Quality Assurance Project Plan

Wenatchee River Temperature, Dissolved Oxygen, pH, and Fecal Coliform Total Maximum Daily Load Year 2 Technical Study

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303(d) Listings Addressed in this Study:

Brender Creek (WA-45-1100): Fecal Coliform, Dissolved Oxygen, Temperature
Chiwaukum Creek (WA-45-1900): Temperature
Chumstick Creek (WA-45-1200): Dissolved Oxygen, pH, Fecal Coliform
Mission Creek (WA-45-1011): Fecal Coliform, Temperature
Nason Creek (WA-45-3000): Temperature
Peshastin Creek (WA-45-1014): Temperature

Ecology EIM Number: WENRTMDL

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Year 2 Technical Study

August 2003

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Abstract

Section 303(d) of the federal Clean Water Act requires Washington State periodically to prepare a list of all surface waters in the state for which beneficial uses of the water--such as for drinking, recreation, aquatic habitat, and industrial use--are impaired by pollutants. These are water quality limited estuaries, lakes, and streams that fall short of state surface water quality standards and are not expected to improve within the next two years. Waters placed on the 303(d) list require the preparation of Total Maximum Daily Loads (TMDLs), a key tool in the work to clean up polluted waters. TMDLs identify the maximum amount of a pollutant allowed to be released into a waterbody so as not to impair uses of the water, and allocate that amount among various sources.

The technical study to address water quality concerns in Water Resource Inventory Area (WRIA) 45 has been split into two years. The first study year focused 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 included Icicle Creek. A separate Quality Assurance (QA) Project Plan was developed for the first study year (Bilhimer et al., 2002). The second study year will focus on the other major tributaries to the Wenatchee River. This QA Project Plan applies only to year two. This QA Project Plan describes the technical study that will evaluate temperature, pH, dissolved oxygen, fecal coliform, and other ancillary parameters in tributaries to the Wenatchee River including Mission, Brender, Chiwaukum, Chumstick, Nason, and Peshastin Creeks. This TMDL, in combination with the year one study on the Wenatchee River and Icicle Creek, will set water quality targets to meet water quality standards and allocate pollutant loads to sources. The study will be conducted by the Washington State Department of Ecology (Ecology) Environmental Assessment Program.

Introduction

The Wenatchee River Subbasin, WRIA 45, is located in Chelan County. Subbasins of WRIA 45 are shown in Figure 1. The technical study to address water quality concerns in WRIA 45 was split into two years. The first study year (2002-03) focused 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 included Icicle Creek. The second study year (2003-04) will focus on the other major tributaries to the Wenatchee River. This QA Project Plan applies only to year two.

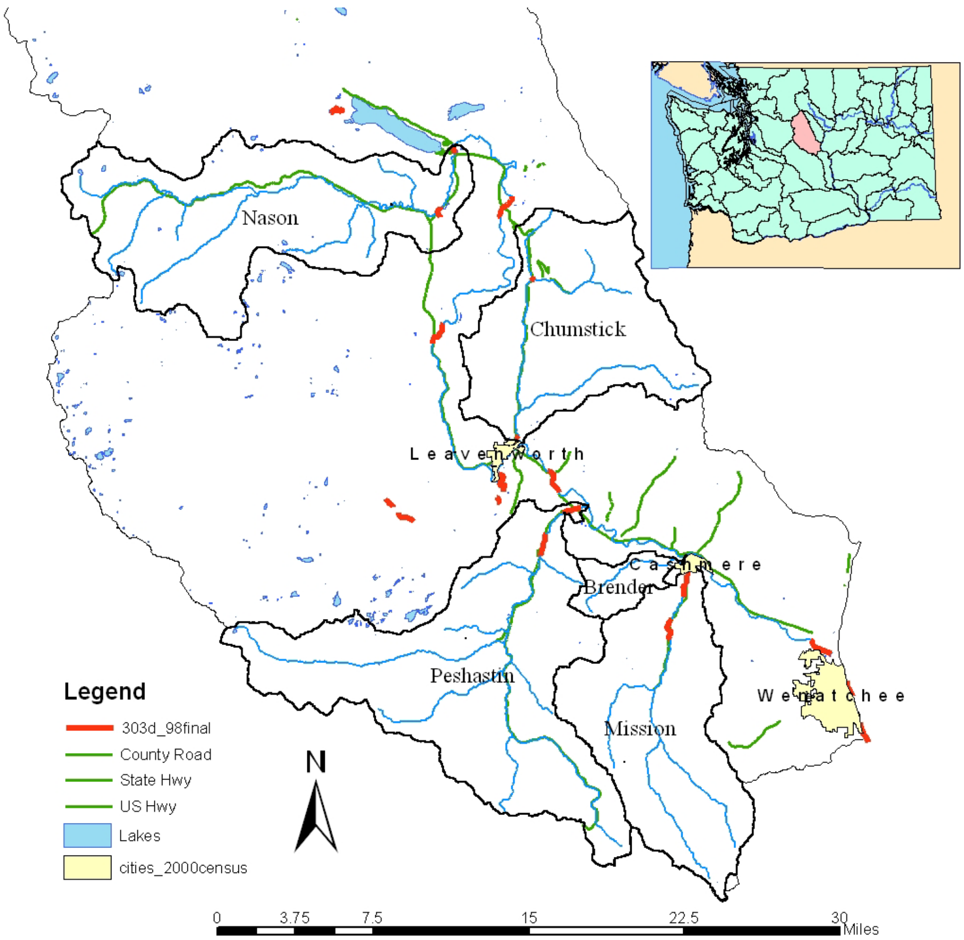

Figure 1. Watershed Resource Inventory Area (WRIA) 45 Subbasins.

In total, the study area has 22 segments that are listed for violating water quality criteria (Table 1). Water quality sampling performed by the Chelan County Conservation District (CCCD) in 1992-93 documented numerous violations of water quality standards, resulting in the listing of several stream segments on Washington's 303(d) list of impaired waters. The CCCD sampling resulting in the listing of Brender Creek for fecal coliform bacteria and for dissolved oxygen (DO), and Brender Creek violated temperature standards during the summer of 2002. Chumstick Creek was additionally placed on the 303(d) list for fecal coliform, DO, and pH violations. Mission Creek was also listed for fecal coliform violations, and violated temperature standards during the summer of 2002 based on preliminary results for Year 1 of this TMDL.

Temperature data collected by the U.S. Forest Service and the Yakama Indian Nation also resulted in 303(d) listings of several stream segments in the basin. Streams listed for temperature violations are Chiwaukum, Nason, and Peshastin Creeks. The Little Wenatchee River is also listed for temperature violations; but, since that waterbody is located on U.S. Forest Service property, a separate study conducted by Ecology's Water Quality Program will address that listing. Mission Creek is additionally listed for several pesticides.

A separate Mission Creek pesticide TMDL by Ecology's Toxic Study Unit will commence this year. A separate QA Project Plan for that study addresses the fate and transport of pesticides in Mission Creek (Serdar and Era-Miller, 2003). Instream flow impairments on Chumstick, Mission, and Peshastin Creeks 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 Watershed Planning Committee as part of the WRIA watershed plan.

The mainstem of the Wenatchee River and Icicle Creek were also placed on the 303(d) list for further DO, pH, and temperature violations. Due to the large area of the subbasin, Ecology conducted a technical study on the Wenatchee mainstem and Icicle Creek in 2002-03. A final interim report summarizing that data will be available in March of 2004.

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

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
	WA-45-1200*	Instream Flow	T26N, R18E, Section 30
Icicle Creek	WA-45-1017*	Dissolved Oxygen***	T24N, R17E, Section 24
	WA-45-1015*	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	WA-45-1011*	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	WA-45-1010*	Instream Flow	T24N, R18E, Section 17
	WA-45-1010*	pH*** Temperature	T23N, R20E, Section 28
	WA-45-1020*	Dissolved Oxygen***	T25N, R17E, Section 9
	WA-45-1020*	Instream Flow	T26N, R17E, Section 12

* = Also listed on the 1996 303(d) List.
** = listings addressed in this QAPP.
*** = listings addressed in the year one study.

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

Project Description

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, waterbody classifications, and numeric and narrative water quality criteria for surface waters of the state.

All waterbodies addressed by this TMDL discharge to the Wenatchee River, which is a tributary to the Class A (excellent) portion of the Columbia River (WAC 173-201A-030). The Wenatchee River from the Wenatchee National Forest boundary (river mile 27.1) to its headwaters is considered Class AA (extraordinary). Because Nason Creek discharges to the AA portion of the Wenatchee River, it is considered Class AA as well. Chumstick, Peshastin, Mission, and Brender Creeks all discharge to the Class A portion of the Wenatchee River. They are consequently considered Class A waterbodies from their respective confluences with the mainstem Wenatchee River to the Wenatchee National Forest boundary. From the Wenatchee National Forest boundary to their headwaters, Chumstick, Peshastin, and Mission Creeks are all considered Class AA waterbodies. Characteristic uses for Class A waterbodies include water supply (domestic, industrial, agricultural), stock watering, fish and shellfish (salmonid and other fish migration, rearing, spawning, and harvesting), wildlife habitat, recreation (primary contact recreation, sport fishing, boating, aesthetic enjoyment), and commerce and navigation. Characteristic uses for Class AA are 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 water 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 freshwater 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."*

[1] The geometric mean is calculated as the nth root of the product of n numbers

- 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 due to human activities. When natural conditions exceed 18.0°C, 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). 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 due to human activities. When natural conditions exceed 16.0°C, 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=23/ (T+5). Incremental temperature increases resulting from nonpoint source activities shall not exceed 2.8°."

Study Area

The study area for the second year of the Wenatchee River TMDL study consists of the streams listed in Table 2. (The first year of the study, during 2002-2003, focused on the mainstem Wenatchee River and Icicle Creek.) Each stream subbasin is described in greater detail in the following paragraphs.

Table 2. Year Two Study Streams.

Stream Name	Approximate River Miles	Comments
Nason Creek	25.1	From mouth to confluence with Stevens Creek
Chumstick Creek	12.3	From mouth to confluence with Second Creek
Peshastin Creek	14.6	From mouth to confluence with Tronsen Creek
Brender Creek	4.1	From mouth to river mile 4.1
Mission Creek	7.3	From mouth to USFS boundary near Sand Creek confluence

Nason Creek

Nason Creek is approximately 27 river miles long and drains a total watershed area of 69,813 acres (28,252 hectares). Table 3 lists the total watershed areas for Nason Creek and its major tributaries. The Nason Creek Subbasin ranges in elevation from 4,830 feet (1,472 meters) at its source at Lake Valhalla to 1,865 feet (568 meters) at its confluence with the Wenatchee River at approximately 0.5 miles below the outlet of Lake Wenatchee. Precipitation ranges from 80 inches per year at Steven's Pass to 35 inches per year at the mouth. U.S. Highway 2 follows most of the Nason Creek valley.

Table 3. Nason Creek Watershed Areas.

Drainage	Stream Class	Acres	Hectares
Nason Creek*	AA	37,251	15,076
Whitepine Creek	AA	15,650	6,333
Mill Creek	AA	6,189	2,505
Roaring Creek	AA	4,652	1,883
Coulter Creek	AA	2,976	1,204
Kahler Creek	AA	2,091	846
Henry Creek	AA	1,004	406
Total		**69,813**	**28,252**

**Nason watershed excluding the above drainages.*

Much of the land ownership in the Nason Creek Subbasin is federally owned, of which 51% is non-designated recreational forest and 21% is part of the Alpine Lakes Wilderness Area (Figure 2). Privately-owned land makes up another 21% of the watershed and includes a mixture of uses including rural home development, a golf course, small businesses, and timber-harvested forests. Forest fires, snow avalanches, and wind play an important role in the natural disturbance regime in this basin.

Anthropogenic impacts in the riparian area include: construction and maintenance for U.S. Highway 2, private homes, campgrounds, power line construction and railroad activities. All of these factors, as described in the Nason Creek Watershed Analysis (USFS, February 1996), have "changed the character of the creek and severely limited the lands ability to produce riparian tree vegetation. Oxbows and wetlands have been cut off from the main flow of Nason Creek depriving it from its natural sources of large woody debris (LWD)." The watershed assessment also noted from aerial photo records that the watershed went from "no observable timber harvest, few roads, and little private land development" in 1967, "to one with many clearcuts, roads, and new private development" in 1992. The harvest activity and road density increased mostly between 1975 and 1985 resulting in increased sediment erosion and slope failures.

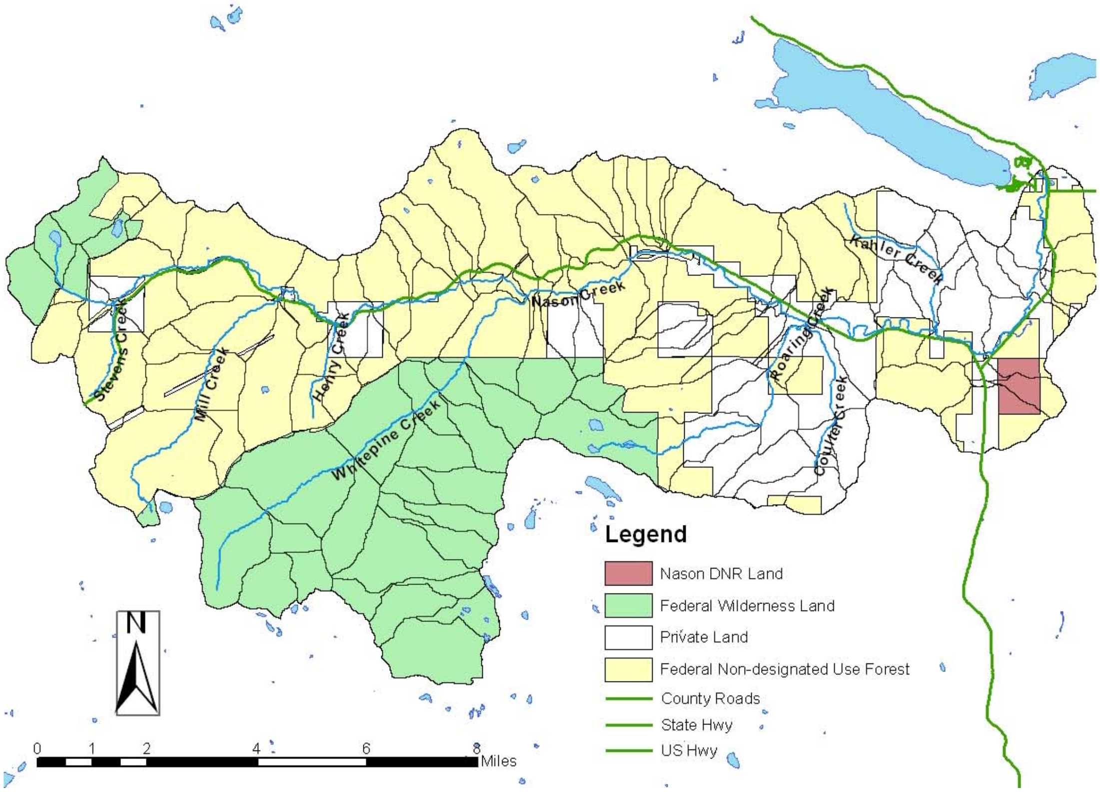

Figure 2. Nason Creek Watershed Land Ownership.

Most of the geology in the watershed consists of intrusive igneous and metamorphic landforms (Figure 3) with glacial fluvial outwash and alluvial fans in the unconsolidated material paralleling streams. These unconsolidated material landforms affect hydrologic and fluvial processes and sediment delivery. The sediments primarily consist of gravel, cobble, sand, and some boulders. Lower Nason Creek has a lot of fine sediments.

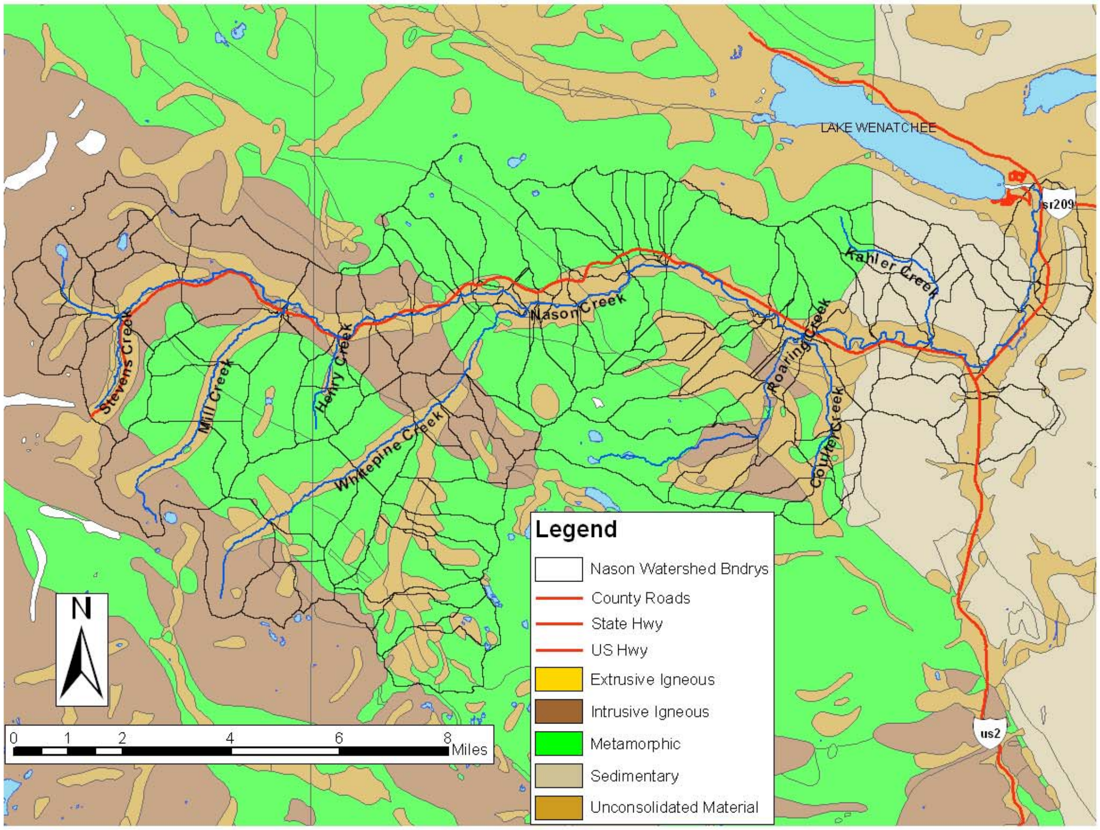

Figure 3. Geomorphology of Nason Creek Watershed.

The Nason Creek watershed analysis described fish habitat quality as poor in lower Nason, Kahler, and Coulter Creeks because of a lack of LWD, pools, and shade. Nason Creek has lost a lot of habitat due to the power lines, railroad, and highway. Anadromous fish utilize habitat in Nason Creek from its mouth to just above Whitepine Creek, including Spring Chinook, sockeye, and (historically) coho. Steelhead also have a similar distribution but their habitat extends a half-mile or so upstream of the Mill Creek tributary. This same extent applies to bull trout and non-anadromous resident trout distributions in Nason Creek (USFS, February 1996).

Chumstick Creek

Chumstick Creek has a total river mileage of 13.0 miles and drains a total watershed area of 49,920 acres (20,202 hectares). The elevation at the headwaters is 2,400 feet (732 meters) and the mouth of Chumstick Creek at its confluence with the Wenatchee River is 1,068 feet (326 meters) feet above mean sea level. There are only minor surface water withdrawals in the watershed for limited agricultural uses and one known irrigation return.

Table 4. Chumstick Creek Watershed Areas.

Chumstick Creek Watershed
Summary

Drainage	Stream Class	Acres	Hectares
Bjork Canyon	AA	2,320	939
Chumstick Creek	A, AA	11,787	4,770
Clark Canyon	A, AA	1,554	629
Douglas Creek	AA	977	395
Dry Creek	AA	2,955	1,196
Eagle Creek	A, AA	9,399	3,803
Freund Creek	A, AA	1,944	787
Little Chumstick	AA	2,153	871
Railroad Canyon	AA	1,205	488
Second Creek	AA	3,986	1,613
Spromberg Canyon	A, AA	2,975	1,204
Stevens Canyon	A, AA	765	310
Sunitsch Canyon	A, AA	2,098	849
Van Creek	AA	5,170	2,092
Walker Canyon	AA	1,164	471
Total		**50,451**	**20,417**

**Chumstick watershed excluding the above drainages.*

Anthropogenic impacts in the watershed include construction and maintenance for State Highway 209 and a utility corridor, railroad activities, and a significant amount of private ownership along the creek with potential for additional development on steep hills with a great potnential for erosion and impact on the creek. Private lands consist of limited agriculture and farming with several small hobby farms and extensive Longview Fiber inholdings. U.S. Forest Service lands in the watershed are used largely for dispersed recreation including camping, mountain biking, some climbing and winter sports, and Christmas tree gathering. There are no wilderness or state forest lands in this subbasin.

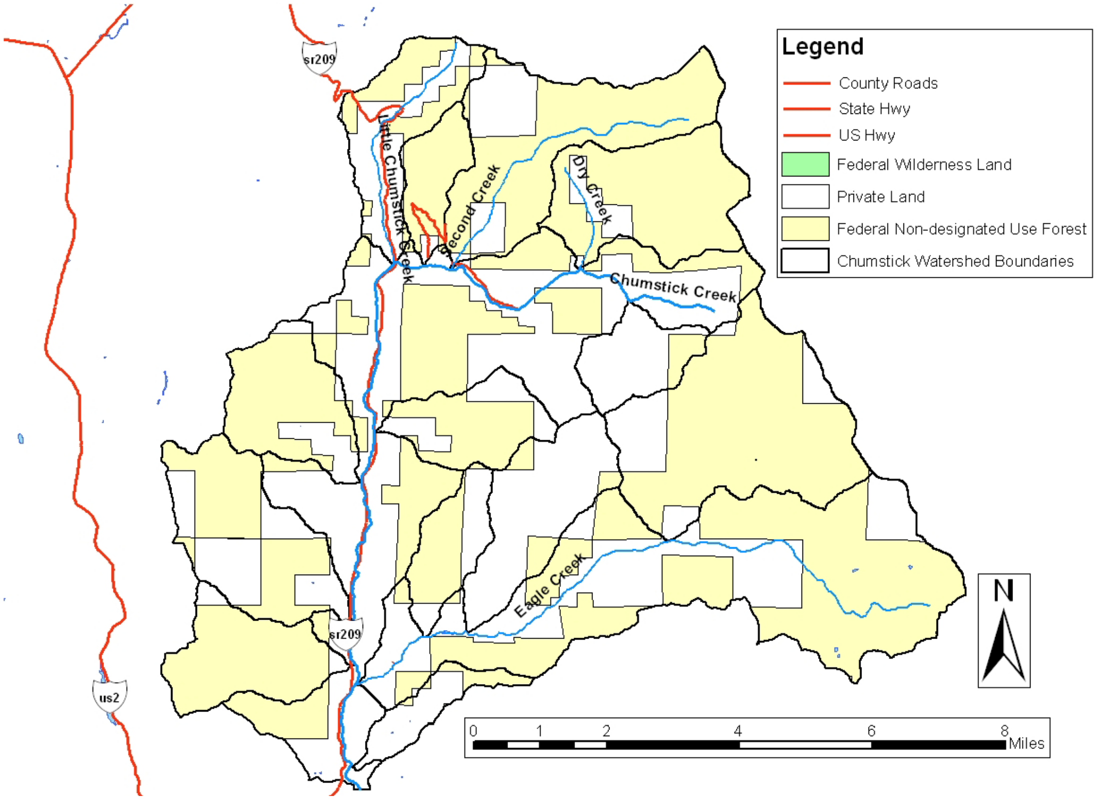

Figure 4. Chumstick Creek Watershed Land Ownership.

The Chumstick Watershed is located within the Swauk Sandstone Hills subsection which is composed of folded, inter-bedded sedimentary rocks of the Chumstick formation that have been modified by fluvial and mass wasting processes. The folded sedimentary rocks control the topography with dip slope/scarp slope structural features very common (USFS, 1999a). 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 (USFS, 1999a). Spring Chinook and winter steelhead historically spawned in lower Chumstick Creek and lower Eagle Creek. Little current information on species distribution exists. Brook trout, an introduced non-native species, and sculpin species are residents in the headwaters of Eagle Creek and in Van and East Van Creek (USFS, 1999a).

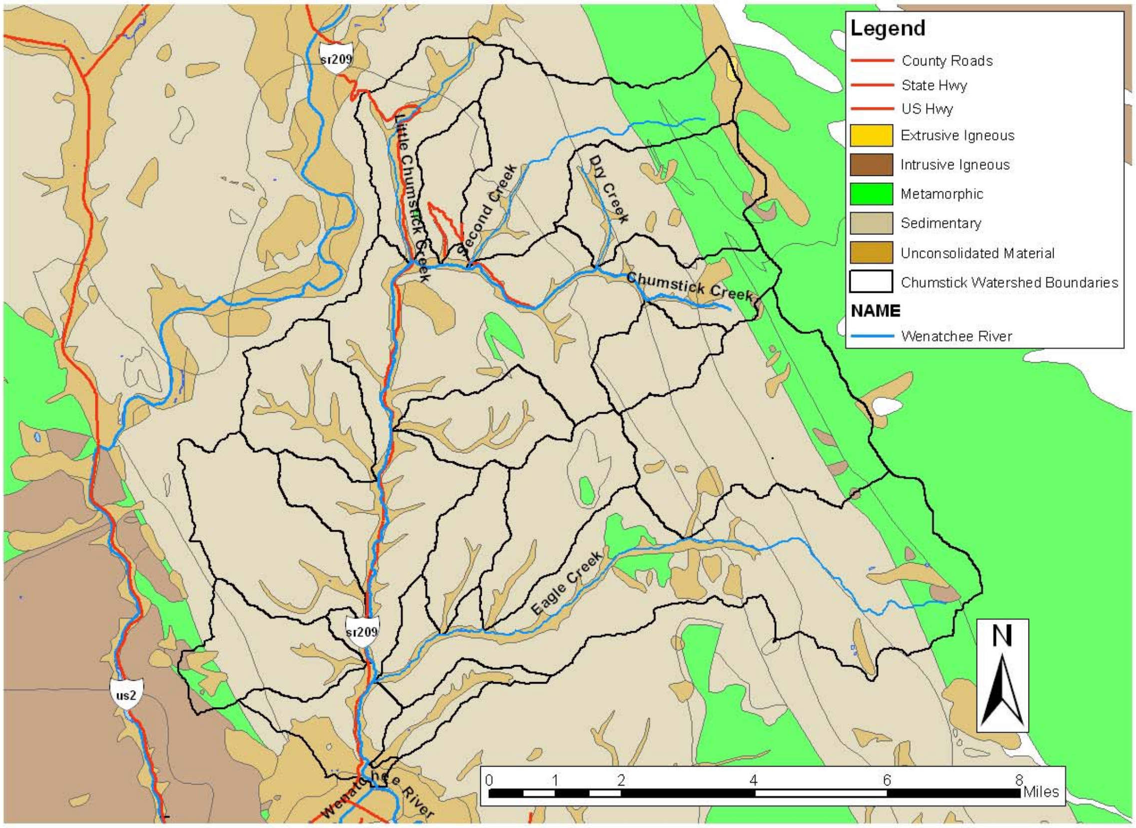

Figure 5. Geomorphology of Chumstick Creek Watershed.

Peshastin Creek

Peshastin Creek has approximately 19 river miles and drains a total watershed area of 86,396 acres (34,963 hectares). The elevation ranges from 3,664 feet (1,117 meters) at the headwaters to 970 feet (296 meters) at the confluence with the Wenatchee River. Precipitation ranges from 70 inches per year in the headwaters of Ingalls Creek to 15 inches per year at the mouth of Peshastin Creek. Ingalls Creek is the largest tributary in the watershed (Table 3).

Table 5. Peshastin Creek Watershed Areas.

Drainage	Stream Class	Acres	Hectares
Ingalls Creek	AA	24,009	9,716
Peshastin Creek*	A, AA	17,236	6,975
Tronsen Creek	AA	10,343	4,186
Negro Creek	AA	7,800	3,157
Camas Creek	A	5,821	2,356
Shaser Creek	AA	5,734	2,320
Scotty Creek	AA	4,557	1,844
Mill Creek	A	3,456	1,399
Ruby Creek	AA	2,951	1,194
Hansel Creek	A	2,421	980
Larsen Creek	A	2,068	837
Total		**86,396**	**34,963**

**Peshastin Creek watershed excluding the above drainages. Peshastin is Class A from mouth to National Forest Boundary, and Class AA upstream including all tributaries.*

Publicly owned land comprises 74% (63, 641 acres or 34,963 hectares) of the area in the watershed and is mainly the upper watershed from about river mile 6.0 to the headwaters (Figure 6). Private land and U.S. Route 97 comprise the remaining 27% of the watershed, located primarily along the highway corridor and throughout the lower 6 river miles to the confluence with the Wenatchee River. There is some orchard agriculture in the lower part of the watershed. The Peshastin Irrigation District operates a diversion dam at river mile 1.7 and a smaller diversion on the west side of Peshastin Creek near the confluence of Mill Creek. Forest fires, snow avalanches, and wind play an important role in the natural disturbance regime in this basin.

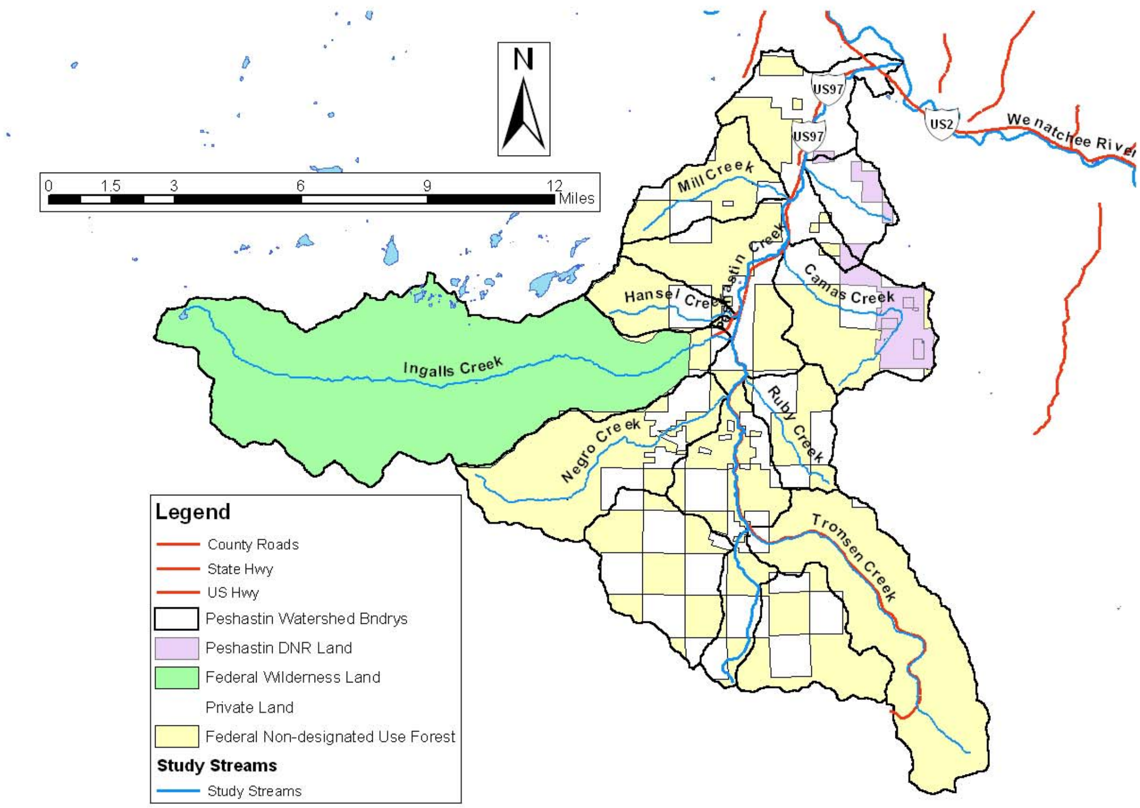

Figure 6. Peshastin Creek Watershed Land Ownership.

Roads have had a big impact on Peshastin Creek and its tributaries. Blewitt Pass, U.S. Highway 97, follows Tronsen Creek and meets Peshastin Creek at the confluence with Tronsen Creek. The highway has altered the channel forming processes along Peshastin cutting off access to floodplains on the highway side of the creek and straightening the stream channel. Highway maintenance also increases sedimentation on Tronsen and Peshastin. Most stream segments on Peshastin Creek have been rated very poor due to roads, and many of the lower tributaries have had extensive negative impacts from roads for timber and fire access.

The geology of the basin is bounded by intrusive igneous landforms on the western side of the creek and sedimentary landforms of the Swauk Formation on the eastern side (Figure 7). The unconsolidated material that parallels streams consist of alluvial and mass-wasting deposits from the surrounding geology. Historically, placer and lode-mining have heavily impacted tributary streams including: Negro, Shaser, Scotty, Ingalls, King, and Magnet Creeks and Culver Gulch

(Peshastin Watershed Assessment, 1999). Mining and timber harvest activity has contributed to a reduction in large woody debris. Direct disturbance from mining activities includes: channelizing, re-routing, disturbing stream sediments, and damming streams. Mining activity presently occurs in many areas in the upper Peshastin watershed and is also allowed in some portions of the Ingalls Creek watershed.

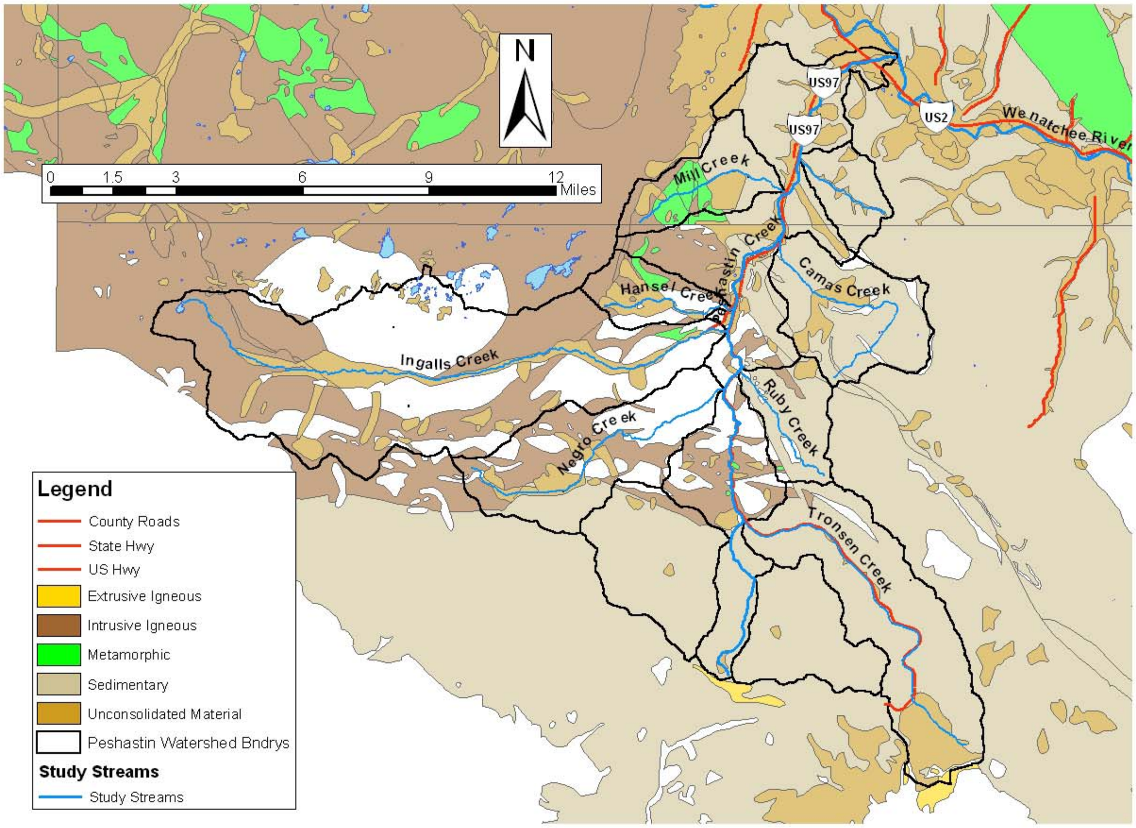

Figure 7. Geomorphology of Peshastin Creek Watershed.

Ingalls Creek is the largest tributary to Peshastin Creek and has had minimum anthropogenic impacts. The majority of the watershed is designated as part of the Alpine Lakes wilderness area, with only seven-tenths of a mile in private ownership at the mouth. Negro Creek is the third largest tributary, next to Tronsen Creek and Ingalls Creek (Table 3), and is also an important contributor of cool water along with Ingalls. Peshastin Creek exceeds state standards for temperature (16ºC for class AA waters) above Negro Creek and is approximately 6ºC warmer just above the confluence with the Wenatchee River (USFS, July 1999).

Peshastin Creek is habitat for summer steelhead, spring chinook, bull trout, and resident trout. High stream temperatures on Peshastin Creek above Negro Creek are considered to be a barrier to upstream bull trout migration. Ingalls Creek supports populations of bull trout and "is considered to be the stronghold for bull trout in the Wenatchee River Watershed. Management in the Ingalls Creek watershed should make preservation of bull trout a high priority."
(USFS, July 1999).

Mission and Brender Ceeks

The mainstem of Mission Creek is 9.4 miles long and drains an area of 58,899 acres (Table 6). The elevation at the headwaters is 6,887 feet (2,099 meters) and the mouth of Mission Creek at its confluence with the Wenatchee River in the town of Cashmere is 783 feet (239 meters). Precipitation ranges from 25 inches per year in the headwaters to 10 inches per year at the mouth of Mission Creek. There are several minor irrigation diversions in the lower six miles of the river which severely limit flow during irrigation season. Additionally, there are two irrigation siphon spills operated by the Icicle-Peshastin Irrigation District.

Table 6. Mission Creek Watershed Areas.

Drainage	Stream Class	Acres	Hectares
East Fork Mission	AA	13,041	5,278
Sand Creek	AA	11,945	4,834
Mission Creek*	A, AA	18,686	7,562
Yaksum Creek	A	4,646	1,880
Bear Gulch	A	2,417	978
Tripp Canyon	A	1,676	678
Brender Creek	A	6,489	2,626
Total		**58,899**	**23,836**

**Mission watershed excluding the above drainages. Mission Creek is Class A until the National Forest boundary, then is Class AA upstream from the boundary.*

Brender Creek is approximately 6.8 miles long and drains an area of 6,489 acres (2,626 hectares). The headwater elevation is 2,666 feet (813 meter) and the confluence with Mission Creek is at 789 feet (240 meter). Precipitation ranges from 20 inches per year in the headwaters to 10 inches per year at the confluence with Mission Creek.

There are two irrigation siphon spills on Brender Creek at about river mile 3.3, and the end of Pioneer Canal returns into Brender Creek at river mile 1.2. There is also a sediment trap at about river mile one. Almost all land ownership in this watershed is private; there are no federal land holdings but there are some DNR-owned lands (Figure 8). Orchards and rural development are the dominant land use along Brender. Riparian vegetation is sparse to non-existent; however, from approximately river mile 1 to 2.5, the creek flows through ravines that may contribute some topographic shading to the creek.

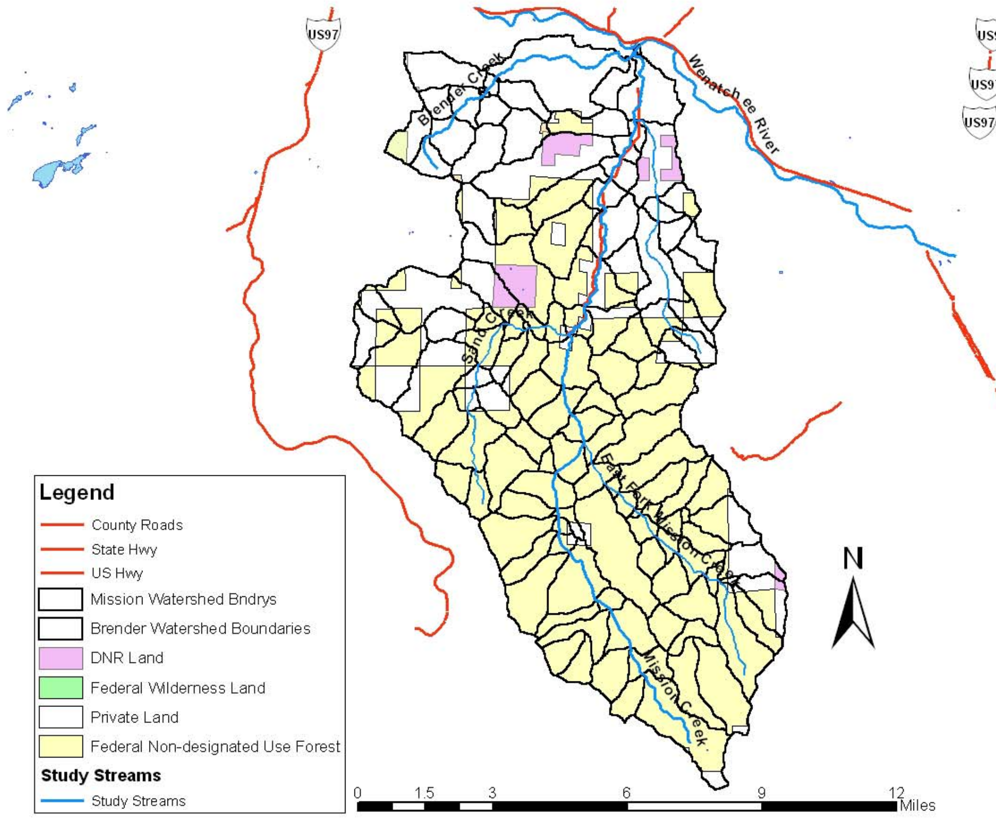

Figure 8. Mission Creek Watershed Land Ownership.

The Mission Creek watershed is located within the Swauk Sandstone Hills subsection (Figure 9). Sandstone bedrock is overlain with a thin mantle of highly erosive soil. This feature combined with steep topography results in high sediment input. Despite contributing less than one percent of flow to the mainstem Wenatchee River, Mission and Chumstick Creeks are the two major sources delivering sediments to the Wenatchee River (Hindes, 1994). Fire, debris slides, and flood events from convective and snowmelt-related storms constitute the natural disturbance regime.

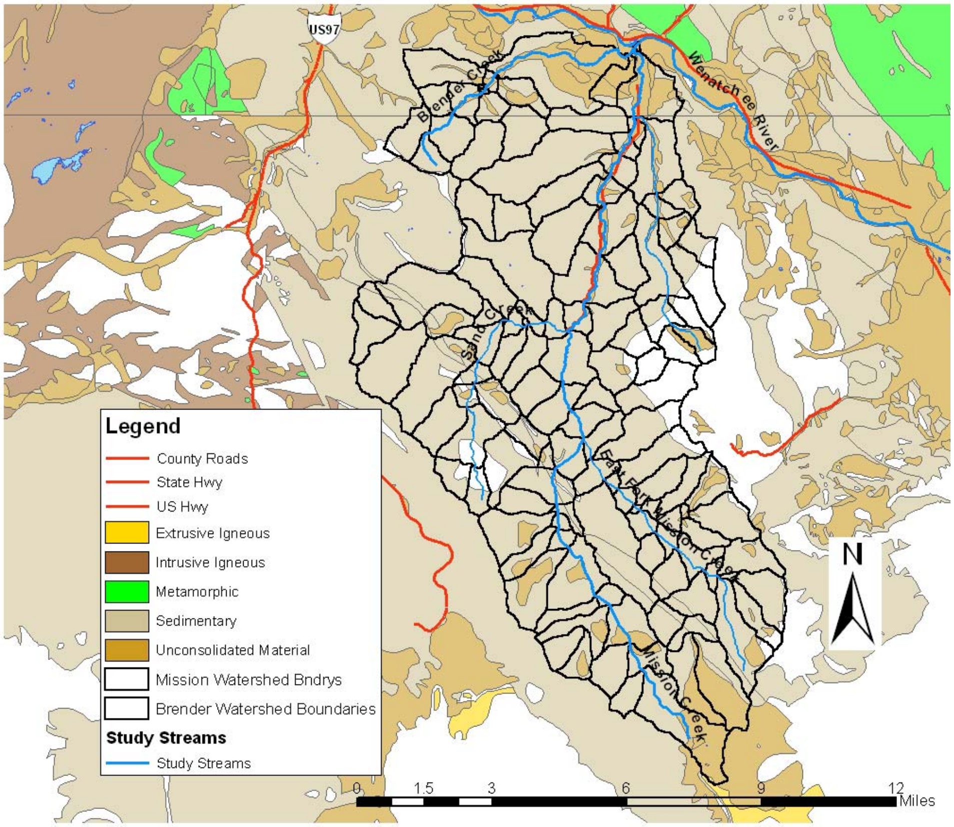

Figure 9. Geomorphology of Mission Creek Watershed.

Low but stable populations of steelhead exist in the watershed. Historic distributions of spring chinook have declined likely due to sediment loading and high instream temperatures. A stable resident trout population exists in the headwaters of the watershed (USFS, 1995b).

Historical Data Review

Organizations that have collected data on the Wenatchee River Subbasin include the Department of Ecology, U.S. Fish & Wildlife, U.S. Forest Service, U.S. 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 5 below. Ecology's ambient monitoring report for the 1997 water year indicated that the "'ten percent not to exceed criterion' for fecal coliform bacteria was exceeded fifty percent of the time in Brender Creek (Hallock and Ehinger, 1999)." Additionally, two samples exceeded water quality standards for high pH in Mission Creek during that water year.

Table 7. 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, 2002 – present
45D070	Brender Creek near Cashmere	1996 – 2000, 2003 – present
45E070	Mission Creek near Cashmere	1996 – 2000, 2002 – present
45Q060	Eagle Creek near Mouth	2003 – present

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, water quality, and fisheries data.

U.S. Fish and Wildlife

The Salmon, Steelhead, and Bull Trout Habitat Limiting Factors Report (Andoneagui, 2001) 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.

U.S. Forest Service

The US Forest Service Lake Wenatchee Leavenworth Ranger Districts have been conducting a stream temperature monitoring program since 1993 (USFS, 2000). 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.

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. 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 are very useful supplements to this 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.

In 2002, the Chelan County Conservation District summarized the activities and results of the Wenatchee River Watershed Action Plan Implementation Project in a project report (CCCD, 2002). These data, along with the conservation district data collected for the ranking report and Ecology ambient monitoring data, were combined and analyzed to determine a sampling plan for the TMDL.

As indicated in Figure 10, dissolved oxygen violations of the water quality standard 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).

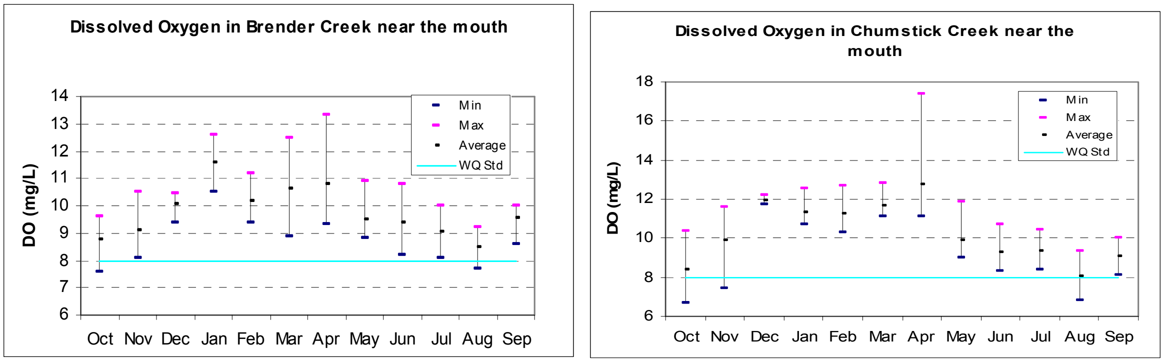

Figure 10. Monthly Dissolved Oxygen Levels at 303(d)-Listed Sites (Data Compiled from Ecology Ambient Monitoring Data and Chelan County Conservation District).

Violations in pH at the mouth of Chumstick Creek occur at various times throughout the year (Figure 11), with low pH violations recorded in the months of November, April, and August and September.

Violations in fecal coliform bacteria occur throughout the year at all 303(d) listed sites, although concentrations tend to be higher during the lower flow, summer months (Figure 12).

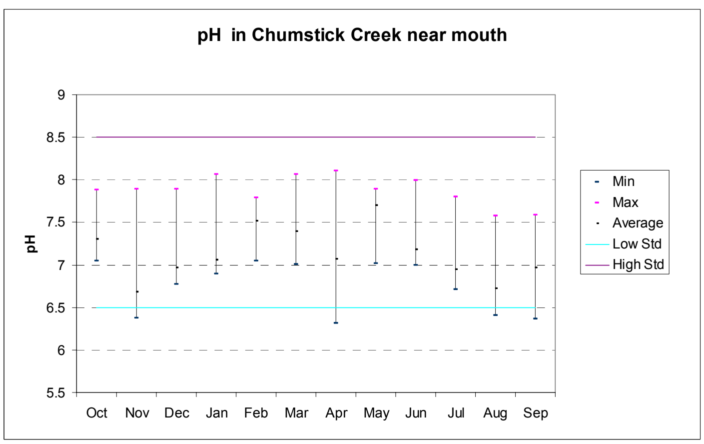

Figure 11. Monthly pH Levels at 303(d)-Listed Sites (Data Compiled from Ecology Ambient Monitoring Data and Chelan County Conservation District).

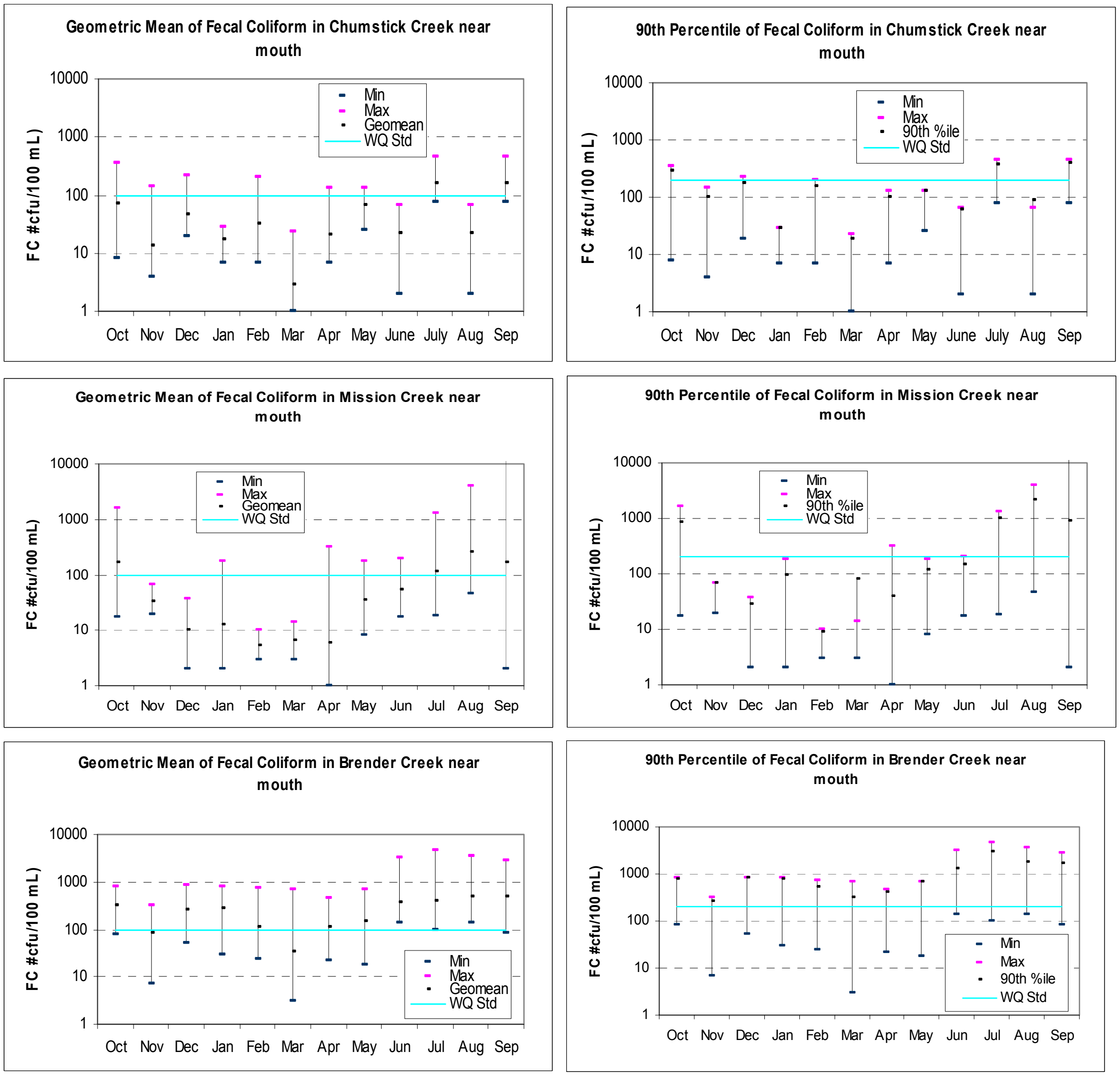

Figure 12. Monthly Fecal Coliform Levels at 303(d)-Listed Sites (Data Compiled from Ecology Ambient Monitoring Data and Chelan County Conservation District).

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. The transport and fate of heat in natural waters has been the subject of extensive study. Edinger et al. (1974) provide an excellent and comprehensive report of this research. Thomann and Mueller (1987) and Chapra (1997) have summarized the fundamental approach to the analysis of heat budgets and temperature in natural waters that will be used in this TMDL. Figure 13 shows the major heat energy processes or fluxes across the water surface or stream bed.

Adams and Sullivan (1987) reported that the following environmental variables were the most important drivers of water temperature in forested streams:

- **Stream depth**. Stream depth is the most important variable of stream size for evaluating energy transfer. Stream depth affects both the magnitude of the stream temperature fluctuations and the response time of the stream to changes in environmental conditions.

- **Air temperature**. Daily average stream temperatures are strongly influenced by daily average air temperatures. When the sun is not shining, the water temperature in a volume of water tends toward the dew-point temperature (Edinger et al., 1974).

- **Solar radiation and riparian vegetation**. The daily *maximum* temperatures in a stream are strongly influenced by removal of riparian vegetation because of diurnal patterns of solar heat flux. Daily *average* temperatures are less affected by removal of riparian vegetation.

- **Groundwater**. Inflows of groundwater can have an important cooling effect on stream temperature. This effect will depend on the rate of groundwater inflow relative the flow in the stream and the difference in temperatures between the groundwater and the stream.

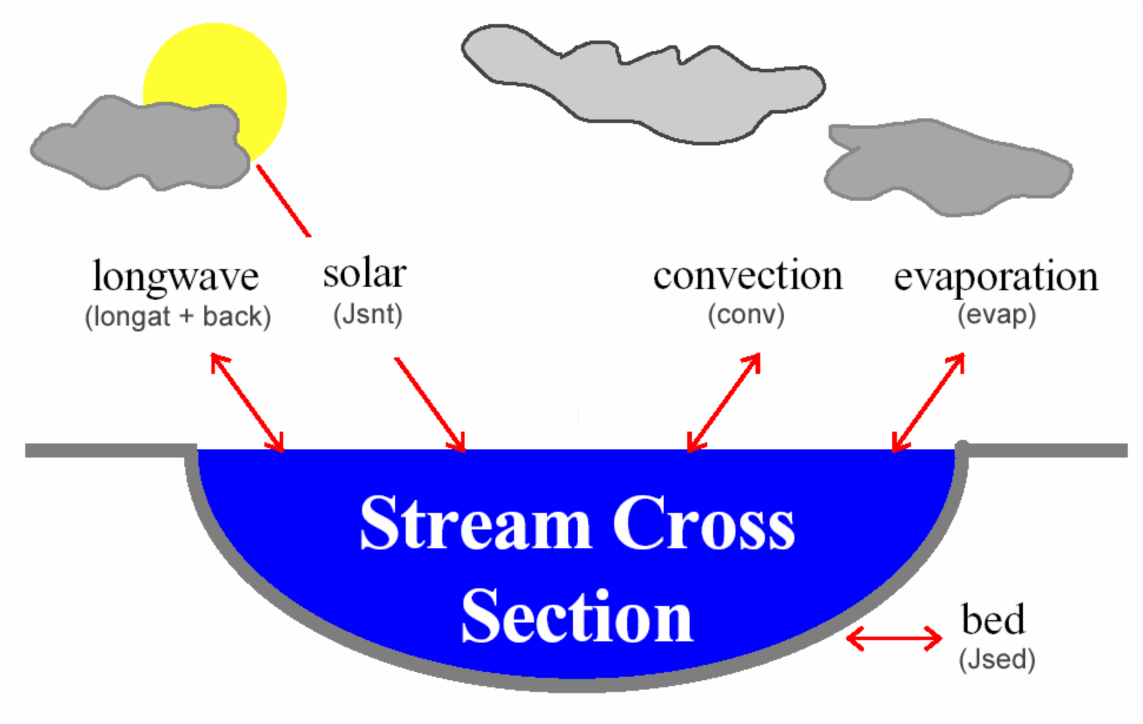

Figure 13. Surface Heat Transfer Processes in the QUAL2K Model that Affect Water Temperature (Net Heat Flux = Jsnt + longat - longback ± conv - evap ± Jsed).

The heat exchange processes with the greatest magnitude are as follows (Edinger et al. 1974):

- **Short-wave solar radiation**. Short-wave solar radiation is the radiant energy which passes directly from the sun to the earth. Short-wave solar radiation is contained in a wavelength range between 0.14 µm and about 4 µm. Daily average solar radiation measured at the Washington State University Public Agricultural Weather System (PAWS) station in Wenatchee during July-August 2002 was 277 Watts/meter^2. The peak values during daylight hours are typically about three times higher than the daily average. Short-wave solar radiation constitutes the major thermal input to an un-shaded body of water during the day when the sky is clear.

- **Long-wave atmospheric radiation**. The long-wave radiation from the atmosphere ranges in wavelength range from about 4 µm to 120 µm. Long-wave atmospheric radiation depends primarily on air temperature and humidity and increases as both of those increase. It constitutes the major thermal input to a body of water at night and on warm cloudy days. The daily average heat flux from long-wave atmospheric radiation typically ranges from about 300 to 450 W/m^2 at mid latitudes (Edinger et al., 1974).

- **Long-wave back radiation from the water to the atmosphere**. Water sends heat energy back to the atmosphere in the form of long-wave radiation in the wavelength range from about 4 µm to 120 µm. Back radiation accounts for a major portion of the heat loss from a body of water. Back radiation increases as water temperature increases. The daily average heat flux out of the water from long-wave back radiation typically ranges from about 300 to 500 W/m^2 (Edinger et al., 1974).

The role of riparian vegetation in maintaining a healthy stream condition and water quality is well documented and accepted in the scientific literature. Summer stream temperature increases due to the removal of riparian vegetation are well documented (for example Holtby, 1988; Lynch et al., 1984; Rishel et al., 1982;, Patric, 1980; Swift and Messer, 1971; Brown et al., 1971; and Levno and Rothacher, 1967). These studies generally support the findings of Brown and Krygier (1970) that loss of riparian vegetation results in larger daily temperature variations and elevated monthly and annual temperatures. Adams and Sullivan (1989) also concluded that daily maximum temperatures are strongly influenced by the removal or riparian vegetation because of the effect of diurnal fluctuations in solar heat flux.

Summaries of the scientific literature on the thermal role of riparian vegetation in forested and agricultural areas are provided by Belt et al., 1992; Beschta et al., 1987; Bolton and Monahan, 2001; Castelle and Johnson, 2000; CH2MHill, 2000; GEI, 2002; Ice, 2001; and Wenger, 1999. All of these summaries recognize that the scientific literature indicates that riparian vegetation plays an important role in controlling stream temperature. The list of important benefits that riparian vegetation has upon the stream temperature includes:

- Near-stream vegetation height, width, and density combine to produce shadows that can reduce solar heat flux to the surface of the water.

- Riparian vegetation creates a thermal microclimate that generally maintains cooler air temperatures, higher relative humidity, lower wind speeds, and cooler ground temperatures along stream corridors.

- Bank stability is largely a function of near stream vegetation. Specifically, channel morphology is often highly influenced by land cover type and condition by affecting flood plain and instream roughness, contributing coarse woody debris and influencing sedimentation, stream substrate composition, and stream bank stability.

The warming of water temperatures as a stream flows downstream is a natural process. However, the rates of heating can be dramatically reduced when high levels of shade exist and heat flux from solar radiation is minimized. The overriding justification for increases in shade from riparian vegetation is to minimize the contribution of solar heat flux in stream heating. There is a natural maximum level of shade that a given stream is capable of attaining. The importance of shade decreases as the width of a stream increases.

The distinction between reduced heating of streams and actual cooling is important. Shade can significantly reduce the amount of heat flux that enters a stream. Whether there is a reduction in the amount of warming of the stream, maintenance of inflowing temperatures, or cooling of a stream as it flows downstream depends on the balance of all of the heat exchange and mass transfer processes in 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 heat budget 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. 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

Dissolved Oxygen 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), altitude (higher atmospheric pressure increases DO at lower altitudes), volume and velocity of water flowing in the waterbody, and amount of organisms using oxygen for respiration.

High (greater than 8.5) or low (less than 6.5) 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 fish metabolism and ability to take water in through the gills, and can kill fish fry.

Fecal coliform bacteria is an indicator of the presence of possible harmful pathogens (e.g. bacteria and viruses) associated with human and animal waste that could impact human health.

Potential causes of low DO, high and low pH, and high bacteria levels are likely due largely to nonpoint sources in the Chumstick and Mission Creek watersheds since point sources are very limited in those areas. There are numerous 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. The Mission Creek watershed in particular was heavily grazed by sheep in the early 20th century. Irrigation diversions in the lower six miles of Mission Creek also severely limit flow (Hindes, 1994).

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, fire suppression, 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. Streamside development and channelization have made lower reaches of Mission Creek particularly vulnerable to stormwater runoff. Landtypes in both the Chumstick and Mission Creek watersheds have naturally high erosion and sediment delivery hazards (USFS, 1995b).

Project Objectives

Temperature

Characterize summer (June – October 2003) water temperature in the watersheds for: Chumstick, Mission, Nason, and Peshastin Creeks.

- 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.

Develop a predictive numerical model of water temperature for the above-listed watersheds to do the following:

- Model the instream temperature regime at critical conditions.

- Evaluate the ability of load allocations for effective shade and other surrogate measures to reduce water temperatures to meet water quality standards.

Establish preliminary TMDL targets for shade and water. Develop models for evaluation 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.

Other Parameters

Conduct water quality monitoring surveys for physical, chemical, and biological parameters to determine sources affecting DO, pH, and bacterial levels in the Mission, Brender, and Chumstick Creeks and their tributaries.

Assess or model productivity in streams using data from all parameters collected during the intensive surveys. Low DO and high pH are associated with high productivity. Several parameters, including turbidity, solids, alkalinity, chloride, nutrients, biological oxygen demand, phytoplankton and organic carbon, will be used to characterize productivity.

Characterize fecal coliform bacteria concentrations and identify major bacterial loading sources along Mission, Brender, and Chumstick Creeks.

Set DO, pH, and fecal coliform TMDL targets, nonpoint load allocations and point source waste load allocations for parameters responsible for causing DO, pH, and fecal coliform violations in the Wenatchee River and Icicle Creek using data collected historically and during the course of this project.

Sampling Design

Temperature

Data collection, compilation, and assessment will be governed by the data set requirements of the two computer temperature models used in this study (Table 8). 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.

Five types of Ecology field surveys will be conducted related to stream temperatures:

- Continuous monitoring of water and air temperature and relative humidity.
- Surveys of riparian vegetation in the study area.
- Surveys of hydraulic geometry in stream reaches.
- Seepage run surveys.
- Remote sensing of surface temperatures using thermal infrared (TIR) and color videography commissioned by Ecology.

Table 8. Temperature Model Data Requirements and Field Data Collection Parameters.

		MODEL		Field Data
	PARAMETER	**Shade**	**Qual2Kw**	**Collection**
Flow	discharge - tributary		x	x
	discharge (upstream & downstream)		x	x
	flow velocity		x	x
	groundwater inflow rate/discharge		x	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	x
	latitude	x	x	x
	longitude	x	x	x
	time zone	x		
Physical	channel azimuth/stream aspect	x		
	cross-sectional area	x	x	x
	Manning's n value	x	x	
	percent bedrock	x	x	x
	reach length	x	x	x
	stream bank slope	x		x
	stream bed slope	x	x	x
	width - bankfull	x		x
	width - stream	x	x	x
Temperature	temperature - groundwater		x	x
	temperature - tributaries		x	x
	temperature - water downstream		x	x
	temperatures - water upstream		x	x
	temperature - air		x	x
Vegetation	% forest cover on each side	x		x
	canopy-shading coefficient/veg density	x		x
	diameter of shade-tree crowns	x		
	distance to shading vegetation	x		
	topographic shade angle	x		
	vegetation height	x		x
	vegetation shade angle	x		
	vegetation width	x		
Weather	relative humidity		x	x
	% possible sun/cloud cover		x	
	solar radiation		x	x
	temperature - air		x	x
	wind speed/direction		x	x

Continuous Monitoring of Relative Humidity and Water and Air Temperature

Sampling sites are listed in Table 9 and shown in Figure 14. There are 63 paired temperature sites (water and air), five of which will also measure relative humidity. All mainstem temperature stations will also be recording hyporheic temperatures (see groundwater sampling section for details on hyporheic temperature stations).

Monitoring locations were selected to characterize thermal loading from the headwaters and tributaries and intermediate locations in the mainstem of the study areas. Monitoring locations are limited by access opportunities.

The headwater station for Peshastin Creek is just above the Tronsen Creek confluence. The Mission Creek headwater station will be located approximately 0.5 river miles upstream from the Sand Creek confluence. Although temperatures above these headwater stations have previously exceeded water quality standards, limited resources constrain the study to these boundaries. The tributaries upstream from each of the headwater stations will be addressed as a group if a load allocation is needed for the headwater station to meet state temperature standards.

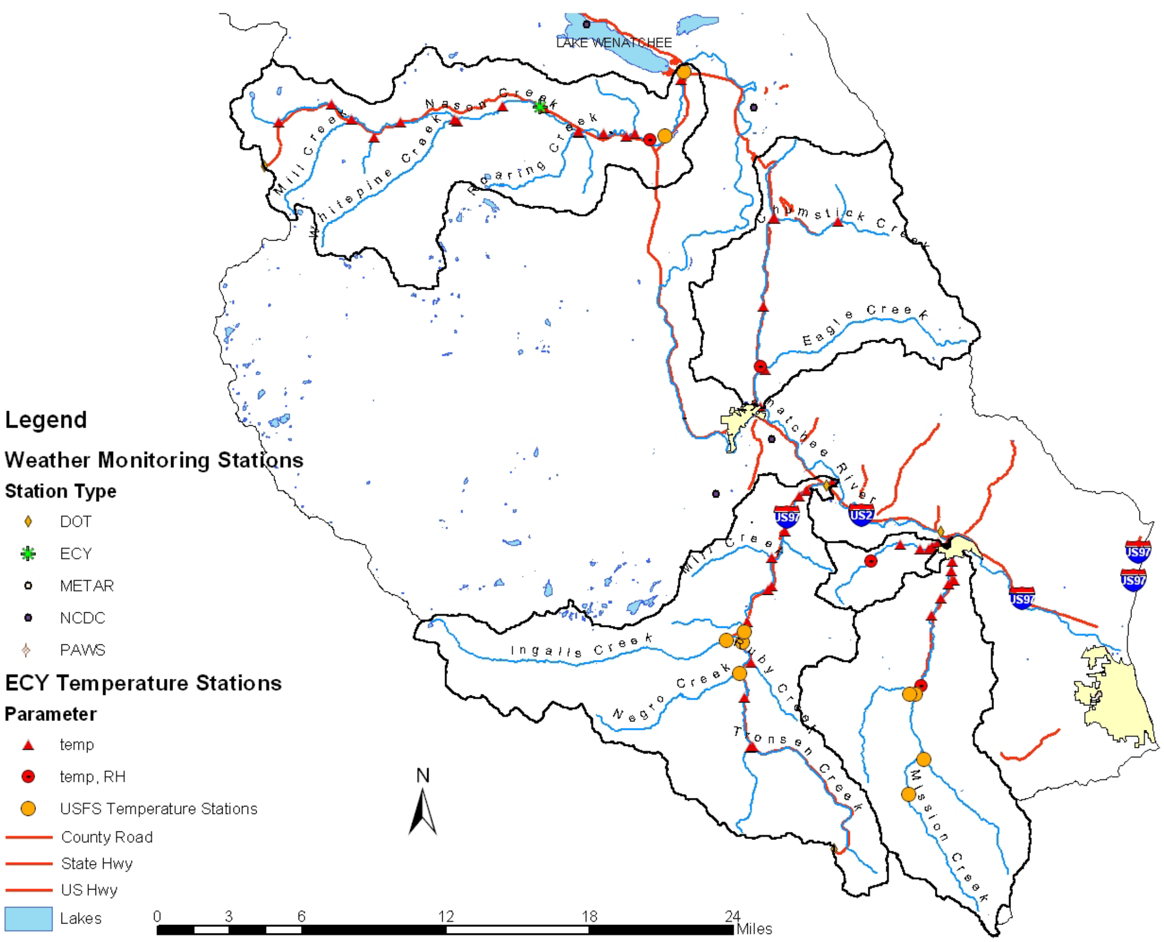

Figure 14. Temperature and Climate Monitoring Stations.

Table 9. Temperature Monitoring Stations.

Station Description	Temperature Monitoring Site	Relative Humidity Monitoring Site	Stream Basin	Responsible Agency	Longitude (NAD27)	Latitude (NAD27)
Brender at Sunset Hwy	X		Brender	EAP, FMU*	-120.47571	47.52131
Chumstick above Eagle Creek	X	X	Chumstick	EAP, NPSU	-120.64335	47.62739
Chumstick above Little Chumstick Creek	X		Chumstick	EAP, NPSU	-120.62808	47.71568
Chumstick below Clark Canyon	X		Chumstick	EAP, NPSU	-120.64147	47.66373
Chumstick Creek Mouth	X		Chumstick	EAP, FMU	-120.64328	47.60323
Eagle Creek Mouth	X		Chumstick	EAP, FMU	-120.63969	47.62568
Mission Creek Devils Gulch	X		Mission	USFS***	-120.51081	47.36870
Mission above Slawson Canyon	X		Mission	EAP, NPSU	-120.49067	47.47728
Mission above Siphon Spills	X		Mission	EAP, NPSU	-120.47338	47.50396
Mission above Tripp Canyon	X		Mission	EAP, NPSU	-120.48216	47.48763
Mission above Yaksum Creek	X		Mission	EAP, NPSU	-120.47547	47.49582
Mission Creek at Sunset Hwy	X		Mission	EAP, FMU	-120.47481	47.52043
Mission below Sand Creek	X	X	Mission	EAP, NPSU	-120.49974	47.43460
Mission below Siphon Spills	X		Mission	EAP, NPSU	-120.47198	47.51000
Mission Creek above NF Boundary	X		Mission	USFS	-120.50522	47.42918
Mission Creek East Fork	X		Mission	USFS	-120.49769	47.39009
Mission Creek near School	X		Mission	EAP, NPSU	-120.47109	47.51711
Sand Creek Mouth	X		Mission	USFS	-120.51034	47.42950
Yaksum Creek Mouth	X		Mission	EAP, NPSU	-120.47369	47.49947
Henry Creek Mouth	X		Nason	EAP, NPSU	-120.99031	47.76517
Kahler Creek Mouth	X		Nason	EAP, NPSU	-120.75609	47.76767
Mill Creek Mouth	X		Nason	EAP, NPSU	-121.01056	47.77585
Nason above Roaring/Coulter Creeks	X		Nason	EAP, NPSU	-120.80757	47.76916
Nason above Gill Creek	X		Nason	EAP, NPSU	-120.83811	47.78302
Nason above Kahler Creek	X		Nason	EAP, NPSU	-120.76419	47.76618
Nason above Mahar Creek	X		Nason	EAP, NPSU	-120.87508	47.78417
Nason above Mill Creek	X		Nason	EAP, NPSU	-121.02844	47.78449
Nason above Whitepine Creek	X		Nason	EAP, NPSU	-120.91806	47.77592
Nason Creek at Streamflow Gage	X		Nason	EAP, SHU****	-120.71517	47.80055
Nason below Coulter Creek	X		Nason	EAP, NPSU	-120.78427	47.76781
Nason below Henry Creek	X		Nason	EAP, NPSU	-120.96638	47.77391

Station Description	Temperature Monitoring Site	Relative Humidity Monitoring Site	Stream Basin	Responsible Agency	Longitude (NAD27)	Latitude (NAD27)
Nason below Kahler Creek	X	X	Nason	EAP, NPSU	-120.74297	47.76388
Nason Creek near Coles Corner	X		Nason	USFS	-120.72906	47.76599
Nason Creek near Mouth	X		Nason	USFS	-120.71237	47.80530
Nason Creek Headwater	X		Nason	EAP, NPSU	-121.07549	47.77365
Roaring/Coulter Creeks Mouth	X		Nason	EAP, NPSU	-120.80654	47.76844
Whitepine Creek Mouth	X		Nason	EAP, NPSU	-120.91573	47.77463
Camas Creek Mouth	X		Peshastin	EAP, NPSU	-120.63296	47.49461
Ingalls Creek Mouth	X		Peshastin	USFS	-120.67332	47.46186
Mill Creek Mouth	X		Peshastin	EAP, NPSU	-120.63292	47.51213
Negro Creek Mouth	X		Peshastin	EAP, NPSU	-120.66227	47.44316
Peshastin above Camas Creek	X		Peshastin	EAP, NPSU	-120.63644	47.49259
Peshastin above Tronsen Creek	X		Peshastin	EAP, NPSU	-120.65224	47.39712
Peshastin Creek at Streamflow Gage	X		Peshastin	EAP, SHU	-120.60909	47.54879
Peshastin below Culver Gulch	X		Peshastin	EAP, NPSU	-120.65702	47.42729
Peshastin below Irrigation Diversion	X		Peshastin	EAP, NPSU	-120.60184	47.55263
Peshastin below Hansel Creek	X		Peshastin	EAP, NPSU	-120.65475	47.47330
Peshastin below Larsen Creek	X		Peshastin	EAP, NPSU	-120.62180	47.52779
Peshastin Creek above Ingalls Creek	X	X	Peshastin	USFS	-120.65933	47.46076
Peshastin Creek above Negro Creek	X		Peshastin	USFS	-120.66154	47.44173
Peshastin Creek below Ingalls Creek	X		Peshastin	USFS	-120.65774	47.46696
Peshastin Creek Mouth	X		Peshastin	EAP, NPSU	-120.57911	47.55761
Ruby Creek Mouth	X		Peshastin	EAP, NPSU	-120.65193	47.44879
Tronsen Creek Mouth	X		Peshastin	EAP, NPSU	-120.64984	47.39787
Sub-Totals	**4.0**	**0.0**		**EAP, FMU**		
	47.0	**5.0**		**EAP, NPSU**		
	2.0	**0.0**		**EAP, SHU**		
	10.0			**USFS**		
Total	**63.0**	**5.0**				

*Environmental Assessment Program, Freshwater Monitoring Unit (Ecology).
** Environmental Assessment Program, Nonpoint Studies Unit (Ecology).
***US Forest Service.
****Environmental Assessment Program, Stream Hydrology Unit (Ecology).

Installation of temperature data loggers and monthly downloads will follow the protocols described in the Timber Fish and Wildlife Temperature Stream Survey Manual (Scheutt-Hames, 1999). Temperature dataloggers will be installed in areas that 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 periodically throughout the sampling season.

Weather Stations

The Department of Ecology will be operating one temporary weather station in the Nason Creek watershed. This station will be located adjacent to Nason Creek, and will collect wind speed and direction, air temperature, relative humidity, solar radiation, and soil temperature. The soil temperature probe will be buried 1 foot deep in the ground.

There are nine weather stations in the Wenatchee subbasin that record wind speed and direction among other helpful climate variables (see Figure 14). Four 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.

Washington State University (WSU) operates a Public Agricultural Weather System (PAWS) weather station at the WSU Tree Forest Research and Extension Center (TFREC), in Wenatchee. Farmers use these systems for agricultural information. Data is obtained through the following website: http://index.prosser.wsu.edu/.

The Washington State Department of Transportation (WADOT) also operates and maintains weather stations in four locations in WRIA 45. These are: Dryden Road, Cashmere, Steven's Pass, and Blewett Pass. These data are available 'real time' through the following website: http://www.wsdot.wa.gov/Rweather/.

The final weather station to be included is the National Weather Service surface weather observation station (a.k.a. METAR station) at Pangborn Airport in East 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. Real time data can be obtained through the following website:
http://www.wrh.noaa.gov/cgi-bin/Missoula/msoobs?site=KEAT&type=1&src=rgl.

Surveys of Riparian Vegetation

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 (see example in Figure 15).

Vegetation polygons in the riparian corridor within 200 feet of each bank of the stream will be digitized from 3-foot resolution full-color digital orthophotos obtained through a cooperative agreement with the Washington State Department of Natural Resources' Orthophoto program.

Vegetation polygon types will be generally classified by species type, tree height, and density. Vegetation heights will be measured from digital stereo-pair orthophotos with 18-inch pixel resolution.

Figure 15. Example of Riparian Vegetation Polygons Using a 500-ft Buffer.

Surveys of Hydraulic Geometry

Bankfull channel cross-sections will be surveyed. There will be three to five transects surveyed at each of the continuous temperature stations in the mainstems of Brender, Mission, Nason, and Peshastin Creeks. Additional surveys will occur in other reaches as necessary. 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.

Manning's equation is commonly used to solve for depth (y) given flow (Q), Manning's roughness coefficient (n), wetted width (B_0), and channel slope (S_e). Manning's equation for a rectangular channel (side slope s=0) is as follows (Chapra, 1997):

Mannings equation

$$Q = \frac{1}{n} \frac{\left[(B_0 + sy)y\right]^{5/3}}{\left(B_0 + 2y\sqrt{s^2 + 1}\right)^{2/3}} S_e^{1/2}$$

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. Relationships between Manning's n and flow will be developed for each subbasin based on field measurements to characterize hydraulic geometry for stream reaches.

Seepage Run Surveys

Flow measurement stations in the Mission and Brender Creek watersheds will be shared by both the temperature data collection team and the conventional data collection team. The temperature data collection team will also collect streamflow information in Nason Creek and Peshastin Creek watersheds (see Figure 16 and Table 10). All stream velocity measurements will be made following the field sampling and measurement protocols described in the WAS protocol manual (WAS, 1993).

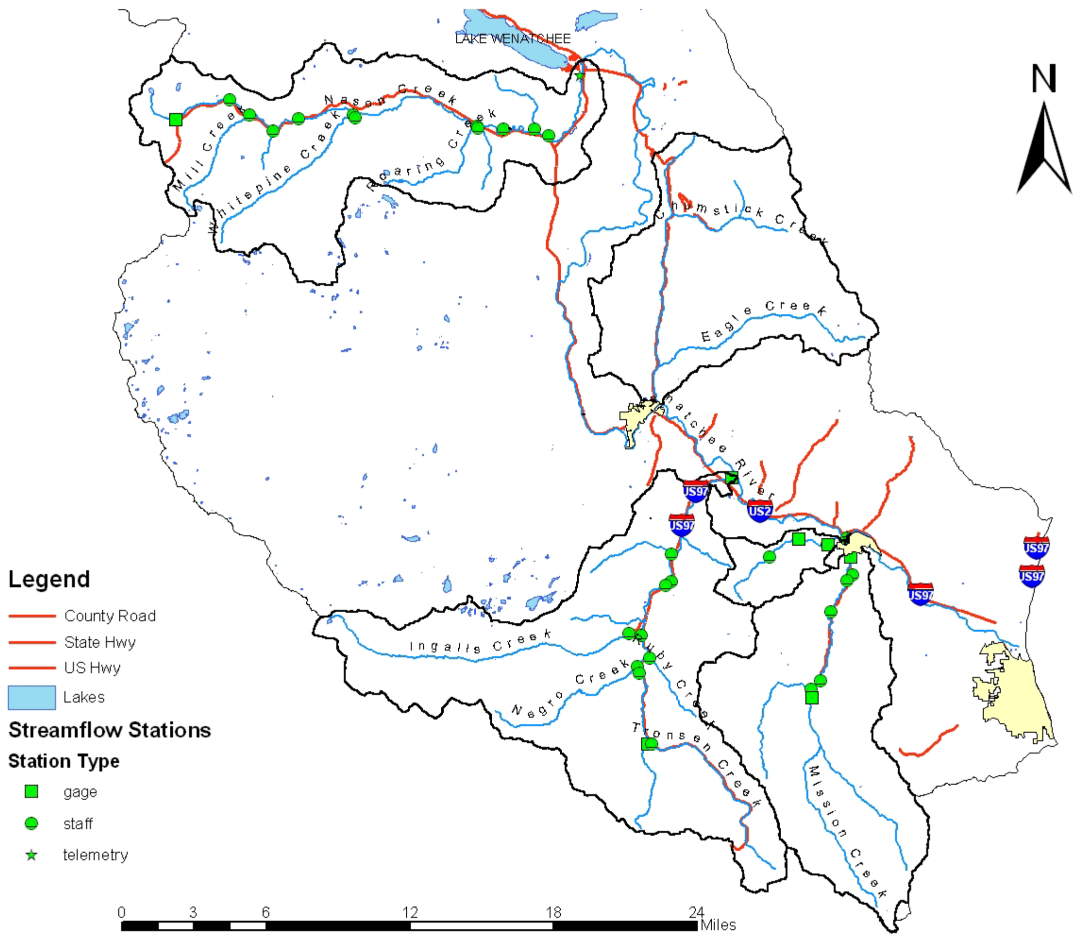

Figure 16. Flow Measurement Stations.

There will be two types of seepage runs: a comprehensive synoptic flow to occur in tandem with the TIR flight in August and a slightly scaled-down seepage run to occur monthly during July, September, and October. Stage height gage sites will be pressure transducers and dataloggers measuring stage height every thirty minutes. Staff gage sites will be instantaneous discharge measurement stations that will generate data for discharge rating curves.

Table 10. Discharge Measurement Stations.

TYPE	UNIT	DESCRIPTION	Basin	River Mile
Staff Gage	SHU*	Brender Cr at Sunset Hwy	Brender	0.1
Stage Height Gage	NPSU	Brender Cr blw spills	Brender	3.2
Staff Gage	NPSU	Sand Cr near mouth	Mission	0.1
Staff Gage	NPSU	Yaksum Canyon	Mission	0.1
Stage Height Gage	SHU	Mission Cr at Sunset Hwy	Mission	0.3
Stage Height Gage	SHU	Mission at Binder Rd	Mission	1.2
Staff Gage	NPSU	Mission Cr abv Yaksum Canyon	Mission	2.1
Staff Gage	NPSU	Mission abv Slawson Cnyn	Mission	3.9
Staff Gage	NPSU	Mission Cr blw Sand Cr	Mission	7.3
Stage Height Gage	USFS	Mission Cr above NF boundary	Mission	8.0
Staff Gage	NPSU	Henry Cr	Nason	0.1
Staff Gage	NPSU	Kahler Cr	Nason	0.1
Staff Gage	NPSU	Mill Cr mouth	Nason	0.1
Staff Gage	NPSU	Roaring Cr and Coulter Cr confluence	Nason	0.1
Staff Gage	NPSU	Whitepine Cr mouth	Nason	0.1
Stage Height Gage	SHU	Nason Creek near mouth	Nason	0.7
Staff Gage	NPSU	Nason Creek near hwy junction	Nason	4.8
Staff Gage	NPSU	Nason Creek above Kahler Cr	Nason	5.6
Staff Gage	NPSU	Nason Creek above Roaring/Coulter Creeks	Nason	10.1
Staff Gage	NPSU	Nason Cr above Whitepine Creek	Nason	16.5
Staff Gage	NPSU	Nason Cr above Mill Cr	Nason	21.3
Stage Height Gage	NPSU	Nason Cr headwater	Nason	25.1
Staff Gage	NPSU	Camas Cr near mouth	Peshastin	0.1
Staff Gage	NPSU	Ingalls Cr near mouth	Peshastin	0.1
Staff Gage	NPSU	Mill Cr in Peshastin basin	Peshastin	0.1
Staff Gage	NPSU	Negro Cr near mouth	Peshastin	0.1
Staff Gage	NPSU	Ruby Cr mouth	Peshastin	0.1
Staff Gage	NPSU	Tronsen Cr near mouth	Peshastin	0.1
Stage Height Gage	NPSU	Peshastin Cr mouth	Peshastin	0.3
Stage Height Gage	SHU	Peshastin Cr gage	Peshastin	1.9
Staff Gage	NPSU	Peshastin above Camas Cr	Peshastin	6.1
Staff Gage	NPSU	Peshastin Cr above Ingalls Cr	Peshastin	9.2
Staff Gage	NPSU	Peshastin above Negro Cr	Peshastin	11.1
Stage Height Gage	NPSU	Peshastin above Tronsen	Peshastin	14.6
Staff Gage	NPSU	Peshastin	Peshastin	18.4
Comprehensive	NPSU	Gill Cr mouth	Nason	0.1
Comprehensive	NPSU	Mahar Cr	Nason	0.1
Comprehensive	NPSU	Smith Brook	Nason	0.1
Comprehensive	NPSU	Butcher Cr	Nason	0.1
Comprehensive	NPSU	Shaser Cr	Peshastin	0.1
Comprehensive	NPSU	Scotty Cr	Peshastin	0.1
Comprehensive	NPSU	Peshastin headwater	Peshastin	16.6
Comprehensive	NPSU	Nason above Mahar	Nason	13.4

Comprehensive stations are additional sites for flow measurement during the comprehensive seepage run survey.
*Stream Hydrology Unit.
**Nonpoint Studies Unit.

Flow measurement stations were chosen to best represent surface water and groundwater interactions as well as capture the streamflow contributed from tributaries important for temperature and fish habitat.

Thermal Infrared (TIR) and Color Videography Surveys

On August 14, 2001, the U.S. Forest Service commissioned a TIR flight along Nason Creek. The Department of Ecology commissioned a TIR flight along the mainstem Wenatchee River and Icicle Creek that occurred August 16, 2002. During August 2003, another TIR flight will be commissioned along the river miles indicated in Table 11.

Table 11. Thermal Infrared Flight Miles and Streams.

River/Stream name	Approximate River miles	FLIR	Description
Peshastin Creek	15	X	Approximately 1 mile upstream of meeting Highway 97
Mission Creek	8	X	To 0.5 miles above Sand Creek
Nason Creek	26	X	From first meeting Highway 2 near pass to confluence with Wenatchee River

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.

Other Parameters

The project objectives will be met through monitoring water quality and flow, modeling DO and pH, characterizing bacteria, and analyzing various pollutant loading scenarios and resulting water quality in Mission, Brender, and Chumstick Creeks. Monitoring of water quality and flow will be conducted to quantify loading contributions from various sources and water quality in the river. Monitoring will consider all pH, DO, and fecal coliform, as well as other parameters which are known to affect these parameters.

Sampling Sites

Figure 17 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 38 total sites: 23 sites in the Mission Creek watershed (8 mainstem sites, 11 sites on tributaries, and 4 sites on irrigation returns) and 15 sites in the Chumstick Creek watershed (6 mainstem sites, 7 sites on tributaries, and two sites on irrigation returns). Sites may be added or removed from the sampling plan depending upon preliminary results.

Sampling sites for Mission Creek were selected to characterize productivity from the USFS property boundary to the river's mouth. Sites were limited by access opportunities. The uppermost Mission Creek site near the USFS property boundary will represent the upper boundary of the non-temperature study area. The lower-most Mission Creek site, just downstream of the confluence of Mission and Brender Creeks, will represent the lower boundary of the study area. Tributaries to Mission Creek will be sampled as close to their confluence with the mainstem as possible.

Sites on Chumstick Creek were similarly selected to characterize loading from tributaries, farms, and other land-use types. The Chumstick watershed will be sampled from the uppermost accessible tributary, Dry Creek, to the mouth of Chumstick Creek.

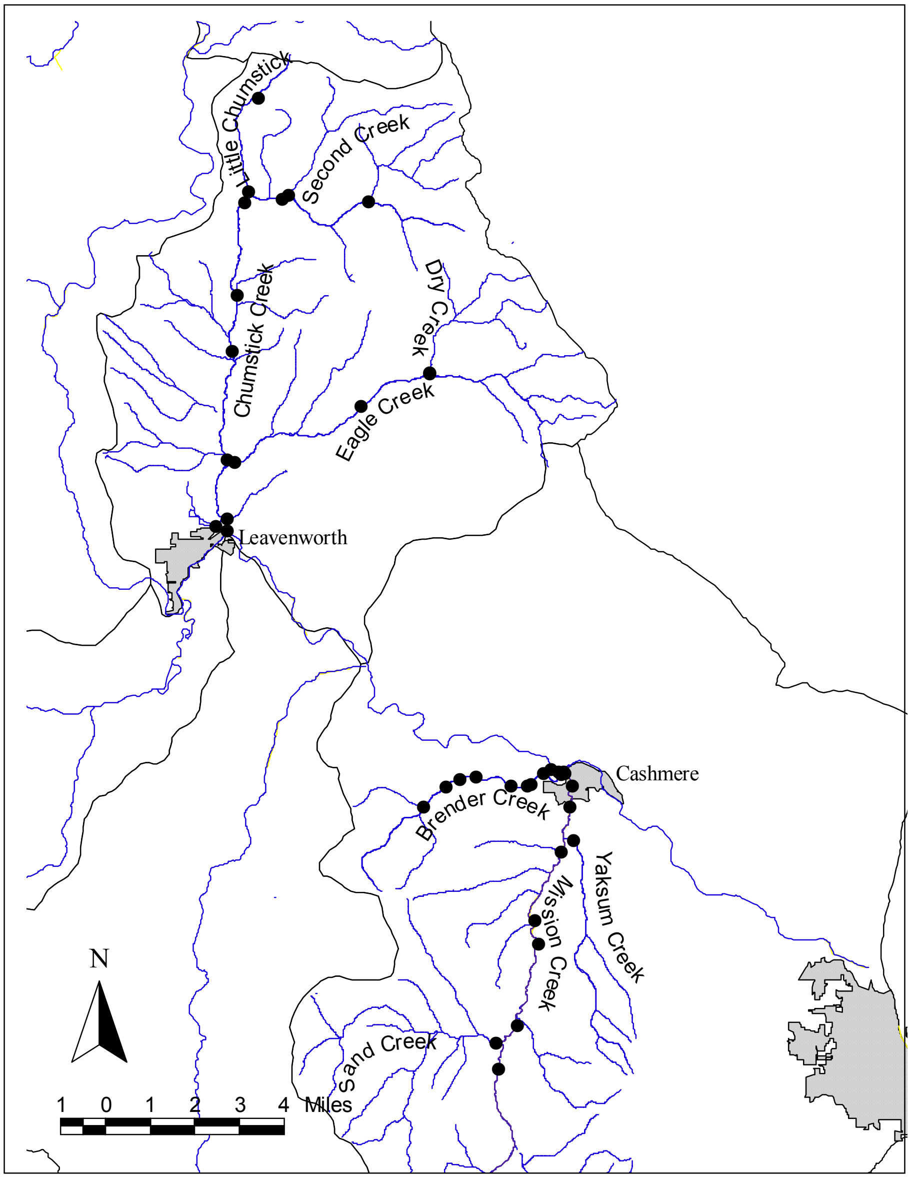

Figure 17. Map of Non-Temperature Monitoring Stations.

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 modeling DO, pH, and fecal coliform responses to productivity in the Mission and Chumstick Basins (See Data Analysis and Use Section).

Baseline Monitoring
Bimonthly field surveys will be conducted from the first week of July through the first week of October, 2003, at all accessible stations indicated in Figure 17. Schedules may change depending on flow conditions and staff availability. Parameters will include pH, DO, conductivity, discrete temperature, flow, total suspended solids (TSS), chloride, and bacteria (fecal coliform – FC – and E. coli). Table 12 lists baseline parameters by station.

Table 12. Baseline Monitoring Parameters by Station.

Station	Field[1]	Flow	TSS	Chloride	FC/ E-Coli
Little Chumstick Cr nr Plain	X	X	X	X	X
Little Chumstick Cr nr Mouth	X	X	X	X	X
Chumstick Cr above Little Chumstick	X	X	X	X	X
Chumstick Creek Midstream at Highway 209	X	X	X	X	X
Chumstick Alternate Site	X	X	X	X	X
Chumstick Cr abv Eagle Cr	X	X	X	X	X
Eagle Cr abv Van Cr	X	X	X	X	X
Eagle Cr nr Mouth	X	X	X	X	X
Fox Irrigation Return nr Mouth	X	X	X	X	X
Chumstick Irrigation Return nr Mouth	X	X	X	X	X
Chumstick Cr nr Mouth	X	X	X	X	X
Mission Cr abv Bear Gulch	X	X	X	X	X
Mission Cr abv Yaksum Cr	X	X	X	X	X
Yaksum Cr nr Mouth	X	X	X	X	X
Mission Cr at Mission Cr Rd	X	X	X	X	X
Mission Creek Alternate site	X	X	X	X	X
Mission Cr at Pioneer Ave	X	X	X	X	X
Mission Cr abv Brender	X	X	X	X	X
Brender Cr at Brender Rd	X	X	X	X	X
Icicle Irrigation Return – US	X	X	X	X	X
Peshastin Irrigation Return	X	X	X	X	X
Brender Cr at Jurgens property	X	X	X	X	X
Brender Cr Alternate Site	X	X	X	X	X
Brender Cr at Pioneer Ave DS	X	X	X	X	X
Pioneer Spill Irrigation Return	X	X	X	X	X
Brender Cr at Evergreen Dr	X	X	X	X	X
Sunset Highway Irrigation Ditch	X	X	X	X	X
No Name Cr at US Mouth	X	X	X	X	X
No Name Cr at DS Mouth	X	X	X	X	X
Brender Cr nr Mouth	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, September, and October, 2003, 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, total non-volatile suspended solids (TNVSS), alkalinity, chloride, chlorophyll, total persulfate nitrogen (TPN), nutrients (ammonia, nitrate-nitrite, orthophosphate, and total phosphorus), ultimate biochemical oxygen demand (UBOD), phytoplankton, dissolved organic carbon (DOC), total organic carbon (TOC), total dissolved solids (TDS), FC, and E. coli. Three or more Hydrolab® meters will be deployed to bracket individual reaches throughout the sampling event and will collect diurnal temperature, DO, pH, and conductivity data. All resulting data will be used to measure productivity. Table 11 lists synoptic survey parameters by station.

Table 13. Synoptic Survey Parameters by Station.

Station	HL[1]	Field	Flow	Turb-idity	TSS/ TNVSS	Alka-linity	Chlor -ide	Chloro-phyll	TPN	Nuts	U BOD	Phyto-plankton	TOC	DOC	TDS	FC/E. Coli
Little Chumstick Cr nr Plain		X	X	X	X		X								X	X
Little Chumstick Cr nr Mouth		X	X	X	X	X	X	X	X	X			X	X	X	X
Chumstick Cr above Little Chumstick		X	X	X	X	X	X		X	X			X	X	X	X
Chumstick Alternate Site		X	X	X	X	X	X		X	X			X	X	X	X
Chumstick Creek Midstream at Highway 209	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Chumstick Cr abv Eagle Cr	X	X	X	X	X	X	X	X	X	X			X	X	X	X
Eagle Cr abv Van Cr		X	X	X	X	X	X		X	X			X	X	X	X
Van Cr nr Mouth		X	X	X	X	X	X								X	X
Eagle Cr abv Bjork Cyn		X	X	X	X	X	X								X	X
Eagle Cr nr Mouth		X	X	X	X	X	X	X	X	X			X	X	X	X
Fox Irrigation Return nr Mouth		X	X	X	X	X	X	X	X	X			X	X	X	X
Chumstick Irrigation Return nr Mouth		X	X	X	X	X	X	X	X	X			X	X	X	X
Chumstick Cr nr Mouth	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Mission Cr at USFS Boundary		X	X	X	X	X	X								X	X
Sand Cr nr Mouth		X	X	X	X	X	X								X	X
Mission Cr abv Bear Gulch		X	X	X	X	X	X	X	X	X			X	X	X	X
Mission Cr blw Bear Gulch		X	X	X	X	X	X								X	X
Mission Cr at Slawson Canyon		X	X	X	X	X	X								X	X
Mission Cr abv Yaksum Cr	X	X	X	X	X	X	X	X	X	X			X	X	X	X
Yaksum Cr nr Mouth		X	X	X	X	X	X	X	X	X			X	X	X	X
Icicle Irrigation Distr. Spill Return		X	X	X	X	X	X	X	X	X			X	X	X	X
Mission Cr at Mission Cr Rd	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Mission Cr alternate Site		X	X	X	X	X	X	X	X	X			X	X	X	X
Mission Cr at Pioneer Ave		X	X	X	X	X	X	X	X	X			X	X	X	X
Mission Cr abv Brender	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Brender Cr at Brender Rd		X	X	X	X	X	X	X	X	X			X	X	X	X
Icicle Irrigation Return – US		X	X	X	X	X	X	X	X	X			X	X	X	X
Peshastin Irrigation Return		X	X	X	X	X	X	X	X	X			X	X	X	X
Brender Cr at Jurgens Property	X	X	X	X	X	X	X	X	X	X			X	X	X	X
Brender Cr Alternate Site		X	X	X	X	X	X		X	X			X	X	X	X
Brender Cr at Pioneer Ave DS	X	X	X	X	X	X	X	X	X	X			X	X	X	X
Pioneer Spill Irrigation Return		X	X	X	X	X	X	X	X	X			X	X	X	X
Brender Cr at Evergreen Dr		X	X	X	X	X	X	X	X	X			X	X	X	X
Sunset Highway Irrigation Ditch		X	X	X	X	X	X	X	X	X			X	X	X	X
No Name Cr at US Mouth		X	X	X	X	X	X		X	X			X	X	X	X
No Name Cr at DS Mouth		X	X	X	X	X	X	X	X	X		X	X	X	X	X
Brender Cr nr Mouth	X	X	X	X	X	X	X	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 at 30-minute intervals for at least 24-hour periods.

Groundwater Sampling

Approximately 20 stream piezometers will be installed in May 2003 at selected points within the Chumstick, Mission, Nason, and Peshastin Creek watersheds to allow monitoring of surface water and groundwater head relationships, groundwater temperature, and water quality. The piezometers will be evenly distributed among the above watersheds and will be co-located with stream thermistors where possible. The piezometers will consist of a 7-foot length of 1-inch diameter galvanized pipe, one end of which is crimped and slotted. The upper end of each piezometer will be 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 driven into the stream bed (within a few feet of the shoreline) to a maximum depth of approximately 5 feet.

Each piezometer will be instrumented with three i-button® thermistors for continuous monitoring of water temperature. In a typical piezometer installation, one thermistor will be located near the bottom of the piezometer, one will be located at a depth of approximately 1 foot below the streambed, and one will be located approximately 0.5 feet above the streambed. The piezometers will be accessed monthly (between June and November) to download the thermistors and to make "spot" measurements of stream and groundwater temperature for later comparison and validation against the thermistor data. The monthly spot measurements will be made with properly maintained and calibrated field meters in accordance with standard Watershed Ecology Section methodology.

During the monthly site visits, surface water and groundwater head relationships 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 is inferred. Similarly when river stage exceeds the head in the piezometer, loss of water from the river to groundwater storage can be inferred.

If, during the site visit, groundwater discharge to the stream is indicated (based on the measured head values) the piezometer will be sampled for the following parameters: conductivity, temperature, TSS, alkalinity, chloride, TPN, nutrients (ammonia, nitrate-nitrite, orthophosphate, and total phosphorus), DOC, TOC, and TDS. All samples will be collected, processed, and transported to the laboratory in accordance with standard WES methodology.

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 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 streams.

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. Duplicate Winkler samplers will be collected periodically to verify the accuracy of the Winkler measurements.

Stream discharge information will be obtained at critical sampling locations to provide loading information. Continuous flow gaging stations will be installed at two locations on Mission Creek, three locations on Brender Creek, and one or two locations on Chumstick Creek. Flows will be determined by the Environmental Monitoring and Trends Section Stream Hydrology Unit (SHU) in addition to project staff. Estimation of discharge and instantaneous flow measurements 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 14. Samples for laboratory analysis will be stored on ice and delivered to MEL within 24 hours of collection.

Table 14. 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	SM2320B	10 mg/L
Biochemical Oxygen Demand (BOD)	1 gallon cubitainer	Cool to 4ºC	48 hours	SM 5210B	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	SM 2510B	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	SM 4500NH3 H	0.01 mg/L
Nitrate/Nitrite	125 mL clear poly	H_2SO_4 to pH < 2, Cool to 4ºC	28 days	SM 4500-NO3 I	0.01 mg/L
Nitrogen – Total Persulfate	125 mL clear poly	H_2SO_4 to pH < 2, Cool to 4ºC	28 days	SM4500[1]	25 ug/L
Orthophosphate	125 mL amber poly	Cool to 4ºC	48 hours	356.3	3 ug/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	SM 4500 P I	0.01 mg/L
Phosphorus, Total Low Level	New 125 mL poly	H_2SO_4 to pH < 2, Cool to 4ºC	28 days	EPA 200.8	3.0 ug/L
Phosphorus, Total Dissolved Soluble Reactive	125 mL clear poly	H_2SO_4 to pH < 2, Cool to 4ºC	28 days	SM 4500 P I	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	SM 2540 D	1 mg/L
Total Nonvolatile Suspended Solids	1000 mL poly	Cool to 4ºC	7 days	SM 2540 E	1 mg/L
Total Dissolved Solids	500 mL poly	Cool to 4ºC	7 days	SM 2540 C	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	2130 B	1 NTU
Fecal Coliform	250 mL glass/poly autoclaved	Cool to 4ºC	30 hours	SM MF 9222D[1]	1 cfu/100 mL
E Coli	250 mL glass/poly autoclaved	Cool to 4ºC	30 hours	EPA 1103.1	1 cfu/100 mL

[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 number 61099-035, serial number 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 number 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.

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 measurement quality objectives are presented in Table 15. The laboratory's measurement quality objectives and quality control procedures are documented in the MEL Lab Users Manual (MEL, 2000).

Table 15. 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; 0.1 f/s	0.1 f/s	N/A	0.05 f/s
pH*	0.20 s.u.	0.05 s.u.	0.10 s.u.	N/A
Air Temperature*	± 0.1°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 Suspended 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	3 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

* as units of measurement, not percentages.

Accuracy is affected by both precision and bias. The targets for analytical precision in Table 15 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 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 protocols 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 measurement quality objectives. Replicate samples will be collected at a rate of 10% of all samples. Bacteria samples tend to have a high percent Relative Standard Deviation (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% 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 measurement 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 Ecology (1993).

Results for check standards will be compared to the DQOs for precision, bias, and accuracy in Table 15 wherever possible. Reporting limits for the project data will be compared to those in Table 15. 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:

- Oregon Department of Environmental Quality's Ttools extension for Arcview (ODEQ, 2001) will be used to sample and process GIS data for input to the Shade and QUAL2Kw models.
- Ecology's Shade model (Ecology, 2003a) will be used to estimate effective shade along the mainstems of the major tributaries in the basin. Effective shade will be calculated at 100-meter intervals along the streams and then averaged over 500-meter intervals for input to the QUAL2Kw model.
- The QUAL2Kw model (Chapra, 2001; Ecology, 2003b) will be used to calculate the components of the heat budget and simulate water temperatures. QUAL2Kw simulates diurnal variations in stream temperature for a steady flow condition. QUAL2Kw will be applied by assuming that flow remains constant for a given condition such as a 7-day or 1-day period, but key variables are allowed to vary with time over the course of a day. For temperature simulation, the solar radiation, air temperature, relative humidity, headwater temperature, and tributary water temperatures are specified or simulated as diurnally varying functions. QUAL2Kw uses the kinetic formulations for the components of the surface water heat budget that are shown in Figure 13 and described in Chapra (1997). Diurnally varying water temperatures at 500-meter intervals along the streams in the basin 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 streams and rivers.

All input data for the Shade and QUAL2Kw models will be longitudinally referenced, allowing spatial and/or continuous inputs to apply to certain zones or specific river segments. Model input data will be determined from GIS coverages using the Ttools extension for Arcview, or from data collected by Ecology or other data sources.

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 non-continuous 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 QUAL2Kw model (Chapra, 2001). QUAL2Kw 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. QUAL2Kw will be developed simultaneously to simulate diurnal variations in stream temperature for steady flow conditions by the temperature TMDL effort. QUAL2Kw 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. QUAL2Kw uses kinetic formulations for simulating DO and pH in the water column as shown in Figure 18 and described in Chapra (1997).

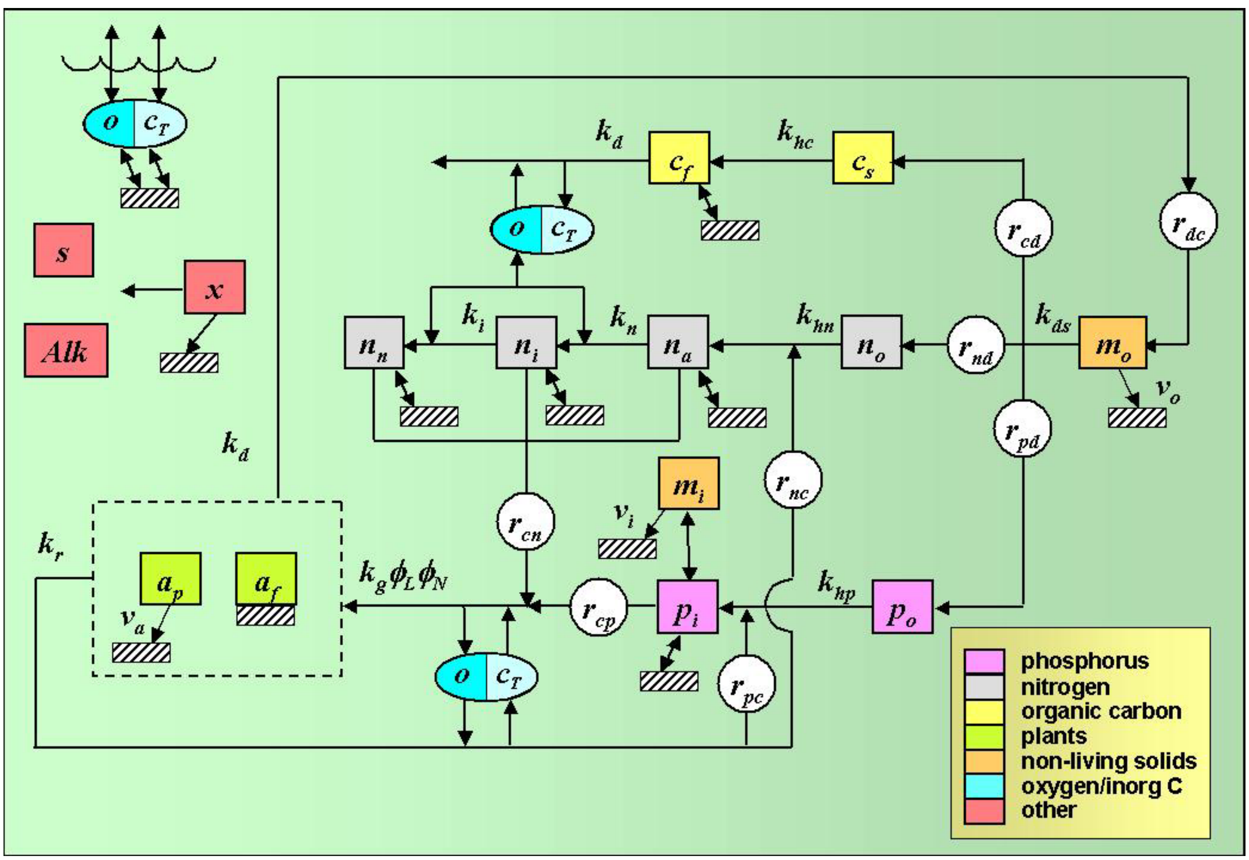

Figure 18. Kinetic Formulations for Simulating Dissolved Oxygen and pH in the Water Column Used by QUAL2K.

Project Organization

The roles and responsibilities of Ecology staff are as follows:

- **Jim Carroll**, Conventional Parameter (DO, pH, and bacteria) 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 Principal 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 final report related to data collection, field methods, 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 Principal Investigator, Environmental Assessment Program, Nonpoint Studies Unit: Assists 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, and data quality review and analysis.

- **David Schneider**, Overall TMDL Project Lead, 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. Is responsible for implementation planning and preparation of TMDL document for submittal to EPA.

- **Jeff Lewis**, 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.

- **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. Reviews 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 Principal 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 16. Proposed Schedule for the TMDL Project.

Event	Date
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
EIM data completion	December, 2004
Year 2 Draft Report	December, 2004
Final Report	March, 2005

Laboratory Budget

Table 17. Wenatchee Basin (WRIA 45) TMDL. Lab estimate for Study Year 2. (Lab Costs reflect Ecology's internal 50% price discount.)

Parameter	Cost/Analysis (water only)	# Samples (incl. field QA)	Cost	Number of Surveys	Cost
Turbidity	7	41	287	4	1148
Total Suspended (TSS) + TNVSS	21	41	861	4	3444
Alkalinity	14	41	574	4	2296
Chloride	12	41	492	4	1968
Chlorophyll	46	28	1288	4	5152
Hardness	12	5	60	1	60
Metals - Cu, Fe, Mg, Si (dissolved and total)	85	5	425	1	425
Total Persulfate Nitrogen (TPN)	16	41	656	4	2624
Nutrients 5 (NH3, NO3, NO2, O-P, low T-P)	70	41	2870	4	11480
UBOD	426	6	2556	2	5112
Phytoplankton (biovolume, ID)	80	6	480	2	960
Dissolved Organic Carbon	34	41	1394	4	5576
Total Organic Carbon	29	41	1189	4	4756
Total Dissolved Solids	10	41	410	2	820
Fecal Coliform/ E. Coli	35	45	1575	4	6300
Total Suspended Solids (TSS)	21	35	735	6	4410
Chloride	12	35	420	6	2520
Fecal Coliform/ E. Coli (MF)	35	72	2520	6	15120
Additional samples (for unknown souces, etc)					11126
	Total:				$85,297

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