Quality Assurance Project Plan

Wenatchee River Temperature, Dissolved Oxygen, and pH Total Maximum Daily Load Year 1 Technical Study

by
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303(d) listings addressed in this study:
Icicle Creek (WA-45-1017): Temperature, Dissolved Oxygen, pH
Wenatchee River (WA-45-1010): Temperature, pH
Wenatchee River (WA-45-1020): Temperature, Dissolved Oxygen, pH

Ecology EIM Number: WENRTMDL

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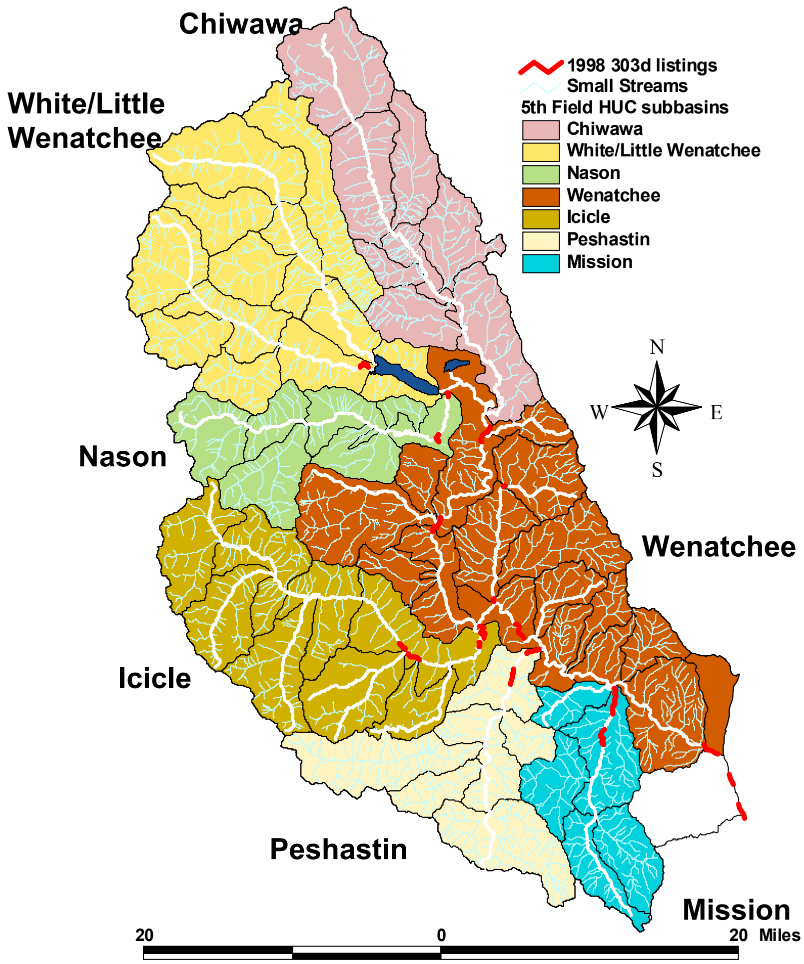
Abstract

The U.S. Environmental Protection Agency (EPA) requires states to set priorities for cleaning up 303(d) listed waters and to establish a Total Maximum Daily Load (TMDL) for each. A TMDL entails an analysis of how much of a pollutant load a waterbody can assimilate without violating water quality standards. This Quality Assurance (QA) Project Plan describes the technical study that will evaluate temperature, pH, dissolved oxygen, and other ancillary parameters in the Wenatchee River mainstem and Icicle Creek. The TMDL will form the basis for a proposal to set instream water quality targets to meet water quality standards and allocate contaminant loads to sources. The study will be conducted by the Ecology Environmental Assessment Program.

The Wenatchee River Subbasin (Water Resource Inventory Area,WRIA 45) is located in Chelan County. Watersheds of WRIA 45 are shown in Figure 1. The technical study to address water quality concerns in WRIA 45 will be split into two years. The first study year will focus on the mainstem Wenatchee River from the outlet of Lake Wenatchee to the river's confluence with the Columbia River at the city of Wenatchee, and include Icicle Creek. The second study year will focus on the other major tributaries to the Wenatchee River. This QA Project Plan applies only to year one, and an additional QA Project Plan will be developed for year two.

Figure 1. Study Area



In total, the study area has 22 segments that are listed for violating water quality criteria (Table 1). Lower Icicle Creek exceeded water quality standards for dissolved oxygen (DO) based on Chelan County Conservation District monitoring data from 1992-93, and two segments of the creek were placed on Washington's 303(d) list of impaired waters. One segment of the creek was placed on the 303(d) list for temperature violations based on data collected by the U.S. Forest Service in 1988. Two segments of the mainstem Wenatchee River were placed on the 303(d) list for violating water quality standards for DO, pH, and temperature based on data collected by the Chelan County Conservation District and Ecology's Ambient Monitoring Program. Instream flow impairments in Icicle Creek at the USGS gaging station and in the Wenatchee River at the USGS gaging station in Monitor will not be addressed by this TMDL technical study. For WRIA 45, the instream flow impairments will be addressed by the Instream Flow Technical Sub-Committee of the 2514 Watershed Planning Committee.

Other tributaries to the Wenatchee River were placed on the 303(d) list for further DO, pH, and temperature violations as well as fecal coliform bacteria violations and pesticide contamination. Due to the large area of the subbasin, Ecology plans to conduct a technical study on the remaining tributaries beginning in 2003. A separate Mission Creek pesticide study by Ecology's Toxic Study Unit will commence this year. A separate QA Project Plan will be developed this summer detailing the study, which will be looking at the fate and transport of pesticides in Mission Creek.

Table 1. Stream Reaches on the 1998 303(d) List for Impaired Water Bodies

Stream	WBID (segment)	Parameter	Section
Brender Creek	*WA-45-1100	Fecal Coliform Dissolved Oxygen	T23N, R19E, Section 5
Chiwaukum Creek	*WA-45-1900	Temperature	T25N, R17E, Section 9
Chumstick Creek	*WA-45-1200	Dissolved Oxygen pH Fecal Coliform	T24N, R17E, Section 1
		Instream Flow	T26N, R18E, Section 30
Icicle Creek	*WA-45-1017	Dissolved Oxygen**	T24N, R17E, Section 24
		Instream Flow	T24N, R17E, Section 13
	*WA-45-1017	Temperature**	T24N, R17E, Section 30
Icicle Creek	*WA-45-1017	Dissolved Oxygen**	T24N, R16E, Section 24
Little Wenatchee River	*WA-45-4000	Temperature	T27N, R16E, Section 15
Mission Creek		Instream Flow	T23N, R19E, Section 8
	*WA-45-1011	Fecal Coliform	T23N, R19E, Section 5
	WA-45-1011	4,4' -DDT 4,4' -DDE Guthion	T23N, R19E, Section 4
	*WA-45-1011	DDT	T23N, R19E, Section 9
Nason Creek	*WA-45-3000	Temperature	T26N, R17E, Section 9
	*WA-45-3000	Temperature	T27N, R17E, Section 27
Peshastin Creek	*WA-45-1013	Temperature Instream Flow	T24N, R18E, Section 21
Peshastin	*WA-45-1014	Temperature	T24N, R18E, Section 32)
Wenatchee River		Instream Flow	T24N, R18E, Section 17
	*WA-45-1010	pH** Temperature**	T23N, R20E, Section 28
	*WA-45-1020	Dissolved Oxygen**	T25N, R17E, Section 9
		Instream Flow	T26N, R17E, Section 12

* = 1996 303(d) Listed
** = listings addressed in this QAPP

Ecology is required by the Clean Water Act to conduct a TMDL evaluation for all waterbodies on the 303(d) list. The evaluation begins with this water quality technical study. The technical study determines the capacity of the water body to absorb pollutants and still meet water quality standards. The study also evaluates the likely sources of those pollutants, and the amount pollutant sources need to be reduced to reach that capacity. During and after the technical study, Ecology will work with other agencies and local citizens to identify water quality-based controls depending on the sources found in the study.

Project Description

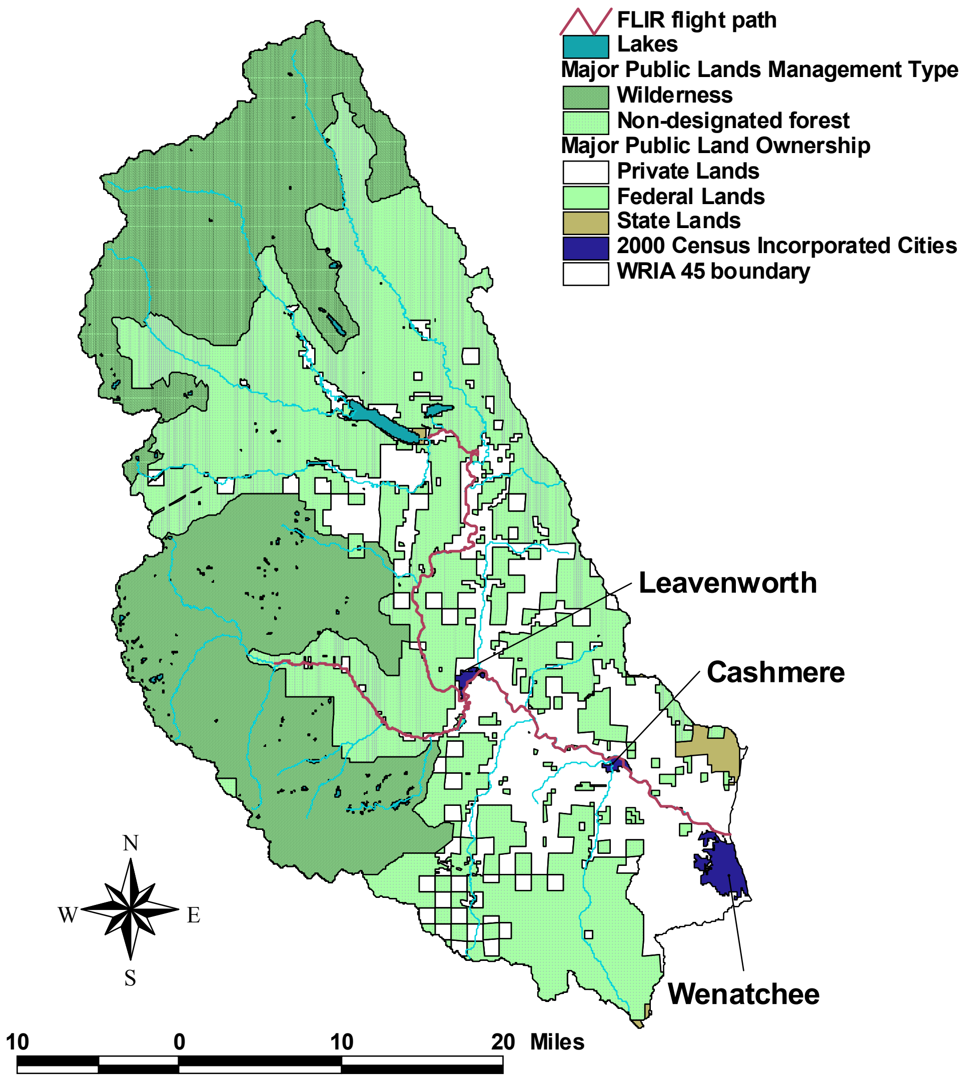
Study Area

The Wenatchee River Subbasin (WRIA 45) encompasses 878,423 acres and is located in the central part of Washington State. The subbasin is bounded on the west by the Cascade Mountians, on the north and east by the Entiat Mountains, and on the south by the Wenatchee Mountains. The Wenatchee is a subbasin to the Columbia River and enters that system at the city of Wenatchee 15 miles upstream of the Rock Island Dam. The geology of the upper subbasin consists of high and low relief landtypes associated with glaciation (e.g. cirque headwalls, glaciated ridges, and glacial/fluvial outwash). The middle part of the subbasin is a mixture of igneous and basalt rock formations and glacial/fluvial outwash terraces. Alluvial fans and terraces are predominant landtypes in the lower Wenatchee (Mainstem Wenatchee Watershed Assessment, 1999).

Annual average precipitation throughout the subbasin ranges from 150 inches at the crest of the Cascades to 8.5 inches in Wenatchee (Mainstem Wenatchee Watershed Assessment, 1999). Streamflow varies during the year, but mean monthly discharge peaks in spring from combined effects of snowmelt and rain on snow events. Most of the annual stream flow in the Wenatchee River originates from tributaries in the upper subbasin: the White River (25%), Icicle Creek (20%), Nason Creek (18%), the Chiwawa River (15%), and the Little Wenatchee River (15%) (Andonaegui, 2001). Both the White and the Little Wenatchee Rivers enter Lake Wenatchee in the upper subbasin; the mouth of the lake is the head of the Wenatchee River and Nason Creek enters the river just below the lake outlet.

There is a mixture of federal, state, county, and private land ownership throughout the subbasin (Figure 2). Most of the upper subbasin is designated federal wilderness areas and is under the jurisdiction of the U.S. Forest Service Lake Wenatchee and Leavenworth Ranger Districts. State Highways 2 and 97 parallel much of the Wenatchee mainstem and Nason Creek and contains portions of their streambanks. The incorporated cities designated in the 2000 census are Wenatchee (population 27,856), Cashmere (population 2,965), and Leavenworth (population 2,074). There are smaller unincorporated towns and communities located along State Highways 2 and 97 (2000 census information).

Figure 2. Land Ownership Map and Proposed Thermal Infrared (TIR) Flight Path



The first year of the study of this subbasin will concentrate on the streams listed in Table 2. The year two study will focus more in-depth on major tributaries to the Wenatchee River other than Icicle Creek.

Table 2. Year One Study Streams

Area	Stream Name	Comments
Wenatchee Subbasin	**Wenatchee River**	**From mouth to Lake Wenatchee**
Wenatchee Subbasin	**White River**	**Mouth only**
Wentachee Subbasin	**Little Wenatchee River**	**Mouth only**
Wenatchee Subbasin	**Nason Creek**	**Near mouth**
Wenatchee Subbasin	**Chiwawa River**	**Mouth only**
Wenatchee Subbasin	**Fish Lake run**	**Mouth only**
Wenatchee Subbasin	**Beaver Creek**	**Mouth only**
Wenatchee Subbasin	**Chiwaukum Creek**	**Near mouth**
Wenatchee Subbasin	**Chumstick Creek**	**Mouth only**
Wenatchee Subbasin	**Derby Canyon Creek**	**Mouth only**
Wenatchee Subbasin	**Peshastin Creek**	**Mouth only**
Wenatchee Subbasin	**Brender Creek**	**Mouth only**
Wenatchee Subbasin	**Mission Creek**	**Mouth only**
Icicle Watershed	**Icicle Creek**	**From mouth to Jack Creek**
Icicle Watershed	**Snow Creek**	**Mouth only**
Icicle Watershed	**Eightmile Creek**	**From mouth to confluence with Mountaineer Cr.**
Icicle Watershed	**Mountaineer Creek**	**Mouth only**
Icicle Watershed	**Jack Creek**	**Mouth only**

Mainstem Wenatchee River

The mainstem Wenatchee River has a total river mileage of 53.6 miles. The elevation at the mouth of the lake is 1,876 feet and the mouth of the Wenatchee River at its confluence with the Columbia River is 615 feet above mean sea level. There is one major diversion of water from the river at the Dryden Dam (River Mile--RM 17.0) that supplies water to the Highline Canal for the Wenatchee Reclamation District. There are two other much smaller diversions: the Pioneer-Gunn (RM 6.6) and the Jones-Shotwell (RM 7.2) water diversions (Andonaegui, 2001).

The section of river above Tumwater Canyon and upstream to the outlet of Lake Wenatchee can be characterized as a U-shaped valley consisting of glaciofluvial outwash deposits on the valley floor. Tumwater Canyon is a narrow V-shaped valley with steep igneous and metamorphic rock formations that cannot regulate precipitation or snowmelt well, creating debris flow hazards and high sediment delivery (USFS, 1999b). The primary natural disturbance processes in the subbasin are fire and debris slides. The natural fire regime in the subbasin increases the occurance of mass wasting processes (Andonaegui, 2001). Summer chinook, spring chinook, bull trout and steelhead/rainbow trout both spawn and rear in waters within the mainstem Wenatchee River Watershed. Sockeye rear but do not spawn within the subbasin boundaries. All of these species rely on the Wenatchee River as a corridor to spawning and rearing habitat throughout this subbasin (Andonaequi, 2001).

Icicle Creek

The Icicle Creek watershed is the largest watershed within the Wenatchee River Subbasin and drains approximately 214 square miles contributing 20% of streamflow to the Wenatchee River. Eighty-seven percent (119,155 acres) of the watershed is publicly owned, 74% (88,175 acres) of which is located in the Alpine Lakes Wilderness (Andonaegui, 2001). Precipitation ranges from 120 inches in the upper watershed at the Cascade crest to 20 inches at the mouth. Elevation in the watershed ranges from 4681 feet in the upper watershed to 1102 feet at the confluence with the Wenatchee River in the city of Leavenworth.

Geomorphic landtypes in this watershed are dominated by glacial troughs and glacial cirques both associated with high sediment delivery. Sediment delivery is also compounded by natural fires disturbing the vegetation on steep slopes thereby increasing erosion and mass wasting processes (USFS, 1995).

There are two main water diversions on Icicle Creek: the Icicle/Peshastin Irrigation District (to Icicle Canal) and city of Leavenworth share one diversion (RM 5.7), and the Cascade Orchards Irrigation District and the Leavenworth National Fish Hatchery (RM 4.5) share the second diversion. The Leavenworth National Fish Hatchery (LNFH) diverted Icicle creek from its historic channel into a spillway as part of the original hatchery design. Streamflow is now diverted back into the historic channel during the summer, and the spillway goes mostly dry. Several control points on the historic channel have lowered stream velocities and trapped sediments and have caused the channel to evolve from riverine to wetland. The Yakima Nation uses the lower part of the historic channel as part of their fishing grounds in the spring, and they dredged part of the historic channel behind the lowermost control point in March, 2002 (Davies, 2002).

Spring chinook, summer chinook, sockeye, steelhead/rainbow trout, and bull trout are known to occur in the Icicle Creek Watershed. Bull trout rearing streams (Eightmile Creek, Jack Creek, and French Creek) also include known spawning and migration habitat (Andonaequi, 2001).

Water Quality Standards and Beneficial Uses

The Washington State Water Quality Standards, set forth in Chapter 173-201A of the Washington Administrative Code, include designated beneficial uses, water body classifications, and numeric and narrative water quality criteria for surface waters of the state.

Icicle Creek discharges to the Wenatchee River, which is a tributary to the Columbia River. Because they discharge to the Class A portion of the Columbia River (WAC 173-201A-030), Icicle Creek and its tributaries from its mouth to the national forest boundary are considered Class A (excellent) water bodies. Similarly, the Wenatchee River from its mouth to the Forest Service boundary is considered a Class A, excellent, water body. Characteristic uses for Class A water bodies include water supply (domestic, industrial, agricultural), stock watering, fish and shellfish (salmonid and other fish migration, rearing, spawning, harvesting), wildlife habitat, recreation (primary contact recreation, sport fishing, boating, aesthetic enjoyment), and commerce and navigation. The Wenatchee River and Icicle Creek from the Wenatchee National Forest boundary (Wenatchee River mile 27.1 and Icicle Creek river mile 3.8) to their headwaters are considered Class AA (extraordinary). Characteristic uses for Class AA are considered identical to Class A characteristic uses.

Numeric criteria for specific water quality parameters are intended to protect designated uses. However, criteria are more stringent in AA waters such that the class shall markedly and uniformly exceed the requirements for all, or substantially all, uses. The water quality standards are currently under revision. Changes have been suggested for DO, microbial pathogens (currently represented by the fecal coliform group), and temperature numerical standards. Current standards are listed below for each parameter of concern in the Wenatchee Subbasin. Proposed new standards can be found on the Ecology website: http://www.ecy.wa.gov/programs/wq/swqs/index.html.

Dissolved Oxygen

- For Class A Waters: *dissolved oxygen shall exceed 8.0 mg/L.*
- For Class AA waters: *dissolved oxygen shall exceed 9.5 mg/L.*

Fecal Coliform Bacteria

- For Class A Waters: *"...fecal coliform organism levels shall both not exceed a geometric mean[1] value of 100 colonies/100mL, and not have more than 10 percent of all samples obtained for calculating the geometric mean value exceeding 200 colonies/100 mL."*
- For Class AA Waters: "…*fecal coliform organism levels shall both not exceed a geometric mean value of 50 colonies/100 mL and not have more than 10 percent of all samples obtained for calculating the geometric mean value exceeding 100 colonies/100 mL."*

pH

- For Class A Waters: *pH shall be within the range of 6.5 to 8.5 with a human-caused variation within the above range of less than 0.5 units*.
- For Class AA Waters: *pH shall be within the range of 6.5 to 8.5 with a human-caused variation within the above range of less than 0.2 units*.

Temperature

- For Class A Waters: "*Temperature shall not exceed 18.0°C (freshwater) or 16.0°C (marine water) due to human activities. When natural conditions exceed 18.0°C (freshwater) and 16.0°C (marine water), no temperature increases will be allowed which will raise the receiving water temperature by greater than 0.3°C.*

  Incremental temperature increases resulting from point source activities shall not, at any time, exceed t=28/ (T+7) (freshwater) or t=12/ (T-2) (marine water). Incremental temperature increases resulting from nonpoint source activities shall not exceed 2.8°C.

  For purposes hereof, "t" represents the maximum permissible temperature increase measured at a mixing zone boundary; and "T" represents the background temperature as measured at a point or points unaffected by the discharge and representative of the highest ambient water temperature in the vicinity of the discharge."
- For Class AA Waters: "*Temperature shall not exceed 16.0°C (freshwater) or 13.0°C (marine water) due to human activities. When natural conditions exceed 16.0°C (freshwater) and 13.0°C (marine water), no temperature increases will be allowed which will raise the receiving water temperature by greater than 0.3°C.*

[1] The geometric mean is calculated as the n^{th} root of the product of n numbers

Incremental temperature increases resulting from point source activities shall not, at any time, exceed t=23/ (T+5) (freshwater) or t=8/ (T-4) (marine water). Incremental temperature increases resulting from nonpoint source activities shall not exceed 2.8°."

Historical Data Review

Organizations that have collected data on the Wenatchee River Subbasin include the Department of Ecology, US Fish & Wildlife, US Forest Service, US Geological Survey, Chelan County, and the Chelan County Conservation District.

Washington State Department of Ecology

Ecology collects ambient monitoring data at locations listed in Table 3 below.

Table 3. Ecology Ambient Monitoring Stations

Station ID	Station Name	Period of Record
45A070	Wenatchee River at Wenatchee	1960-67; 1969-70; 1972; 1975-76; 1978 – present
45A085	Wenatchee River near Dryden	1976
45A100	Wenatchee River at Leavenworth	1976
45A110	Wenatchee River near Leavenworth	1978 – present
45B070	Icicle Creek near Leavenworth	1976; 1993
45C070	Chumstick Creek near Leavenworth	1996 – 2000
45D070	Brender Creek near Cashmere	1996 – 2000
45E070	Mission Creek near Cashmere	1996 - 2000

Ecology's ambient data resulted in the Wenatchee River 303(d) listings for temperature, pH, and DO. In 1993, Ehinger summarized and analyzed long-term data for linear trends. Linear trend analysis revealed a significant increasing trend in percent saturation DO and pH at the Wenatchee River site near Wenatchee (45A070), as well as marginal trends in increasing temperature and decreasing nitrate/nitrite concentration. Upstream, at the Wenatchee River site near Leavenworth (45A110), a significant upward trend in pH and downward trend in nitrate/nitrite concentration was detected. Significant differences in many parameters were detected between the two sites as well. pH was noted as being "chronically high" in subsequent ambient monitoring reports (Hallock and Ehinger, 1999), "exceeding the upper [water quality] criterion four times…not just during low flow, productive summer months" in 1997.

Lake Wenatchee, the source of the Wenatchee River, was assessed annually by Ecology's former Lake Water Quality Assessment Program from 1989 until 1999. For each study year, the lake was classified as oligotrophic, meaning that it has low nutrient concentrations, little plant or algae growth, and very clear water. In 1992 (Rector, 1994), Lake Wenatchee had the lowest total phosphorus concentrations of all 46 lakes monitored for the program that year. In 1990 (Rector and Hallock, 1993), Lake Wenatchee ranked 54th out of 71 lakes according to need for management of eutrophication due to its excellent water quality.

Ecology completed Class II Inspections at the City of Leavenworth Wastewater Treatment Plant in 1993 (Das, 1994), 1984 (Heffner, 1985), and in 1980 (Chase, 1980). Data include effluent and receiving water quality. In 1993, effluent fecal coliform levels exceeded permit limits but the treatment plant otherwise performed well.

Similar inspections occurred at the Cashmere Wastewater Treatment Plant in 1987 (Heffner) and in 1993 (Das, 1994). In 1993, effluent fecal coliform and pH levels exceeded permit limits and minor problems with lab procedures were noted. Currently there is concern about leakage from the unlined sewage lagoons along the Wenatchee River just downstream of the city of Cashmere. A monitoring program is in place to investigate this concern. In 1984, Ecology completed a Class II inspection of the Stevens Pass Wastewater Treatment Plant (Clark, 1984). The plant appeared well operated and maintained and only minor suggestions for improvement were recommended.

Ecology's Water Quality Investigations Section conducted a limited water quality study of the lower ten miles of Icicle Creek after concerns were raised about the possibility of inadequate sewage disposal systems on a small, residential island in the creek (Singleton, 1982). Water quality samples were taken above and below the island, and septic system inspections of island residences were conducted. The collected data indicated that water quality above and below the Icicle Island Club was the same except for the observed presence of phytoplankton downstream from the island. The septic system inspections revealed a high potential for nutrient and bacterial addition to the creek, and the need for replacement of some systems.

In 1995, Ecology's Water Resources Program coordinated an Initial Watershed Assessment of the Wenatchee River Subbasin (Montgomery Water Group et al., 1995). The purpose of the document was to assess the availability of ground and surface water in order to make the water rights decision making process more efficient. The assessment includes hydrologic data, water rights and use data, water quality data, and fisheries data.

Ecology conducted continuous stream temperature monitoring throughout the entire year at four stations in the Chiwawa River watershed as part of the Salmon Index Watershed Monitoring Program (SIWMP) in 2000. Hourly temperatures were recorded using stowaway tidbits. Data are available as well as a final report.

US Fish and Wildlife

The US Fish and Wildlife Service (USFWS) conducted temperature monitoring on Icicle Creek as it passes through the Leavenworth National Fish Hatchery (LNFH) from 1999 to 2001. Hourly temperature readings were collected using instream temperature data loggers at four sites. Temperature monitoring is planned to continue in 2002 with two more temperature sites added. Ecology is coordinating sampling efforts with the USFWS to collect temperature data in Icicle Creek during 2002.

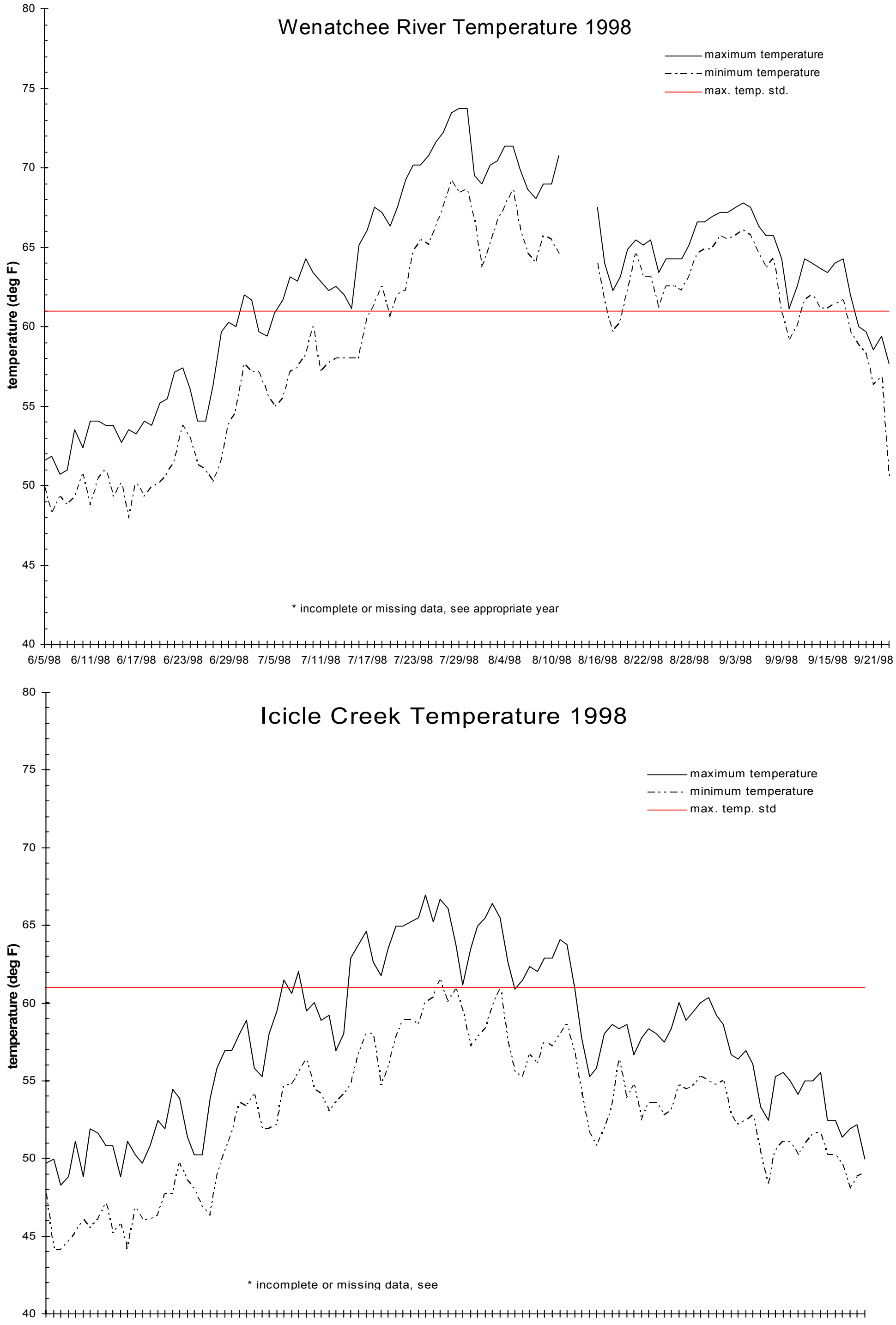
The Salmon, Steelhead, and Bull Trout Habitat Limiting Factors Report (Andoneagui) for WRIA 45 (published by the Washington State Conservation Commission) provides descriptions of salmon habitat areas throughout the subbasin. The report identifies data gaps in this subbasin for defining current floodplains and riparian habitat in the Wenatchee River Corridor, and a need for a hydrologic assessment to evaluate groundwater and surface water interactions. More data collection is also prescribed for bull trout distribution and habitat for all life history forms in the Wenatchee River Subbasin.

US Forest Service

The US Forest Service Lake Wenatchee/Leavenworth Ranger Districts have been conducting a stream temperature monitoring program since 1993 (Karrer). The temperature monitoring had a relatively small scope in 1993, with only five stations on USFS-owned land, but has since grown to monitor 42 stations during 2001. Instream continuous data loggers were used to record temperature measurements and an excellent data set has been accumulated. The temperature data can be used in this TMDL assessment as needed, and Ecology is coordinating the temperature data collection effort for 2002 and 2003 with the U.S. Forest Service office in Wenatchee.

Water temperature data collected during June - September 1998 from Icicle Creek and from the Wenatchee River above Icicle Creek are shown in Figure 3. Water temperatures increased during June and exceeded water quality standards for an extended period during July and August in Icicle Creek, and July through September in the Wenatchee River. Conditions during 1998 are probably representative of regional worse-case climatic conditions as discussed in Pelletier (2002) and Stohr (2000).

Figure 3. Temperature in the Wenatchee River and Icicle Creek During the Summer of 1998 (USFS Data)



The U.S. Forest Service has completed watershed assessments for the following watersheds in WRIA 45: Mainstem Wenatchee River, Little Wenatchee and White Rivers (covered under one assessment), Nason Creek, Chiwawa River, Chumstick Creek, Icicle Creek, Peshastin Creek, and Mission Creek (USFS et al). Dates for these reports range from 1995 for Icicle Creek to 1999 for the mainstem Wenatchee River. These reports provide data for geology landtypes, hydrology, and vegetation that will be useful supplements to this TMDL study.

US Geological Survey

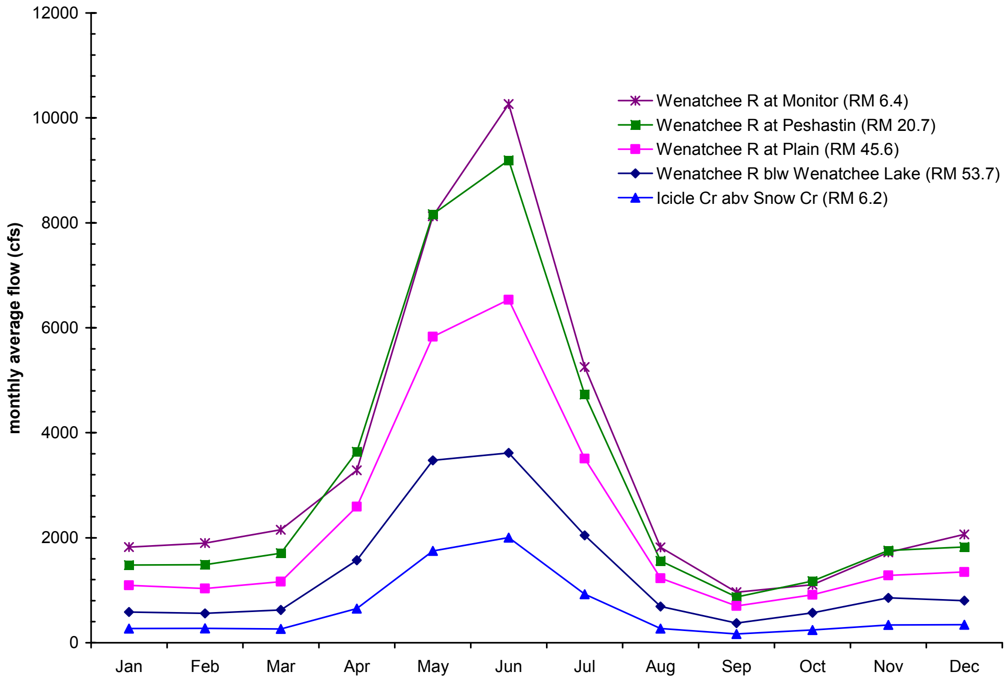
USGS presently maintains four gaging stations in the Wenatchee River Subbasin. Gage location and other information are listed in Table 4 below.

Table 4. USGS Gages in the Wenatchee River Subbasin

Station ID	Name	Min Flow (cfs)	Max Flow (cfs)	Avg Flow (cfs)	Median Flow (cfs)	Period of Record
12456500	Chiwawa River near Plain	n/a	n/a	n/a	n/a	May 1911 – present
1245700	Wenatchee River at Plain	505	4120	1440	1170	October 1920 – present
12459000	Wenatchee River at Peshastin	849	5830	2160	1910	March 1929 – present
12462500	Wenatchee River at Monitor	1120	6680	2660	2360	October 1962 – present

Monthly average flows from selected current and historical gaging stations in the Wenatchee mainstem and Icicle Creek are presented in Figure 4 (Williams and Pearson, 1985). Flows typically peak in June and are at an annual minimum in September.

Figure 4. Monthly Average Flows at USGS Gaging Stations in the Wenatchee River Subbasin



USGS also evaluated surface-water flow, ground-water levels, and water quality from early September to early October, 1991 in the vicinity of the Leavenworth National Fish Hatchery (Drzymkowski and Swift, 1991). The measurements were made to establish baseline data for comparison with future information for streams that supply water to the hatchery, water flow in surface diversions, and water levels and quality of water from wells that supply water to the hatchery.

Chelan County

A provisional Wenatchee Channel Migration Study conducted by Chelan County is, as yet, unpublished. The channel geometry measurements from this study should augment the measurements made in Ecology's TMDL study.

Chelan County Conservation District

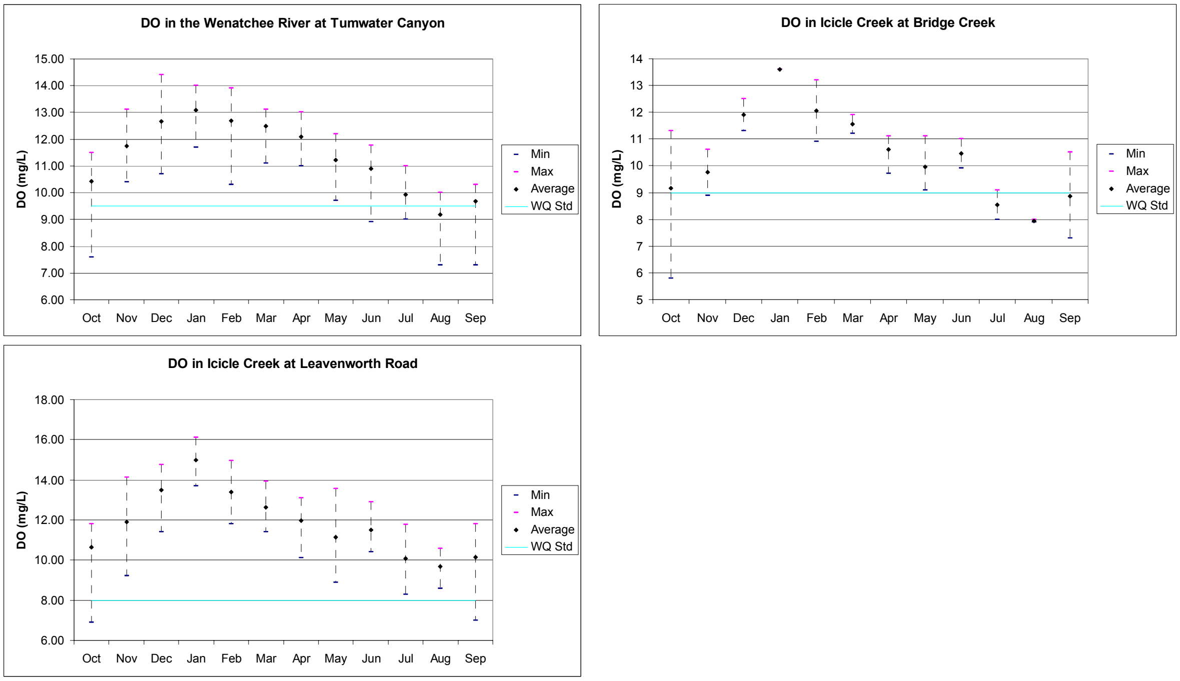
In 1994, the Chelan County Conservation District, along with 28 other public and private interests, completed a project to rank the watersheds of the Wenatchee River Subbasin based on their current or potential impact on water quality in the subbasin (Hindes, 1994). The large committee based the ranking on extensive discussions and the results of data collected by the conservation district from October of 1992 to September of 1993. The data collected included water quality samples from twenty sites in the subbasin analyzed for temperature, DO, conductivity, total dissolved solids, pH, ammonia, nitrate, nitrite, phosphorus, turbidity, fecal coliform, and total suspended solids as well as aquatic life samples. Water quality data resulted in several 303(d) listings in the subbasin for pH, DO, and fecal coliform. The committee ranked the watersheds in the following manner from most impact to least impact on water quality: Mission Creek, Chumstick Creek, White River, Mainstem Wenatchee River, Nason Creek, Peshastin Creek, Icicle Creek, Chiwawa River, Little Wenatchee River.

A technical advisory committee to the committee responsible for the ranking report published an addendum to that report in 1996 titled Technical Supplement I (Davis, 1996). The supplement contains a more complete characterization of the Wenatchee River Subbasin and Mission Creek watershed including information on geography, land use, climate, geology, soils, hydrology, water quality, wildfire, vegetation, fish and wildlife, and stream corridors. It also provides a detailed description of beneficial uses in the subbasin including fisheries, irrigation, domestic, municipal and industrial uses, recreation, scenic values, wildlife, and wetlands.

In 1998, the Wenatchee River Watershed Steering Committee, led by the Chelan County Conservation District, completed a Watershed Action Plan for the Wenatchee River Subbasin (Davis, 1998). The purpose of the plan was to provide guidance for individuals, citizen groups, agencies, tribes and other entities responsible for protecting and restoring water quality from the effects of nonpoint source water pollution in the Wenatchee Subbasin. This document also contains water quality data collected by the Chelan County Conservation District from August 1995 through July 1996. This data, along with the conservation district data collected for the ranking report and Ecology ambient monitoring data was combined and analyzed in order to determine a sampling plan for the TMDL.

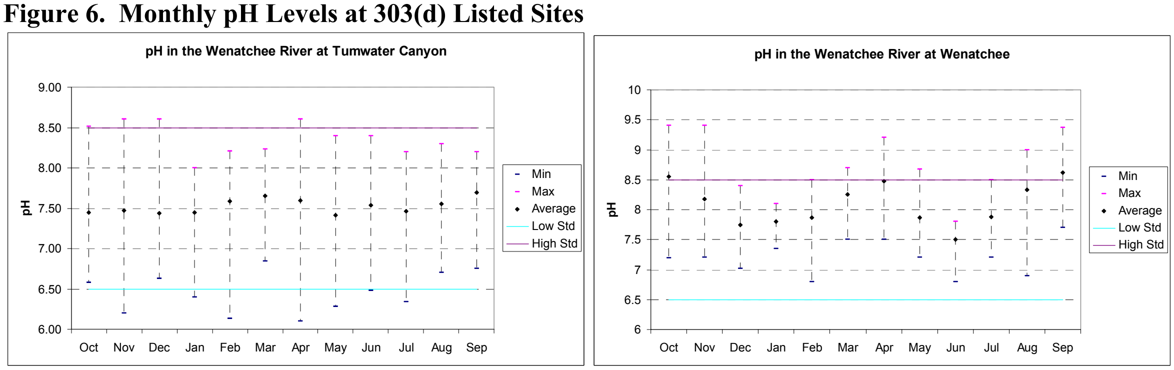
As indicated in the graphs below (Figure 5), DO violations tend to occur during the warmer summer months from June or July through October. While warmer water temperatures reduce the amount of DO saturation in water, further DO depression is suspected due to productivity issues (a high oxygen demand by biological constituents made abundant by high nutrient levels).

Figure 5. Monthly Dissolved Oxygen Levels at 303(d) Listed Sites



Violations in pH at the mouth of the Wenatchee River appear to exhibit a seasonal trend (Figure 6), with both high and low pH violations generally occurring during the growing season from March through November, with the exception of the high-flow months around June.

Figure 6. Monthly pH Levels at 303(d) Listed Sites



Sources of Pollution

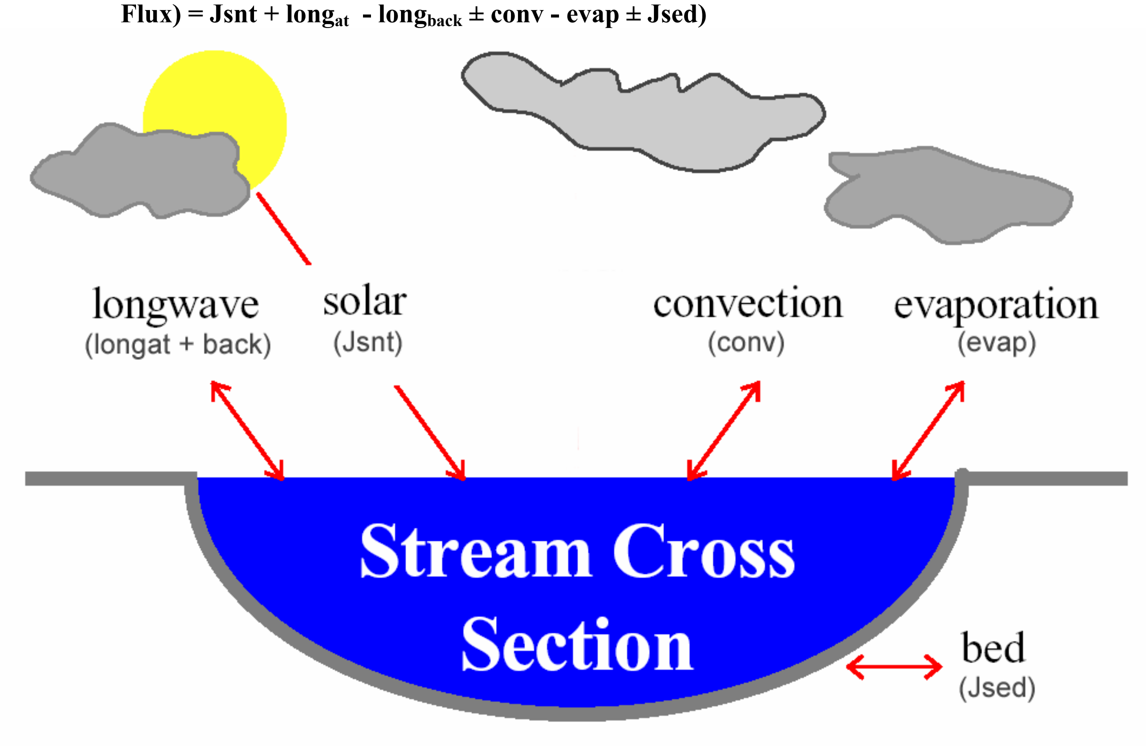
Temperature

The Wenatchee River Subbasin TMDL will be developed for heat (i.e., incoming solar radiation). Heat is considered a pollutant under Section 502(6) of the Clean Water Act. Heat generated by solar radiation reaching the stream provides energy to raise water temperatures. Heat can be defined as molecular kinetic energy, in this case the kinetic energy of water molecules. Temperature is a scale of measurement that is proportional to the average kinetic energy of the water molecules. Elevated summertime stream temperatures may result from anthropogenic influences. The following processes affect water temperatures in the Wenatchee River Subbasin:

- Riparian vegetation disturbance that compromises stream surface shading, through reductions in riparian vegetation height and density (shade is commonly measured as percent effective shade).
- Channel widening (increased width-to-depth ratios) that increases the stream surface area exposed to energy processes, namely solar radiation.
- Reduced summertime baseflows that result from instream withdrawals or from wells in hydraulic continuity with the stream.

Figure 7 shows the heat energy processes or fluxes that control heat energy transfer to and from the surface of a waterbody.

Figure 7. Surface Heat Transfer Processes in the QUAL2K Model that Affect Water Temperature (Net Heat Flux) = Jsnt + $long_{at}$ - $long_{back}$ ± conv - evap ± Jsed)



The solar short wave radiation flux (Jsnt) is typically the dominant component of the heat budget in unshaded streams. Other heat transfer components include: groundwater interactions with the stream, convection (the heat transfer interaction between water and air) and evaporation (loss of heat and water molecules to the air). The daily changes in water temperature typically follow the same pattern as solar radiation delivered to a stream. The solar shortwave flux can be controlled by managing vegetation in the riparian areas adjacent to the stream. Shade that is produced by riparian vegetation can reduce the solar shortwave flux. The net heat flux to a stream can be reduced by increasing the shade produced by vegetation, which reduces the shortwave solar flux and causes a reduction in the water temperature of a stream during the hottest part of a day.

Other processes, such as longwave radiation and convection, also introduce energy into a stream, but usually at smaller rates when compared with solar short wave radiation in un-shaded waterbodies (Chapra, 1997; Beschta and Weatherred, 1984; Boyd, 1996). If streamflow increased the volume of water available, these same surface heat transfer processes would be in place but would usually result in a smaller temperature gain to the stream.

Mass transfer processes refer to the downstream transport and mixing of water throughout a stream system and inflows of surface water and groundwater. The downstream transport of dissolved/suspended substances and heat associated with flowing water is called advection. Dispersion results from turbulent diffusion that mixes the water column. Due to dispersion, flowing water is usually well mixed vertically. Stream water mixing with inflows from surface tributaries and subsurface groundwater sources also redistributes heat within the stream system. These processes (advection, dispersion and mixing of surface and subsurface waters) redistribute the heat of a stream system via mass transfer. Turbulent diffusion can be calculated as a function of stream dimensions, channel roughness and average flow velocity. Dispersion occurs in both the upstream and downstream directions. Tributaries and groundwater inflows can change the temperature of a stream segment when the inflow temperature is different from the receiving water.

This TMDL technical assessment for the Wenatchee River will use riparian shade as a surrogate measure of heat flux to fulfill the requirements of Section 303(d). Effective shade is defined as the fraction of the potential solar shortwave radiation that is blocked by vegetation and topography before it reaches the stream surface. Effective shade accounts for the interception of solar radiation by vegetation and topography.

Heat loads to the stream will be calculated in the TMDL in a numerical model that accounts for surface heat flux and mass transfer processes. Heat loads are of limited value in guiding management activities needed to solve identified water quality problems. Shade will be used as a surrogate to thermal load as allowed under EPA regulations (defined as “other appropriate measure” in 40 CFR §130.2(i)). A decrease in shade due to inadequate riparian vegetation causes an increase in solar radiation and thermal load upon the affected stream section. Human-caused activities that contribute to lack of shade include livestock grazing, recreation, agriculture, and logging. Other factors influencing the distribution of the solar heat load will also be assessed, including increases in the wetted width-to-depth ratios of stream channels and instream flow.

The “Report of the Federal Advisory Committee on the Total Maximum Daily Load (TMDL) Program” (EPA, 1998) includes the following guidance on the use of surrogate measures for TMDL development:

“When the impairment is tied to a pollutant for which a numeric criterion is not possible, or where the impairment is identified but cannot be attributed to a single traditional “pollutant,” the state should try to identify another (surrogate) environmental indicator that can be used to develop a quantified TMDL, using numeric analytical techniques where they are available, and best professional judgment (BPJ) where they are not.”

Other Parameters

DO is a very important indicator of a waterbody’s ability to support aquatic life. Fish "breathe" by absorbing DO through their gills. Oxygen enters the water by absorption directly from the atmosphere or by aquatic plant and algae photosynthesis. Oxygen is removed from the water by plant and algae respiration, decomposition of organic matter, or degassing to the atmosphere. The amount of DO in water depends on several factors, including temperature (the colder the water, the more oxygen can be dissolved); the altitude (higher atmospheric pressure increases

DO at lower altitudes); the volume and velocity of water flowing in the water body; and the amount of organisms using oxygen for respiration.

Very high (greater than 9.5) or very low (less than 4.5) pH values are unsuitable for most aquatic organisms. Changes in pH can also affect aquatic life indirectly by altering other aspects of water chemistry. Low pH levels accelerate the release of metals from rocks or sediments in the stream. These metals can affect a fish's metabolism and the fish's ability to take water in through the gills, and can kill fish fry.

Potential causes of low DO and high and low pH levels include both point and nonpoint sources. Table 5 lists the facilities under permit from Ecology for discharging wastewater to the Wenatchee River and to Icicle Creek.

Table 5. NPDES Permitted Dischargers

Facility Name	Type	Receiving Waterbody	Discharge Period
Stevens Pass	Publicly owned Treatment Plant	Nason Creek	Continuous
Lake Wenatchee	Publicly owned Treatment Plant	Wenatchee River	November – April
Chiwawa Ponds	Fish Hatchery	Chiwawa River and Wenatchee River	Approximately September – May
Leavenworth National Fish Hatchery	Fish Hatchery	Icicle Creek	Continuous
City of Leavenworth	Potable Water Treatment Plant	Icicle Creek	Continuous
City of Leavenworth	Publicly owned Treatment Plant	Wenatchee River	Continuous
Community of Peshastin	Publicly owned Treatment Plant	Wenatchee River	Continuous
City of Cashmere	Publicly owned Treatment Plant	Wenatchee River	Continuous
Dryden Ponds	Fish Hatchery	Wenatchee River	March - April

There are additionally several possible nonpoint sources of pollution in the subbasin. On-site septic systems are common throughout the unincorporated areas of the Wenatchee River Subbasin. They present a potential source of nonpoint pollution when individual systems fail to function properly and/or when they are installed at densities higher than an area's soil can accommodate.

Agricultural practices comprise over 25,000 acres of land in the Wenatchee Subbasin (Davis, 1998). Farmland located directly on the Wenatchee River or on its tributaries can cause water quality problems due to soil compaction and runoff, unmanaged animal access and improper manure storage and disposal, a lack of best management practices for pesticides, poor fertilizer and irrigation water management, and removal of riparian zone vegetation.

Another cause of reduced DO levels may be related to forest management practices. Forest land is by far the largest cover type in the Wenatchee River Subbasin, covering approximately 86% (Hindes, 1994). Forestry practices can have a number of impacts, but those impacting DO and pH include logging and road building which can add slash and other organic debris to streams.

Finally, stormwater, surface rainfall and snowmelt runoff, can have a low concentration of DO as well as pH levels in violation of water quality standards. Stormwater tends to have greater impacts on a stream in more urban, developed areas where impervious surfaces are greater.

Project Objectives

Year One Temperature Study

1. Characterize summer (June – October 2002) water temperature in the mainstem of the Wenatchee River from Lake Wenatchee to the mouth, and in Icicle Creek from Jack Creek to the mouth, and near the mouths of major tributaries to the Wenatchee River and Icicle Creek.
    - Compile existing data, including:
        - Data collected during an ongoing temperature study performed by the Leavenworth and Lake Wenatchee Ranger Districts.
        - Data collected by the U.S. Forest Service, the U.S. Fish & Wildlife Service, the Chelan County Conservation District, and Chelan County.
    - Collect field data at selected sites throughout the subbasin.
2. Develop a predictive computer temperature model of the Wenatchee mainstem and Icicle Creek to do the following:
    - Model the instream temperature regime at critical conditions.
    - Create the framework to incorporate a year two study of the other major tributaries (Mission Creek, Peshastin Creek, Chumstick Creek, Chiwaukum Creek, Nason Creek, and Little Wenatchee River).
    - Evaluate the ability of load allocations for effective shade and other surrogate measures to reduce water temperatures to meet water quality standards.
3. Establish preliminary TMDL targets for temperature in the Wenatchee River mainstem and Icicle Creek.
    - Develop models for evaluations of load allocations for a TMDL for thermal load to the stream.
    - Load allocations will eventually be estimated in terms of effective shade and other surrogate measures such as channel width, and/or channel width-to-depth ratio.
    - Final load allocations and TMDL will be reported at the end of the year 2 study as a subbasin-wide TMDL.

Year One Study of Other Parameters

1. Conduct water quality monitoring surveys for physical, chemical, and biological parameters to determine sources affecting DO and pH levels in the Wenatchee River and Icicle Creek.
2. Calibrate and verify a water quality computer model for DO and pH.
3. Set DO and pH TMDL targets, nonpoint load allocations and point source waste load allocations for parameters responsible for causing DO and pH violations in the Wenatchee River and Icicle Creek.

Sampling Design

Temperature

Data collection, compilation, and assessment will be governed by the data set requirements of the computer temperature model (Table 6). The data will be assembled from local third party studies and Ecology field surveys. Third party studies include investigations by the U.S. Forest Service, U.S. Fish and Wildlife Service, Chelan County, and Chelan County Conservation District.

Four types of Ecology field surveys will be conducted related to stream temperatures: 1) continuous monitoring of water and air temperature and relative humidity, 2) surveys of riparian vegetation in the study area, 3) surveys of hydraulic geometry in stream reaches, and 4) remote sensing of surface temperatures using thermal infrared (TIR) and color videography.

1. Continuous Monitoring of Water and Air Temperature and Relative Humidity

Sampling sites are listed in Table 7 as well as graphically displayed in Figure 8. There are 46 total sites: 30 sites in the Wenatchee River Mainstem study area (19 mainstem sites and 11 sites on tributaries), and 16 sites in the Icicle Creek Watershed.

Monitoring locations were selected to characterize thermal loading from the headwaters and tributaries and intermediate locations in the mainstem of the Wenatchee River and Icicle Creek. Monitoring locations are limited by access opportunities. The uppermost boundary of the temperature study of the Wenatchee River will be the outlet of Lake Wenatchee. The lower-most mainstem site at RM 1 is near the Highway 285 bridge crossing in the city of Wenatchee and will represent the lower boundary of the study area. It is also one of Ecology's ambient water quality monitoring stations. Tributaries to the Wenatchee River will be sampled as close to their confluence with the mainstem as possible. The Icicle Creek Watershed will be sampled from the uppermost accessible tributary, Jack Creek, to the mouth of Icicle Creek.

Instantaneous flows will be measured about 4-5 times at the stations shown in Table 7 at approximately monthly intervals during June-October. Instantaneous flows will also include a measurement taken during the synoptic flow survey that coincides with the TIR survey (see below).

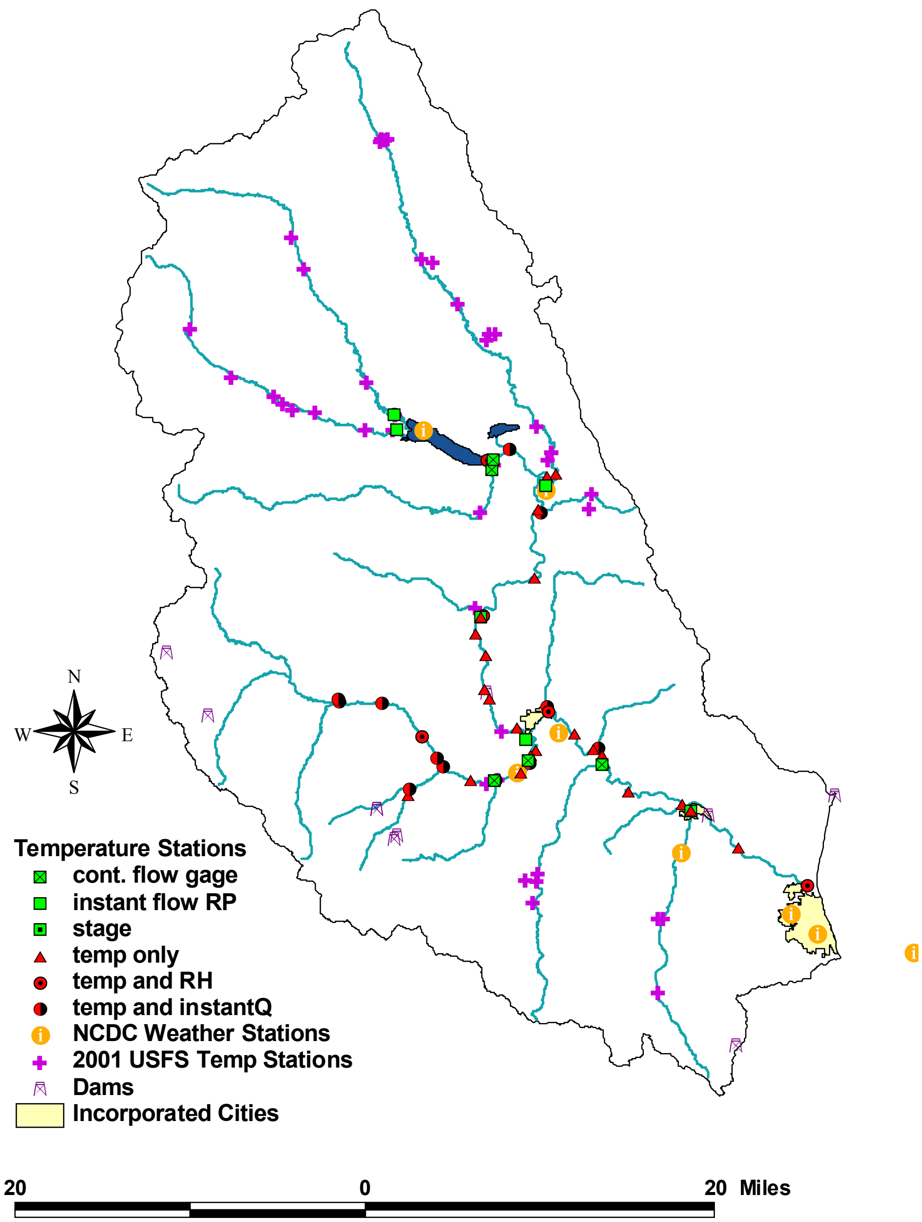
Table 6. Temperature Model Data Requirements

		MODEL	
	PARAMETER	**HeatSource/Shadealator**	**Qual2K**
Flow	discharge - tributary		x
	discharge (upstream & downstream)		x
	flow velocity		x
	groundwater inflow rate/discharge		x
	travel time		x
General	calendar day/date	x	x
	duration of simulation	x	x
	elevation - downstrean	x	x
	elevation - upstream	x	x
	elevation/altitude	x	x
	latitude	x	x
	longitude	x	x
	time zone	x	
Physical	channel azimuth/stream aspect	x	
	cross-sectional area	x	x
	Manning's n value	x	x
	percent bedrock	x	x
	reach length	x	x
	stream bank slope	x	
	stream bed slope	x	x
	width - bankfull	x	
	width - stream	x	x
	temperature - groundwater		x
	temperature - tributaries		x
	temperature - water downstream		x
	temperatures - water upstream		x
	temperature - air		x
Vegetation	% forest cover on each side	x	
	canopy-shading coefficient/veg density	x	
	diameter of shade-tree crowns	x	
	distance to shading vegetation	x	
	topographic shade angle	x	
	vegetation height	x	
	vegetation shade angle	x	
	vegetation width	x	
Weather	relative humidity		x
	% possible sun/cloud cover		x
	solar radiation		x
	temperature - air		x
	wind speed/velocity		x

Table 7. Monitoring Stations for Water Temperature, Air Temperature, Relative Humidity, Instantaneous Flow, and Wetted Width

STREAM	Water Temp. Site	Air Temp. Site	Air Temp. and Relative Humidity Site	Instantaneous Flow Site	Responsible Agency
Beaver Cr nr Mouth	X	X		X	WDOE
Brender Cr nr Mouth	X	X			WDOE
Cascade Orchard return	X				WDOE
Chiwaukum Cr nr mouth	X	X			USFS
Chiwawa at hatchery	X	X			WDOE
Chumstick Cr nr mouth	X	X			WDOE
Eightmile abv Mountaineer	X	X		X	WDOE
Eightmile Cr nr mouth	X	X		X	WDOE
Fish Lake outlet	X	X		X	WDOE
Highline ditch return	X				WDOE
Icicle blw Eightmile Cr	X	X			WDOE
Icicle at Ida Cr campground	X	X			WDOE
Icicle Cr abv hatchery	X	X			USFWS
Icicle Cr abv Snow Cr	X	X			USFS
Icicle Cr at Bridge Cr campground	X	X		X	WDOE
Icicle Cr at East Leavenworth Rd xing	X	X			WDOE
Icicle Cr at Ida Cr campground	X	X			WDOE
Icicle Cr blw hatchery	X	X		X	WDOE
Icicle Cr RM11.4	X		X	X	WDOE
Icicle Cr nr mouth	X		X		WDOE
Icicle old channel at hatchery	X	X		X	USFWS
Jack Cr nr mouth	X	X		X	WDOE
Lil Wenatchee nr mouth	X	X			USFS
LNFH abatement pond	X	X			WDOE
LNFH outlet	X				WDOE
Mission Cr nr mouth	X	X			WDOE
Mountaineer Cr nr mouth	X	X		X	WDOE
Nason Cr nr mouth	X	X			USFS
Peshastin Cr nr mouth	X	X			WDOE
Snow Cr nr mouth (blw diversion)	X	X		X	WDOE
Wenatche blw Tumwater dam	X	X			WDOE
Wenatchee abv Beaver Cr	X	X			WDOE
Wenatchee abv Chiwaukum	X		X		WDOE
Wenatchee abv Chiwawa	X	X			WDOE
Wenatchee abv Chumstick	X	X			WDOE
Wenatchee abv Derby	X	X			WDOE
Wenatchee abv Icicle	X	X			USFS
Wenatchee abv Mission	X	X			WDOE
Wenatchee abv Olalla	X	X			WDOE
Wenatchee abv Peshastin	X	X			WDOE
Wenatchee abv Tumwater dam	X	X			WDOE
Wenatchee blw Chumstick	X	X			WDOE
Wenatchee R blw Chiwaukum	X	X			WDOE
Wenatchee R blw Lk outlet	X		X		WDOE
Wenatchee R nr Monitor	X	X			WDOE
Wenatchee R nr mouth	X		X		WDOE
Wenatchee R south of Plain	X	X			WDOE
Wenatchee RM33.0	X	X			WDOE
White River nr mouth	X	X		X	USFS
Totals	**49**	**41**	**5**	**12**	

Figure 8. Temperature Monitoring Stations



Installation of temperature data loggers and monthly downloads will follow those protocols described in the TFW Temperature Stream Survey Manual (Scheutt-Hames, 1999). Temperature dataloggers 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. To safeguard against data loss, data from the loggers will be downloaded several times monthly throughout the sampling season.

Weather Stations
One of the important model variables that Ecology will not be directly measuring in the field is wind speed and direction. There are eight real-time weather stations in the Wenatchee Subbasin that record wind speed and direction among other helpful climate variables (see Table 8 and Figure 9 below). Six of those stations are operated by the National Climate Data Center and data can be obtained through the following website:
http://lwf.ncdc.noaa.gov/oa/climate/stationlocator.html

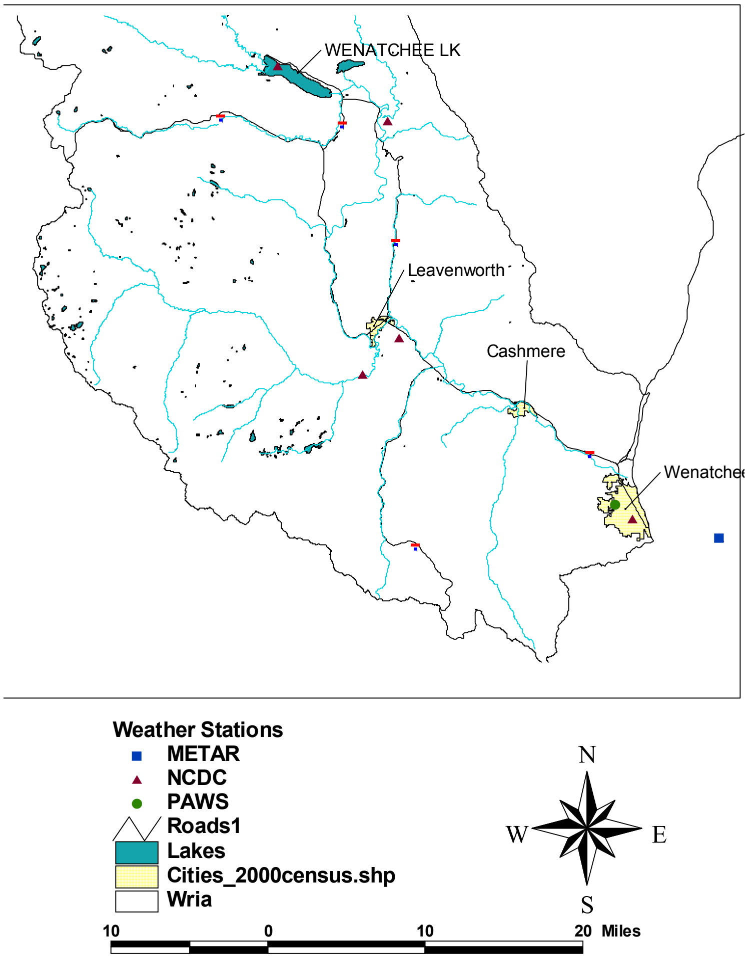
Another real-time station is a WSU Public Agricultural Weather System (PAWS) located at the WSU TFREC, Tree Forest Research and Extension Center in Wenatchee. These systems are setup as an agricultural information aid for farmers. There are many climate data variables available from the PAWS station that can be viewed as 15 minute or 1 hour averages. Data can be obtained after purchasing a subscription through the following website:
http://index.prosser.wsu.edu/

The other weather station that will be included is a National Weather Service surface weather observation station (a.k.a. METAR station) in Wenatchee. Traditional weather observations are transmitted in METAR format by various agencies and governments around the world. In the United States, the National Weather Service produces the majority of METAR observations, but other agencies, such as the Federal Aviation Administration (FAA) provide some observations as well. Many METAR observations are made by automated equipment such as Automated Surface Observing Systems (ASOS) in the United States. Realtime data can be obtained through the following website: http://www.wrh.noaa.gov/cgi-bin/Missoula/msoobs?site=KEAT&type=1&src=rgl

Table 8. Real-Time Weather Stations

Station Type	Station Name	Coop ID	Climate Division	Service Date	Elevation (ft)	Latitude	Longitude	Max air temp.	Min air temp.	Max soil temp.	Min soil temp.	Average soil temp.	Wind speed and direction	Evapo-ration	Precipi-tation	Snow depth	Water equivalent of snow depth	Relative Humidity (%)
NCDC	Wenatchee	459074	WA-08-Central Basin	06/01/48 to present	639.9	47.25	120.19	x	x	x	x		x	x	x	x	x	
NCDC	Plain	456534	WA-06-East Slope Cascades	06/01/48 to present	1939.5	47.47	120.39	x	x	x	x		x	x	x	x	x	
NCDC	Peshastin Telemetering	456472	WA-06-East Slope Cascades	11/0167 to present	1027.6	47.35	120.38								x			
NCDC	Leavenworth 3S	454572	WA-06-East Slope Cascades	06/0148 to present	1127.7	47.33	120.41	x	x	x	x		x	x	x	x	x	
NCDC	Lake Wenatchee	454446	WA-06-East Slope Cascades	06/0148 to present	2004.4	47.5	120.48	?	?	?	?		?	?	?	?	?	
NCDC	Wenatchee Pangborn Airport	459082	WA-08-Central Basin	11/0159 to present	1228.7	47.24	120.12	x	x	x	x		x	x	x	x	x	
PAWS	WSU Wenatchee			10/0693 to present	730	47.43	120.34	x	x			x	x		x			x
METAR	Wenatchee		WAZ041	? to present	1243	47.4	120.2	x	x			x	x					x

Figure 9. Real-Time Weather Stations



2. Surveys of Effective Shade in Stream Reaches

Effective shade measurements for riparian vegetation will be collected using hemispherical digital photography and analyzed using the Hemi-view 2.1 software from Delta-T Devices. Sites for hemispherical photography will be selected randomly from a subset of representative vegetation polygons to provide a statistically-based effective shade of each vegetation type (e.g. Figure 10). Vegetation polygons in the riparian corridor within 500 feet of each bank of the stream will be digitized from 1:24,000 scale digital orthophotos (ODEQ, 2001). Vegetation polygon types will be generally classified by species type and density as well as tree height.

Figure 10. Example of Riparian Vegetation Polygons Using a 500 ft Buffer

3. Surveys of Hydraulic Geometry in Stream Reaches

Channel width measurements will be taken about 4-5 times during the June-October period at approximately monthly intervals at 3 cross-sections at each of the continuous temperature stations in the mainstem of the Wenatchee River and Icicle Creek shown in Table 7. These measurements will be used to determine the relationship between channel geometry and flow. Effective shade measurements at the stream center of each transect will also be made using a solar pathfinder or hemispherical photography.

In addition to the measurements of width at the temperature monitoring stations, channel geometry surveys will be conducted during the period of peak summer temperature (mid July to mid August) at additional stations at representative locations within each reach of the mainstem of the Wenatchee River and Icicle Creek (Figure 11). Reaches were identified for channel geometry characterization based on channel gradient, contributing watershed areas, and land type association. Cross-section measurement stations within each reach will include measurements from 3-5 cross-sections per station depending on the uniformity of the channel geometry. Bankfull width and wetted width will be measured at each cross-section. If the cross-section is wadeable, then depth will also be measured. Flows will also be measured at a subset of the stations as time allows. Effective shade measurements at the stream center of each transect will be made using a solar pathfinder or hemispherical photography. Percent canopy cover will also be measured using a concave spherical densiometer to provide a correlation between solar pathfinder measurements and densiometer measurements.

Manning's equation is commonly used to estimate depth (d) from flow (Q), Manning's roughness coefficient (n), width (w), and slope (S), assuming the hydraulic radius equals the depth and the width is large compared to the depth (Lindeberg, 1989; metric units):

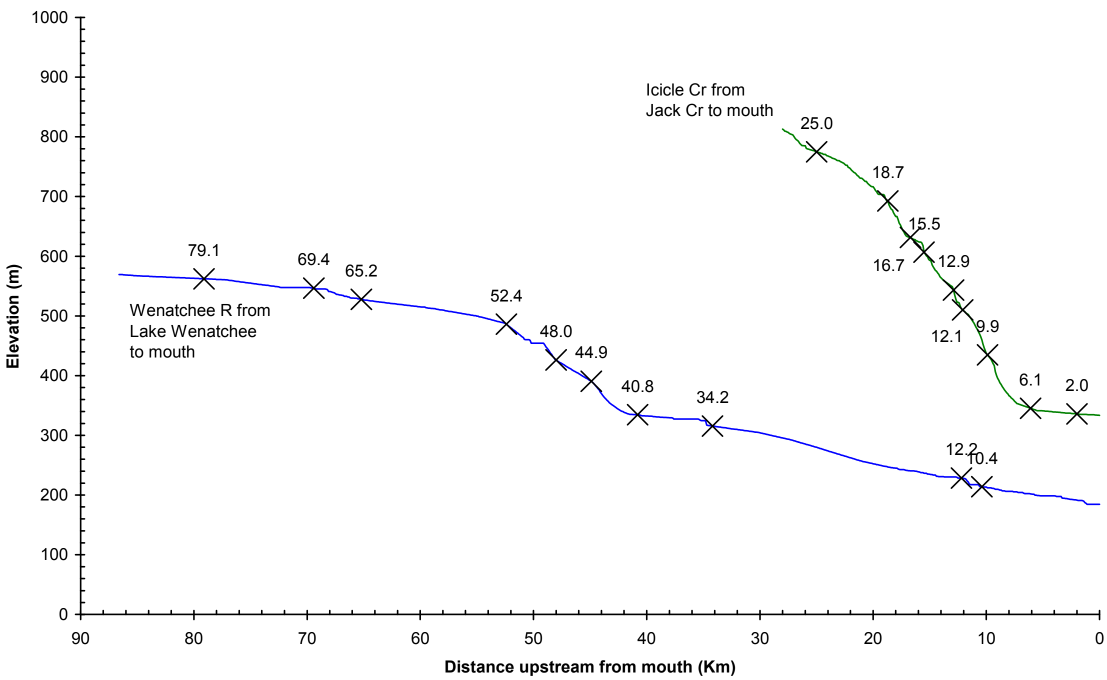
- $d = [(n * Q)/(S0.5 * w)]0.6$

If the flow (Q), width (w), and depth (d) are known, then the continuity equation can be used to estimate velocity (u):

- $u = Q / (w * d)$

Manning's n typically varies with flow and depth (Gordon et al., 1992). As the depth decreases at low flow, the relative roughness increases. Typical published values of Manning's n, which range from about 0.02 for smooth channels to about 0.15 for rough natural channels, are representative of conditions when the flow is at the bankfull capacity (Rosgen, 1996). Critical conditions of depth for evaluating the period of highest stream temperatures are generally much less than bankfull depth, and the relative roughness may be much higher.

Figure 11. Channel Gradients and Reach Breaks for the Wenatchee River and Icicle Creek



4. Thermal Infrared (TIR) and Color Videography Surveys

During the summer of 2001, the U.S. Forest Service commissioned a TIR flight along segments of the Chiwawa River, Nason Creek, White River, and Little Wenatchee River. During the summer of 2002, the Department of Ecology will commission a TIR flight along the mainstem Wenatchee River and Icicle Creek (Figure 2).

A helicopter-mounted TIR sensor and color video camera will be used to take thermal infrared and visible color images of the rivers to provide a spatially continuous image of surface temperature. The contractor will place temperature gauges in the rivers to confirm flight data with field readings. The helicopters will fly no lower than 1,000 feet and will work between 2:00 and 5:00 p.m., when daytime temperatures are highest.

The focus of images will be the center of the stream. It will cover an area of approximately 100 by 150 meters (330 by 490 feet) and will have a spatial resolution of approximately 0.5 meters (less than 2 feet). Infrared and photographic images will be collected along the entire length of the streams. Ecology will use the information collected from the surface of the streams to measure the stream temperatures on a spatial scale and to support the heat budget development. The information from the adjacent land areas may be used to estimate shading from vegetation.

A synoptic flow survey will occur on the same day as the TIR flight, if possible, or on a day within a reasonable time frame with the flight. All Stream velocity measurements will be made following the field sampling and measurement protocols described in the WAS protocol manual (WAS, 1993).

Other Parameters

The project objectives will be met through a combination of monitoring of water quality and flow, modeling of DO concentrations and pH levels in the Wenatchee River and Icicle Creek, and analysis of various loading scenarios and resulting water quality. Monitoring of water quality and quantity will be conducted to quantify water quality in the river and loading contributions from various sources. Monitoring will consider all parameters included on the 303(d) list (pH and DO) as well as other parameters which are known to affect pH and DO.

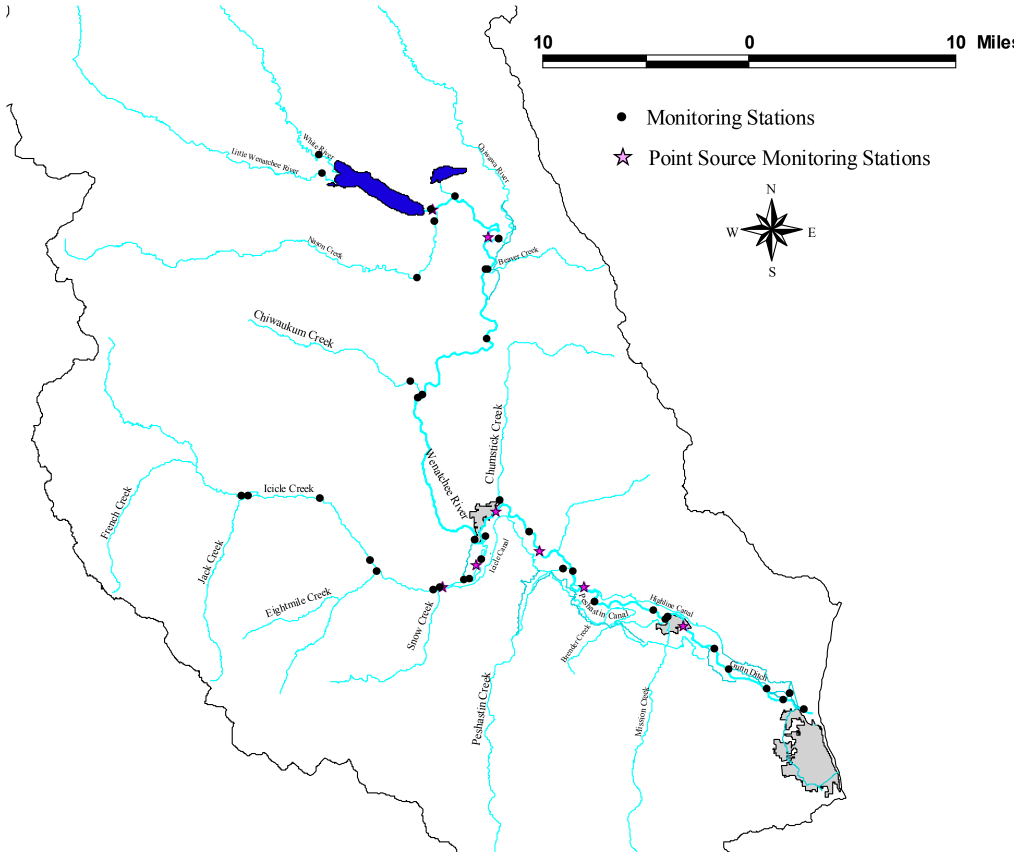
Sampling Sites

Figure 12 presents the locations of the water quality stations to be monitored. Stations were selected to distinguish upstream and tributary contributions from main stem contributions, and to distinguish among residential, agricultural and recreational contributions. There are 42 total sites: 28 sites in the Wenatchee River Mainstem study area (12 mainstem sites and 16 sites on tributaries), and 14 sites in the Icicle Creek Watershed (8 mainstem sites and 6 sites on tributaries).

Sampling sites for the Mainstem Wenatchee River were selected to characterize productivity from Lake Wenatchee to the river's mouth. Sites were limited by access opportunities. The uppermost Wenatchee River sites on the inlets to Lake Wenatchee (Little Wenatchee River and White River) will represent the upper boundary of the non-temperature study area. The lower-most mainstem site, just downstream of RM 1 at a pedestrian bridge accessible from Confluence State Park, will represent the lower boundary of the study area. Tributaries to the Wenatchee River will be sampled as close to their confluence with the mainstem as possible.

Sites on Icicle Creek were similarly selected to characterize loading from tributaries, campgrounds, and other land-use types. The Icicle Watershed will be sampled from the uppermost accessible tributary, Jack Creek, to the mouth of Icicle Creek.

Figure 12. Map of Non-Temperature Monitoring Stations



Monitoring Programs

Monitoring includes several programs described in detail below. All stations and parameters are subject to change depending on results of initial data collection. In general, the large number of parameters collected during the field season will assist in the modeling DO and pH responses to productivity in the Wenatchee and Icicle basins (see below: Data Analysis and Use).

Baseline Monitoring

Monthly field surveys will be conducted from the first week of June through the first week of December, 2002, at 22 baseline stations indicated in Figure 13. Schedules may change depending on flow conditions and staff availability. Parameters will include pH, DO, conductivity, discrete temperature, turbidity, total suspended solids (TSS), total nonvolatile suspended solids (TNVSS), alkalinity, total persulfate nitrogen (TPN), nutrients (ammonia, nitrate-nitrite, orthophosphate and total phosphorus), total organic carbon (TOC), total dissolved solids (TDS), and bacteria (fecal coliform – FC – and E. coli). Table 9 lists baseline parameters by station.

Figure 13. Baseline Monitoring Stations.

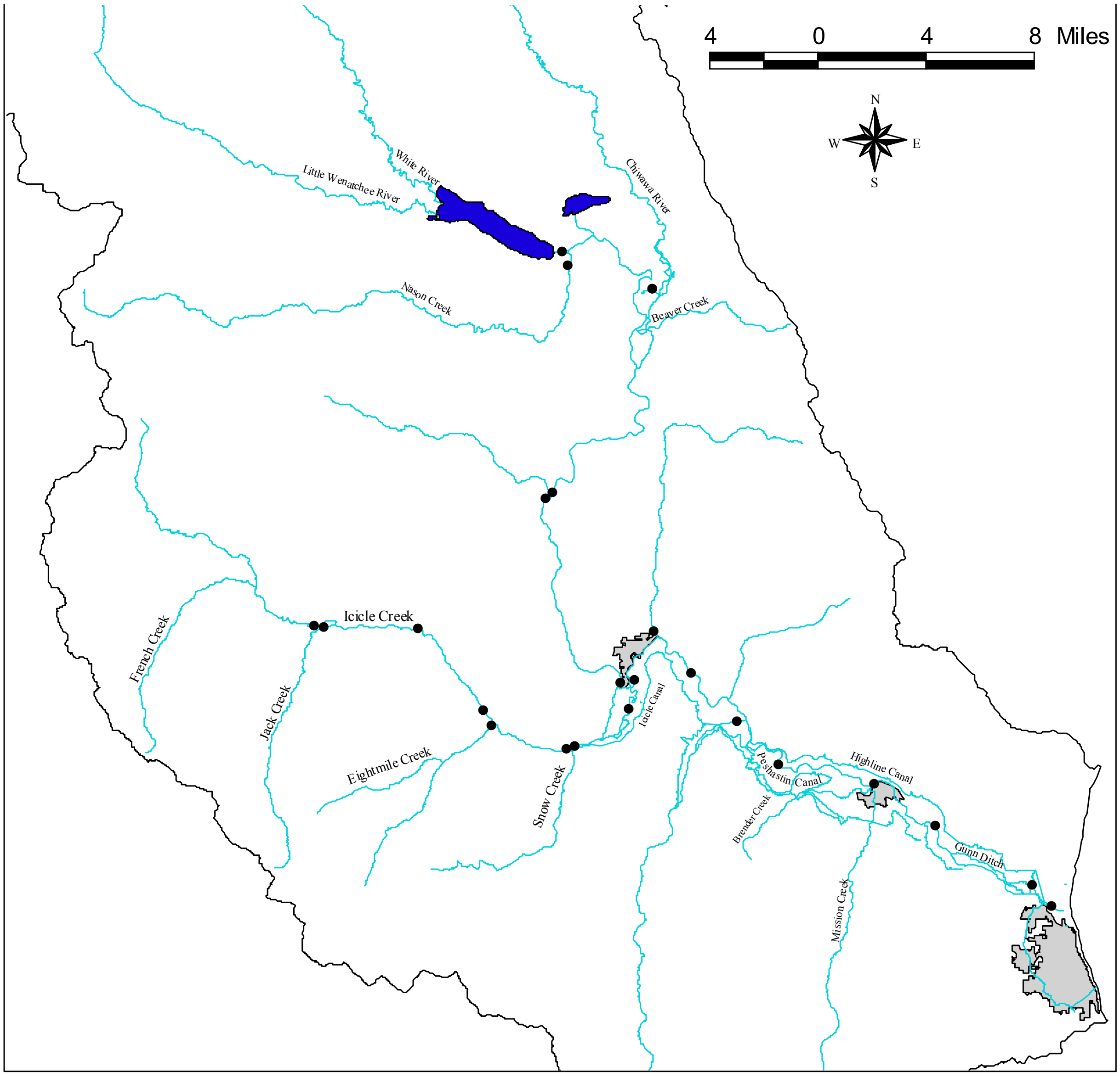


Table 9. Baseline Monitoring Parameters by Station

Station	Parameters									
	Field[1]	Turb-idity	TSS	TNVSS	Alk-alinity	TPN	Nutrients[2]	TOC	TDS	FC/ E-Coli
Wenatchee R at Lake Wenatchee	X	X	X	X	X	X	X	X	X	X
Wenatchee R nr Tumwater CG	X	X	X	X	X	X	X	X	X	X
Wenatchee R nr Peshastin	X	X	X	X	X	X	X	X	X	
Wenatchee R DS of Dryden	X	X	X		X	X	X	X	X	
Wenatchee R nr Monitor	X	X	X	X	X	X	X	X	X	
Wenatchee R nr mouth	X	X	X	X	X	X	X	X	X	
Nason Ck nr mouth	X	X	X	X	X	X	X	X	X	X
Chiwawa R. nr mouth	X	X	X	X	X	X	X	X	X	X
Chiwaukum Ck nr mouth	X	X	X		X	X	X	X	X	X
Highline return at Gunn Ditch Rd	X	X	X		X	X	X	X	X	
Icicle Cr near mouth	X	X	X	X	X	X	X	X	X	
Icicle C at Leavenworth Rd	X	X	X	X	X	X	X	X	X	
Icicle C US of Snow C	X	X	X	X	X	X	X	X	X	
Icicle C US of Eightmile C	X	X	X		X	X	X	X	X	
Icicle C nr Big Slide C	X	X	X		X	X	X	X	X	
Icicle C US of Jack Ck	X	X	X		X	X	X	X	X	
Snow C nr mouth	X	X	X		X	X	X	X	X	
Eightmile C nr mouth	X	X	X		X	X	X	X	X	
Jack C nr mouth	X	X	X		X	X	X	X	X	
Chumstick Ck nr mouth	X	X	X	X	X	X	X	X	X	X
Peshastin Ck nr mouth	X		X	X	X	X	X	X	X	X
Mission Ck nr mouth	X		X	X	X	X	X	X	X	X

[1]Field parameters include discrete temperature, conductivity, pH, and dissolved oxygen
[2]Nutrients include ammonia, nitrate-nitrite, ortho-phosphate, and low level total phosphorus

Intensive Synoptic Surveys

For the most productive months of July, August, and September, 2002, more intensive data collection will be performed during the third week of the month at all sampling stations. Parameters will include pH, DO, conductivity, discrete temperature, turbidity, flow, TSS, TNVSS, alkalinity, chloride, chlorophyll, dissolved total phosphorus (DTP), TPN, nutrients (ammonia, nitrate-nitrite, orthophosphate and total phosphorus), ultimate biochemical oxygen demand (UBOD), phytoplankton, DOC, TOC, TDS, FC, and E. coli. Two or more Hydrolab® meters will be deployed to bracket individual reaches throughout the sampling event. Resulting data will be used to measure productivity. Table 10 lists synoptic survey parameters by station.

Table 10. Synoptic Monitoring Parameters by Station

Station	Parameters																
	HL[1]	Field	Flow	Turb	TSS/ TNVSS	Alkalinity	Chloride	Chloro- phyll	DTP	TPN	Nuts	BOD (Ult.)	Phyto- plankton	DOC	TOC	TDS	FC/ E.coli
Wenatchee R at Lake Wenatchee	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Wenatchee R nr Plain	X	X		X	X	X	X			X	X				X	X	
Wenatchee R DS of Plain	X	X		X	X	X	X			X	X				X	X	
Wenatchee R nr Tumwater CG	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Wenatchee R nr Leavenworth	X	X		X	X	X	X	X	X	X	X			X	X	X	
Wenatchee R nr Peshastin	X	X		X	X	X	X	X		X	X	X	X		X	X	X
Wenatchee R at Highline Diversion	X	X		X	X	X	X	X	X	X	X			X	X	X	
Wenatchee R DS of Dryden	X	X		X	X	X	X	X	X	X	X			X	X	X	
Wenatchee R nr Cashmere	X	X		X	X	X	X	X	X	X	X			X	X	X	
Wenatchee R nr Monitor	X	X		X	X	X	X	X	X	X	X		X	X	X	X	X
Wenatchee R at Sleepy Hollow Br		X		X	X	X	X			X	X				X	X	
Wenatchee R nr mouth	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
White R nr mouth		X	X	X	X	X	X			X	X				X	X	
Little Wenatchee R nr mouth		X	X	X	X	X	X			X	X				X	X	
Nason Ck nr mouth		X	X	X	X	X	X	X	X	X	X			X	X	X	X
Nason Ck US of CG		X	X	X	X	X	X			X	X				X	X	X
Fish Lake Run nr mouth		X	X	X	X	X	X			X	X				X	X	
Chiwawa R nr mouth		X	X	X	X	X	X	X	X	X	X			X	X	X	X
Chiwaukum R nr mouth		X	X	X	X	X	X	X	X	X	X			X	X	X	X
Chiwaukum R US of CG		X	X	X	X	X	X			X	X				X	X	
Chumstick C nr mouth		X	X	X	X	X	X	X	X	X	X			X	X	X	X
Peshastin C nr mouth		X	X	X	X	X	X	X	X	X	X			X	X	X	X
Mission C nr mouth		X	X	X	X	X	X	X	X	X	X			X	X	X	X
Brender C nr mouth		X	X	X	X	X	X	X	X	X	X			X	X	X	X
Icicle C US of Jack C	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	
Icicle C nr Big Slide C		X	X	X	X	X	X	X		X	X		X		X	X	
Icicle C US of Eightmile C	X	X	X	X	X	X	X	X		X	X				X	X	
Icicle C US of Snow C	X	X		X	X	X	X	X		X	X		X		X	X	X
Icicle C at LNFH diversion		X	X	X	X	X	X			X	X				X	X	
Icicle C US of LNFH above canal	X	X		X	X	X	X	X	X	X	X			X	X	X	X
Icicle C at E Leavenworth Rd	X	X	X	X	X	X	X	X		X	X			X	X	X	X
Icicle Cr nr mouth	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X
Jack C nr mouth		X	X	X	X	X	X	X		X	X			X	X	X	
Eightmile C nr mouth		X	X	X	X	X	X	X		X	X			X	X	X	
Snow C nr mouth		X	X	X	X	X	X	X		X	X			X	X	X	
Chiwawa Ditch Return to Wenatchee R		X	X	X	X	X	X			X	X			X	X	X	
Highline return at Gunn Ditch Rd		X	X	X	X	X	X	X		X	X			X	X	X	
Gunn Ditch Diversion		X	X	X	X	X	X			X	X				X	X	
Gunn Ditch Return		X	X	X	X	X	X			X	X				X	X	
LNFH return		X	X	X	X	X	X	X		X	X			X	X	X	
LNFH old historic channel return		X	X	X	X	X	X	X		X	X			X	X	X	
LNFH end of canal		X		X	X	X	X			X	X				X	X	

[1] HL = Hydrolab®, a multi-parameter meter which will record temperature, pH, dissolved oxygen, and conductivity regularly throughout sampling event

Additional Monthly Surveys

During the months of June, October, and November (depending upon flow conditions and staff availability), when synoptic surveys are not taking place, less intensive monthly surveys will be performed during the third week of each month. These surveys will encompass the same survey sites as synoptic surveys (Figure 12), but DTP, UBOD, and phytoplankton samples will be excluded during these surveys and other parameters (Chlorophyll, FC, and DOC) will be sampled less frequently. Additionally, the ability to measure flows may be limited by time and high velocities. Table 11 lists monthly survey parameters by station.

Table 11. Additional Monthly Parameters by Station

Station	Parameters											
	Field	Turb	TSS/ TNVSS	Alkalinity	Chloride	Chloro- phyll	TPN	Nuts	DOC	TOC	TDS	FC/ E.coli
Wenatchee R at Lake Wenatchee	X	X	X	X	X	X	X	X	X	X	X	X
Wenatchee R nr Plain	X	X	X	X	X		X	X		X	X	
Wenatchee R DS of Plain	X	X	X	X	X		X	X		X	X	
Wenatchee R nr Tumwater CG	X	X	X	X	X	X	X	X	X	X	X	
Wenatchee R nr Leavenworth	X	X	X	X	X		X	X	X	X	X	
Wenatchee R nr Peshastin	X	X	X	X	X	X	X	X		X	X	
Wenatchee R at Highline Diversion	X	X	X	X	X		X	X		X	X	
Wenatchee R DS of Dryden	X	X	X	X	X		X	X		X	X	
Wenatchee R nr Cashmere	X	X	X	X	X		X	X		X	X	
Wenatchee R nr Monitor	X	X	X	X	X	X	X	X	X	X	X	
Wenatchee R at Sleepy Hollow Br	X	X	X	X	X		X	X		X	X	
Wenatchee R nr mouth	X	X	X	X	X	X	X	X	X	X	X	
White R nr mouth	X	X	X	X	X		X	X		X	X	
Little Wenatchee R nr mouth	X	X	X	X	X		X	X		X	X	
Nason Ck nr mouth	X	X	X	X	X	X	X	X	X	X	X	
Nason Ck US of CG	X	X	X	X	X		X	X		X	X	
Fish Lake Run nr mouth	X	X	X	X	X		X	X		X	X	
Chiwawa R nr mouth	X	X	X	X	X	X	X	X	X	X	X	
Chiwaukum R nr mouth	X	X	X	X	X	X	X	X	X	X	X	
Chiwaukum R US of CG	X	X	X	X	X		X	X		X	X	
Chumstick C nr mouth	X	X	X	X	X	X	X	X	X	X	X	X
Peshastin C nr mouth	X	X	X	X	X	X	X	X	X	X	X	X
Mission C nr mouth	X	X	X	X	X	X	X	X	X	X	X	X
Brender C nr mouth	X	X	X	X	X	X	X	X	X	X	X	X
Icicle C US of Jack C	X	X	X	X	X		X	X	X	X	X	
Icicle C nr Big Slide C	X	X	X	X	X		X	X		X	X	
Icicle C US of Eightmile C	X	X	X	X	X		X	X		X	X	
Icicle C US of Snow C	X	X	X	X	X		X	X		X	X	
Icicle C at LNFH diversion	X	X	X	X	X		X	X		X	X	
Icicle C US of LNFH (above canal)	X	X	X	X	X		X	X		X	X	
Icicle C at E Leavenworth Rd												
Icicle C nr mouth	X	X	X	X	X	X	X	X	X	X	X	X
Jack C nr mouth	X	X	X	X	X		X	X		X	X	
Eightmile C nr mouth	X	X	X	X	X		X	X		X	X	
Snow C nr mouth	X	X	X	X	X		X	X		X	X	
Chiwawa Ditch Return to Wenatchee R	X	X	X	X	X		X	X	X	X	X	
Highline return at Gunn Ditch Rd	X	X	X	X	X		X	X	X	X	X	
Gunn Ditch Diversion	X	X	X	X	X		X	X	X	X	X	
Gunn Ditch Return	X	X	X	X	X		X	X	X	X	X	
LNFH return	X	X	X	X	X		X	X	X	X	X	
LNFH old historic channel return	X	X	X	X	X		X	X	X	X	X	
LNFH end of canal	X	X	X	X	X		X	X		X	X	

Groundwater Sampling

Groundwater discharge to Icicle Creek and the Wenatchee River will be characterized for water quality parameters as well. Mini instream piezometers will be installed at approximately 2-mile intervals along the Mainstem Wenatchee River and Icicle Creek to define the vertical hydraulic gradient between area streams and groundwater. The mini-piezometers consist of a seven foot length of ½ inch diameter galvanized pipe, one end of which is crimped and slotted. The upper end of each piezometer is fitted with a standard pipe coupler to provide a robust strike surface and to enable the piezometers to be securely capped between sampling events. The piezometers will be hand driven into the stream bed (within a few feet of the shoreline) with a fence post driver to a depth of approximately 5 feet.

A subset of 6 to 10 piezometers will be installed and sampled monthly between June and November 2002 for the following parameters: water levels, conductivity, pH, DO, discrete temperature, TSS, alkalinity, chloride, TPN, nutrients (ammonia, nitrate-nitrite, orthophosphate and total phosphorus), DOC, TOC, and TDS. The remaining piezometers will be temporary installations and will remain in place only long enough to be developed and sampled. The piezometer water levels will be measured using a calibrated electric well probe, steel tape, or manometer board in accordance with standard USGS methodology (Stallman, 1983). The head difference between the internal piezometer water level and the external river stage provides an indication of the vertical hydraulic gradient and the direction of flow between the river and groundwater. When the piezometer head exceeds the river stage, ground water discharge into the river can be inferred. Similarly when river stage exceeds the head in the piezometer, loss of water from the river to groundwater storage can be inferred.

Surface water and groundwater temperature/conductivity will be measured during each piezometer survey. Stream reaches with significant ground-water input (especially during low flow periods) should have similar water chemistry to area ground water. Measurements will be made with properly maintained and calibrated field meters in accordance with standard USGS methodology.

Point Source Sampling

Point sources in the study area include wastewater treatment plants (WWTPs), fish hatcheries (hatcheries) and a potable water treatment plant (WTP). The WTP will not be sampled because it is not considered to be a significant source of pollutants. Stevens Pass WWTP will not be sampled because of its low flow and loading.

Point sources listed in Table 5, and illustrated in Figure 12, will be sampled during the intensive synoptic surveys by Ecology's Contaminant Studies Unit. Final effluents will be sampled during periods when they discharge to receiving waters for the parameters listed in Table 12. Two grab samples per day will be collected as well as 24-hour composite samples. The composite samples will consist of 48 subsamples collected with portable automatic compositors on a time-weighted basis (every 30 minutes).

Table 12. Point Source Parameters by Station

Station	pH	DO	Conduc-tivity	Temp-erature	TSS	Alka-inity	Chloride	TPN	Nuts	DOC	TOC	TDS	FC/ Ecoli
Stevens Pass WWTP	-	-	-	-	-	-	-	-	-	-	-	-	-
Lake Wenatchee WWTP*	D	G	DG	D	CG	CG	CG	CG	CG	CG	CG	CG	G
Chiwawa Ponds Hatchery	D	G	DG	D	CG	CG	CG	CG	CG	CG	CG	CG	G
Leavenworth National Fish Hatchery	D	G	DG	D	CG	CG	CG	CG	CG	CG	CG	CG	G
City of Leavenworth Potable WTP	-	-	-	-	-	-	-	-	-	-	-	-	-
City of Leavenworth WWTP	D	G	DG	D	CG	CG	CG	CG	CG	CG	CG	CG	G
Community of Peshastin WWTP	D	G	DG	D	CG	CG	CG	CG	CG	CG	CG	CG	G
City of Cashmere WWTP	D	G	DG	D	CG	CG	CG	CG	CG	CG	CG	CG	G
Dryden Ponds Hatchery*	D	G	DG	D	CG	CG	CG	CG	CG	CG	CG	CG	G

* Seasonal dischargers will not be sampled during months of no discharge.
C- composite sample
G – grab sample
CG – discrete and grab samples
D – discrete sample

Travel Time Estimates

Travel time, the movement of water from point to point in the stream, will be estimated at several locations during low and moderate flows, in September and January or February, respectively. A tracer will be used to measure the travel time of the water by observing the time required for the tracer to move between sampling sites (Hubbard et al., 1982). In addition, the data can be used to determine dispersion characteristics of the stream.

Field and Laboratory Analyses

Field sampling and measurement protocols will follow those listed in the Watershed Assessment Section protocols manual (Ecology, 1993). Field measurements at all sampling stations will include conductivity, DO, Ph, and temperature. All meters will be pre- and post-calibrated in accordance with the manufacturer's instructions. Pre- and post-checks with standards will evaluate field measurement accuracy. A minimum of ten percent of all DO measurements will be checked by a Winkler titration.

Stream discharge information will be obtained at critical sampling locations to provide loading information. Data obtained from USGS gages will be used where available. Continuous flow gaging stations will be installed at five locations in the subbasin on Nason Creek, the Wenatchee River near Lake Wenatchee, Icicle Creek near the mouth, Chiwaukum Creek near the mouth, and

Chumstick Creek at the existing continuous flow gage station. Flows will be determined by the Environmental Monitoring and Trends Section Stream Hydrology Unit (SHU). Estimation of discharge and instantaneous flow measurement will follow the SHU protocols manual (Ecology, 1999). Flows will be calculated from continuous stage height records and rating curves developed prior to and during the project. Stage height will be measured by pressure transducer and recorded by a data logger every 15 minutes. All data loggers will be downloaded monthly. Staff gages and/or capacitive probes will be installed at other selected sites. During the field surveys, flows will be measured at selected stations and/or staff gauge readings will be recorded. A flow rating curve will be developed for sites with a staff gauge.

Grab samples will be collected directly into pre-cleaned containers supplied by Manchester Environmental Laboratory (MEL) and described in MEL (2000). Analytical methods, sample containers, volumes, preservation and hold time are listed in Table 13. Samples for laboratory analysis will be stored on ice and delivered to MEL within 24 hours of collection.

Table 13. Summary of Laboratory Measurements and Methods

Parameter	Bottle	Preservative	Holding Time	EPA Method	Reporting Limit
Alkalinity	500 mL polypropylene (poly)	Cool to 4ºC	14 days	310.2	10 mg/L
Biochemical Oxygen Demand (BOD)	1 gallon cubitainer	Cool to 4ºC	48 hours	405.1	2 mg/L
Chloride	500 mL poly	Cool to 4ºC	28 day	300.0	0.1 mg/L
Chlorophyll a	1000 mL amber	Cool to 4ºC	24 to filter 28 hours after filter	SM 10200H(3)[1]	0.05 ug/L
Conductivity	500 mL poly	Cool to 4ºC	28 days	120.2	1 µmhos/cm
DOC	60 mL poly	HCl to pH<2, Cool to 4ºC	28 days	415.1	1.0 mg/L
Ammonia	125 mL clear poly	H_2SO_4 to pH < 2, Cool to 4ºC	28 days	350.1	0.01 mg/L
Nitrate/Nitrite	125 mL clear poly	H_2SO_4 to pH < 2, Cool to 4ºC	28 days	353.2	0.01 mg/L
Nitrogen – Total Persulfate	125 mL clear poly	H_2SO_4 to pH < 2, Cool to 4ºC	28 days	SM4500[1]	0.01 mg/L
Orthophosphate	125 mL amber poly	Cool to 4ºC	48 hours	356.3	0.01 mg/L
pH	500 mL poly	Cool to 4ºC	24 hours	150.1	
Phosphorus, total	125 mL clear poly	H_2SO_4 to pH < 2, Cool to 4ºC	28 days	365.3	0.01 mg/L
Phosphorus, total low level	New 125 mL poly	H_2SO_4 to pH < 2, Cool to 4ºC	28 days	365.1	3.0 ug/L
Phosphorus, total dissolved	125 mL clear poly	H_2SO_4 to pH < 2, Cool to 4ºC	28 days	365.3	0.01 mg/L
Phytoplankton	500 mL amber	Lugol's solution	n/a	hand ID	n/a
Total Suspended Solids	1000 mL poly	Cool to 4ºC	7 days	160.3	1 mg/L
Total Nonvolatile Suspended Solids	1000 mL poly	Cool to 4ºC	7 days	160.4	1 mg/L
Total Dissolved Solids	500 mL poly	Cool to 4ºC	7 days	160.1	1 mg/L
TOC	60 mL poly	HCl to pH<2, Cool to 4ºC	28 days	415.1	1.0 mg/L
Turbidity	500 mL poly	Cool to 4ºC	48 hours	180.1	1 NTU
Fecal Coliform	250 mL glass/poly autoclaved	Cool to 4ºC	30 hours	SM MF 9222D	1 cfu/100 mL
E Coli	250 mL glass/poly autoclaved	Cool to 4ºC	30 hours		

[1] SM indicates Standard Methods rather than EPA method.

Measurement Quality Objectives

Temperature

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 an NIST certified 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.

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 NIST certified thermometer and the thermal data loggers differs by more than the manufacturer's reported specifications during the pre-study calibration, the thermal data logger will not be used during field work.

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 subbasin. 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

Other Parameters

The data quality objectives are presented in Table 14. The laboratory's measurement quality objectives and quality control procedures are documented in the MEL Lab Users Manual (MEL, 2000).

Table 14. Targets for Accuracy, Precision, Bias, and Reporting Limits for the Measurement Systems

Analysis	**Accuracy** % deviation from true value	**Precision** Relative Standard Deviation	**Bias** % deviation from true value	**Required Reporting Limits** Concentration units
Field Measurements				
Velocity*	± 2% of reading +0.05 f/s 0.1 f/s	0.1 f/s	N/A	0.05 f/s
pH*	0.15 s.u.	0.05 s.u.	0.10 s.u.	N/A
Air Temperature*	± 0.4°C	0.025 °C	0.05 °C	N/A
Water Temperature*	± 0.2°C			N/A
Relative Humidity	± 3%			N/A
Dissolved Oxygen	15	< 5	5	1 mg/L
Specific Conductivity	25	<10	5	1 umhos/cm
Laboratory Analyses				
Fecal Coliform (MF)	N/A	<25 [2]	N/A	1 cfu/100 mL
Biochemical oxygen demand	N/A	<25	N/A	2 mg/L
Chlorophyll a	N/A	<20	N/A	0.05 ug/L
Total Organic Carbon	30	<10	10	1 mg/L
Dissolved Organic Carbon	30	<10	10	1 mg/L
E. Coli	N/A	<25	N/A	1 cfu/100 mL
Total Suspended/Dissolved Solids	30	<10	10	1 mg/L
Total Nonvolatile Supsended Solids	N/A	<10	N/A	1 mg/L
Alkalinity	N/A	<10	N/A	10 mg/L
Turbidity	N/A	<10	N/A	1 NTU
Chloride	15	< 5	5	0.1 mg/L
Total Persulfate Nitrogen	30	<10	10	25 ug/L
Ammonia Nitrogen	25	<10	5	10 ug/L
Nitrate & Nitrite Nitrogen	25	<10	5	10 ug/L
Orthophosphate P	25	<10	5	10 ug/L
Total Phosphorus	25	<10	5	3 ug/L
Dissolved Total Phosphorus	25	<10	5	10 ug/L
Phytoplankton	N/A	N/A	N/A	N/A

[2] Logtransformed data
* as units of measurement, not percentages

Accuracy is affected by both precision and bias. The targets for analytical precision in Table 14 are based on the standard deviation of the results for check standards used to monitor measurement system performance. Targets for analytical bias are based on the difference between the mean of those results and the actual value for the check standard. Targets for accuracy are calculated at two times the target for precision plus the target for bias.

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.

Quality Control Procedures

Temperature

The Optic Stowaway Tidbits will be pre-study and post-study calibrated in accordance with TFW Stream Temperature Survey protocol to document instrument bias and performance at representative temperatures. A NIST 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 or ± 0.4ºC depending on the temperature accuracy of the tidbit.

Variation for field sampling of instream temperatures will be addressed with a field check of the data loggers with a hand held thermometer at all thermograph sites upon deployment, download events, and at tidbit removals at the end of the study period. 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).

Other Parameters

Total variation for field sampling and analytical variation will be assessed by collecting replicate samples in addition to lab duplicates and comparing those data to data quality objectives. Replicate samples will be collected at a rate of 10% of all samples. Bacteria samples tend to have a high percent RSD compared to other water quality analyses. Total variation for field sampling and laboratory analysis of bacteria samples will be assessed by collecting duplicates for approximately 20 percent of samples. Ten percent of the filtered orthophosphate samples sent to the lab will be filter blanks to ensure filter and container quality. In addition, field blanks and total phosphorus standards will be submitted with routine samples to the laboratory to determine the presence of bias in analytical methods.

All samples will be analyzed at MEL. The laboratory's data quality objectives and quality control procedures are documented in the MEL Lab Users Manual (MEL, 2000). MEL will follow standard quality control procedures (MEL, 2000). Field sampling and measurements will follow quality control protocols described in WAS (1993).

Results for check standards will be compared to the MQOs for precision, bias, and accuracy in Table 14 wherever possible. Reporting limits for the project data will be compared to those in Table 14. If any of these targets are not met, the associated results will be qualified and used with caution.

Data Analysis and Use

Temperature

Data collected during this TMDL effort will allow the development of a temperature simulation methodology that is both spatially continuous and which spans full-day lengths (quasi-dynamic, steady-state diel simulations). The GIS and modeling analysis will be conducted using three specialized software tools:

- ODEQ's Ttools extension for Arcview (ODEQ, 2001) will be used to sample and process GIS data for input to the HeatSource/Shadealator and QUAL2K models.

- ODEQ's HeatSource/Shadealator model (ODEQ, 2000) will be used to estimate effective shade along the mainstems of the major tributaries in the Wenatchee River Subbasin. Effective shade will be calculated at 50- to 100-meter intervals along the streams and then averaged over 500- to 1000-meter intervals for input to the QUAL2K model.

- The QUAL2K model (Chapra, 2001) will be used 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 were specified or simulated as diurnally varying functions. QUAL2K uses the kinetic formulations for the components of the surface water heat budget that are shown in Figure 14 and described in Chapra (1997). Diurnally varying water temperatures at 500 to 1000-meter intervals along the streams in the Wenatchee River Subbasin will be simulated using a finite difference numerical method. The water temperature model will be calibrated to in-stream data along the mainstems of the Wenatchee River and Icicle Creek in year 1 of the study.

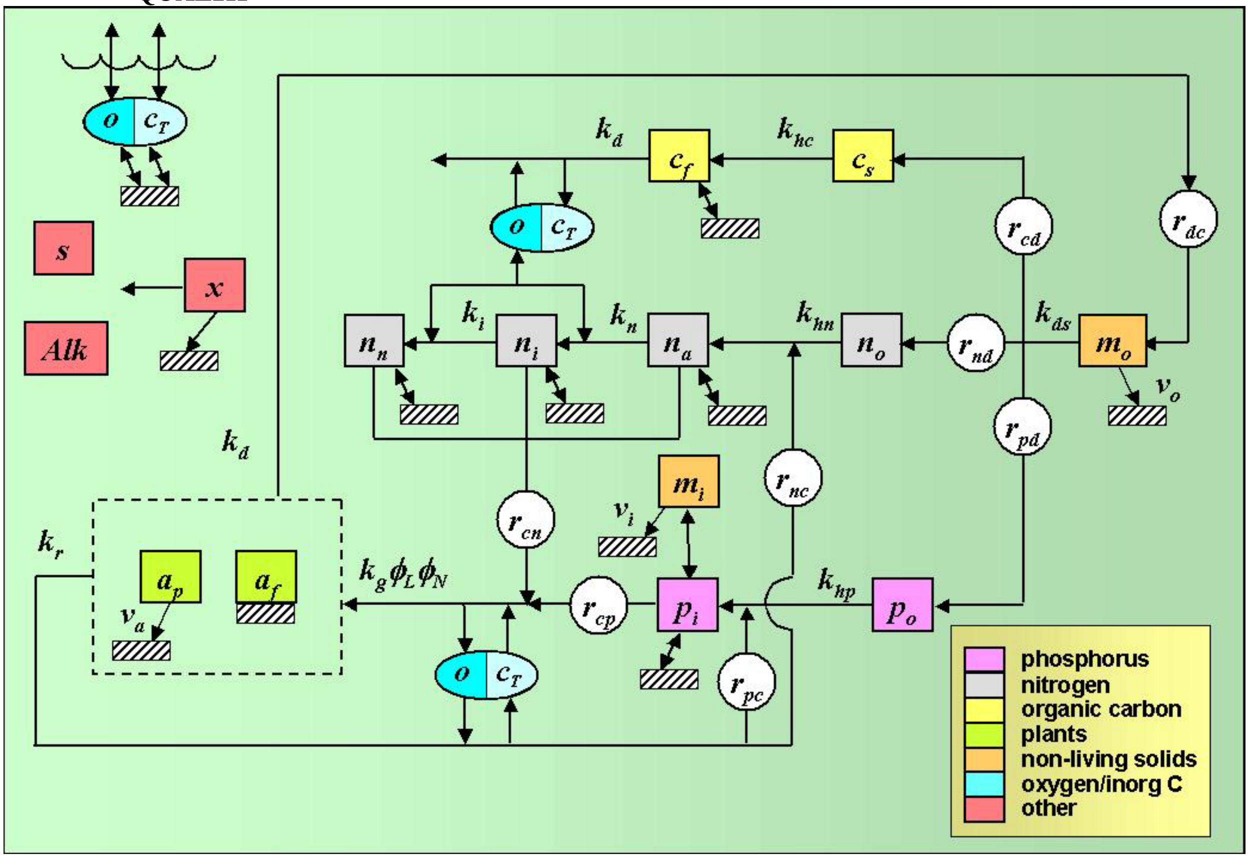
Other Parameters

Data reduction, review, and reporting will follow the procedures outlined in MEL's Lab Users Manual (MEL, 2000). In addition, lab results will be checked for missing and/or improbable data. Variability of field replicates and lab duplicates will be quantified using the methods described above. Should concentrations vary over an order of magnitude during the study at any given station, standard deviation and other parameters may be analyzed using the logarithms of concentration. If lab blanks show levels of analyte above reporting limits, the resulting data will be qualified and their use restricted as appropriate.

All water quality data will be entered into Ecology's Environmental Information Management (EIM) system. Data will be verified and data entry will be reviewed for errors. Data analysis will include evaluation of data distribution characteristics and, if necessary, appropriate distribution of transformations. Estimation of univariate statistical parameters and graphical presentation of the data (box plots, time series, regressions) will be made using SYSTAT/SYGRAPH8 (SPSS, 1997) and EXCEL (Microsoft, 2001) software.

Water quality modeling will be conducted using the QUAL2K model (Chapra, 2001). QUAL2K will be used to calculate and assess the fate and transport of water quality variables relating to DO and pH interactions in the water column. QUAL2K will be developed simultaneously to simulate diurnal variations in stream temperature for steady flow conditions by the temperature TMDL effort. 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 productivity simulation, DO, pH, solar radiation, air temperature, relative humidity, headwater temperature, and tributary water temperatures will be specified or simulated as diurnally varying functions. QUAL2K uses kinetic formulations for simulating DO and pH in the water column as shown in Figure 14 and described in Chapra (1997). Diurnally varying DO concentrations and pH at 500- to 1000-meter intervals along the streams in the Wenatchee River Subbasin will be simulated using a finite difference numerical method. The QUAL2K water quality model will be calibrated to in-stream data along the mainstem of the Wenatchee River and Icicle Creek in year 1 of the study.

Figure 14. Kinetic Formulations for Simulating Dissolved Oxygen and pH in the Water Column Used by QUAL2K



Project Organization

The roles and responsibilities of Ecology staff are as follows:

- **Jim Carroll**, Conventional Parameter Project Manager, Environmental Assessment Program, Water Quality Studies Unit: Responsible for overall conventional parameter project management. Defines project objectives, scope, and study design. Co-author of the project QA Project Plan. Manages data collection program. Writes TMDL technical study report.

- **Sarah O'Neal,** Conventional Parameter Principle Investigator, Environmental Assessment Program, Water Quality Studies Unit: Assists in defining project objectives, scope, and study design. Responsible for writing the QA Project Plan, data collection, entering project data into the Environmental Information Management (EIM) system, and data quality review. Responsible for technical coordination with the CCCD.

- **Greg Pelletier**, Temperature Study Project Manager, Environmental Assessment Program, Nonpoint Studies Unit: Responsible for overall temperature project management. Defines project objectives, scope, and study design. Responsible for review of the project QA Project Plan and final report. Manages data collection program. Writes TMDL technical study report.

- **Dustin Bilhimer**, Temperature Study Principle Investigator, Environmental Assessment Program, Nonpoint Studies Unit: Assist in defining project objectives, scope, and study design. Coordinates and conducts field sampling and data collection, data analysis, and modeling tasks. Responsible for writing the temperature portions of the QA Project Plan and draft and final report related to data collection, field methods, data quality review and analysis.

- **David Schneider**, Public Involvement Coordinator, Water Quality Program, Central Regional Office: Acts as point of contact between Ecology technical study staff and interested parties and coordinates information exchange and meetings. Supports, reviews, and comments on QA Project Plan, and technical report. Coordinates implementation planning and preparation of TMDL document for submittal to EPA.

- **Max Linden**, Unit Supervisor, Water Quality Program, Central Regional Office: Responsible for approval of TMDL submittal to EPA.

- **Will Kendra,** Section Manager, Environmental Assessment Program, Watershed Ecology Section: Responsible for approval of project QA Project Plan and final TMDL report.

- **Karol Erickson,** Unit Supervisor, Environmental Assessment Program, Water Quality Studies Unit: Reviews and approves project QA Project Plan, final TMDL report, and technical study budget.

- **Darrel Anderson,** Unit Supervisor, Environmental Assessment Program, Nonpoint Studies Unit: Reviews project QA Project Plan, final TMDL report, and technical study budget.

- **Kirk Sinclair**, Environmental Assessment Program, Contaminant Nonpoint Studies Unit: Installs mini-piezometer network for the purpose of sampling groundwater quality.

- **Steve Golding,** Environmental Assessment Program, Contaminant Studies Unit: Responsible for point source sampling from July through September.

- **Stuart Magoon, Will White, and Pam Covey,** Ecology Manchester Laboratory, Environmental Assessment Program: Provides laboratory staff and resources, sample processing, analytical results, laboratory contract services, and QA/QC data. Review sections of the QA Project Plan relating to laboratory analysis.

- **Chuck Springer,** Environmental Assessment Program, Stream Hydrology Unit: Responsible for the deployment and maintenance of continuous flow loggers and staff gauges. Responsible for producing records of hourly flow data at select sites for the study period.

- **Mike Rickel**, Chelan County Conservation District: Provides critical link for local information exchange and site selection. Coordinates with Ecology for data quality and sample collection.

- **Matt Karrer**, U.S. Forest Service, Lake Wenatchee/Leavenworth Ranger Districts: Coordinates with Ecology for the USFS temperature monitoring effort and data quality.

- **Field Assistants**, Environmental Assessment Program, Watershed Ecology Section: Conducts monitoring program under the supervision of Principle Investigators.

- **Cliff Kirchmer,** Quality Assurance Officer, Environmental Assessment Program: Reviews QA Project Plan and all Ecology quality assurance programs. Provides technical assistance on QA/QC issues during the implementation and assessment of project.

Project Schedule

The proposed schedule for both the temperature and other parameter portions of the TMDL project is as follows:

Table 15. Proposed Schedule for the TMDL Project

Event	Date
Temperature Datalogger Preliminary Installation (second installation will occur after spring flows recede)	April, 2002
Submit Draft Year 1 QAPP for Review	May, 2002
Finalize Year 1 QAPP	June, 2002
Year 1 Sampling Surveys Begin	July, 2002
TIR Flight	August, 2002
Temperature Datalogger Removals	October, 2002
Submit Draft Year 2 QAPP for Review	May, 2003
Year 1 Sampling Surveys End	June, 2003
Finalize Year 2 QAPP	June, 2003
Year 2 Sampling Surveys Begin	July, 2003
Year 1 Draft Interim Report	December, 2003
Year 1 Final Interim Report	March, 2004
Year 2 Sampling Surveys End	June, 2004
Year 2 Draft Report	December, 2004
Year 2 Final Report	March, 2005

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