temperatures in the bypass reach of the White River during June through September.
    - Compile existing temperature data collected by Department of Ecology, the Puyallup Indian Tribe, the University of Washington and Puget Sound Energy, flow data from U.S. Geological Survey, groundwater inflow data from Ecology and river cross-sectional data from Puget Sound Energy.
    - Collect additional data from continuous temperature monitors in the White River and Boise Creek, air temperature monitors, relative humidity monitors, tributary surveys, and wetted width measurements at different flows.
    - Make a determination whether developing a temperature model for the study area would be useful and appropriate.

2. If appropriate, develop a predictive computer temperature model of the White River bypass reach.
    - Estimate shading from orthophotos and Geographic Information Systems data.
    - Model the study area temperature regime at critical conditions.
    - Evaluate the ability of flow, permitted discharges, and watershed Best Management Practices to reduce water temperatures to meet water quality standards.
    - Make a determination whether developing a TMDL for the study area would be useful and appropriate.

3. If appropriate, establish a Total Maximum Daily Load for temperature in the lower White River.
    - Develop a TMDL for thermal loads to the creek.
    - For nonpoint source loads, identify and recommend appropriate surrogates for solar radiation, such as flow and shading.
    - With involvement of the public, develop an implementation plan with recommended pollution controls.

Water Quality Standards and Beneficial Uses

The state portion of the White River in the study area is classified as Class A, “excellent” as defined by the Water Quality Standards for Surface Waters of the State of Washington (Chapters 173-201A-030 and 173-201A-120 WAC). Numeric freshwater quality criteria for Class A streams state that temperature shall not exceed 18.0°C due to human activities. When natural conditions exceed 18.0°C, no temperature increases will be allowed which will raise the receiving water temperature greater than 0.3°C. If natural conditions are below 18.0°C, incremental temperature increases resulting from point source activities at the mixing zone boundary shall not, at any time, exceed 28/(background temperature+7)°C. Incremental temperature increases from nonpoint source activities shall not exceed 2.8°C or bring the stream temperature above 18.0°C at any time (Chapter 173-201A-030 WAC).

Characteristic uses for Class A waters include water supply (domestic, industrial, and agricultural), stock watering, fish and shellfish (salmonid and other fish migration, rearing, spawning and harvesting), wildlife habitat, recreation (primary contact recreation, sport fishing, boating, and aesthetic enjoyment), and commerce and navigation.

Temperature is a water quality concern because most aquatic organisms, including salmonids, are “cold-blooded,” and are strongly influenced by water temperature (Schuett-Hames et al., 1999). Elevated temperature limits available spawning and rearing habitat for chinook salmon and other anadromous salmonids.

Temperature is a concern in the White River because of the use of its waters by chinook salmon, a species listed in 1999 as threatened under the Endangered Species Act, as a migration corridor and as spawning and rearing habitat. Of prime importance to the White River system is the White River spring chinook, the sole remaining spring chinook stock in South Puget Sound. The South Sound Spring Chinook Salmon Technical Committee (WDFW et al., 1996) reports that the

White River spring chinook are among the most depressed salmon stocks in the Pacific Northwest outside of the Columbia River Basin.

An adult chinook tracking study was conducted in 1996 by the Puyallup Indian Tribe (Ladley *et al*., 1996). This study found spawning areas in the upper range of the study area (upstream of river mile 21.0). Extended holding behavior was observed in the bypass reach at the Tacoma Public Utilities pipeline crossing (about 0.8 miles downstream of the diversion dam), and just below the diversion dam. This study did not address juvenile usage.

In addition to spring chinook, other important species of fish occur in the lower White River. According to the Salmon Habitat Limiting Factors Report (Washington Conservation Commission 1999) the following species use the White River bypass reach: coho, steelhead, spring and fall chinook, chum, cutthroat trout, bull trout, sockeye, and pink salmon. Most spawning occurred in the tributaries but spawner surveys found coho, chum, and chinook spawning in the mainstem White River.

Sources of Thermal Pollution

Many environmental variables affect water temperature, including: solar radiation, air temperature, stream width and depth, stream flow, and tributary and ground water influences (Brown, 1969). In the bypass reach of the lower White River, the river naturally becomes wider and shallower in a downstream direction, allowing increased exposure of the water to solar radiation. Most of the riparian corridor is forested. Anthropogenic sources of thermal pollution in this reach include:

1. Reduced flows. The largest reduction in flow in the study area is due to Puget Sound Energy's diversion of up to 2000 cfs near Buckley to Lake Tapps for hydropower generation. PSE is currently required to leave at least 250 cfs in the bypass reach, as measured at the USGS gage below Boise Creek, June-August, and 275 cfs in September. In addition, urbanization in some areas can potentially reduce baseflows which would otherwise help cool the river.

2. There are four point sources of wastewater in the study area that may discharge water warmer than the White River:
   - Rainier School wastewater treatment plant (RM 25)
   - White River Fish Hatchery (RM 24)
   - City of Enumclaw wastewater treatment plant (RM 23)
   - City of Buckley wastewater treatment plant (RM 22)

3. Boise Creek and numerous small tributaries, including a fish return flow from Puget Sound Energy's diversion flume, potentially could contribute water that is warmer than the White River. The tributaries may have reduced shading due to a loss of riparian vegetation. There also may be impacts from forest practices and development in the Upper White River Basin, (see http://www.ecy.wa.gov/biblio/0110038.html).

Historical Data Review

Department of Ecology

- In September and October, 1990, Ecology conducted a Total Maximum Daily Load study for Biochemical Oxygen Demand and Ammonia in the Puyallup basin, including the White River (Pelletier, 1993). Temperatures exceeding the water quality standard (18ºC) were measured on 9-18-90 (at River Miles 8 and 10.3), on 9-25-90 (at RM 4.9), and on 10-3-90 (at RMs 4.9 and 10.3). (See Appendix A for historical data.)

- Ecology conducted the "Assimilative Capacity Study for Nutrient Loading in the Lower White River" (Total Maximum Daily Load study for pH) in June-October 1996 (Erickson, 1999). Temperatures exceeding 18ºC were measured on 7-31-96 (at RM 14.9), on 8-22-96 (at RMs 6.3, 10.3 and 14.9), on 9-12-96 (at RMs 6.3 and 8.0) on 9-24-96 (at RM 4.9) and on 10-9-96 (at RM 4.9).

- Ecology has had an ambient water quality monitoring station at White River mile 8.0 since October, 1998. Sampling is conducted once a month for standard parameters, including temperature, pH, conductivity, dissolved oxygen, turbidity, total suspended solids, fecal coliform bacteria, and nutrients. Temperature exceedences were measured on 7-24-01 and 8-28-01.

University of Washington

- Under a contract with Ecology, the University of Washington Department of Civil and Environmental Engineering collected additional data related to the Total Maximum Daily Load study for pH from Sept. 2000 to Sept. 2001, at five sites in the bypass reach and one upstream site. Thermometer readings on several field visits exceeded 18ºC in July and August 2001. There were excursions at RM 6.3 on July 3 and July 30, RM 8.0 on July 3, 11, 30 and Aug. 20, and at RM 16.4 on July 3 and July 8, 2001. Hydrolabs were deployed for several days at a time at two stations and measured excursions at RM 8.0 on July 3-8, 12-13, 20, 23-27, 30, Aug. 14 and Sept. 2, 2001. At RM 16.4, the hydrolab recorded excursions on July 3-4, 23, 25 and Aug. 14, 2001.

Puyallup Tribe of Indians

- The Puyallup Tribe measured temperature using a continuous On-set Optic Stow Away data logger July 8 - October 9, 2001 on the White River at RM 4.9. The data logger recorded temperature every 30 minutes. Ecology analyzed the data for maximum daily temperatures (Table 1). Temperature excursions were recorded for 50% of the days in the study period and 13.6% of the hours at RM 4.9. The Puyallup Tribe also used a data logger July 4-Sept. 27 at White River mile 38 and recorded maximum water temperatures above 16ºC (the water quality standard for the upper White River) on July 4 and 5, 2001.

Table 1. Maximum temperatures at White River mile 4.9 July 8 - October 9, 2001 (Puyallup Tribe data). Bolded numbers do not meet water quality standards.

Date	T ºC
7/8/01	**21.74**
7/9/01	**22.57**
7/10/01	**22.57**
7/11/01	**22.57**
7/12/01	**22.41**
7/13/01	**20.43**
7/14/01	**19.94**
7/15/01	16.72
7/16/01	14.67
7/17/01	14.99
7/18/01	16.88
7/19/01	**19.13**
7/20/01	**19.13**
7/21/01	**19.13**
7/22/01	18
7/23/01	**21.08**
7/24/01	**21.08**
7/25/01	**21.24**
7/26/01	**21.24**
7/27/01	**19.94**
7/28/01	**18.32**
7/29/01	17.52
7/30/01	**18.64**

Date	T ºC
7/31/01	**18.64**
8/1/01	17.52
8/2/01	**19.29**
8/3/01	**18.81**
8/4/01	17.84
8/5/01	17.84
8/6/01	**19.29**
8/7/01	**20.27**
8/8/01	**20.27**
8/9/01	**20.76**
8/10/01	**20.92**
8/11/01	**21.08**
8/12/01	**20.76**
8/13/01	**20.76**
8/14/01	**20.11**
8/15/01	**18.81**
8/16/01	18
8/17/01	17.2
8/18/01	17.36
8/19/01	**18.48**
8/20/01	**18.32**
8/21/01	18
8/22/01	15.14
8/23/01	15.62

Date	T ºC
8/24/01	17.52
8/25/01	**18.48**
8/26/01	**18.97**
8/27/01	**18.97**
8/28/01	**19.46**
8/29/01	**19.29**
8/30/01	**19.46**
8/31/01	**19.62**
9/1/01	**18.64**
9/2/01	**18.16**
9/3/01	**18.16**
9/4/01	17.2
9/5/01	16.72
9/6/01	15.31
9/7/01	17.04
9/8/01	17.68
9/9/01	17.68
9/10/01	17.36
9/11/01	17.68
9/12/01	**18.32**
9/13/01	**18.48**
9/14/01	**18.64**
9/15/01	**18.97**
9/16/01	**18.81**

Date	T ºC
9/17/01	14.67
9/18/01	14.52
9/19/01	15.94
9/20/01	15.46
9/21/01	15.46
9/22/01	16.88
9/23/01	17.68
9/24/01	17.52
9/25/01	15.62
9/26/01	14.21
9/27/01	13.13
9/28/01	13.74
9/29/01	13.59
9/30/01	13.43
10/1/01	13.74
10/2/01	14.21
10/3/01	14.05
10/4/01	13.43
10/5/01	13.28
10/6/01	13.13
10/7/01	12.51
10/8/01	12.35
10/9/01	12.04

Puget Sound Energy

- Puget Sound Energy (PSE) has been recording temperatures using continuous On-set Optic Stow Away data loggers at several locations in the White River since 1-25-2000, as required by the Federal Energy Regulatory Commission (FERC). The data is recorded hourly and the instruments are downloaded twice a year (occasionally there are data gaps due to displaced or unrecoverable loggers). Maximum, minimum and mean temperatures for each date and station are reported to FERC semi-annually (FERC Project No. 2494). There are two monitoring sites above the diversion, two in the bypass reach (near RM 24 and RM 4), two downstream of the tailrace, one in the tailrace, one in Boise Creek and two in side channels. Maximum temperatures (and some mean temperatures) above water quality standards were recorded at RM 4.0 June 25-29, 2000, July 5-7, July 12-Aug. 9, 2000, Aug. 12-13, 14-17, and 21, 2000. No data is available from RM 4 after August 22 for the year 2000, and the instruments at RM 4 and RM 0.5 were apparently buried or malfunctioning June-August 20, 2001. Temperature excursions were recorded Aug. 25-31, Sept. 2 and Sept.12-15, 2001 at RM 4. There were also excursions recorded downstream of the tailrace at RM 0.5 in July and August 2000, and in late August 2001 (Puget Sound Energy, 2001 and 2002).

- Puget Sound Energy measured various parameters continuously, including temperature in the White River August 22-October 16 as part of a water right application for the Lake Tapps Reservoir (HDR Engineering, Inc., 2001). Hydrolabs recording at 30 minute intervals were used at RM 4.9 and in the tailrace. Temperature excursions were recorded for Aug. 26-31 and Sept. 2 and 12-15, 2001 at RM 4.9.

- Puget Sound Power and Light Company, which later became PSE, collected cross-section data at five sites in the bypass reach at three different flows in 1985-1986 to support its FERC license application. Cross-section information and velocity data are available for river miles 4.3, 6.0, 10.0, 13.8 and 21.2 (Puget Sound Power and Light Company, August 1987).

Study Design

Heat Energy Processes

Heat energy processes that control energy transfer to and from a given volume of water include:

- ♦ Shortwave solar radiation.
- ♦ Longwave radiation exchange between the stream and both the adjacent vegetation and the sky.
- ♦ Evaporative exchange between the stream and the air.
- ♦ Convective exchange between the stream and the air.
- ♦ Conduction transfer between stream and the streambed.
- ♦ Groundwater exchange with the stream (Adams and Sullivan, 1989).

If the heat energy entering the water from these sources is greater than the heat energy leaving the water, then stream water temperature will rise. Water temperature change, which is an expression of heat energy exchange per unit volume, is most strongly influenced by solar radiation input (Adams and Sullivan, 1989).

Increased solar radiation levels at the stream surface due to anthropogenic causes result from the following conditions:

- ♦ Reduced summertime baseflows resulting from instream withdrawals, wells in hydraulic continuity with the stream, or altered stream flow patterns due to land use practices that increase runoff instead of storage and/or natural conditions.
- ♦ Channel widening (increased width-to-depth ratios) that increases the stream surface area exposed to energy processes.
- ♦ Riparian vegetation disturbance that reduces stream surface shading through reductions in riparian vegetation height and density (shade is commonly measured as percent effective shade).

Model Data Requirements

The preferred water temperature model for the lower White River is QUAL2K (Chapra, 2001). Data collection, compilation, and assessment will be governed by the data set requirements of the model (Table 1).

Table 2. Dataset requirements of computer temperature model.

	PARAMETER	Qual2K	USGS	Ecology	PSE	Puy. Tribe	NOAA/WRCC
Flow	discharge - tributary	x	x	x			
	discharge (upstream & downstream)	x	x				
	flow regression constants	x					
	flow velocity	x					
	groundwater inflow rate/discharge	x		x			
	travel time	x					
General	calendar day/date	x					
	duration of simulation	x					
	elevation - downstrean	x	x				
	elevation - upstream	x	x				
	elevation/altitude	x	x				
	latitude	x	x				
	longitude	x	x				
	time zone						
Physical	channel azimuth/stream aspect						
	cross-sectional area	x			x		
	Manning's n value	x					
	percent bedrock	x					
	reach length	x					
	stream bank slope						
	stream bed slope	x					
	width - bankfull						
	width - stream	x	x				
	effective shade	x					
Temperature	temperature - ground	x					
	temperature - groundwater	x					
	temperature - water downstream	x	x	x		x	
	temperatures - water upstream	x	x	x		x	
	temperature - air	x		x			
	thermal gradient	x					
Weather	relative humidity	x		x			x
	% possible sun/cloud cover	x					x
	solar radiation	x					x
	temperature - air	x		x			x
	wind speed/velocity	x					x

Qual2K - temperature model
USGS - United States Geological Survey
Ecology - Washington State Department of Ecology
PSE - Puget Sound Energy
Puy. Tribe - Puyallup Tribe of Indians
NOAA/WRCC - National Oceanic and Atmospheric Administration/Western Regional Climate Center

Data Collection and Surveys

Field surveys will include temperature and relative humidity monitoring, wetted width measurements and flow monitoring. (See Figure 1 on page 5 for monitoring locations.)

The preparation, installation and downloading of temperature data loggers will follow those protocols described in the TFW Temperature Stream Survey Manual (Schuett-Hames et al., 1999). Temperature data loggers will be installed in the water and air in areas which are representative of the surrounding environment interacting with the stream, and are shaded from direct sunlight. Relative humidity data loggers will be installed near two of Ecology's water temperature stations and at one site selected by the Muckleshoot Indian Tribe. Data from the loggers will be downloaded when they are retrieved in October.

Table 3. Temperature and Relative Humidity Monitoring Sites

Site Name and Description	White River River Mile	Types of Monitors	Monitoring Agency
White River near Sumner at 8th Street Bridge	4.9	Water, Air/RH	Ecology
White River at "R" Street in Auburn	8.0	Water, Air	Ecology
White River at RM 8.9	8.9	Air/RH	Muckleshoot Indian Tribe
White River at 274th Ave. E. and 80th St. E	20.4	Water, Air	Ecology
Boise Creek mouth in Enumclaw	near 23.31	Water, Air	Puyallup Tribe
White River above Rainier School Sewage Treatment Plant	25.2	Water, Air/RH	Ecology

Wetted width measurements of the White River will be taken approximately once a month throughout the study period, using a laser range finder (Ecology will use an Impulse Rangefinder Model 200 by Laser Technical Inc.) Measurements will be taken where temperature data loggers have been deployed and at additional points along the bypass reach where there is access. The goal will be to measure stream width at a variety of flows, and to correlate the measurements with flow data from USGS gages.

Table 4. Wetted Width Measurement Stations on the Lower White River

Station Name	White River River Mile
White River near Sumner at 8th Street Bridge	4.9
White River near Auburn at A St.	6.3
White River at "R" Street in Auburn	8.0
White River at 274th Ave. E. and 80th St. E	20.4
White River at Hwy 410 at Buckley (below Boise Cr.)	23.3
White River above Rainier School STP	25.2

U.S. Geological Survey gages on the White River will be relied on for flow measurements of the mainstem and Boise Creek, the only major tributary to the bypass reach.

Table 5. USGS Gages on the Lower White River and Boise Creek

Station Number	Station Name	White River River Mile
12100496	White River near Auburn (in bypass reach)	6.3
12100000	White River at Buckley (in bypass reach)	23.3
12099600	Boise Creek at Buckley (tributary to bypass reach)	near 23.31
12098500	White River near Buckley (upstream of bypass reach)	27.9

Stream velocity measurements of tributaries to the bypass reach other than Boise Creek, with flow rates of more than 1 cfs, will be made monthly, July-Sept. The results from a July 18, 2001 synoptic survey of White River tributaries, conducted by the University of Washington to supplement the White River nutrient study, will be used to select candidate streams for flow monitoring. The U.W. survey estimated flows of 1.6 cfs in Bowman Creek and 1.2 cfs in Tributary 4 near Enumclaw, using a floating cork and assumptions regarding the stream profiles. The same study measured a flow of 0.6 cfs in U.W. Tributary 1 west of Enumclaw, using a velocity meter.

Table 6. Tributaries to be monitored for flow using field measurements

Station Name	White River River Mile
Bowman Creek southwest of "R" Street Bridge in Auburn	8.0
U.W. Tributary 1, SW of the west end of SE 432nd St., west of Enumclaw	16.6
Tributary 4 southwest of 220th Ave SE and SE 464th St. near Enumclaw	20.41

Table 7. 2002 Field Schedule

Data logger deployment, wetted width measurements	Ecology	mid-June
Data logger deployment	Puyallup Tribe	mid-June
Synoptic survey of tributaries, mainstem wetted width measurements	Ecology, Muckleshoot Indian Tribe	mid-July
Synoptic survey of tributaries, mainstem wetted width measurements	Ecology	mid-August
Synoptic survey of tributaries, mainstem wetted width measurements	Ecology	mid-September
Retrieve data loggers	Ecology	late September/ October
Retrieve data loggers	Puyallup Tribe	October

Department of Ecology will use a Marsh-McBirney flow meter and the Muckleshoot Indian Tribe will use a Swaffer Flow Meter for the tributary measurements. Both instruments will be adjusted according to manufacturer instructions and used side by side at one stream for comparison purposes. Field crews will use the TFW Monitoring Program method manual for the wadable stream discharge measurement (Pleus, 1999). During streamflow sampling, temperature will be measured with a thermometer calibrated to a certified reference thermometer. If a tributary has a streamflow on the July 2002 sampling date of less than 1 cfs, it will not be monitored in August or September 2002.

Project Organization

The roles and responsibilities of staff involved in this project are provided below:

Jeannette Barreca *(Temperature Study Project Lead, Water Quality Program, Southwest Regional Office)*: Responsible for managing temperature study and data collection, and for writing QAPP. Defines project objectives, scope, and study design and coordinates between Ecology programs and cooperating agencies. Coordinates local outreach.

William Ward *(Temperature Monitoring Lead, Environmental Assessment Program)*: Responsible for continuous monitor deployment and data quality review for Dept. of Ecology. Responsible for temperature data logger initial calibration and post-retrieval calibration.

Anise Ahmed *(Technical Review and Analysis, Water Quality Program, Southwest Regional Office)*: Reviews and comments on QAPP, manages data analysis and potential modeling.

Anita Stohr and Greg Pelletier *(Technical Advice, Environmental Assessment Program)*: Provide technical assistance for study design and potential modeling.

Joanne Schuett-Hames and Roberta Woods *(Water Quality Program, Southwest Regional Office)*: Provide assistance with flow and temperature monitoring of significant tributaries, and with data analysis.

Craig Graber, Cindy James and Glenn Pieritz *(Water Quality Program, Southwest Regional Office)*: Responsible for collection of wetted width data for Dept. of Ecology.

Kelly Susewind *(Water Quality Program, Southwest Regional Office)*: Responsible for approval of Project QAPP and technical report.

Nancy Rapin and Joseph Simmons *(Muckleshoot Indian Tribe)*: Responsible for data collection for Muckleshoot Indian Tribe, including relative humidity/air temperature continuous monitor deployment and joint flow monitoring with Ecology of significant tributaries.

Char Naylor and Mary Brown *(Puyallup Tribe of Indians)*: Responsible for data collection for Puyallup Tribe, including continuous monitor deployment for Boise Creek and data quality review.

Data Quality Objectives

Accuracy objectives for field measurements are presented in Table 8. Experience at the Department of Ecology has shown that duplicate field thermometer readings consistently show a high level of precision, rarely varying by more than 0.2°C. Therefore, replicate field thermometer readings were not deemed to be necessary and will not be taken. Accuracy of the thermograph data loggers and the field thermometers will be maintained through pre-and post-calibration in accordance with TFW stream temperature survey protocol to document instrument bias and performance at representative temperatures. A certified reference thermometer will be used for the calibration. The reference thermometer, manufactured by HB Instrument Co. (part No. 61099-035, serial No. 2L2087), is certified to meet ISO9000 standards and calibrated against National Institute of Standards and Technology (NIST) traceable equipment. The field thermometers Ecology uses are Brooklyn Alcohol Thermometers (Part No. 3546 RL). If there is a temperature difference of greater than 0.2° C, the field thermometer's temperature readings will be adjusted by the mean difference.

Manufacturer specifications report an accuracy of ± 0.2° C for the Onset Stowaway Tidbit (-5° C to + 37° C). If the mean difference between the NIST thermometer and the thermal data loggers differs by more than the manufacturer's reported specification, the thermal data logger will not be used during fieldwork.

Representativeness of the data is achieved by a sampling scheme that accounts for variation of instream flow and temperatures in this reach and flow contribution of tributaries.

Table 8. Summary of field measurements, target accuracy or reporting values, and methods.

Parameter	**Accuracy or Reporting Values**	**Method**[1]
Temperature	Air ± 0.4°C Water ± 0.2°C	Thermograph
Wetted Width		Laser Range Finder
Velocity	± 2% of reading	Marsh-McBirney model 2000 flow meter

[1]Method references: Schuett-Hames et al., 1999; WAS, 1993

Measurement and Sampling Procedures

Field sampling and measurement protocols will follow those described in the TFW Temperature Stream Survey Manual (Schuett-Hames, 1999) and the WAS protocol manual (WAS, 1993). Temperature monitors will be installed in the water and air in early June in areas which are representative of the surrounding environment and are shaded from direct sunlight. Data from the loggers will be downloaded following retrieval in early fall.

Quality Control Procedures

Variation for field sampling will be addressed with a field check of the instruments with a hand held thermometer at all thermograph sites upon deployment and retrieval. Field measurements will also be taken during monthly wetted width measurements. Field sampling and measurements will follow quality control protocols described in the WAS protocol manual (WAS 1993) and the TFW Stream Temperature Survey Manual (Schuett-Hames et al., 1999). The Onset Stowaway Tidbits will be pre- and post-calibrated in accordance with TFW Stream Temperature Survey protocol to document instrument bias and performance at representative temperatures. A certified reference thermometer will be used for the calibration. At the completion of the monitoring, the raw data will be adjusted for instrument bias, based on the pre- and post-calibration results, if the bias is greater than ±0.2°C (Schuett-Hames et. al, 1999).

Data Analysis and Modeling Procedures

From the raw data collected at each monitoring location the maximum, minimum, and daily average will be determined. The data will be used to characterize the water temperature regime of the basin and to determine periods when the water temperatures are above state numeric water quality standards (18°C).

If appropriate, a model will be developed for observed and critical conditions. Critical conditions for temperature are characterized by a period of low flow and high water temperatures. The model potentially will be used to develop load and wasteload allocations for heat energy to the stream. Sensitivity analysis will be run to assess the reliability of the model results.

Data collected during this study will allow for the development of a temperature simulation methodology that is both spatially continuous and which spans full-day lengths. If appropriate, the GIS and modeling analysis will be conducted using the QUAL2K model (Chapra, 2001) to calculate the components of the heat budget and simulate water temperatures. QUAL2K simulates diurnal variations in stream temperature for a steady flow condition. QUAL2K will be applied by assuming that flow remains constant for a given condition such as a 7-day or 1-day period, but key variables are allowed to vary with time over the course of a day. For temperature simulation, the solar radiation, air temperature, relative humidity, headwater temperature, and tributary water temperatures are specified or simulated as diurnally varying functions. QUAL2K uses the kinetic formulations for the components of the surface water heat budget that are described in Chapra (1997). The water temperature model will be calibrated to in-stream temperature data from the mainstem and tributaries.

At this point Qual2K is the preferred tool to model temperature, and can be used for other parameters. So using Qual2K provides the opportunity to incorporate temperature modeling with other modeling efforts.

If appropriate, heat loads to the stream will be calculated in a numerical model that accounts for surface heat flux and mass transfer processes. Because heat loads are of limited value in guiding management activities needed to solve identified water quality problems, instream flow will be used as a surrogate to thermal load. Other factors influencing the distribution of the solar heat load will also be assessed, including tributary discharges, point source discharges, and shade (estimated from orthophotos and GIS data).

Reporting Schedule

The results of the temperature study will be published on-line, on Ecology's web site, http://www.ecy.wa.gov/, by January 2003. If modeling is conducted, those results and a technical report will also be available on-line after approval from the agencies involved.

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