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Little Klickitat River Temperature Total Maximum Daily Load

Quality Assurance Project Plan

by
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Environmental Assessment Program
Olympia, WA 98504

1998 303(d) listings addressed in this study:

Waterbody	T	R	S	new ID	old WBID	Parameter
Butler Creek	05N	17E	17	YU86SG	WA-30-1029	Temperature
Little Klickitat River	04N	14E	09	AY21LB	WA-30-1020	Temperature
Little Klickitat River, East Prong	06N	17E	35	PU81CT	WA-30-1028	Temperature
Little Klickitat River, East Prong	05N	17E	10	PW77VQ	WA-30-1028	Temperature
Little Klickitat River, East Prong	05N	17E	03	PW77VQ	WA-30-1028	Temperature
Little Klickitat River, East Prong	05N	17E	09	PW77VQ	WA-30-1028	Temperature
Little Klickitat River, East Prong	05N	17E	16	AG85MX	WA-30-1028	Temperature
Little Klickitat River, West Prong	05N	17E	18	XU61EK	WA-30-1027	Temperature

Approvals

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Introduction

The Little Klickitat River Basin is located in south-central Washington State. It flows from the southwest flank of the Simco Mountains, west across the Munson Prairie and through the Little Klickitat canyon to its confluence with the Klickitat River. Ecology's assessment of the Klickitat/Horseheaven Watershed identified the system as a high priority for development of a Temperature Total Maximum Daily Load (TMDL). The purpose of the Little Klickitat River Temperature TMDL is to characterize the water temperature in the basin and establish load and wasteload allocations for the heat sources to meet water quality standards for surface water temperature. This study was initiated because of the 303(d) listings of river segments in the Little Klickitat Watershed which are water quality limited for temperature.

In total the Little Klickitat River has 14 water quality impaired sections. Table 1 provides a list of all river segments and corresponding parameters identified as limited according to the Water Quality Standards for Surface Waters of the State of Washington (segments listed for temperature are shown in italics). Temperature problems in the basin may or may not be limited to the 8 segments reported on the 303(d) list; therefore, this study concentrates not only on the temperature problems of the 8 listed segments but those in the entire Little Klickitat Watershed as well. Because instream flow is not considered a "pollutant," load allocations will not be developed. However, flow does impact temperature and this study will evaluate its effect on temperature.

Table 1. 303(d) Listings for the Little Klickitat River basin (segments listed for temperature are shown in italics)

Name	T	R	S	Parameter	Medium	Action?	96list?	98list?
Butler Creek	*05N*	*17E*	*17*	*Temp*	*Water*	*TMDL*	*yes*	*yes*
East Prong	*06N*	*17E*	*35*	*Temp*	*Water*	*TMDL*	*yes*	*yes*
East Prong	*05N*	*17E*	*10*	*Temp*	*Water*	*TMDL*	*yes*	*yes*
East Prong	*05N*	*17E*	*03*	*Temp*	*Water*	*TMDL*	*yes*	*yes*
East Prong	*05N*	*17E*	*09*	*Temp*	*Water*	*TMDL*	*yes*	*yes*
East Prong	*05N*	*17E*	*16*	*Temp*	*Water*	*TMDL*	*yes*	*yes*
Little Klickitat River	*04N*	*14E*	*09*	*Temp*	*Water*	*TMDL*	*yes*	*yes*
West Prong	*05N*	*17E*	*18*	*Temp*	*Water*	*TMDL*	*yes*	*yes*
Blockhouse Creek	04N	15E	17	Instream Flow	Habitat	Other Control	yes	yes
Bloodgood Creek	04N	16E	17	Instream Flow	Habitat	Other Control	yes	yes
Bowman Creek	05N	14E	35	Instream Flow	Habitat	Other Control	yes	yes
Little Klickitat River	04N	15E	28	Instream Flow	Habitat	Other Control	yes	yes
Little Klickitat River	04N	14E	09	Instream Flow	Habitat	Other Control	yes	yes
Mill Creek	04N	15E	05	Instream Flow	Habitat	Other Control	yes	yes

Project Description

Study Area

The Little Klickitat Watershed (Figure 1), a sub-basin of the Horseheaven/Klickitat Watershed, encompasses approximately 285 square-miles and falls solely in Klickitat County and the Central Klickitat Conservation District. Land ownership in the basin is a mix of private (logging companies/land holders), city (Goldendale), state (DNR), federal (BLM), and tribal land (Yakama Nation). The elevation ranges from 600 feet at the confluence with the Klickitat River to 5823 feet at Indian Rock. Land use in the area is comprised of agriculture (farming and ranching) in the lower elevations, forestry/timber management and limited mining in the upper elevations, and urban lands around the city of Goldendale. Most of the timberlands are currently leased for grazing. The higher elevation range areas are grazed in summer by cattle and during spring through fall by elk and deer (Clayton, 1999a; Clayton, 1999b; Raines et al., 1999; Cusimano 1993).

Two-thirds of the upper watershed is privately owned timber land. These forested lands are addressed under the Forests and Fish Report, which prescribes Forest Practice Board (FPB) regulations to private land owners for attainment of water quality standards. The agreement, included in the Forests and Fish Report, offers the assurance that lands regulated under FPB regulations do not require development of TMDLs prior to July 1, 2009. However, "if a TMDL is produced in mixed use watersheds, and if achievement of the TMDL load allocations cannot be met through the forest practices regulations, the adjustment of those management practices will be through adaptive management as contained in the Adaptive Management appendix of the Report." Over the long term, failure of adaptive management to meet CWA goals is a potential for withdrawal of the assurance (DNR, 1999).

The climate in the basin is characteristic of eastern Washington, consisting of warm, dry summers and cold winters with the majority of the precipitation falling from November to March. Snowmelt, surface runoff and groundwater feed the Little Klickitat and its tributaries. The mainstem of the Little Klickitat River begins with the convergence of the West Prong and East Prong Little Klickitat River at river mile (RM) 25.7. The river flows southwesterly across the Munson Prairie to the eastern edge of the town of Goldendale at RM 16.3. At RM 14.1, the river passes the outfall of the Goldendale Wastewater Treatment Plant (WWTP). The outfall pipe is the outlet of the lagoon settling ponds of the WWTP. Effluent is typically only released during high flow periods (Joy, 1985). From Goldendale the river continues westerly to RM 8.3 where it enters a 4.5-mile long canyon area, which acts to cool the warm water, before bending northwesterly and flowing to its confluence with the Klickitat River (RM 19.8) north of Wahkiacus. Principle tributaries to the Little Klickitat River include Butler Creek (RM 26), Jenkins Creek (RM 20.2), Bloodgood Creek (RM 14.9), Spring Creek (RM 8.6), Blockhouse Creek (RM 6.3), Mill Creek (RM 3.6), Bowman Creek (RM 1.2) and Dry Canyon Creek (RM 1.2) (Caldwell and Hirschey, 1990).

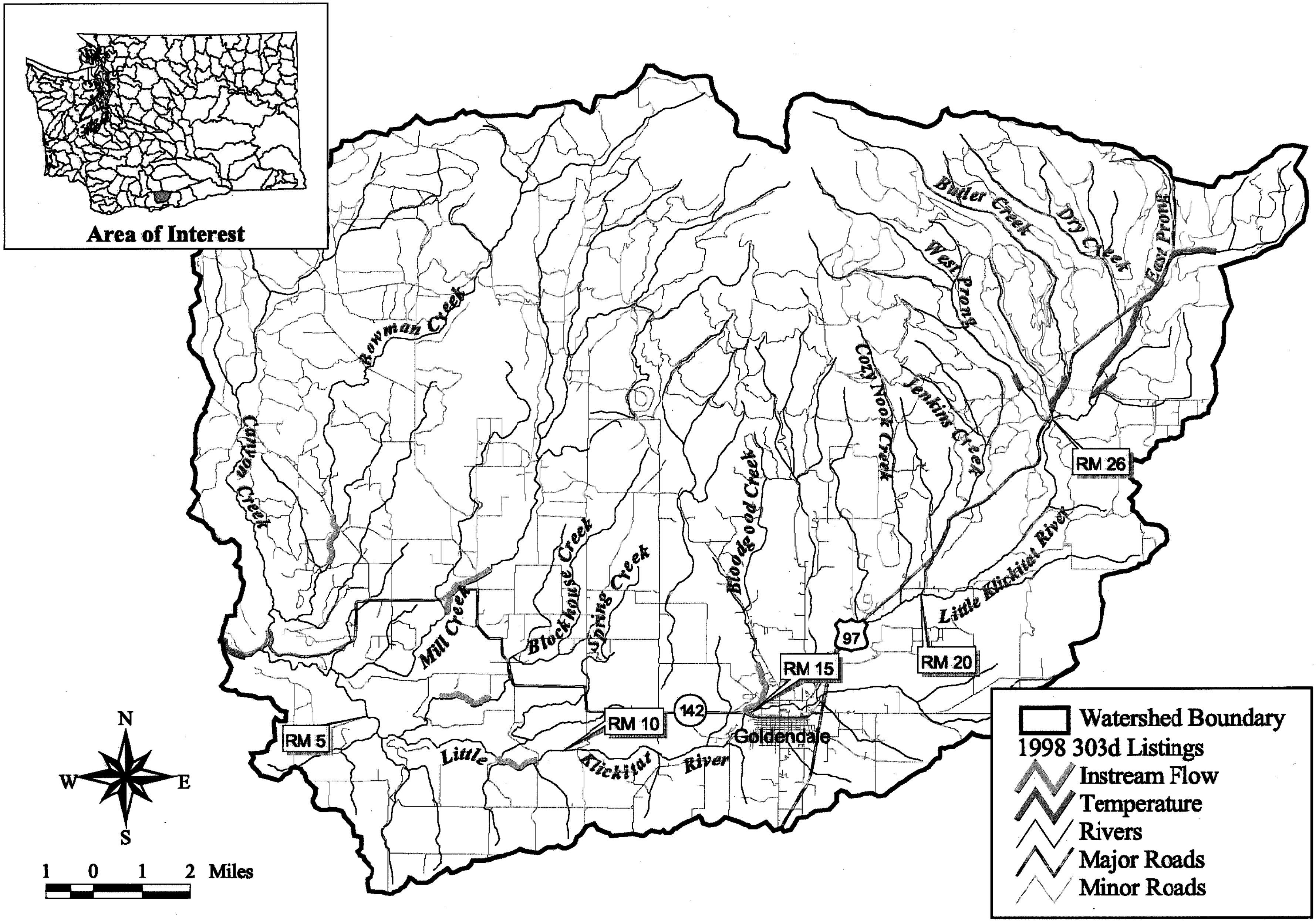

Figure 1. Little Klickitat River Temperature TMDL Study Area (WRIA 30)

Project Objectives

1. Characterize summer (June – October) water temperature in the Little Klickitat Watershed.
   - Compile existing data, including:
     - Data collected during an ongoing study performed by the Central Klickitat Conservation District.
     - Data collected by the Yakama Nation Fisheries.
     - Data collected during the upper Little Klickitat Watershed Analysis prepared for Boise Cascade Corporation.
   - Collect additional data at selected sites throughout the basin.

2. Develop a predictive computer temperature model of the Little Klickitat stream network.
   - Model the basin temperature regime at critical conditions.
   - Evaluate the ability of various watershed Best Management Practices (BMPs) to reduce water temperatures to meet water quality standards.

3. Establish a Total Maximum Daily Load for temperature in the Little Klickitat Watershed.
   - Develop TMDL for thermal load to the stream (expressed as incoming solar radiation in units of joules/meter^2/second).
   - For ease of implementation, load allocations will be reported in terms of a surrogate for solar radiation such as shade, size of tree necessary in the riparian zone to produce adequate shade, channel width, channel width-to-depth ratio, or miles of active eroding stream banks.

Sources of Thermal Pollution

The Goldendale Wastewater Treatment Plant (WWTP) produces the only known point source of thermal pollution in the basin. During a 1985 low-flow survey study the WWTP discharged to the river at a mean temperature of 19.5°C; however, generally discharge occurs during high instream flows. The Goldendale WWTP outfall, located at RM 14.1, is permitted to discharge into the river at a minimum river-to-effluent dilution ratio of 20:1. If the minimum dilution ratio prevents discharge, well water is pumped by the city into the river at a rate equal to the diverted effluent (Joy, 1986). It can be spray- irrigated onto nearby fields or stored in lagoons for later discharge into the river during higher in-stream flows (Joy, 1985).

Sources of nonpoint thermal pollution are:
- Riparian vegetation disturbance and loss of shade due to:
  - Removal of trees and shrubs for pasture, crops, or timber harvest.
  - Heavy grazing by livestock.
  - Conversion from forest to pasture land.
- Channel morphology impacts resulting from:
  - Removal of large woody debris by commercial harvest and agriculture.
  - Increased sediment loading from agriculture, timber harvest, and roads.
  - Channel constraint/diking for agriculture and flood control.

- Bank instability/erosion and sedimentation from removal of root structure and increased land use practices in the watershed.
- Hydrologic changes from:
  - Extraction of water for irrigation or other purposes.
  - Altered stream flow patterns from urbanized and timber harvest areas resulting in increased spring runoff and decreased summertime base flows.

These activities potentially raise the water temperature of rivers due to increased solar input resulting from lack of shade along streams, reduction of river water volume from withdrawals, and increased water surface area from sedimentation, making the channel wider and shallower.

Beneficial Uses

The Little Klickitat River and its tributaries are classified as Class A, excellent, as defined by the Water Quality Standards for Surface Waters of the State of Washington (Hicks, 2000; Chapter 173-201A-030 WAC). The standards establish beneficial uses of waters and incorporate specific numeric and narrative criteria for parameters such as water temperature. The criteria are intended to define the level of protection necessary to support the beneficial uses (Rashin and Graber, 1992). The beneficial uses of the waters in this specific area are:

- *Recreation:* fishing and swimming.
- *Fish and Shellfish:* Steelhead use lower reaches for spawning and as a migration corridor to upper, more favorable spawning sites on the Little Klickitat, Bowman Creek, and Butler Creek. Resident rainbow trout use the waters for migration, rearing, and spawning. Spring chinook, cutthroat, and coho use the lower reaches of the Little Klickitat for rearing and spawning during the winter months.
- *Water Supply & Stock Watering:* agriculture extracts water for irrigation and stock watering.
- *Wildlife habitat:* Riparian areas are used by a variety of wildlife species which are dependent on the habitat.

Numeric water quality criteria for Class A streams state that temperature shall not exceed 18.0°C (freshwater) due to human activities. When natural conditions exceed 18.0°C (freshwater), 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 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).

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). Temperature is a major concern in the Little Klickitat and its tributaries because of the use of its waters by steelhead, a species listed as threatened under the Endangered Species Act, as a migration corridor and as spawning and rearing habitat. Elevated temperature and altered channel morphology resulting from various land use activities, such as timber harvest and agriculture in the area, limit available spawning and rearing habitat for steelhead.

Historic Data Review

James Matthews (1992) of the Yakama Nation compiled temperature data within five watersheds in Eastern Washington. The purpose of the study was to:

- Gather baseline data in several watersheds within Yakama's Ceded Area, including the Little Klickitat River basin.
- Identify streams at greatest risk for impacts to salmonid populations.
- Determine the adequacy of proposed temperature sensitivity models for Eastern Washington.
- Investigate the influence of elevation, canopy, and distance from the divide on stream water temperature.

Matthews observed that the Little Klickitat River and Big White Salmon River basins had the highest observed maximum water temperatures. He concluded that high summer air temperatures are a significant factor in causing these problems. However, most of the temperature sites in the Little Klickitat and Big White Salmon watersheds also had been impacted by significant human disturbance in the past, which has aggravated an already tenuous condition. The more intensively disturbed sites, such as Butler Creek and the lower West Prong, were quite open and had unnaturally wide channels and shallow depths. Matthews observed considerable past riparian harvest, relocation of channels, roads/skid trails adjacent to waters, and grazing impacts near monitoring stations. Regression analysis found canopy cover as the primary influencing factor on stream temperatures in the Little Klickitat River basin. He concluded that greater canopy cover is necessary in the Little Klickitat watershed to meet state water quality standards.

M. Raines, et al. (1999) cooperatively characterized the biological and physical conditions of watershed processes and resource conditions associated with sediment in the Upper Little Klickitat River Watershed. Ultimately, the assessment resulted in the development of specific forest practices prescriptions to protect public resources in the watershed including fish and water quality. Sediment transport and delivery in the basin is of concern because of the potential for sediment (erosion, deposition, or transport in the water column) to alter the temperature regime of the stream channel through channel widening, shallowing, and incision.

The report by M. Raines, et al., prepared for Boise-Cascade Corporation, divides the physical and biological assessment into the following modules: Mass Wasting, Surface Erosion, Hydrology, Riparian Function, Stream Channels, Fish Distribution and Habitat, Water Supply and Public Works, and Water Quality. The mass wasting, surface erosion, hydrologic condition, and riparian condition modules address hillslope hazards. The vulnerability of resources are addressed by the fish habitat, stream channel, water quality, and public works/water supply modules. In general, the assessment found that in the Upper Little Klickitat Watershed:

- Mass wasting is not the major source of sediment in the watershed.
- Channel incision produces a large amount of sediment; although, it is not clear if the source of incision is management related (removal of LWD, riparian harvest, stream skidding, increased drainage from roads) or climate related.
- Road surface erosion and gullying produce the largest input of management-related sediment in the basin.

- The total amount of sediment delivered to streams from current land management activities in the basin is well above background levels.
- Bank erosion was widespread in channels of all gradients.
- A great deal of uncertainty remains regarding whether or not forest road drainage has a significant effect on peak flows.
- To attain water quality standards for temperature on streams at 2,800-feet of elevation or more, target canopy coverage is approximately 70%.
- Only 18% (by number) of the channel reaches in which functional LWD was counted had good levels of functional wood, and 60% had poor levels.

Two studies by Joy (1985 and 1986) evaluated the impact of the Goldendale Wastewater Treatment Plant on the Little Klickitat River receiving water. The study area for both surveys was comprised of 5.8 miles of the Little Klickitat River between RM 10.5 and 16.3. The 1985 study focused on the effect of effluent discharge during a low flow event (August 27-28, 1985). A similar field study, completed in 1986, compared low- (August 27-28, 1985) and high-flow (March 11-12, 1986) surveys. Both surveys measured the following field parameters: temperature, dissolved oxygen, pH, conductivity, discharge/flow, fecal coliform, nutrients (phosphorus and nitrogen), turbidity, chloride, sodium, magnesium, and calcium. Of primary concern to the Little Klickitat TMDL are the temperature findings.

The data reveals that the temperature of the Little Klickitat exceeded the numeric water quality standard for Class A waters of 18.0°C at some stations monitored. The summer low-flow survey shows that the Goldendale WWTP effluent, which had a mean temperature of 19.5°C upon release to the river, increased the water temperature from a mean of 12.9°C to 17.3°C. Water quality standards state that if natural conditions are below 18°C, incremental increases occurring from point sources can not exceed $t = 28/(T+7)$, where t is the maximum incremental increase and T is the background temperature measured at a point unaffected by the discharge. The mean background temperature of the water prior to effluent discharge was 12.9°C during the 1985 low-flow survey. Using the formula above, the maximum allowable incremental increase in stream temperature caused by the point source is 1.4°C. The stream temperature downstream from the effluent discharge is 17.3°C. Therefore, the incremental water temperature increase due to the effluent discharge during the summer low-flow survey exceeded water quality standards at the time. Conversely, the high-flow survey did not result in any instances of temperature exceedance.

Brown (1979) completed a cooperative study to inventory the geology and water resources of Klickitat County to facilitate the understanding and subsequent management of the area's valuable water resources. The study was designed to present basic information about Klickitat County and the upper Klickitat River basin. It combined existing data on meteorology, geology, surface and ground water, and water quality with information gathered during additional field work. Due to the extent of the area studied and the parameters researched, very little of the data available in the report pertains to the Little Klickitat River basin. However, the report does offer relevant discharge and surface water quality data, including temperature, for selected streams in the Little Klickitat basin. The report also presents data on water quality for selected wells and springs in the Little Klickitat basin.

Caldwell and Hirschey (1990) conducted an Instream Flow Incremental Methodology (IFIM) study on the lower Little Klickitat River (below Goldendale) to determine minimum instream flows. The method predicts how fish habitat may respond to incremental changes in stream flow. The majority of the information presented focuses on computer model output and the instream flow requirement for tributaries in the basin. However, as part of the field surveys conducted for the project, temperature was collected at each monitoring station during site visits. The sites were visited once a month from May through September during 1987. Their data shows that July water temperatures exceed those recorded for other months in the 1997 sampling season. They report a total of six instances of water temperature exceedance (based on numeric criteria of 18.0°C) out of thirty-one data points presented for all stations and all sampling events.

The River and Ambient Water Monitoring Report for Wateryear 1995 (Hallock, Ehinger, and Hopkins, 1996) and Timber/Fish/Wildlife Ecoregion Bioassessment Pilot Project (Plotnikoff, 1992) surveyed one site on the Little Klickitat River as part of their assessment. The Ambient Water Monitoring Report provides monthly temperature, flow, and suspended sediment data, among the other surface water quality data collected. The Ecoregion Bioassessment provides an invertebrate inventory and surface water quality data, including temperature and discharge, for the 1991 wateryear. Both reports show higher summertime water temperatures and lower summertime flows.

Study Design

Approach

The Little Klickitat Temperature TMDL will be developed for heat, which is considered a pollutant under Section 502(6) of the Clean Water Act. 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 (Equation 1), is most strongly influenced by solar radiation input (Adams and Sullivan, 1989; Matthews, 1992).

Equation 1. Relationship between temperature and Heat Energy for Surface Waters.

$$\Delta Temperature = \frac{\Delta Heat\ Energy}{Volume.}$$

Increased solar radiation levels at the stream surface due to anthropogenic causes result from the following 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).
- 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.

The sources of increased stream temperatures will be examined in the Little Klickitat Temperature TMDL to produce a loading capacity and load and wasteload allocations for the heat load sources. Loading capacity and allocations will be established via field surveys and development of a predictive computer temperature model. Field data collection and assessment will be governed by the data set requirements of the computer temperature model.

Model Data Requirements

Six water quality/temperature models gathered from EPA, Timber-Fish-Wildlife, and Oregon DEQ were evaluated to determine the most practical application to model the temperature regime in the basin (Sullivan et al., 1990; USEPA, 1997; Oregon DEQ website, 2000). Criteria for model selection were ease of use, public availability, reliability of predictions, data requirements, region for which it was developed, applicability to the Little Klickitat region, and model sensitivity to selected parameters. At this point the final model has not been selected; however, the list of potential models has been narrowed down to three: MNSTREM - Minnesota Stream Temperature Model, SNTEMP - Stream Network Segment Temperature Model, and HeatSource. Data input parameters required for all three models (Table 2) are combined to ensure complete coverage of all data needs.

Data Collection

Data collection, compilation, and assessment will be governed by the data set requirements of the computer temperature model. The data will be assembled from local third party studies and Ecology field surveys. Local third party studies include investigations by Central Klickitat Conservation District (CKCD), Boise Cascade, AgriMet, and Yakama Nation Fisheries. Table 2 displays data requirements by model and collection source.

Table 2. Model Data Requirements and collection source.

		MODEL			Collection By		
	PARAMETER	**HeatSource**	**MNSTREM**	**SNTEMP**	**CKCD**	**Yakama Nation**	**Ecology**
Flow	discharge - tributary		x		x		x
	discharge (upstream & downstream)	x	x	x	x		x
	flow regression constants			x			
	flow velocity	x			x		x
	groundwater inflow rate/discharge		x	x			x
	travel time			x			
General	calendar day/date	x	x	x	all		
	duration of simulation	x			data		
	elevation - downstrean			x	collected		
	elevation - upstream			x	from		
	elevation/altitude	x	x	x	USGS		
	latitude	x	x	x	or		
	longitude	x		x	GIS		
	time zone	x			maps		
Physical	channel azimuth/stream aspect	x		x	x	x	
	cross-sectional area		x			x	
	Manning's n value		x			x	
	percent bedrock	x			x	x	
	reach length	x				x	
	stream bank slope	x			x	x	
	stream bed slope	x			x	x	
	width - bankfull	x			x	x	x
	width - stream		x	x	x	x	x
Temperature	temperature - ground			x			
	temperature - groundwater	x	x	x			
	temperature - water downstream	x	x	x	x	x	x
	temperatures - water upstream	x	x	x	x	x	x
	temperature - air	x	x	x	x		x
	thermal gradient			x			
Vegetation	% forest cover on each side			x		x	x
	% possible sun/cloud cover	x	x	x		x	x
	canopy-shading coefficient/veg density	x	x	x	x	x	x
	diameter of shade-tree crowns			x		x	x
	distance to shading vegetation			x		x	x
	forest shading in various directions			x		x	x
	topographic shade angle	x					x
	vegetation height	x					x
	vegetation shade angle	x					x
	vegetation width	x				x	x
Weather	relative humidity	x	x	x	AgriMet		
	solar radiation		x	x	Goldendale		
	temperature - air	x	x	x	Airport		
	wind speed/velocity	x	x	x	Weather Staion		

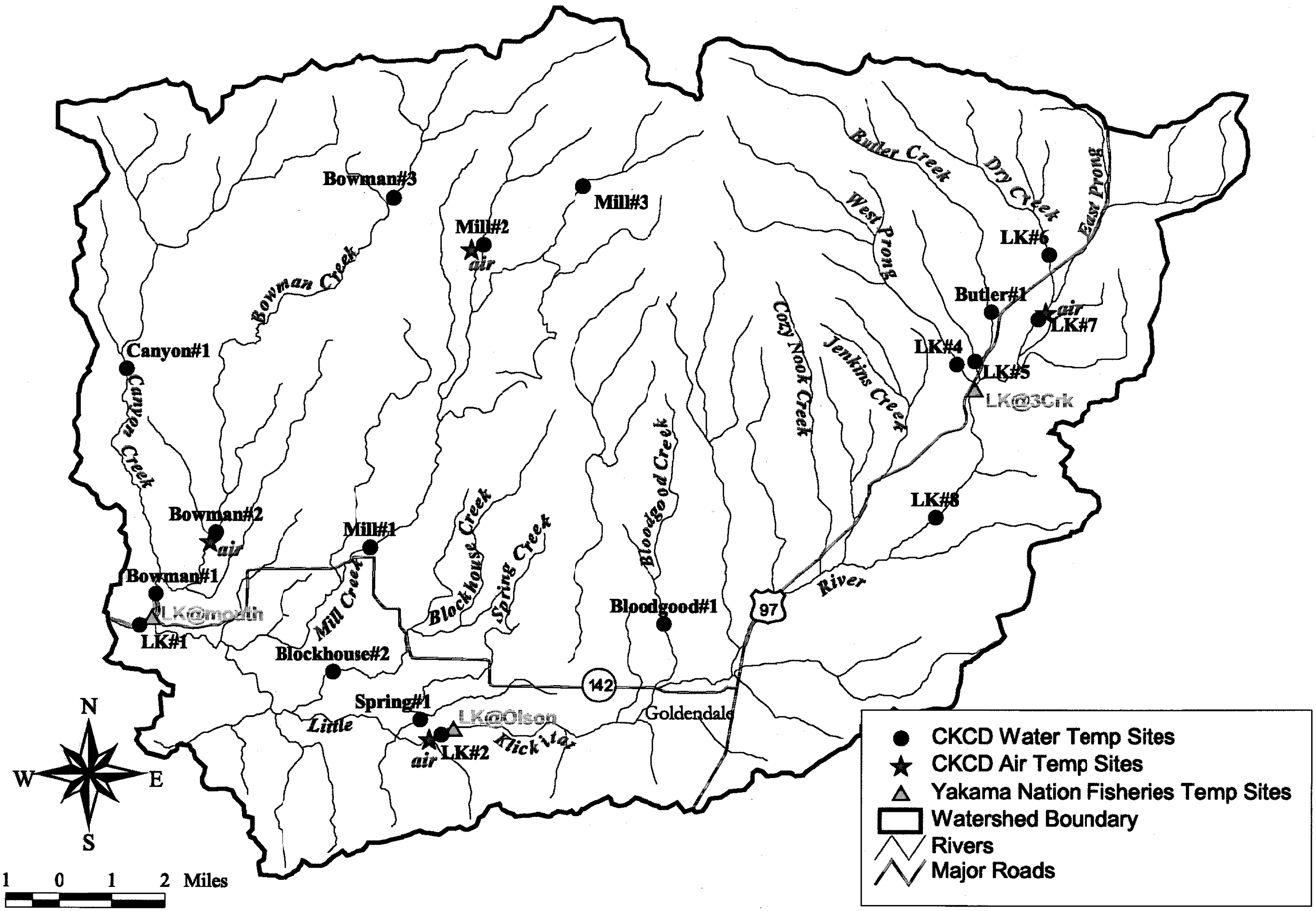

Figure 2. Central Klickitat Conservation District and Yakama Nation Fisheries Monitoring Sites

Central Klickitat Conservation District Data

A majority of the field data for this project will be obtained from an ongoing basin study managed by Dave Clayton of the CKCD. Monitoring by the CKCD is part of the CKCD Little Klickitat Watershed Management Plan (WMP) which outlines goals to maintain the highest water quality and quantity in the Little Klickitat River that are reasonably and economically practical (Clayton, 1999a; Clayton, 1999b). Under the WMP, monitoring has occurred at sites throughout the basin (Figure 2) every summer, May through October, since 1995. Data measurements taken at each site include water temperature, instream flow, stream width, depth, canopy cover, and a limited habitat assessment. Air temperature is not measured at every established site, instead it is measured at representative sites throughout the basin (Figure 2). Table 3 gives a more detailed description of the parameters measured and the frequency of the measurements.

Table 3. CKCD Data collection parameters and frequency

	FREQUENCY			
Measurement	**installation**	**1/month**	**2/month**	**30 min.**
Optic Stowaway Water Temp				X
Air Temp			X	
Temperature			X	
turbidity			X	
dissolved oxygen			X	
pH level			X	
Instream flow		X		
width		X		
average depth		X		
velocity		X		
Aspect and stream gradient	X			
Description of stream channel (entrenched, moderately entrenched, slightly entrenched)	X			
Estimate of land uses(forest, range, farm, residential)	X			
Estimate of amount of local erosion	X			
Existence of dams, culverts, or channelization	X			
Brief habitat assessment	X			
Estimate of inorganic substrate component	X			
Estimate of organic substrate component	X			
Canopy cover	X			
Description of riparian veg. types and condition	X			
Description of weather		X		
Stream or sediment odors		X		
Sample of macroinvertebrates and fish species	X			

Yakama Nation Fisheries Data

Bill Sharp, of Yakama Nation Fisheries, is currently collecting stream temperature and habitat data in the area (Table 2). Three year-round water temperature sites have been in operation on the mainstem Little Klickitat River since November 1996 (Figure 2). Water temperature data is measured using an Onset Hobo Temperature Data Logger. Basin wide sampling includes:

- Water quality data collected using a Hydrolab logger.
- Past collection of sediment samples using McNeal cores.
- Seven stream surveys performed over 1,500-foot transects. Data collected includes bankfull width, width-to-depth ratio, pool-riffle ratios, instream wood count, and channel canopy cover. [I will add these sites to Figure 2 once Bill sends a copy of the data].
- Spawning ground surveys.

All survey field measurement protocols and methods follow the TFW Ambient Monitoring Program Manual (Schuett-Hames, 1994).

Ecology Field Surveys

Three types of Ecology field surveys will be conducted: 1) continuous flow monitoring on the mainstem Little Klickitat, 2) stream surveys of the Little Klickitat and its tributaries, and 3) temperature surveys. Figure 3 illustrates the sites established by Ecology.

1. Continuous Flow monitoring

Three on-site continuous flow-monitoring stations will be established on the mainstem Little Klickitat during the duration of the sampling season – June through October. Synoptic flow measurements, which include data from the continuous flow-monitoring stations and instantaneous flows taken during stream surveys, will be used to estimate groundwater inflow by difference. These on-site data loggers will be installed and maintained by Ecology's Environmental Assessment Program's Stream Hydrology Unit. The standard protocols for the on-site continuous data loggers will follow those currently established by Ecology's Hydrology Unit (Ecology, 2000).

2. Stream and Habitat Surveys

TFW Stream Temperature Survey methods will be followed for the collection of data during thermal reach surveys (Schuett-Hames et al., 1999). The surveys will be conducted during mid-August, 2000 at the temperature sites established by Dave Clayton of the CKCD. Field measurements taken every 30-meters over a 300-meter thermal reach will consist of bankfull width and depth, wetted width and depth, canopy closure, stream gradient and channel type. Riparian Management Zone (RMZ) characteristics, such as active channel width, cover, size, density, bank erosion, and windthrow, will also be recorded during the surveys. Instream flow will be measured at the upstream and downstream boundaries of the thermal reach.

3. Temperature sites

Air and water temperature sites will be established where continuous flow monitoring devices are installed. A water temperature site will be established on the Little Klickitat River at the downstream boundary of Goldendale (Figure 3). Air temperature will be measured with an Onset StowAway Tidbit (–20°C to +50°C) and water temperature with an Onset StowAway Tidbit (-5°C to +37°C). The temperature data loggers will be installed in a location in the stream or riparian forest which is shaded from direct sunlight. They will be placed in an area which is representative of the surrounding environment. The water temperature logger will be installed at approximately one-half of the water depth and as close to the center of the thalweg as possible. The installation site will be located where there is obvious water mixing and at a depth that will not become exposed if the water level drops but will not be affected by groundwater inflow or stratification. The air temperature data loggers will be installed adjacent to the water temperature probe about one to three meters into the riparian zone from the edge of the bankfull channel and about one meter off the ground.

The field schedule outlines approximate dates of logger installation and data download:

June 19-23	-	Temperature data logger installation
June 19-23	-	Continuous Flow Monitoring devices installed and launched
July 18-20	-	Synoptic Flow Measurements taken on tributaries and mainstem
July 18-20	-	Download temperature data from loggers
August 14-18	-	Download temperature data from loggers
August 14-18	-	Stream and Habitat Surveys
Sept. 11-14	-	Download temperature data from loggers
Oct. 16-20	-	Download final temperature data

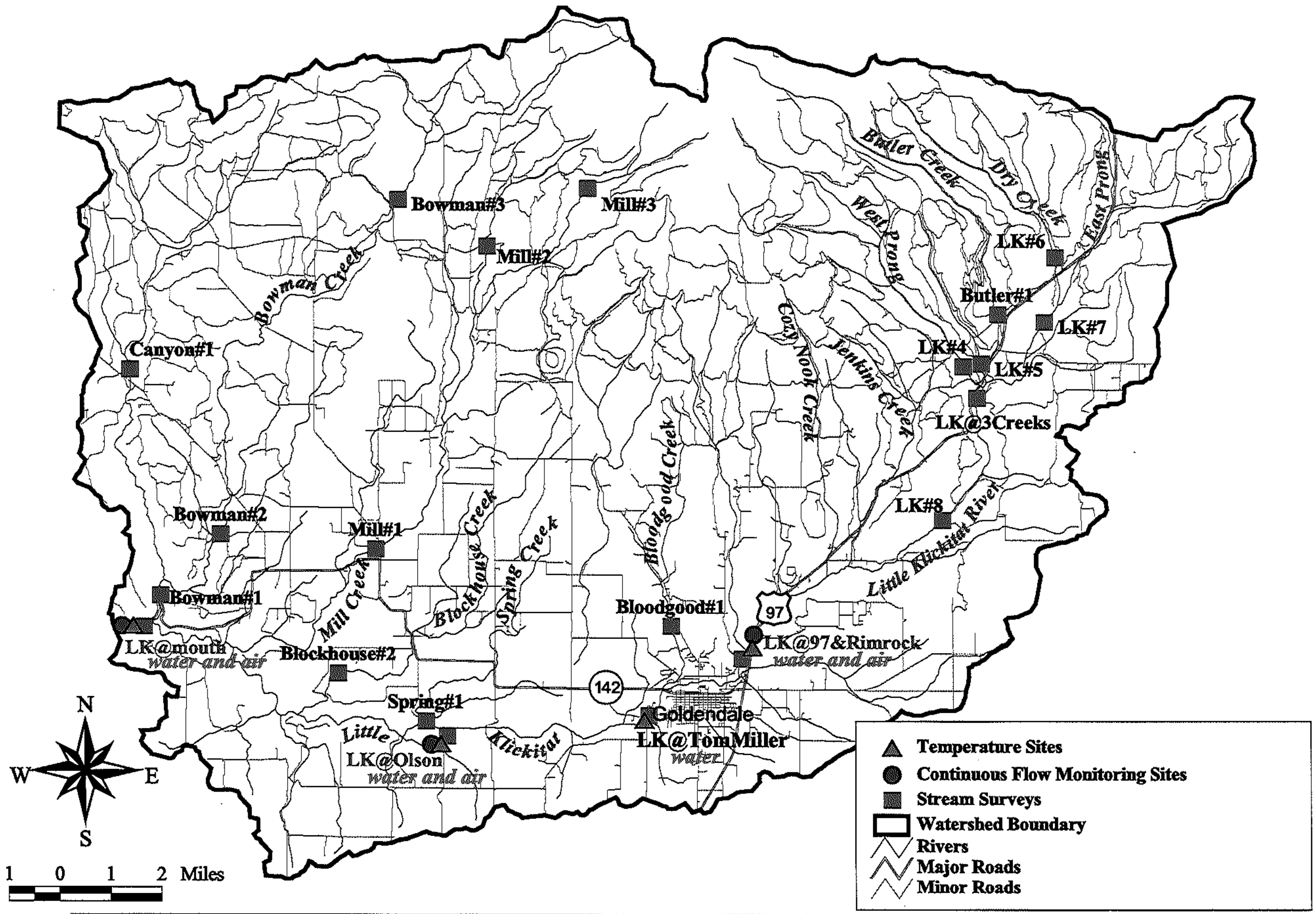

Figure 3. Ecology Field Survey Sites

Project Organization

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

Anita Stohr: Project manager for TMDL technical study, Environmental Assessment Program, Watershed Ecology Section. Responsible for overall project management. Defines project objectives, scope, and study design. Responsible for review of the project QAPP and final report. Responsible for primary contact with the client and stakeholders.

Stephanie Brock: Principal Investigator, Environmental Assessment Program, Watershed Ecology Section. Assists in defining project objectives, scope, and study design. Responsible for writing the quality assurance project plan (QAPP), data collection, data quality review and analysis, and report writing.

Pat Irle: Water Quality Program TMDL Lead, Central Regional Office (CRO). Reviews and comments on QAPP and reports. Coordinates local outreach and information exchange about the technical study and local development of implementation and monitoring plans between Ecology and local planning groups. Supports data collection as part of the TMDL implementation monitoring.

Brad Hopkins and Chris Evans: Environmental Assessment Program, Environmental Monitoring and Trends Section, Stream Hydrology Unit. Responsible for the deployment and maintenance of continuous flow loggers and staff gages on mainstem tributaries. Responsible for producing records of hourly flow data at select sites for the study period.

Acting Section Supervisor: Water Quality Program, CRO. Reviews and comments on QAPP and reports. Responsible for approval of TMDL submittal to EPA.

Will Kendra: Environmental Assessment Program. Section supervisor of the Watershed Ecology Section. Responsible for approval of the project QAPP and final report.

Karol Erickson: Environmental Assessment Program. Unit supervisor of the Watershed Studies Unit. Responsible for review of the project QAPP, final technical report, and budget technical study.

Cliff Kirchmer: Environmental Assessment Program, Quality Assurance Unit. Responsible for review of QAPP. Available for technical assistance on quality assurance issues and problems.

Valuable assistance for this project will be provided by outside support from Dave Clayton, Bill Sharp, and Ray Hennekey. Dave Clayton is responsible for providing a majority of the field work/data collection. Bill Sharp is providing additional temperature and habitat data for the mainstem Little Klickitat. Ray Hennekey supports local outreach and information exchange about the TMDL. He will act as a local contact and coordinator for technical information exchange with the local interests.

Data Quality Objectives

Accuracy objectives for field measurements are presented in Table 4. 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 will be maintained by a two-point comparison between the thermograph, a field thermometer, and a certified reference thermometer. The Certified 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 traceable equipment. The field thermometer is a Brooklyn Alcohol Thermometer (model no. 67857). First, the field thermometer's accuracy will be evaluated by comparison to a certified reference thermometer. 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. Secondly, the accuracy of the thermal data loggers will be evaluated by comparison to the field thermometer. Manufacturer specifications report an accuracy of ±0.2°C for the Onset StowAway Tidbit (-5°C to +37°C) and ±0.4°C for the Onset StowAway Tidbit (-20°C to +50°C). If the mean difference between the field thermometer and the thermal data loggers differs by more than the manufacturer's reported specifications the thermal data logger will not be used during field work.

Ecology will install two water temperature thermographs at sites on the mainstem Little Klickitat River that correspond to temperature sites established by the CKCD and Yakama Nation Fisheries. At these two sites, all three groups operate water thermographs during the summer season. Accuracy of the data loggers will be evaluated by comparing data downloaded from the three groups to reference temperature readings taken with a calibrated field thermometer during site visits throughout the sampling season. The mean difference between the downloaded data and the reference thermometer readings will be calculated. Data is only acceptable if it does not exceed a maximum mean difference of 0.2C. The comparability of the three groups' data loggers will be determined by comparing the mean difference between each groups downloaded temperature data. The data is deemed acceptable if the mean difference does not exceed 0.2C.

Representativeness of the data is achieved by a sampling scheme that accounts for land practices, flow contribution of tributaries, and seasonal variation of instream flow and temperatures in the basin. Extra calibrated field thermometers and thermograph data loggers will be taken in the field during site visits and surveys to minimize data loss due to damaged or lost equipment

Table 4. 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
Velocity	± 0.5 feet/second	Marsh-McBirney model 201 current meter

[1]Method references: TFW Stream Survey, 1999; WAS, 1993

Measurement and Sampling Procedures

Field sampling and measurement protocols will follow those described in the TFW Temperature Stream Survey Manual (Scheutt-Hames, 1999) and the WAS protocol manual (WAS, 1993). Temperature thermographs will be installed in the water and air in areas which are representative of the surrounding environmental and are shaded from direct sunlight. To safeguard against data loss, data from the loggers will be downloaded midway through the sampling season. The stream surveys will collect data according to TFW protocols for bankfull width and depth, wetted width and depth, canopy closure, stream gradient and channel type. Riparian Management Zone (RMZ) characteristics, such as width, cover, size, density, and windthrow, will also be recorded during the surveys. Instream flow will be measured at the upstream and downstream boundaries of the thermal reach (Scheutt-Hames et al., 1999).

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, retrieval, and also once during the sampling season (mid-August). 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 Optic 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). Estimates of groundwater inflow will be calculated by constructing a water mass balance from continuous and instantaneous streamflow data. Methods to quantify or evaluate sediment inputs to the stream have not been determined. Potentially, estimates for sediment will be derived from the sediment budget presented by Raines et al. (1999) for the upper Little Klickitat Watershed, field measurements, and GIS analysis.

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 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.

Reporting Schedule

The reporting schedule for this project is as follows:

March 30, 2001	Draft report due to Project Manager
April 30, 2001	Draft report due to Watershed Studies Unit Supervisor
May 31, 2001	Draft Report due to clients
July 13, 2001	Draft Report out for external review
September 28, 2001	Final report to printer

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