Stillaguamish River Basin and Port Susan Total Maximum Daily Load Evaluation Update

Quality Assurance Project Plan

by
Joe Joy

December 12, 2001

Washington State Department of Ecology
Environmental Assessment Program
Olympia, WA 98504-7710

Publication No. 01-03-065

303(d) listings addressed in this study: See Table 2

Approvals:

Dave Garland, Northwest Regional Office	Date
Kevin Fitzpatrick, Section Manager, Northwest Regional Office	Date
Will Kendra, Section Manager, Watershed Ecology Section	Date
Stuart Magoon, Director, Manchester Environmental Laboratory	Date
Cliff Kirchmer, Ecology Quality Assurance Officer	Date

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Project Organization and Schedule

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

- *Joe Joy* (Ecology): Project manager and principal investigator, Environmental Assessment Program, Watershed Ecology Section. Responsible for overall project supervision and for preparation of Quality Assurance Project Plan (QAPP), project design, collecting and analyzing data, modeling, developing graphs and figures, and writing and editing draft and final reports (360-407-6486).

- *Norm Glenn* (Ecology): Assistant investigator, Environmental Assessment Program, Watershed Ecology Section. Responsible for assisting in point source monitoring consultation (360-407-6683).

- *Robert Garrigues* (Ecology): Hydrologist, Environmental Assessment Program, Surface Hydrology Unit. Responsible for the deployment and maintenance of two gaging stations with continuous flow data and retrieving, evaluating, and reporting the data (360-407-6638).

- *Will Kendra* (Ecology): Section Supervisor of the Watershed Ecology Section of the Environmental Assessment Program. Responsible for approving the project QAPP, project budget, and project reports (360-407-6698).

- *Karol Erickson* (Ecology): Unit Lead of the Watershed Studies Unit of the Environmental Assessment Program. Responsible for internal review of the project QAPP and draft data summary reports (360-407-6694).

- *Stuart Magoon, Will White, and Karin Feddersen* (Ecology): Manchester Environmental Laboratory (MEL) staff responsible for sample delivery and analysis/reporting of chemical data (360-871-8860).

- *Cliff Kirchmer* (Ecology): Quality Assurance Section staff responsible for review of the project QAPP (360-407-6455).

- *Kevin Fitzpatrick* (Ecology): Northwest Regional Office Water Quality Section Manager. Responsible for internal review of the project QAPP and draft data summary reports (425-649-7033).

- *Dave Garland* (Ecology): Northwest Regional Office TMDL coordinator. Responsible for directing NWRO staff to conduct outreach to the local community and informing them about the TMDL project and process (425-649-7031).

- *Mike Dawda* (Ecology): Northwest Regional Office Municipal Facilities Engineer. Responsible for keeping the municipal wastewater treatment plant operators informed on monitoring and TMDL issues pertaining to the project (425-649-7027).

- *Kathy Thornburgh* (Snohomish County Surface Water Management): Snohomish County cooperative monitoring contact (425-388-3464 ext. 4542).

- *Don Klopfer and Pat Stevenson* (Stillaguamish Tribe, Natural Resources): Stillaguamish Tribe cooperative monitoring contacts (360-435-2755).

The proposed schedule for the TMDL project is as follows:

Submit initial QAPP for internal review:	August 18, 2000
Submit initial QAPP for external review:	September 8, 2000
Reconnaissance survey sampling:	August 2000
TMDL survey sampling:	August 2000 – December 2001
Submit revised QAPP for internal review:	April 16, 2001
Revised QAPP approval:	October 1, 2001
EIM entry complete:	February 15, 2002
Data review and analysis:	June 29, 2002
Technical concept advisory group review:	July 31, 2002
Draft final report:	November 30, 2002
Final report:	January 31, 2003

The laboratory budget for monitoring performed in 2000 was $34,700. The budget for FY01 is outlined in Table 1. The cost of analyses for 32 metal samples represents 27% of the budget. Additional costs of gage installation by the Stream Hydrology Unit have not been calculated.

Table 1. Stillaguamish TMDL laboratory sample cost estimate in 2001.

	# sites	QA/survey	price	Total per survey	# surveys	Analysis cost/study	Total
Stillaguamish Main Stem							
Basin-wide	(13 x 2)						
FC+EC	26	4	$ 20	$ 600	2	$ 1,200	
Entero	26	4	$ 29	$ 870	2	$ 1,740	
Chloride	26	2	12	$ 336	2	$ 672	
TSS	26	2	10	$ 280	2	$ 560	$ 4,172
Run-off Synoptic Surveys	(15 x 2)						
Inorganic N	30	2	$ 24	$ 768	2	$ 1,536	
Total P (Low Level)	30	2	$ 34	$ 1,088	2	$ 2,176	
Total Persulfate N	30	2	$ 16	$ 512	2	$ 1,024	
Dissolved Ortho P	30	2	$ 12	$ 384	2	$ 768	
Chloride	30	2	$ 12	$ 384	2	$ 768	
UBOD	3		$ 115	$ 345	2	$ 690	
BOD5	11	2	46	$ 598	2	$ 1,196	
TOC	15	2	29	$ 493	2	$ 986	$ 9,144
Dissolved Oxygen Surveys							
Chloride	10	1	12	$ 132	2	$ 264	
Periphyton chl a	15	3	46	$ 828	1	$ 828	
Inorganic N	10	1	24	$ 264	2	$ 528	
Dissolved Inorganic N	10	1	24	$ 264	2	$ 528	
Dissolved ortho P	10	1	12	$ 132	2	$ 264	
Total Persulfate N	10	1	16	$ 176	2	$ 352	
Total P	10	1	34	$ 374	2	$ 748	$ 3,512
Old Stillaguamish Channel							
Synoptic Surveys	(15 x 2)						
Inorganic N	30	2	$ 24	$ 768	3	$ 2,304	
Total P (Low Level)	30	2	$ 16	$ 512	3	$ 1,536	
Total Persulfate N	30	2	$ 16	$ 512	3	$ 1,536	
Dissolved Ortho P	30	2	$ 12	$ 384	3	$ 1,152	
BOD	9	2	46	$ 506	3	$ 1,518	
UBOD	3		115	$ 345	2	$ 690	
TOC	15	1	29	$ 464	3	$ 1,392	
TSS	30	2	10	$ 320	3	$ 960	
Fecal Coliform	30	2	20	$ 640	3	$ 1,920	
Enterococcus	15	2	29	$ 493	3	$ 1,479	
Chlorophyll a	8	2	46	$ 460	3	$ 1,380	$ 15,867
Metals Surveys					(3 basin + 1 OC)		
As-dissolved	7	1	41	$ 328	4	$ 1,312	
As-total recoverable	7	1	41	$ 328	4	$ 1,312	
Hg	7	1	48	$ 384	4	$ 1,536	
ICPMS- dissolved	7	1	136	$ 1,088	4	$ 4,352	
ICPMS- total recov.	7	1	136	$ 1,088	4	$ 4,352	
Hardness	7	1	12	$ 96	4	$ 384	
TSS	7	1	10	$ 80	4	$ 320	
Sample Prep	8	0	35	$ 280	4	$ 1,120	
Filter blank	1		437	$ 437	1	$ 437	
Bottle blank	1		437	$ 437	1	$ 437	
Matrix spike	1		184	$ 184	1	$ 184	
Matrix spike duplicate	1		184	$ 184	1	$ 184	
Filters	8		21	$ 168	4	$ 672	
Bottles	8		14	$ 112	4	$ 448	$ 17,050
Port Susan Bacteria Sampling							
FC (MPN)	11	1	39	$ 468	10	$ 4,680	
Enterococcus (MF)	11	1	29	$ 348	10	$ 3,480	
TSS	11	1	10	$ 120	10	$ 1,200	$ 9,360
						Total	**$ 59,105**

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Background and Problem Statement

Setting

Several rivers and streams in the Stillaguamish River basin are on the 1996 and 1998 303(d) list because of violations of one or more water quality criteria. The Department of Ecology Water Quality Program (WQP) selected the basin for a total maximum daily load (TMDL) assessment in 2000. The Environmental Assessment Program (EAP) has been asked to design and conduct the TMDL evaluation for the basin. This document outlines the findings from historical data and discussions with local agencies pertaining to the water quality problems in the basin. From these findings, a TMDL evaluation project design and quality assurance project plan is described.

The Stillaguamish basin drains approximately 684 $miles^2$ from the Cascade Range to Puget Sound in Snohomish County and Skagit counties (Figure 1). The Stillaguamish River has two major forks at river mile 17.8--the North Fork drains 284 $miles^2$ and the South Fork drains 255 $miles^2$. Some of the tributaries to these forks start in the Cascade Mountains at elevations above 3000 feet. Most have steep gradients and are contained within narrow valleys. The South Fork enters a floodplain four miles before the confluence with the North Fork. The mainstem at the confluence is at an elevation of 51 feet and the gradient is fairly even to the mouth. At river mile 2.75 is another important hydrologic feature – a split between the Old Stillaguamish Channel and Hat Slough. Most flow was redirected out of the Old Stillaguamish Channel by a series of major floods that released logjams more than 70 years ago. Hat Slough provided a straight path to Port Susan for the floodwaters and now is the primary channel of the river. The Old Channel meanders for eight miles until it bifurcates at about river mile (RM) 1.5; South Pass transports about 80 percent of the flow to and from Port Susan; and West Pass carries the remaining flow to and from Skagit Bay. During the dry season, the Old Channel is almost a tidal slough; namely, Church Creek, Miller Creek, and intermittent Stanwood WWTP effluent discharges are the only additional freshwater inflows to a small amount of Stillaguamish River inflow. During the wet season, freshwater from the main channel flows into this remnant channel. With fewer flood events in the past couple of years, the remnant channel has experienced a build up of sediment and vegetation.

Both Hat Slough and the Old Stillaguamish Channel transport Stillaguamish River water to Port Susan--a Puget Sound estuary. The Warm Beach area south of Hat Slough also contributes run-off through several small drainages to Port Susan, and it is considered part of the Stillaguamish water quality management area. Port Susan is a relatively shallow and poorly flushed bay. For several years, commercial shellfish harvesting has been restricted or prohibited in the bay by the Department of Health because of fecal coliform contamination in the water column.

The upper basin is primarily forested (Figure 2). Much of it is managed by the US Forest Service within the Mount Baker-Snoqualmie National Forest (269 mi^2) or by the Washington State Department of Natural Resources (DNR) (81 mi^2). Timber harvesting and recreational uses predominate. Granite Falls (population est. 1,737) and Darrington (population est. 1,245) have growth management areas that influence some residential development in the upper basin (Figure 1). Other small residential, business, and agricultural properties are scattered along the valleys of

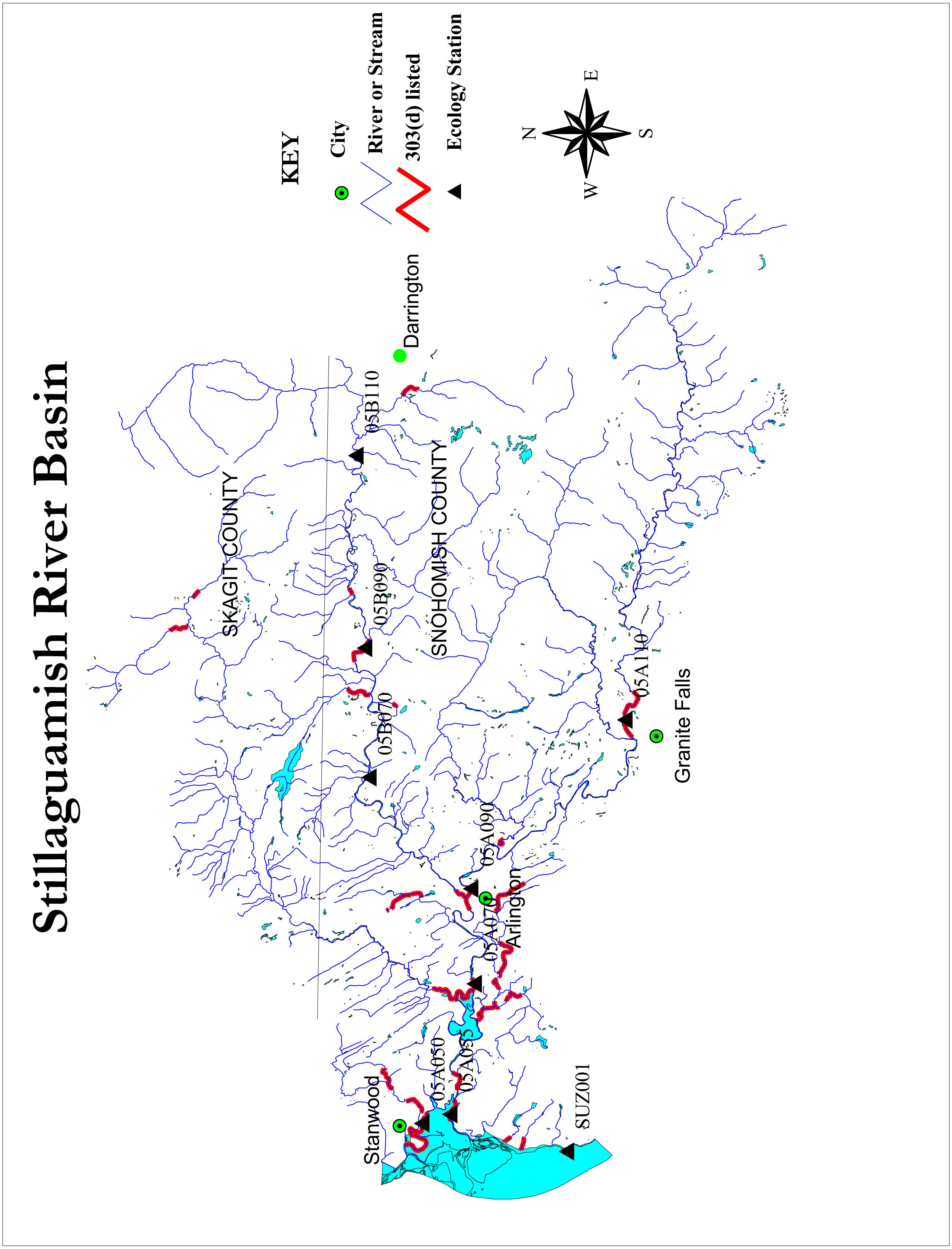
Stillaguamish River Basin
KEY
City
River or Stream
303(d) listed
Ecology Station
N
E
S
W
SKAGIT COUNTY
SNOHOMISH COUNTY
Darrington
Granite Falls
Arlington
Stanwood
05B110
05B090
05B070
05A110
05A090
05A070
05A055
05A050
SUZ001

Figure 1

Stillaguamish Basin Land Ownership

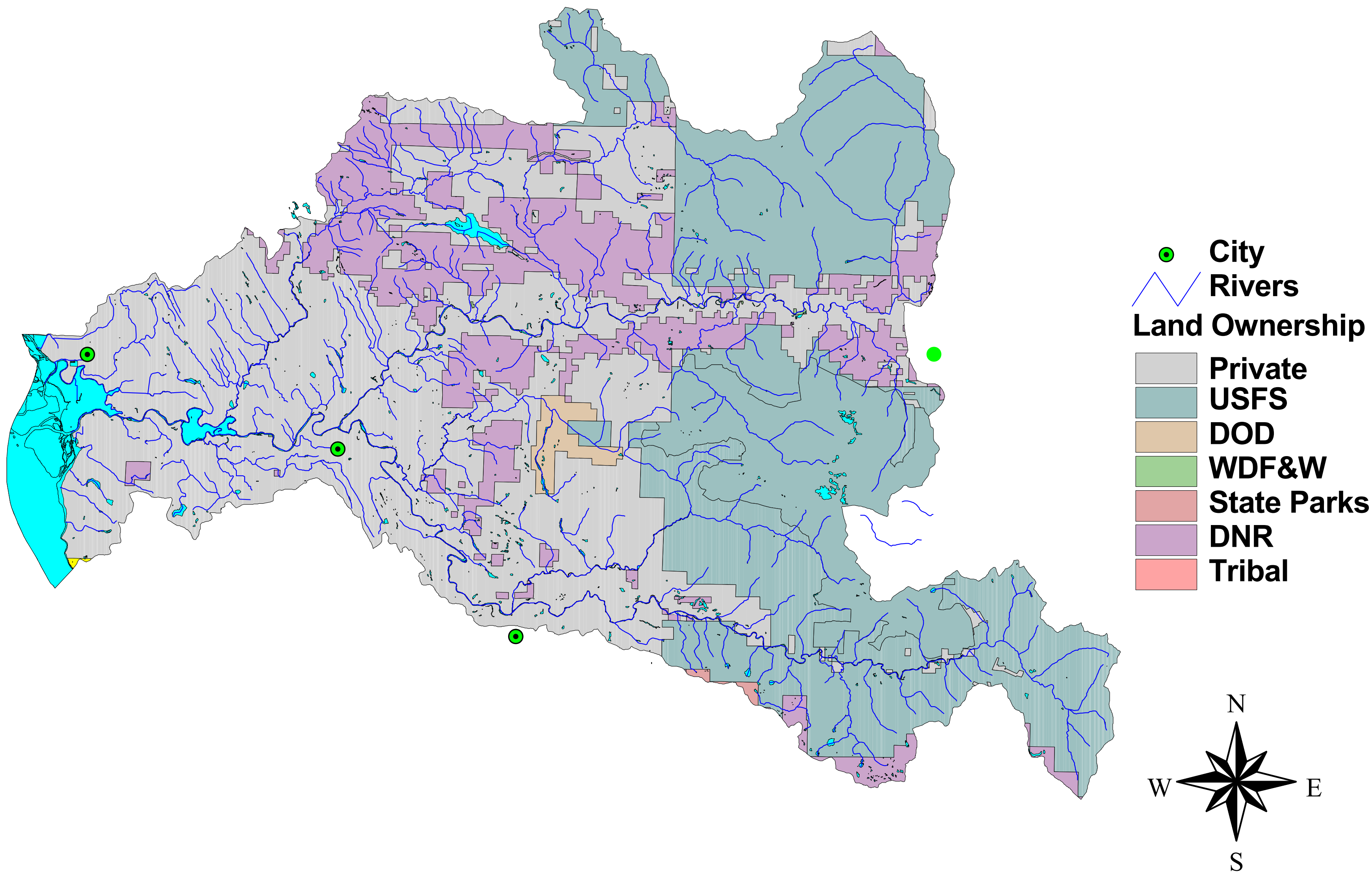

Figure 2

the two forks. The Department of Defense controls approximately 7 mi^2 in the Jim Creek sub-basin of the South Fork.

The lower basin has more diverse land uses and is primarily privately owned. Arlington (population est. 7,275) and Stanwood (population est. 3,345) have active urban growth areas. In 1995, Stienbarger (1995) estimated there were at least 909 commercial and non-commercial farms in the lower basin. Agriculture is still quite active in the lower basin, but conversions from agriculture to rural residential uses are becoming common along the Interstate 5 corridor. The distinction between non-commercial farm and rural residential use is vague. The DNR controls approximately 28 mi^2 in the Pilchuck Creek sub-basin. Privately held forests are scattered throughout the upper reaches of other sub-basins as well.

The Stillaguamish Tribe, Tulalip Tribes, and Sauk-Suiattle Tribe have cultural and economic interests in the Stillaguamish River basin. The Stillaguamish Tribe's offices are located in Arlington, the Sauk-Suiattle Tribe's offices are located in Darrington, and the Tulalip Tribes' offices are located on the Tulalip Indian Reservation immediately south of the basin.

The mainstem of the Stillaguamish River--the Old Stillaguamish Channel--and all the tributaries to those water bodies are designated as Class A waters. The North Fork to Squire Creek at RM 31.2 and tributaries to that point are Class A as well. Above Squire Creek, the North Fork and tributaries are Class AA. The South Fork to Canyon Creek at RM 33.7 and tributaries to that point are Class A. The South Fork and tributaries above Canyon Creek are Class AA. Port Susan is a Class A marine water body. The beneficial uses and water quality criteria associated with the classifications are described in Appendix 1.

In 1987, the Department of Ecology selected the Stillaguamish River basin as one of six "Early Action Watersheds" in the Puget Sound basin. As such, a watershed management committee was formed and received grant money to write the Stillaguamish Watershed Action Plan. The 1990 plan and accompanying technical supplement addressed the magnitude of various nonpoint sources of pollution and the actions needed to control and prevent problems from those sources. The Stillaguamish Clean Water District continues to direct and fund implementation of the tasks stated in the action plan. Snohomish County Surface Water Management, Snohomish Conservation District, the Stillaguamish Tribe, the Tulalip Tribes, and other local groups have been working together to control and prevent the nonpoint sources in the Stillaguamish basin and in Port Susan.

Water Quality Issues

Approximately 16 streams and rivers in the Stillaguamish Basin are on the 1998 303(d) list (Table 2). These water bodies are on the list based on previous monitoring work. Some of these water bodies have more than one reach or water body identification number and others should be separated into multiple identification numbers. One lake, Sunday Lake, is listed for nutrients. Port Susan is listed because of fecal coliform violations near Warm Beach (WRIA 5) and Juniper Beach on Camano Island (WRIA 6). A majority of the river and stream listings also are for fecal coliform bacteria violations. Temperature and dissolved oxygen (D.O.) are the next most prevalent followed by single listings for ammonia, pH, turbidity, copper, lead, nickel and arsenic.

Sources related to agricultural land uses have historically been the focus of water quality actions in the lower basin and along the upper basin valleys. The 1999 dairy farm inventory shows 31 active dairies in the basin with approximately 8000 cows and 3000 heifers and calves (Ecology, 2000). As mentioned earlier, some horse, cattle, and other farms are also present in the lower basin.

However, land use in the basin is rapidly changing. Properties near Arlington and Stanwood are converting from agricultural to rural residential uses. The majority of water quality problems associated with rural residential uses are categorized as noncommercial agricultural because they are related to animal-keeping practices, but onsite septic system maintenance and storm water treatment are also concerns. The converted properties within the municipal service areas also become a concern for increased capacity in the municipal wastewater treatment plants.

Table 2. Stillaguamish River Basin water bodies on the 1998 303(d) list.
Bold type indicates parameters addressed in this TMDL evaluation.

Old WBID	Newer WBID	Name	Parameters
WA-05-1021	PA13UD	Deer Creek	Temperature
WA-05-1016	QJ28UC	Fish Creek	Fecal Coliform
	HD76OJ	Harvey Creek	**Fecal Coliform**
WA-05-1025	BH79GG	Higgins Creek	Temperature
	JU33JU	Jim Creek	**Fecal Coliform**
WA-05-1012	GH05SX	Jorgenson Slough (Church Creek)	**Fecal Coliform**
WA-05-1023	EX67XM	Little Deer Creek	Temperature
	IJ55EP	Martha Lake Creek	**Fecal Coliform**
	QE93BW	Old Stillaguamish River	**Fecal Coliform, Ammonia, Lead, Copper, Nickel**
WA-05-1018	VJ74AO	Pilchuck Creek	Temperature, **Dissolved Oxygen**
WA-PS-0020	390KRD	Port Susan	**Fecal Coliform**
WA-05-1015	OT80TY	Portage Creek	**Fecal Coliform, Dissolved Oxygen, Turbidity**
WA-05-1015	YF03BC	Portage Creek	**Fecal Coliform, Dissolved Oxygen**
WA-05-1015	QJ28UC	Portage Creek	**Fecal Coliform, Dissolved Oxygen**
WA-05-1010	QE93BW	Stillaguamish River	**Fecal Coliform**, Temperature, **Dissolved Oxygen, Arsenic**
WA-05-1010	ZO73WL	Stillaguamish River (Hat Slough)	**Fecal Coliform**, Temperature, **Dissolved Oxygen**
WA-05-1020	WO38NV	N. F. Stillaguamish River	**Fecal Coliform**
WA-05-1020	XN66YN	N. F. Stillaguamish River	Temperature
WA-05-1050	SN06ZT	S. F. Stillaguamish River	**Fecal Coliform**, Temperature, **pH**, **Dissolved Oxygen**
WA-05-9160	350KXA	Sunday Lake	Total Phosphorus, Total Nitrogen
	LU17DC	Unnamed Creek #0456	**Fecal Coliform**

Temperature and sedimentation are of concern in the upper basin especially as they affect salmon spawning areas. The upper basin is dominated by forest harvest activities. Natural slides and areas with poor timber harvest practices have contributed to sedimentation and temperature problems some of which are not adequately addressed in the 303(d) listing process because criteria are lacking. Bacteria and some temperature listings in the upper basin valleys may be related to residential and agricultural development.

Most of the water quality monitoring (and most of the 303(d) listed waters) in the Stillaguamish Basin has been conducted below or near the confluence of the North and South Forks where most of the people reside (Figure 1). The data indicate that no single point source or type of nonpoint source is responsible for water quality problems in the lower basin. Arlington WWTP is the largest municipal point source located in this area and is a source of nutrients and oxygen demand. The Indian Ridge Youth Camp also has a wastewater discharge into Jim Creek--a tributary to the South Fork Stillaguamish River. The Warm Beach Community Treatment Plant discharges to one of the small tributaries to Port Susan. Most of the dairies and commercial and non-commercial livestock farms are located below the confluence and are potential sources of fecal coliform, biochemical oxygen demand, and nutrients. Residential on-site septic systems and residential development may also contribute to these same water quality problems.

The single listings for ammonia, copper, lead, and nickel are directly related to data collected in the vicinity of the Stanwood wastewater treatment plant (WWTP) outfall located in the Old Stillaguamish River channel – not for the Stillaguamish River as posted in the 1998 Needs Assessment (Table 2). Twin City Foods also applies wastewater from its food processing plant onto land adjacent to the channel. While this same segment isn't listed for dissolved oxygen (due to an oversight during the transition to a new water segment identification system), data collected during the Stanwood WWTP study support the listing (Glenn, 1996). EAP has made a request to the Water Quality Program to provide the Old Stillaguamish Channel with a unique water body identification number to avoid future confusion.

Good water quality is essential in the Stillaguamish River basin to support a wide variety of beneficial uses. The Stillaguamish River is affected by the Puget Sound salmon Endangered Species Act listings. In March 1999, the Puget Sound chinook stocks were designated as threatened under the federal Endangered Species Act. In June 1998, the US Fish and Wildlife Service proposed the federal listing of the Puget Sound bull trout as threatened. Between 1956 and 1965, the Stillaguamish is estimated to have contributed about 21 percent of the anadromous fish production in Puget Sound (Washington Conservation Commission, 2000). There are few large public access sites to the river and its tributaries for recreation, but the upper forks and lower river have several heavily used formal riverside facilities and informal recreational access areas. Drinking water supplies for Arlington and Marysville are shallow wells in the alluvium near or under the Stillaguamish River Channel. Port Susan has a health population of soft-shelled clams near the mouth of the Stillaguamish River. The shellfish beds have not been commercially harvested because past water quality data from the Washington Department of Health showed bacteria levels were too high.

Monitoring Activities

Portions of the Stillaguamish River basin are rich in data--especially data collected over the past ten years. As shown in Figure 1, EAP has monitored nine different sites in the basin. These sites have been monitored at monthly intervals but during various times over the past 30 years (Table 3). Portage Creek (the Old Stillaguamish Channel at Stanwood) and the Stillaguamish River below the Arlington WWTP outfall have also been the subject of EAP studies in the past (Plotnikoff and Michaud, 1991; Glenn, 1996; Kendra, 1987). Areas in the forested upper basin have been part of a few EAP-conducted Timber, Fish, and Wildlife (TFW) studies (Sullivan, Tooley, Doughty, Caldwell, and Knudsen, 1990; Rashin, Bell, and Clishe, 1992, 1994; Rashin, Clishe, and Loch, 1994). Lakes in the basin have been visited as part of the EAP lake monitoring program (Rector and Hallock, 1992, 1995; Rector, 1994, 1996; Smith and Rector, 1997). The Tulalip Tribe, Stillaguamish Tribe, and Snohomish County Surface Water Management (SCSWM) have been monitoring extensively since 1989 (Table 4).

Table 3. Ecology ambient water quality monitoring sites in the Stillaguamish Basin.

I.D.	Station Name	Monitoring Years Since 1970
05A050	Stillaguamish River at Stanwood	1971
05A055	Hat Slough near Stanwood	1977
05A070	Stillaguamish River near Silvana	1970-1; 1974; 1977 - present
05A090	S. F. Stillaguamish River at Arlington	1971; 1974; 1978-90; 1993; 1995 - present
05A110	S. F. Stillaguamish near Granite Falls	1974; 1993; 1995 - present
05B070	N. F. Stillaguamish River at Cicero	1970-1; 1974; 1978 - present
05B090	N. F. Stillaguamish River at Oso	1974
05B110	N. F. Stillaguamish near Darrington	1974; 1993; 1995 - present
SUZ001	Port Susan at Kayak Point	1973-75; 1977-88; 1995; 1998

The three Ecology stations in the basin with the longest monitoring records have been the Stillaguamish River near Silvana (05A070), S. F. Stillaguamish River at Arlington (05A090), and N. F. Stillaguamish River at Cicero (05B070). The Silvana station is located 11 miles upstream of the river's mouth (at Interstate 5) and does not include water from the Pilchuck Creek and Portage Creek sub-basins, but it is downstream of Arlington.

The Tulalip Tribes undertook initial sampling in the basin with a volunteer monitoring team in 1989. Their sampling continued until 1994. The network of 24 freshwater and marine stations they established formed a base on which the Stillaguamish Tribe and SCSWM built. The data from both tribes and the county have been helpful for directing nonpoint source control activities in the basin.

The Stillaguamish Tribe has monitored 150 sites in the basin over the past five years. They currently collect data at approximately 45 freshwater sites--half of which are upstream on the two forks. In addition, they also monitor several sites in the Port Susan estuary, and they have begun to sample the Old Stillaguamish Channel at several locations in cooperation with the Stillaguamish Flood Control District (Klopfer, 2000). Common data collected by the Tribe are temperature, conductivity, salinity, D.O., fecal coliform, hardness, alkalinity, turbidity, and total suspended solids. Some sites have continuously recording thermographic units.

SCSWM monitors eight sites monthly in the basin (Table 4). All are below the confluence of the forks and were formerly Tulalip Tribes' sites. SCSWM also has conducted a special water quality monitoring study on Glade Bekken--formerly known as Tributary 30. The county collects monthly data on temperature, pH, conductivity, turbidity, total suspended solids, fecal coliform, nitrate-nitrite, total phosphorus, copper, lead, and zinc (Thornburgh, 2000).

There appears to be a lack of discharge monitoring in the basin at the current time. The Stillaguamish Tribe and SCSWM do not measure stream discharges although SCSWM does record the depth to the water's surface from a fixed mark at some sites. SCSWM had seven gaging sites but only the tide gages in Hat Slough and the Old Stillaguamish Channel are in operation (Collins, 2000). USGS has an operational gage on the North Fork at RM 6.5 (12167000) and a stage-only recording gage on the South Fork near Granite Falls above Canyon Creek at RM 34.9 (1216100). Seasonal and historical gaging have been performed by USGS at several sites. USGS maintains a rating curve for the wire weight gage at the Stillaguamish River at Interstate 5 under an Ecology contract. The South Fork Stillaguamish River at Arlington is no longer measured.

Table 4. Key Tulalip Tribes (TT), Stillaguamish Tribe (ST), and Snohomish County Surface Water Management (SCSWM) ambient water quality monitoring sites in the Stillaguamish Basin. * Multiple sites established on these water bodies by the Stillaguamish Tribe.

I.D.	Station Name	Years and Monitoring Group
MSAR	Stillaguamish River at Hwy 9 Arlington	1991-94 (TT); 1994 – present (SCSWM)
MSMD	Hat (sic) Slough Marine Drive	1989-94 (TT); 1994 – present (SCSWM) (ST)
CCPK	Church Cr. at Church Cr. Park	1992-94 (TT); 1994 – present (SCSWM)
TR30	Glade Bekken (Trib. No. 30)	1991-94 (TT); 1994 – present (SCSWM)
PILC	Pilchuck Cr. near mouth	1991-94 (TT); 1994 – present (SCSWM) (ST)
PORL	Portage Cr. at 212th St. NE	1991-94 (TT); 1994 – present (SCSWM) (ST)
PORU	Portage Cr. at 43rd Ave. NE	1990-94 (TT); 1994 – present (SCSWM)
FISH	Fish Creek near mouth	1991-94 (TT); 1994 – present (SCSWM)
Multiple*	Harvey Creek	1994 – present (ST)
Multiple*	Portage Creek	1994 – present (ST)
Multiple*	Deer Creek	1994 – present (ST)
19	Prairie Creek at 69th and 204th	1994 – present (ST)
Multiple*	Old Stillaguamish Channel	1996 – present (ST)
Multiple*	Lower Stillaguamish River	1996 – present (ST)
Multiple*	Port Susan	1998 – present (ST)
Multiple*	S. Fork Stillaguamish River	1994 – present (ST)
Multiple*	N. Fork Stillaguamish River	1994 – present (ST)
Multiple*	Jim Creek	1994 – present (ST)
Multiple*	Canyon Creek	1994 – present (ST)
Multiple*	Church Creek	1999 – present (ST)

Monitoring funds have come from a variety of sources. Ecology grants supplied funds to initiate the Tulalip Tribes and county monitoring programs. Much of the county's monitoring work is now funded through the Clean Water District. The Stillaguamish Tribe gets funding from the US Environmental Protection Agency.

Historical and 2000 Data Assessment

Historical monitoring data and results from initial TMDL sampling from July to October 2000 provide a description of water quality problems in the Stillaguamish Basin. Ecology ambient monitoring data and some Stillaguamish Tribe and SCSWM monitoring data were analyzed to determine seasonal characteristics, criteria violation frequency, and long-term trends. The software package WQHYDRO (Aroner, 1995) was used for this preliminary look at the historical water quality data. The graphs generated from these analyses are located in the Appendix. These data analyses focused the monitoring conducted in 2000 under the initial QAPP (Joy, 2000b).

Fecal Coliform and Enterococcus

Fecal coliform counts have declined significantly since 1977 in the mainstem Stillaguamish River. Some of the improvement in bacterial densities seen in the mid-1980s is characteristic of that seen in other basins from the Federal dairy buy-out program (Joy, 2000a). The Ecology station below Arlington (05A070) shows a significant improving step-trend for data collected from 1989 to 1993 compared to 1994 to 1999 data. This may be a strong indication that many of the implementation tasks of the Stillaguamish Watershed Plan have been successful. Fecal coliform data collected during the past five years suggest that both parts of the state water quality criteria are now met (geometric mean of 12 cfu/100 mL and a 90th percentile count of 78 cfu/100 mL).[1] The last two counts over 200 cfu/100 mL occurred in June 1997 and April 1999. The 1989 to 1993 period had a geometric mean density of 55 cfu/100 ml and a 90th percentile of 244 cfu/100 mL.

Data collected by Snohomish County Surface Water Management (SCSWM) and the Stillaguamish Tribe and evaluated by EAP has confirmed the improving bacterial condition in the lower river. Data collected since 1995 at Hat Slough from Marine Drive (MSMD) indicate that state freshwater quality criteria for fecal coliform are met with a geometric mean of 33 cfu/100 mL and a 90th percentile of 189 cfu/100 mL. Summary statistics for data collected from Hat Slough from 1998 through 2000 show the geometric mean value near 14 MPN/100 mL, and the 90th percentile value decreasing from 100 MPN/100 ml to 60 MPN/100 mL.

The Stillaguamish Tribe has been sampling fecal coliform bacteria at several sites in northern Port Susan since summer 1998 (Klopfer, 2000). Most sites have shown slight improvements in the 30-sample running geometric mean and 90th percentile statistics or have stayed steady. However, most marine water sites off the mouth of Hat Slough have not yet met the National Shellfish Sanitation Standards of 14 MPN/100 mL geometric mean with not more than 10 percent exceeding 43 MPN/100 mL (Table 5). The sites south (Warm Beach Point and Kayak

[1] cfu/100 mL is colony forming unit per 100 milliliters

Point) and the sites to the northwest (North Port Susan and Peripheral Site 4) appear to be within criteria (Table 5). The site near Warm Beach Slough has experienced the worst bacterial water quality of the sites monitored. The Hat Slough site is located close to Snohomish County's site on the Stillaguamish River. Note that the geometric mean and 90th percentile statistics in Table 5 at Hat Slough are well within the Class A freshwater criteria but do not meet the Class A marine standards (Appendix 1). The challenge is to find out why the fecal coliform densities are not decreasing as they are transported into Port Susan.

Samples collected from Glade Bekken, Fish Creek, and Church Creek by SCSWM and the Stillaguamish Tribe have shown some improvements over the past five years. Based on the geometric mean and 90th percentile statistics, there has been about a 40% reduction in fecal coliform in all three tributaries. However, none is yet meeting Class A criteria. Since no discharge measurements are available, it is difficult to assess any difference in hydrological conditions over the period of record and what part loading plays in the apparent improvements.

Table 5. Statistical summary of fecal coliform data collected in Port Susan from July 1998 to November 2000 by the Stillaguamish Tribe. The 30-sample geometric mean and 90th percentile are calculated on the last 30 samples collected at the site. The Washington Department of Health uses the method to evaluate water quality in commercial shellfish harvesting areas. Bold values are over the criteria of a 14 MPN/100 mL geometric mean with not more than 10 percent exceeding 43 MPN/100 mL.

	Number of Sample Collected	11/2/00 30-sample geometric mean	11/2/00 30-sample 90th percentile	Maximum Value	Minimum Value
		MPN/100 mL	MPN/100 mL	MPN/100 mL	MPN/100 mL
120 Hat Slough	47	**16**	**67**	110	1.5
121 West Branch	46	**19**	**67**	80	2.0
122 South Branch	46	**20**	**112**	130	1.5
123 South Branch Pilings	47	14	**51**	80	1.5
124 Warm Beach Point	47	7	38	130	1.5
125 Kayak Point	31	4	21	80	1.5
126 North Port Susan	39	3	12	80	1.5
127 Warm Beach Slough	46	**39**	**191**	500	1.5
128 Peripheral Site 2	37	**22**	**139**	500	1.5
129 Peripheral Site 3	43	14	**64**	140	1.5
130 Peripheral Site 4	43	5	26	70	1.5

An improving fecal coliform trend is present in the South Fork data collected near Arlington (05A090) but no step trend is apparent in 1990s. Improvements may have coincided with the Federal Dairy Buyout Program in the mid-1980s. Fecal coliform data collected during the past five years suggest that both parts of the state water quality criteria are being met (geometric mean of 15 cfu/100 mL and a 90th percentile count of 84 cfu/100 mL). Fecal coliform counts are in compliance with Class AA standards at Granite Falls (05A110). Jim Creek fecal coliform densities have also been in compliance with Class A standards through 1999 (Klopfer, 2000).

The fecal coliform listing on the North Fork is based on SCSWM, Tulalip Tribes, and Stillaguamish Tribe data. Ecology data does not indicate a problem serious enough to warrant 303(d) listing. A 1995 step trend is evident that shows water quality improvement at Cicero, but the data are not lognormally distributed so that the defining population statistics (geometric mean and 90th percentile densities) have a low level of confidence. Ecology data at both Cicero (05B070) and near Darrington (05B110) meet their respective Class A or Class AA criteria. However, an August 1999 sample collected at Cicero had 2800 cfu/100 mL with elevated ammonia that could have been a manure spill, livestock in the river, or other source just upstream of the station.

Fecal coliform data collected by SCSWM and the Stillaguamish Tribe from Portage Creek show some signs of improving bacterial quality, but the creek is far from meeting Class A criteria. At the lower station (PORL), the winter season trend shows a decline in fecal coliform densities, but the summer densities are either poor or have been getting worse. At the upper station (PORU), the densities have been dropping over the past two years, but a significant trend is not yet apparent.

No historical enterococcus data were found for sites in the Stillaguamish basin. Ecology is proposing a switch from fecal coliform to enterococcus as a freshwater bacterial quality indicator to comply with US Environmental Protection Agency standards (Ecology, 2000a). Enterococcus is considered a better indicator to evaluate recreational uses. Shellfish harvest areas would still be required to meet the existing fecal coliform criteria. The proposed enterococcus marine and freshwater criteria state that the geometric mean shall not exceed 35 cfu/100 mL and that not more 10% of the samples exceed 61 cfu/100 mL.

Seven informal recreational bathing beaches were monitored weekly for bacterial quality in August 2000 under the initial QAPP. A statistical summary of the results is shown in Table 6.

Table 6. Statistical summary of bacteria indicator samples collected weekly from informal recreational beach sites in the Stillaguamish River basin August 7 to September 5, 2000, n=5.

Informal Recreational Beach Sites	Fecal Coliform (cfu/100 mL)		Enterococcus (cfu/100 mL)	
	Geometric Mean	90th percentile	Geometric Mean	90th percentile
S. F. Stillaguamish at Jordan	34	63	20	42
S. F. Stillaguamish at Twin Rivers	34	112	18	**85**
N.F. Stillaguamish at Twin Rivers	19	49	8	20
N.F. Stillaguamish at Whitman Br.	3	11	6	22
Stillaguamish River at Marine Dr.	27	74	9	27
Pilchuck Creek at Jackson Gulch	86	**285**	10	31
Church Creek at Stanwood Park	**101**	**197**	**89**	**368**
Current and Proposed Criteria	100	200	35	61

Bold values exceed current fecal coliform or proposed enterococcus criteria.

Church Creek at Stanwood Park did not meet fecal coliform and enterococcus criteria. The August 21st sample collected from the South Fork of the Stillaguamish River at Twin Rivers Park had elevated densities of fecal coliform and enterococcus that sent the 90th percentile value above the enterococcus criterion for that site. The Pilchuck Creek site fecal coliform densities did not meet the 90th percentile criterion but enterococcus densities met criteria. The other four sites met all the bacteriological criteria.

Additional monitoring in 2000 of fecal coliform and enterococcus indicators had mixed results for compliance with criteria. Some areas will need further investigation. Samples from treatment plant effluent and some tributaries with very high densities of fecal coliform often had excessive enterococcus as well. Enterococcus densities were more often elevated above criteria than fecal coliform in the mainstem Stillaguamish River. The opposite was more often the case in the Old Stillaguamish Channel.

Dissolved Oxygen

Most of the dissolved oxygen (D.O.) sample results reported in the Stillaguamish River basin have been from instantaneous daytime collections. Few diel monitoring surveys have been conducted; therefore, the range of D.O. concentrations over 24-hours is not well known. Of these daytime samples, enough have been below the Class A criterion of 8 mg/L to have resulted in 303(d) listings in parts of the basin (Table 2).

Dissolved oxygen concentrations on the mainstem at Interstate 5 (05A050) are lowest in July and August when temperatures are highest. The closest to a violation of the 8 mg/L D.O. criterion occurred in August 1981; however, no trend is evident in the data. Sampling time changes over the years limit the usefulness of this data for trend analysis. Dissolved oxygen saturation maxima are in August and minima in February and July. Summer supersaturated conditions suggest upstream benthic or macrophyte productivity and the possibility of nutrient enrichment problems.

Consultants considered nutrient enrichment and periphyton the primary cause of low diel D.O. concentrations during a survey conducted below the Arlington WWTP (Earth Tech, 1997). D.O. concentrations at RM 13.5 dropped to 7.3 mg/L in the early morning, and rose to 11 mg/L in the late afternoon over a 24-hour period in August 1997. The consultants modeled the effluent biochemical oxygen demand (BOD) from the Arlington WWTP and found it had little effect on instream D.O. concentrations. Diel concentrations above the WWTP outfall or below RM 13.5 were not recorded; therefore, the extent of the D.O. problem was not known. Diel data collected in September 2000 at the confluence and at two sites in the mainstem below Arlington had D.O. concentrations in compliance with the Class A criterion.

Dissolved oxygen criteria violations at river miles 2.0 and 4.0, reported by the Tulalip Tribes in 1989 to 1991, are not evident in more recent data collected by the Stillaguamish Tribe and SCSWM. Marine Drive (MSMD) D.O. concentrations have demonstrated a significant increasing trend since 1994. Summer low D.O.s were 7.8 mg/L and are now above 9.0 mg/L. No significant change in sample collection time took place.

Historical and recent data indicate a chronic D.O. problem in the Old Stillaguamish Channel. As mentioned earlier, diel monitoring was conducted near the Stanwood WWTP outfall in the Old Stillaguamish Channel in 1992 (Glenn, 1996). In September 1992, the recording probe monitored continuously for three days. Salinities were always greater than 1 part per thousand; therefore, marine criteria applied. D.O. concentrations dropped below the 6 mg/L marine criterion during low tide all three days. In July and August 2000, the Stillaguamish Tribe conducted 24-hour sampling between Peterson Bridge on the Norman Road and the Old Florence Dock--a distance of 3 miles (Klopfer, 2000). On both occasions, dissolved oxygen fell below 5 mg/L at Peterson Bridge and shot above 15 mg/L at Florence dock. Several small drains and tributaries to the Old Channel show evidence of elevated biochemical oxygen demand loading which require further investigations. Irvine Slough, Miller Creek, and Douglas Slough also had low D.O. concentrations.

Tributaries to the lower mainstem have shown some D.O. improvements according to Stillaguamish Tribe and SCSWM data. Pilchuck Creek and Fish Creek D.O. concentrations have not been below 8 mg/L since 1995. Church Creek D.O. data at the SCSWM site (CCPK) are similarly within the criterion and have shown a significant improving trend but the Stillaguamish Tribe's data collected in 1999 from Church Creek at Marine Drive (#142) have values below 8 mg/L. Portage Creek D.O. concentrations remain a water quality problem at some sites monitored by both groups. Dissolved oxygen grab samples collected in 2000 confirmed that Portage Creek and Church Creek continue to have D.O. problems.

Dissolved oxygen concentrations at the Ecology station in the South Fork (05A090) have only dropped below the criterion of 8 mg/L once in the past 20 years of monitoring. The 303(d) D.O. listing is based on 1994 Snohomish County data collected at the Mountain Highway (SFGF) which is co-located with the Ecology station. No newer data are available from the county. Dissolved oxygen problems were not observed in the grab samples collected in 2000 from the sites on the forks.

pH

The single listing for pH is located in the South Fork Stillaguamish for data collected by Ecology in 1987 and 1990. No pH violations have been observed at Ecology's South Fork Stillaguamish station (05A090) since 1990. A significant improving step trend is evident for data collected after 1992 compared to data collected before 1992. The data may reflect a sampling protocol change, or an actual improvement in water quality.

No other Ecology stations have detected pH problems, but some data collected by local groups have occasionally found criteria violations. The SCSWM data collected from the mainstem at Marine Drive (MSMD) and at Arlington (MSAR) have several values less than 6.5. These do not appear to be consistently associated with any other water quality condition although most have been recorded during the wet season (October through April). The SWM data collected at Pilchuck Creek (PLC), Fish Creek (FISH), and lower Portage Creek (PORL) have all had low pH values over the past couple of years. Only two smaller tributaries, Kackman Creek (#46) and Prairie Creek (#19), monitored by the Stillaguamish Tribe have had more than one pH value greater than 8.5.

Monitoring conducted in 2000 did not uncover mainstem or tributary pH problems. South Fork pH values sometimes were near the 6.5 criterion and will be further investigated. Old Stillaguamish Channel monitoring documented pH values greater than 8.5 that will require further investigation.

Metals

The Stillaguamish River basin has four metals on the 303(d) list in two areas of the mainstem. Three of these metals (copper, lead, and nickel) are listed for data collected at Stanwood within the Old Stillaguamish River Channel (Glenn, 1996). The fourth, arsenic, is listed for human health criteria for samples collected on the mainstem Stillaguamish River by Ecology.
Glenn (1995) determined that lead, copper, and nickel concentrations in the Stanwood WWTP effluent had reasonable potential to exceed water quality criteria in the Old Stillaguamish Channel when the effluent is continuously discharged. The concentrations of copper and nickel in the receiving water exceeded marine water criteria. Samples collected twice in 1999 from Thomle and Peterson bridges indicate copper concentrations exceed marine criteria (Glenn, unpublished data).

Arsenic samples from the Stillaguamish River at Silvana (05A070) were collected six times from May 1994 to March 1995. No arsenic was detected at the 30 ug/L limit of the analysis. The National Toxics Rule criteria for arsenic are two to three orders of magnitude lower in concentration than the analytical detection limit at that time (e.g., 0.018 ug/L for consumption of fish and water and 0.14 ug/L for consumption of fish only). The maximum contaminant level for drinking water supplies is 50 ug/L. The reason for the 303(d) listing is not known at this time, but it may be that the data qualifier was not recorded in the STORET database or in the 303(d) screening program. Therefore, the listing may be an error.

The SCSWM has collected total recoverable copper, lead, and zinc from all 10 of its sites since 1994. Using default dissolved to total metal ratios, some copper and lead concentrations may exceed chronic and acute toxicity criteria for aquatic life. Since accompanying hardness analyses were dropped in 1995, more recent data are difficult to evaluate.

Mercury is not a 303(d) listed metal for the Stillaguamish Basin. However, a report by the Puget Sound Water Quality Action Team (1998) presented mercury data collected by Ecology that showed two violations of the chronic freshwater aquatic criterion in 1995. This has caused some concern with the local community. Closer examination of the data (Ecology, 2000b) reveal that both values were qualified concentrations: the January result came from a data set with a spike sample recovery out of control limits, and the December result was an estimated concentration. Unfortunately, more recent samples have not been collected to determine if mercury contamination is a problem in the basin.

Detectable metals concentrations in most samples collected in 2000 were below chronic and acute toxicity criteria for aquatic life. Dissolved copper concentrations in the Old Stillaguamish Channel exceeded the chronic aquatic toxicity criteria for marine life at two sites in October. Mercury and arsenic concentrations in some samples exceeded human health criteria. Further investigation of these samples and the sites will continue.

Nutrients

Nutrients affect the health of the aquatic system directly and indirectly. Ammonia can be a toxicant at high concentrations or when pH and temperature conditions are elevated. Organic nitrogen and ammonia can also exert an oxygen demand as the aquatic community converts them to nitrite and nitrate. Nitrogen and phosphorus are essential for a healthy community, but they can overstimulate aquatic growth and cause D.O. and pH problems in the water column.

Stillaguamish River monitoring by Ecology indicates there have been some changes in nutrient concentrations over the past 25 years. Ecology data collected at Silvana (05A070) indicate a significant downward trend in ammonia concentrations occurred between 1977 and 1994. A step trend in the Silvana data coincides with the FC improvements mentioned earlier. On the other hand, no trend is apparent with nitrate-nitrite results, and increasing trend may be present with total phosphorus and suspended sediment. The South Fork at Arlington (05A090) ammonia concentrations have dropped significantly since 1977 as well. The Earth Tech (1997) report suggested that nutrients in the mainstem Stillaguamish River may be causing increased periphyton growth that result in D.O. criteria violations.

Ammonia from the Stanwood WWTP had a reasonable potential to create or exacerbate toxic conditions outside the mixing zone in the Old Stillaguamish Channel (Glenn, 1996). Samples were collected while marine water conditions were present in the vicinity of the outfall. Old Channel ammonia concentrations exceeded chronic or acute criteria to protect aquatic life. Toxic conditions for marine aquatic life were also present in October 1999 based on samples collected by Ecology at Marine Drive (Thomle) Bridge (Appendix). Freshwater conditions at Peterson Bridge at the same time did not result in toxic conditions.

According to SCSWM data collected in the basin, few changes have occurred. At lower Portage Creek (PORL), nitrate-nitrite and total phosphorus concentrations appear to be increasing. No change in nutrients is evident in samples collected at Church Creek (CCPK). Tributary #30, Glade Bekken, has experienced decreasing total phosphorus concentrations but no change in nitrate-nitrite concentrations.

Results from samples collected in 2000 have not been evaluated. Chlorophyll a concentrations in the Old Stillaguamish Channel were very elevated as were nutrient concentrations delivered from several tributaries and ditches. Tributaries in the lower basin to the mainstem Stillaguamish River also had somewhat elevated concentrations of phosphorus and nitrogen.

Project Description

The primary purpose of the TMDL evaluation is to determine if 303(d) listed segments of the Stillaguamish River, its tributaries, and Port Susan are in compliance with water quality standards so that all applicable beneficial uses are available. Through the TMDL study, historical and current water quality data are evaluated and the decision for de-listing or TMDL target setting is made. The TMDL targets are set when the loading capacities of water bodies are determined and contaminant limits are recommended for point and nonpoint sources. An implementation strategy is designed around these recommendations to reduce contamination from the sources and to meet the TMDL limits within a set schedule. Public participation is a key feature throughout the entire TMDL process.

Based on the historical data review and meetings with interested citizens, the following TMDL and water quality issues have been raised:

- Fecal coliform densities in the lower mainstem Stillaguamish, South Fork Stillaguamish, and North Fork Stillaguamish may have improved, and may meet water quality criteria. Improvements have not resulted in reopening shellfish harvesting areas in Port Susan.
- Dissolved oxygen (D.O.) concentrations in the lower mainstem have improved, but nutrient enrichment problems may cause diel minimum D.O. to drop below the state criterion.
- Pilchuck Creek D.O. concentrations have improved and may meet the water quality criterion.
- The 303(d) listing for arsenic may have been a database error.
- The Old Stillaguamish Channel has several water quality problems during the low flow season that require better understanding and definition.
- Water quality in Portage Creek and other tributaries has improved; however, it fails fecal coliform and D.O. criteria and has elevated nutrient concentrations.
- Samples collected for metals analyses have given inconsistent results so that the effect of metals on the aquatic system is uncertain.

The following goals are recommended for the Stillaguamish River TMDL evaluation:

- Verify that the improved fecal coliform bacteria densities, D.O. concentrations, and pH values in the lower mainstem, North Fork, and South Fork Stillaguamish meet Class A freshwater criteria and can be taken from the 303(d) list.
- Check that 303(d) listed waters for fecal coliform that can now be de-listed can also meet the proposed enterococcus criteria. Set fecal coliform TMDL targets for those water bodies that do not meet criteria.
- Determine the sources of bacterial contamination to Port Susan and propose reductions in the form of TMDL load and wasteload allocations of those sources so shellfish harvesting areas can reopen.

- Verify improvements in mainstem Stillaguamish River D.O. concentrations, or calculate the seasonal loading capacity for limiting nutrient(s) and oxygen-demanding substances in the lower mainstem Stillaguamish River to meet the D.O. criterion. Set seasonal load allocations and wasteload allocations for sources.
- Calculate the loading capacity for ammonia, oxygen demand, and fecal coliform bacteria in the Old Stillaguamish Channel for the late-summer and fall seasons. Set load allocations and wasteload allocations for sources. Also, provide a water quality database for comparison after the Stillaguamish Flood District and Corps of Engineers' tide gate project is complete.
- Calculate the loading capacity for D.O., fecal coliform, and turbidity in Portage Creek. Set load allocations for various tributaries and reaches using a land-based water quality model.
- Determine the presence or absence of arsenic, mercury, and dissolved copper, lead, and nickel in the South Fork, North Fork, and mainstem Stillaguamish River and compare detectable concentrations to criteria.
- Determine the range of dissolved copper, lead, and nickel in the Old Stillaguamish Channel without and with the presence of Stanwood WWTP effluent.

Additional monitoring data and the evaluation of historical data will be used to meet the objectives for the TMDL project. As described in the *Historical and 2000 Data Assessment,* the primary data of interest are for the 303(d) listed parameters of indicator bacteria, dissolved oxygen, pH, and various metals. The data collected to date indicate the water quality problems are not limited to one season or source type, but that some problems are low-flow related and some are run-off related. Additional monitoring data are necessary to better describe both the spatial and temporal extent of the problems as well as describing the current population statistics compared to state water quality criteria. The TMDL evaluation report will contain recommendations for de-listing parameters or setting TMDL targets based on comparisons of data to the criteria in Table 7. Additional water bodies or parameters may be added to the 303(d) list in the Stillaguamish River basin as a result of the data collection and analysis.

The combined historical and recent data will not be totally adequate to determine if some criteria in Table 7 are met. For example, multiple ammonia and metal sample collections over a short period of time (averages over 4-days or within 1-hour) are impractical for the project budget but are necessary for criteria evaluation. Ecology has policies and guidance in place to evaluate these situations. Ecology Water Quality Program Policy 1-11 (Ecology, 1997) guidance on data interpretation will be followed to determine if water bodies or contaminants can be de-listed (Appendix 2). Statistical characteristics such as geometric means and 90^{th} percentiles will be calculated for annual and seasonal periods when data are available. Individual data from sites within the study area that meet all quality control requirements and show a clear violation of criteria, such as falling below a minimum allowable value or exceeding a maximum value, will result in a TMDL target calculation. Ambient and effluent ammonia and metals results from individual sites will be evaluated by comparing the criteria to statistical characteristics using conservative procedures and assumptions outlined in the Ecology Permit Writer's Manual (Ecology, 2000) and Ecology Water Quality Program Policy 1-11 (Ecology, 1997) for toxic contaminants (Appendix 2).

Enterococcus and dissolved oxygen data will be compared to the criteria proposed for the revised water quality standards. However, the listing or de-listing decisions and TMDL targets will not be based on those criteria unless the new standards are approved by December 2001. To meet some of the proposed D.O. criteria, all tributaries and mainstem reaches will be assumed to be capable of salmon rearing and migration. Fisheries technical reports will be used to define areas of salmon spawning where more stringent criteria are proposed.

Marine and freshwater determinations, especially in the Old Stillaguamish Channel, will be made using salinity and specific conductance data collected while sampling and using historical data from previous Ecology and Stillaguamish Tribe data.

Table 7. Water quality criteria that will be used to determine if Stillaguamish River basin waters and Port Susan are supporting beneficial uses.

Parameter	Criteria Category	Statistic	Criterion	Ancillary Data Required
Dissolved Oxygen	Class A Freshwater	Minimum	8.0 mg/L	
	Class AA Freshwater	Minimum	9.5 mg/L	
	Class A Marine	Minimum	6.0 mg/L	95% vertically avg. daily max. salinity > 1ppt
Dissolved Oxygen*	Freshwater	Daily average	10.5 mg/L	September 15 to May 31 in salmon, steelhead, and non-resident cutthroat spawning areas
		Minimum	9.0 mg/L	September 15 to May 31 in salmon, steelhead, and non-resident cutthroat spawning areas
		Minimum	8.0 mg/L	June 1st to September 14th in salmon, steelhead, and non-resident cutthroat spawning areas
		Minimum	8.0 mg/L	Salmon, steelhead, and non-resident cutthroat migration and rearing areas
	Marine	Minimum	7.0 mg/L	Extraordinary quality salmonid and other fish migration, rearing, and spawning
		Minimum	6.0 mg/L	Excellent quality salmonid and other fish migration, rearing, and spawning
		Minimum	5.0 mg/L	Good quality salmonid and other fish migration, rearing, and spawning
		Minimum	4.0 mg/L	Fair quality salmonid and other fish migration, rearing, and spawning
Fecal coliform	Class A Freshwater	Geometric Mean	100 cfu/100 mL	
		90th percentile value**	200 cfu/100 mL	
	Class AA Freshwater	Geometric Mean	50 cfu/100 mL	
		90th percentile value*	100 cfu/100 mL	
	Class A Marine	Geometric Mean	14 cfu/100 mL	Vertically averaged salinity equal or greater than 10 ppt
		90th percentile value*	43 cfu/100 mL	
	FDA Shellfish harvesting	Geometric Mean	14 MPN/100 mL	
		90th percentile value*	43 MPN/100 mL	
Enterococcus*	Freshwater	Geometric Mean	33 cfu/100 mL	
		90th percentile value*	61 cfu/100 mL	
	Marine	Geometric Mean	35 cfu/100 mL	
		90th percentile value*	104 cfu/100 mL	
pH	Freshwater	Maximum	8.5	
		Minimum	6.5	
	Marine	Maximum	7.0	
		Minimum	8.5	
Ammonia* **	Freshwater	4-day average/3 years	1.35 mg/L as N	Example: 20 deg. C; pH = 7
		1-hr average/3years	17.9 mg/L as N	Example: 20 deg. C; pH = 7
	Marine	4-day average/3 years	0.035 mg/L	95% vertically avg. daily max. salinity > 1ppt
		1-hr average/3years	0.233 mg/L	95% vertically avg. daily max. salinity > 1ppt

Dissolved Arsenic	Freshwater Aquatic Toxicity	4-day average/3 years	190 ug/L	
		1-hr average/3years	360 ug/L	
	Marine Aquatic Toxicity	4-day average/3 years	36 ug/L	21 ug/L to prevent non-lethal effects to diatoms
		1-hr average/3years	69 ug/L	95% vertically avg. daily max. salinity > 1ppt
	Human Health (carcinogenic)	Maximum	0.018 ug/L	Consumption of water and organisms
	Human Health (carcinogenic)	Maximum	0.14 ug/L	Consumption of organisms only
Dissolved Copper	Freshwater Aquatic Toxicity	4-day average/3 years	2.2 ug/L	At a hardness of 15 mg/L as CaCO3
		1-hr average/3years	2.8 ug/L	At a hardness of 15 mg/L as CaCO3
	Marine Aquatic Toxicity	4-day average/3 years	3.1 ug/L	95% vertically avg. daily max. salinity > 1ppt
		1-hr average/3years	4.8 ug/L	95% vertically avg. daily max. salinity > 1ppt
Dissolved Lead	Freshwater Aquatic Toxicity	4-day average/3 years	7.7 ug/L	At a hardness of 15 mg/L as CaCO3
		1-hr average/3years	0.3 ug/L	At a hardness of 15 mg/L as CaCO3
	Marine Aquatic Toxicity	4-day average/3 years	8.1 ug/L	95% vertically avg. daily max. salinity > 1ppt
		1-hr average/3years	210 ug/L	95% vertically avg. daily max. salinity > 1ppt
Mercury	Freshwater Aquatic Toxicity	4-day average/3 years	0.012 ug/L	
		1-hr average/3years	2.1 ug/L	
	Marine Aquatic Toxicity	4-day average/3 years	0.025 ug/L	95% vertically avg. daily max. salinity > 1ppt
		1-hr average/3years	1.8 ug/L	95% vertically avg. daily max. salinity > 1ppt
	Human Health	Maximum	0.14 ug/L	Consumption of water and organisms
	Human Health	Maximum	0.15 ug/L	Consumption of organisms only
Dissolved Nickel	Freshwater Aquatic Toxicity	4-day average/3 years	31.6 ug/L	
		1-hr average/3years	2.84 ug/L	
	Marine Aquatic Toxicity	4-day average/3 years	8.2 ug/L	95% vertically avg. daily max. salinity > 1ppt
		1-hr average/3years	74 ug/L	95% vertically avg. daily max. salinity > 1ppt
	Human Health	Maximum	610 ug/L	Consumption of water and organisms
	Human Health	Maximum	4600 ug/L	Consumption of organisms only

* Proposed water quality criteria, Ecology, 2001.
** Criteria wording states that not more than 10% of the samples used to calculate the geometric mean.
*** New ammonia criteria are proposed but are not presented here.

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Data Quality Objectives

The decision to de-list or set TMDL targets on a water body for a particular parameter will require data adequate to reliably estimate the temporal and spatial variability of that parameter. Sampling, laboratory analysis, and data evaluation steps have several sources of error that should be addressed by data quality objectives. Accuracy in laboratory measurements (measurement quality objectives) can be more easily controlled than field sampling variability. Analytical bias needs to be low and precision as high as possible in the laboratory. Sampling variability can be somewhat controlled by strictly following standard procedures and collecting quality control samples, but natural spatial and temporal variability can contribute greatly to the overall error in the parameter value. Resources limit the number of samples that can be taken at one site spatially or over various intervals of time. Finally, laboratory and field errors are further expanded by estimate errors in seasonal loading calculations and modeling estimates.

The Stillaguamish TMDL study poses some very significant challenges. The primary 303(d) list parameters (e.g., fecal coliform, dissolved oxygen, metals, and pH) are either quite reactive in the aquatic environment, or they are prone to sample contamination problems. Table 8 summarizes the laboratory accuracy and analytical reporting limits for parameters for reasonable decisions for the study. Stratified seasonal sampling and multiple event sampling and other sampling design features will be used to better evaluate critical conditions on which to develop TMDL targets for the parameters.

Data quality objectives are more stringent for parameters at sites with few samples over the course of the survey than for parameters with a large sample sets. Parameters with relatively large field and laboratory variability (e.g., fecal coliform, enterococcus, and chlorophyll a) will need to have increased numbers of replicate samples in the field and laboratory to increase precision. Some parameters that demonstrate strong diel changes (e.g. D.O., and pH) will need accurate and nearly continuous monitoring during critical seasonal events so rates of change, and diel minimums and/or maximums can be observed. These issues will be discussed in *Sampling Design, Field Procedures, Laboratory Procedures*, and *Quality Control* Sections.

Table 8. Summary of the accuracy, precision, and bias of laboratory analyses expressed as relative standard deviation (RSD). The required reporting limits are also listed.

Analysis	**Accuracy** % deviation from true value	**Precision** Relative Standard Deviation	**Bias** % deviation from true value	**Required Reporting Limits** Concentration units
Field Measurements				
Velocity*	0.1 f/s	0.1 f/s	N/A	0.05 f/s
pH*	0.15 s.u.	0.05 s.u.	0.10 s.u.	1 to 14 s.u.
Temperature*	0.1 °C	0.025 °C	0.05 °C	1°C to 40°C
Dissolved Oxygen	15	< 5% RSD	5	0.1 mg/L to 15 mg/L
Specific Conductivity	25	<10% RSD	5	1 umhos/cm
Laboratory Analyses				
Fecal Coliform (MF)	N/A	<25% RSD[2]	N/A	1 cfu/100 mL
Fecal coliform (MPN)	N/A	<25% RSD[2]	N/A	3 MPN/100 mL
Biochemical oxygen demand	N/A	<25% RSD	N/A	1 mg/L
Chlorophyll a	N/A	<20% RSD	N/A	0.05 ug/L
Total organic carbon	30	<10% RSD	10	1 mg/L
Enterococcus	N/A	<25% RSD[2]	N/A	1 cfu/100mL
Total Suspended Solids	20	<10% RSD	N/A	1 mg/L
Turbidity	20	<10% RSD	N/A	1 NTU
Chloride	15	< 5% RSD	5	0.1 mg/L
Total Persulfate Nitrogen	30	<10% RSD	10	25 ug/L
Ammonia Nitrogen	25	<10% RSD	5	10 ug/L
Nitrate & Nitrite Nitrogen	25	<10% RSD	5	10 ug/L
Orthophosphate P	25	<10% RSD	5	2 ug/L
Total Phosphorus	25	<10% RSD	5	2 ug/L
Arsenic	25	<10% RSD	5	0.02 ug/L
Copper	25	<10% RSD	5	3 ug/L
Nickel	25	<10% RSD	5	8 ug/L
Lead	25	<10% RSD	5	0.3 ug/L
Mercury	25	<10% RSD	5	0.012 ug/L

[2] Logtransformed data

* as units of measurement, not percentages

Sampling Design

General Approach

The TMDL evaluation study will require field data collection and a closer analysis of historical data. Ecology's field surveys will build on the monitoring data currently collected by SCSWM and the Stillaguamish Tribe since these two groups and the Tulalip Tribes have established a comprehensive database for the basin. The TMDL surveys will be conducted to answer specific issues from the 303(d) listings. The primary focus of the evaluation will be in the lower basin--especially in the Old Stillaguamish Channel, the mainstem Stillaguamish River, and Port Susan north of Kayak Point.

Field surveys will examine the following special monitoring issues: diel changes in D.O. and pH, nutrient effects on productivity, metal concentration verifications, water quality response to storm events, and monthly variability in indicator bacteria. A few synoptic surveys will be coordinated with local monitoring groups for critical condition evaluation. Port Susan bacteria monitoring will be coordinated with the Stillaguamish Tribe effort. Land use inventory and remote image mapping data will be collected in the Portage Creek area for water quality modeling.

Monitoring Schedule

The Stillaguamish Tribe and Snohomish County Surface Water Management (SCSWM) are currently monitoring the basin at regular intervals. In the initial QAPP, Ecology began monitoring in August 2000 (Joy, 2000b). Many of the tasks in Table 9 were completed but some were delayed because a rainy season failed to materialize in fall 2000. Ecology conducted weekly sampling for bacteria indicators at selected recreational sites to address 303(d) issues. Synoptic surveys in the Old Channel and below Arlington WWTP identified low-flow related issues that will be revisited in 2001. Quarterly metals sampling from October 2000 through October 2001 will provide an adequate database to verify any metal contamination problem. Higher flow synoptic surveys in spring and fall 2001 will address nonpoint issues not fully explored in the local data set.

Old Stillaguamish Channel

Intensive fieldwork will be conducted in the Old Stillaguamish Channel to calculate its loading capacity for oxygen consuming materials, ammonia, selected metals, and bacteria. The data collected will fulfill two roles. First, the Corps of Army Engineers (Corps) is planning to construct a reverse tide gate at the Hat Slough and Old Channel divergence to help with low flow circulation and dilution in the Old Channel (Cagney, 2000). The Corps' project has a high priority for construction and its completion is planned for September 2001 (Stillaguamish Flood District, 2001). The Stillaguamish Flood Control District and Stillaguamish Tribe have been monitoring water quality in the channel. A better definition of D.O. and other water quality

Table 9. Monitoring tasks planned for the Stillaguamish River TMDL project in 2000/2001 and the status of those tasks on March 2, 2001.

Monitoring Task	Status	Approximate Date
Old Stillaguamish Channel Reconnaissance Survey	Complete	August 2000
Lower Stillaguamish Diel D.O. Survey		August 2001
Lower Stillaguamish River Low-flow Period Survey	Complete	September 2000
Basin Bacteria Synoptic Low-flow Survey	Complete	September 2000
Old Stillaguamish Channel Low-flow Period Survey	Underway	October 2000; repeat July 2001
Basin Indicator Bacteria Recreational Area Survey	Complete	Weekly: August – September 2000
Lower Stillaguamish/ Old Channel Metals Monitoring	Underway	Quarterly: October - October
Run-off period Old Stillaguamish Channel Survey		Spring and Fall 2001
Run-off period lower Stillaguamish River Survey		Spring and Fall 2001
Two Basin Bacteria Synoptic Surveys		Spring and Fall 2001
Port Susan Bacteria Source Surveys	Underway	Monthly: Feb. – Nov. 2001

problems in the Old Channel through the TMDL surveys will enhance their data set. The data would be helpful to designers of the Corps' project. Second, the TMDL data will also immediately assist the Northwest Regional Office (NWRO) staff as they set NPDES permit limits for Stanwood WWTP discharge and the Twin County Foods land application site. We will also evaluate nonpoint contributions of BOD, bacteria, and nutrients along the channel and from Jorgenson Slough and Church Creek, Miller Creek, and other tributaries. We will also try to determine the concentrations of dissolved copper, lead, and nickel in the Channel.

Glenn (1995) calculated the flushing rate to be three days while the Old Stillaguamish Channel was a tidal bay. Poor flushing of contaminants from point and nonpoint sources can cause severe water quality problems in the Channel. Poor D.O., warm temperatures, elevated dissolved copper concentrations and elevated nutrient concentrations were observed in the August 2000 survey. A repeat survey is planned for August 2001. Stanwood WWTP does not usually continuously discharge in August and September and other surface sources may also be minimal. Water quality conditions shortly after seasonal rains return have not been assessed. The extent of any run-off related problems and sources will be examined in spring and fall 2001. The run-off period water quality conditions in the Channel may show a response from Stanwood, Twin City Foods, drainage and tributary points, and nonpoint sources.

As planned in the initial QAPP (Joy, 2000b), two multi-probe meters were deployed for two days in August 2000: one in the lower channel near Stanwood and the other in the upper channel above the Marine Drive Bridge (at Site OC3) as low tide depth allowed (Figure 3). The probes were anchored in place and with a float to be a fixed depth below the surface but also to avoid contact with the channel bottom. The probes monitored and recorded temperature, D.O., pH, and conductivity at 15-minute intervals. The probe at Site OC3 was stolen, so data were lost at that site. The incomplete data record requires us to repeat the survey in July or August 2001.

Old Stillaguamish Channel Sites

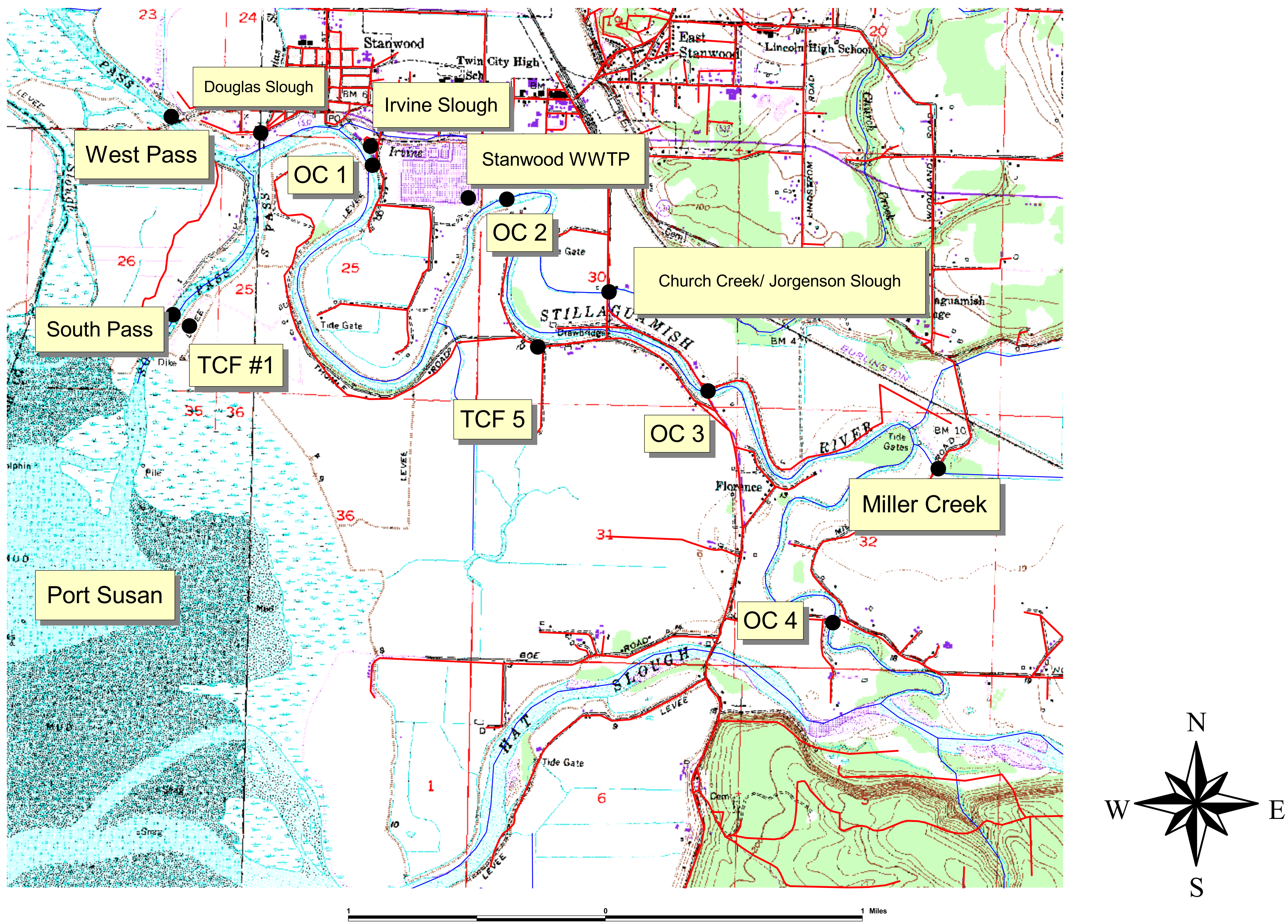

Figure 3

While the meters are deployed, grab samples will be collected during falling and rising tides from the following points: Church Creek, Miller Creek, incoming marine water, incoming Stillaguamish main channel water, Douglas Slough, Irvine Slough, and Twin City Foods drainage points (Figure 3). We may coordinate this sampling with Stillaguamish Tribe/ Stillaguamish Flood District monitoring on one of the sampling days. Samples will be taken from the channel at the meter sites and at approximately two-mile intervals (Figure 3). Salinity and temperature profiles will also be taken at these points to evaluate stratification. Fecal coliform and enterococcus indicator bacteria will be analyzed in surface samples. Sampling sites and the analyses performed on grab samples are listed in Table 10.

Table 10. Old Stillaguamish Channel monitoring sites and parameters. Site name referenced to Figure 3.

Site Name	Parameters						
	Hydrolab*	FC/Entero	BOD	Nutrients	Metals[3]	Field**	Flow
West Pass		X		X		X	
South Pass		X		X		X	
Douglas Slough		X[1]	X[1]	X[1]	X[1]	X[1]	X[1]
Irvine Slough		X[1]	X[1]	X[1]	X[1]	X[1]	X[1]
OC 1	X	X	X	X	X[2]		
TCF 1		X[1]	X[1]	X[1]		X[1]	X[1]
TCF 2		X[1]	X[1]	X[1]		X[1]	X[1]
TCF 3		X[1]	X[1]	X[1]		X[1]	X[1]
Stanwood WWTP		X[1]	X[1]	X[1]	X[1]	X[1]	X[1]
OC 2		X		X		X	
Jorgenson/Church		X	X	X	X[2]	X	X
TCF 5		X[1]	X[1]	X[1]	X[1]	X[1]	X[1]
OC 3	X	X		X		X	
Miller Creek		X	X	X		X	X
OC 4		X	X	X	X		X

* Hydrolab® Datasonde probe includes: dissolved oxygen, pH, temperature, and conductivity.
** Field parameters: Winkler method D.O.; pH, temperature, and conductivity by meter.
[1] Collected and analyzed if flowing.
[2] Monthly metals monitoring site.
[3] Hardness and TSS collected with metals.

Metals samples will be collected at two sites at quarterly intervals between October 2000 and October 2001 in conjunction with SCSWM sample collection on Church Creek. (Note that the SCSWM Church Creek site, CCPK, is upstream of the Jorgenson Slough site.) Stanwood WWTP effluent will be monitored for metals in spring, summer and fall 2001. Quality assurance samples will be collected and split with all cooperating groups to compare inter-laboratory variability.

Stillaguamish River and Major Forks

Several tasks are required to meet the project objectives outlined for the Stillaguamish River, South Fork, and North Fork reaches. Fecal coliform, dissolved oxygen, pH, and metals listings require varying degrees of additional investigation and data collection. Some of the tasks were completed under the initial QAPP (Joy, 2000b) as indicated in Table 9. The field data collection sites will be less densely placed in these areas than on the Old Stillaguamish Channel.
The statistical rollback method (Ott, 1995) has proven to be a useful tool for assessing indicator bacteria compliance with state criteria (Cusimano and Giglio, 1995; Cusimano and Coots, 1997; Joy, 2000a). The tool is most useful when the population distribution of bacteria from long-term and peak event monitoring can be evaluated together. The historical data evaluation appears to be strong enough to use as a basis for removal of fecal coliform listing for the following mainstem, North Fork, and South Fork reaches: WO38NV, SN06ZT, QE93BW, and ZO73WL. Synoptic sampling and storm event monitoring in the lower Stillaguamish River basin will provide the additional data to complete the bacteria population distribution analysis and to verify that Class A criteria are being met.

We plan to continue to collect fecal coliform and enterococcus bacteria samples from sites distributed through the Stillaguamish basin. The indicators are used to determine recreational use compliance. Two warm weather bacterial monitoring tasks for the Stillaguamish Basin were completed in 2000 but bacterial run-off evaluations are still needed (Table 9). We have monitored sites along the North Fork from the mouth to river mile (RM) 21 near Rowan and along the South Fork from the mouth to Granite Falls (RM 35) during a fair-weather synoptic survey in the summer of 2000. Weekly monitoring of seven informal swimming or public recreation areas was conducted over a 30-day period. Results from recreational beach survey were presented in Table 6. Run-off bacterial quality will be monitored during synoptic surveys in the spring and fall of 2001 (Figure 4). Tributary and point sources along the lower mainstem will be sampled as well (Table 11). We will attempt to co-sample with SCSWM and the Stillaguamish Tribe on at least one occasion at two sites. Although 1999 and 2000 data from the Stillaguamish Tribe (Klopfer, 2000) show that it is now in compliance, Jim Creek has been added to the sites to be sampled because it is on the 303(d) list for violations of criteria at Jordan Road.

Dissolved oxygen and pH undergo natural diel changes in response to physical and chemical influences on the aquatic community. Although the monthly monitoring record shows an improvement in D.O. concentrations, the Earth Tech (1997) survey below the Arlington WWTP showed that low D.O. concentrations are often missed unless continuous monitoring is undertaken. They found D.O. concentrations below 8 mg/L at RM 13.5 in the early morning of their August and early September surveys. The survey data suggested respiration by periphyton in the river may cause the low D.O. concentrations not the BOD and nitrogenous BOD input from the Arlington WWTP. Excessive nutrient loading from point and nonpoint sources may be stimulating periphyton growth beyond the river’s capacity.

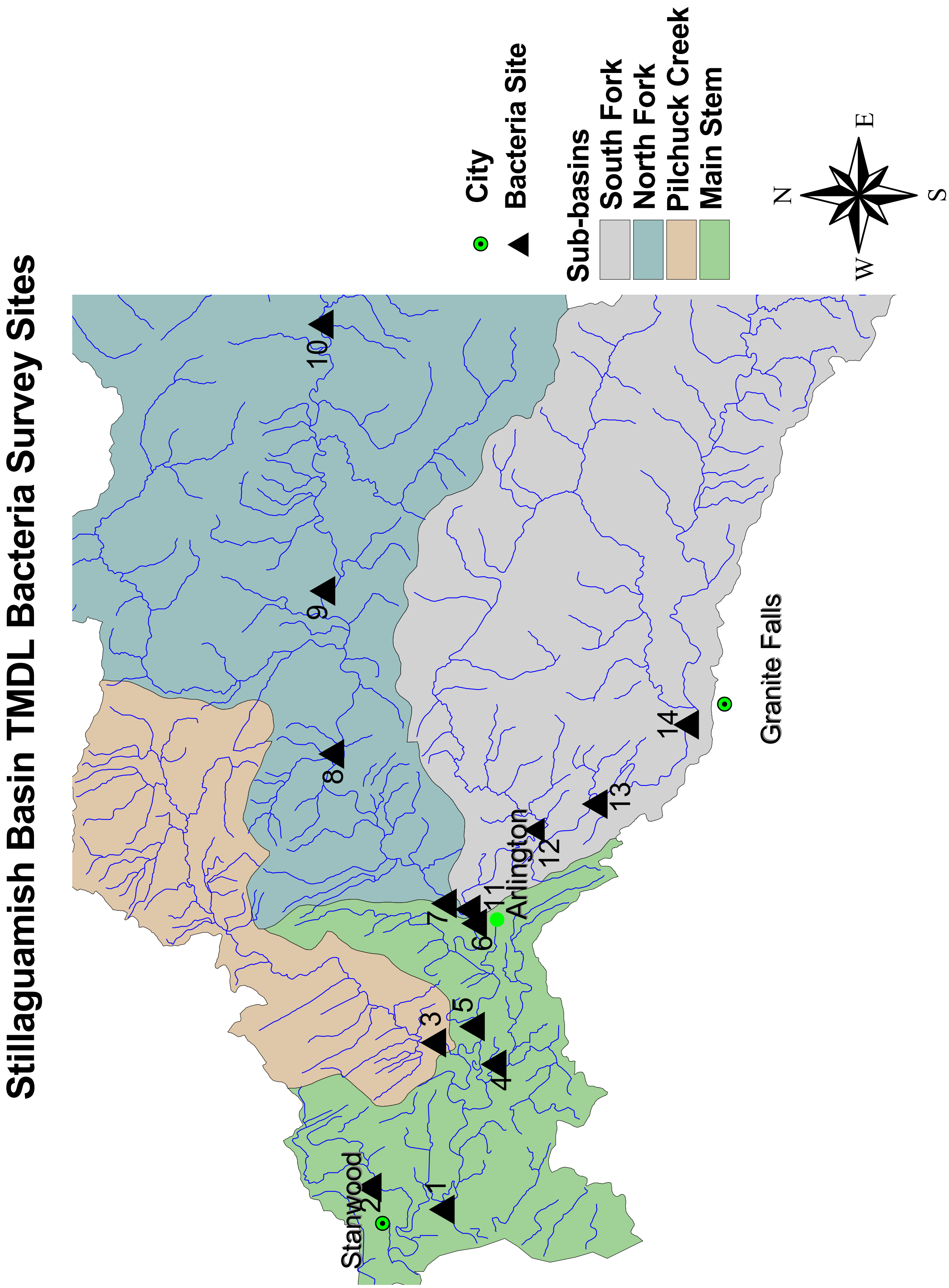
Stillaguamish Basin TMDL Bacteria Survey Sites
City
Bacteria Site
Sub-basins
South Fork
North Fork
Pilchuck Creek
Main Stem
N
E
S
W
Stanwood
Arlington
Granite Falls
1
2
3
4
5
6
7
8
9
10
11
12
13
14

Figure 4

Table 11. Bacteria indicator sampling sites for TMDL evaluation. The recreational beach survey and a low-flow synoptic survey were completed September, 2000.

#	Site	RM	Sample Frequency
1	Mainstem Stillaguamish at Marine Drive	1.9	Synoptic and recreational
2	Church Creek at Park	CC 3.4	Recreational survey
3	Pilchuck Creek at Jackson Gulch Road	PC 0.1	Synoptic and recreational
4	Portage Creek at 212th Street Bridge	PC 1.1	Synoptic
5	Mainstem at I-5	11.1	Synoptic
6	Arlington WWTP	17.7	Synoptic
7	North Fork at Twin Rivers Park	NF 0.1	Synoptic and recreational
8	North Fork at Cicero Bridge	NF 9.6	Synoptic
9	North Fork at Whitman Bridge	NF 17.5	Synoptic and recreational
10	North Fork at C-Post Bridge	NF 21.1	Synoptic
11	South Fork at Twin Rivers Park	18	Synoptic and recreational
12	Jim Creek at Jordan Road	0.1	Synoptic
13	South Fork at Jordan Pedestrian Bridge	26.1	Synoptic and recreational
14	South Fork at Granite Falls	33.5	Synoptic

As was done in 1997 by Earth Tech, late summer conditions of low flow, elevated temperature, and high aquatic productivity will be monitored to evaluate the Stillaguamish River's compliance with state criteria and the spatial extent of any water quality problems. Low flow D.O. surveys will be conducted in July or August 2001. Two or more multi-probe meters will be deployed bracketing individual reaches between RM 6, the lower channel in Hat Slough, and RM 17, the confluence of the forks above the Arlington WWTP outfall (Figure 5). Meters will be repositioned to bracket individual reaches through the week. Probe data will allow us to use the free-water diurnal curve method to measure productivity (APHA, AWWA, and WEF, 1998). If additional monitoring equipment can be located, reaches up one of the forks will be monitored for comparison purposes. Periphyton biomass samples collected within the reaches and analyzed for chlorophyll a may provide additional insights into the relationship between nutrient availability and biomass. Tributary (e.g. Portage Creek, Pilchuck Creek, Armstrong Creek, and Glade Bekken), point source and mainstem sites between the confluence of the forks and the mouth of the river will be sampled for nutrients, biochemical oxygen demand, total organic carbon, and associated parameters (Table 12). Instantaneous flow measurements will be taken at tributary sites. These surveys will provide data for a mass balance approach to nutrients in the lower river.

Analytical results also will be used to calibrate and run a model that simulates the influence of nutrients on aquatic productivity, D.O., and pH. If water quality conditions do not meet state criteria, the model will be used to calculate a seasonal nutrient TMDL targets with associated load allocations and waste load allocations.

Main Stem Stillaguamish TMDL Monitoring Sites

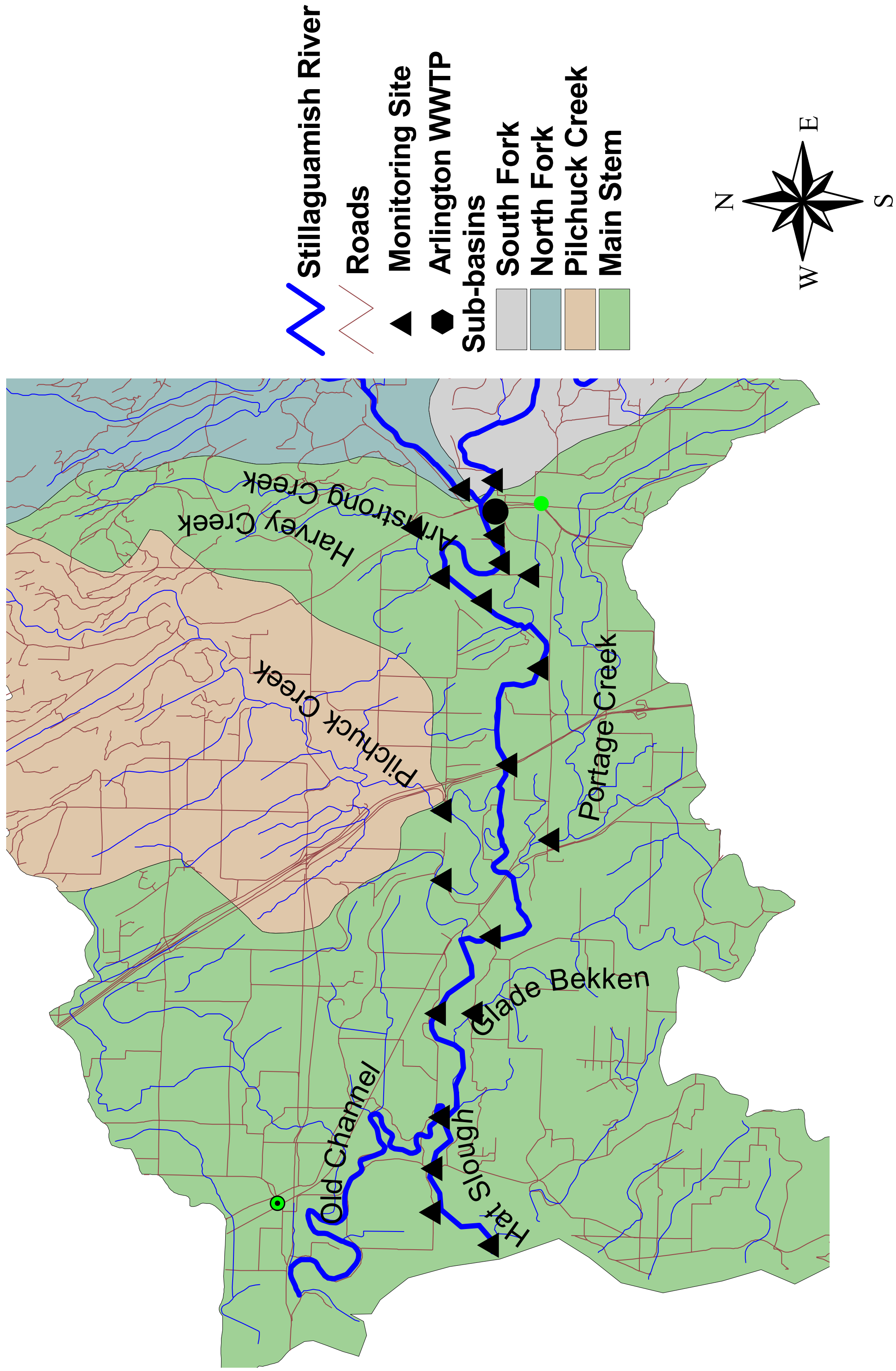

Figure 5

Table 12. Stillaguamish mainstem and major tributary sampling sites for dissolved oxygen and nutrient loading investigations.

Site Name	Parameters						
	HL*	Field**	BOD	Nutrients	Chloride	TOC	Flow
S.F. Stillaguamish		X		X	X		X
N.F. Stillaguamish		X		X	X		X
Below Confluence	X	X	X			X	
Arlington WWTP		X	X	X	X	X	X
Mainstem at Mixing Zone		X		X	X	X	
Mainstem at RM 17		X		X	X		
Harvey/Armstrong Cr.		X	X	X	X	X	X
Mainstem at RM 14.5	X	X	X	X	X	X	
March Creek		X	X	X	X	X	X
Mainstem at RM 13		X		X	X		
Mainstem at Interstate 5	X	X	X	X	X	X	X
Pilchuck Creek		X	X	X	X	X	X
Mainstem - Cook Slough		X		X	X	X	
Mainstem – North Branch		X		X	X	X	
Portage Creek		X	X	X	X	X	X
Mainstem Below Silvana	X	X	X	X	X	X	
Glade Bekken		X	X	X	X	X	X
Hat Slough at Old Channel		X		X	X	X	
Hat Slough at Marine Dr.	X	X		X		X	
TCF Site 4		X	X	X	X	X	X
Mouth below TCF 4		X		X		X	

* Hydrolab® Datasonde probe includes: dissolved oxygen, pH, temperature, and conductivity.
** Field parameters: Winkler method D.O.; pH, temperature, and conductivity by meter.

Samples for metals analyses will be collected at three sites: North Fork at Cicero (05B070), South Fork at Arlington (05A090), the mainstem Stillaguamish at Marine Drive during a low tide, and from the two sites on the Old Stillaguamish Channel. Dissolved and total recoverable arsenic, copper, lead, nickel analyses will be performed along with total mercury. Samples will be collected quarterly from October 2000 through October 2001. Arlington WWTP will be sampled in spring, summer and fall 2001.

Portage Creek and Lower Basin Tributaries

Steinbarger (1995) predicted that water quality in the main channel of the Stillaguamish River would improve as pollution controls were implemented on commercial dairies and farms. He added that in order to improve water quality in smaller creeks, pollution controls would need to be implemented on small non-commercial farms. Church Creek, Portage Creek, and Pilchuck Creek all appear to have lingering water quality problems, according to the historical data assessment. These areas have experienced increasing conversions of commercial to non-commercial farm properties (SCD Staff, 2000).

The analysis of the Portage Creek sub-basin primarily will use locally generated monitoring data. The Stillaguamish Tribe and SCSWM continue to monitor six sites in the Portage Creek sub-basin (Figure 6). Data from the six sites will be closely evaluated to set TMDL targets; for example, by using the statistical roll-back method.

Consultations with the Stillaguamish Tribe, SCSWM, the City of Arlington, the Snohomish County Conservation District, and others will be used to identify potential areas for implementation activities. All potential sources from all land uses will be considered for activities. The Portage Creek work performed by Plotnikoff and Michaud (1991) and the Puget Sound Cooperative River Basins Team (1990) will be used to construct and calibrate a land use-based model such as AnnAGNPS or BASINS. The results from the 1990 data will be compared to results from current (1999 – 2000) monitoring data and land use patterns. Model results will provide an assessment tool for testing potential outcomes of management practices that may achieve the TMDL targets. This may give implementing agencies focus on specific geographic areas or practices.

Port Susan Bacteria Evaluation

The Stillaguamish Tribe has monitored Hat Slough and several sites in Port Susan north of Kayak Point since 1998 (Klopfer, 2000). Tribal technicians have collected some additional samples from small tributaries such as Martha Lake Creek and the unnamed tributary to the south, both of which are on the 303(d) list for fecal coliform criteria violations. The monitoring data to date show that marine water bacterial quality has improved, but fecal coliform densities are still not meeting state criteria for shellfish harvesting and Class A marine waters.

As part of the TMDL, Ecology staff will monitor several additional tributaries and drains discharging to Port Susan while Stillaguamish Tribe technicians collect samples in the open water. The ten sampling sites listed in Table 13 include: the Warm Beach Christian Conference Center wastewater treatment plant and adjacent drains, Martha Lake Creek, an unnamed creek at Warm Beach, two drains from the Twin City Foods land application site, South Pass, and Juniper Beach on Camano Island (Figure 7). Although the tribal technicians sample twice a month, Ecology will conduct the concurrent tributary sampling once a month (February to November 2001) due to budget constraints. Additional bacteria data collected prior to February 2001 by the Warm Beach Conference Center may be evaluated as well.

Portage Creek Sub-basin Sites

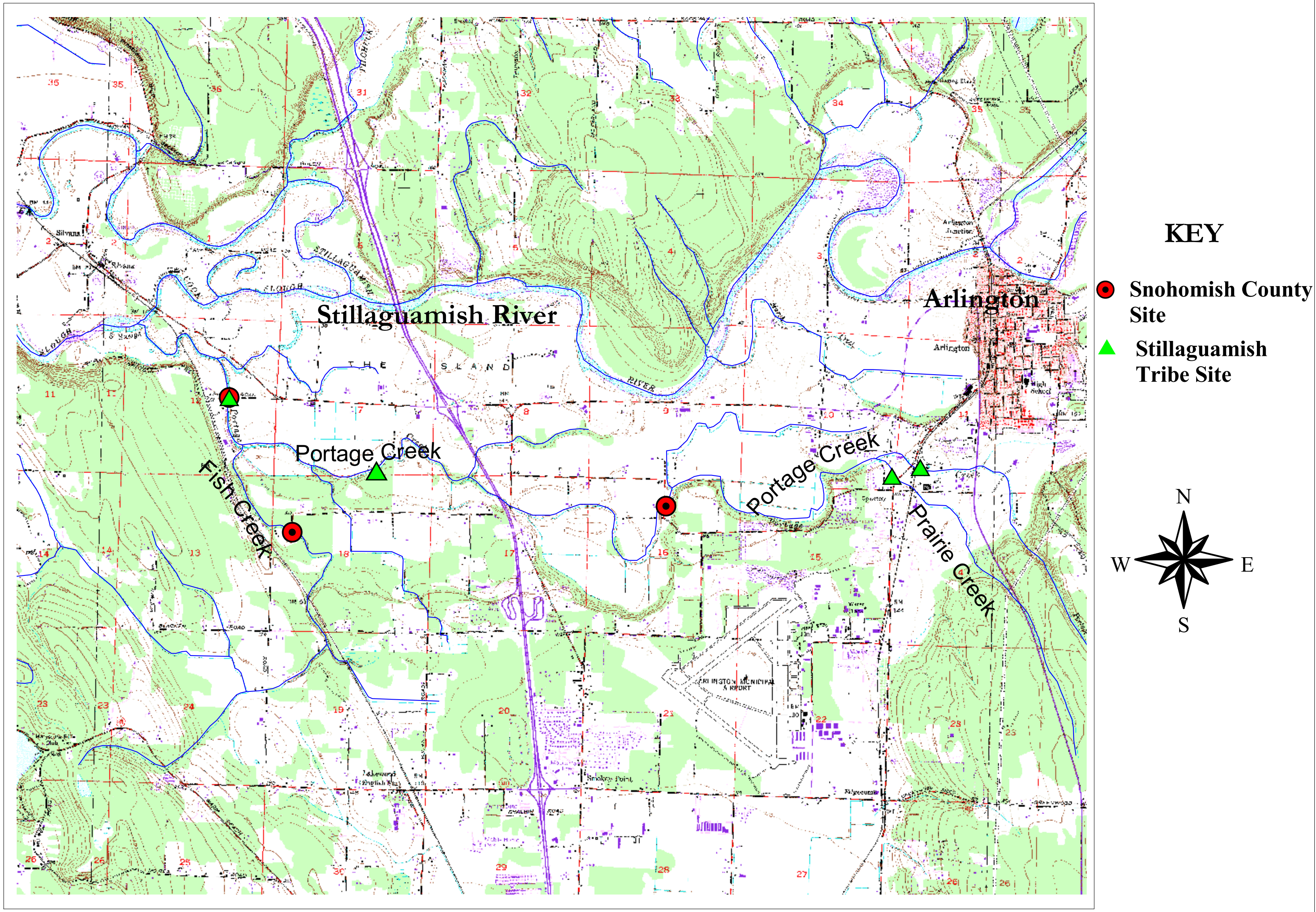

Figure 6

Port Susan Tributary Sampling Sites

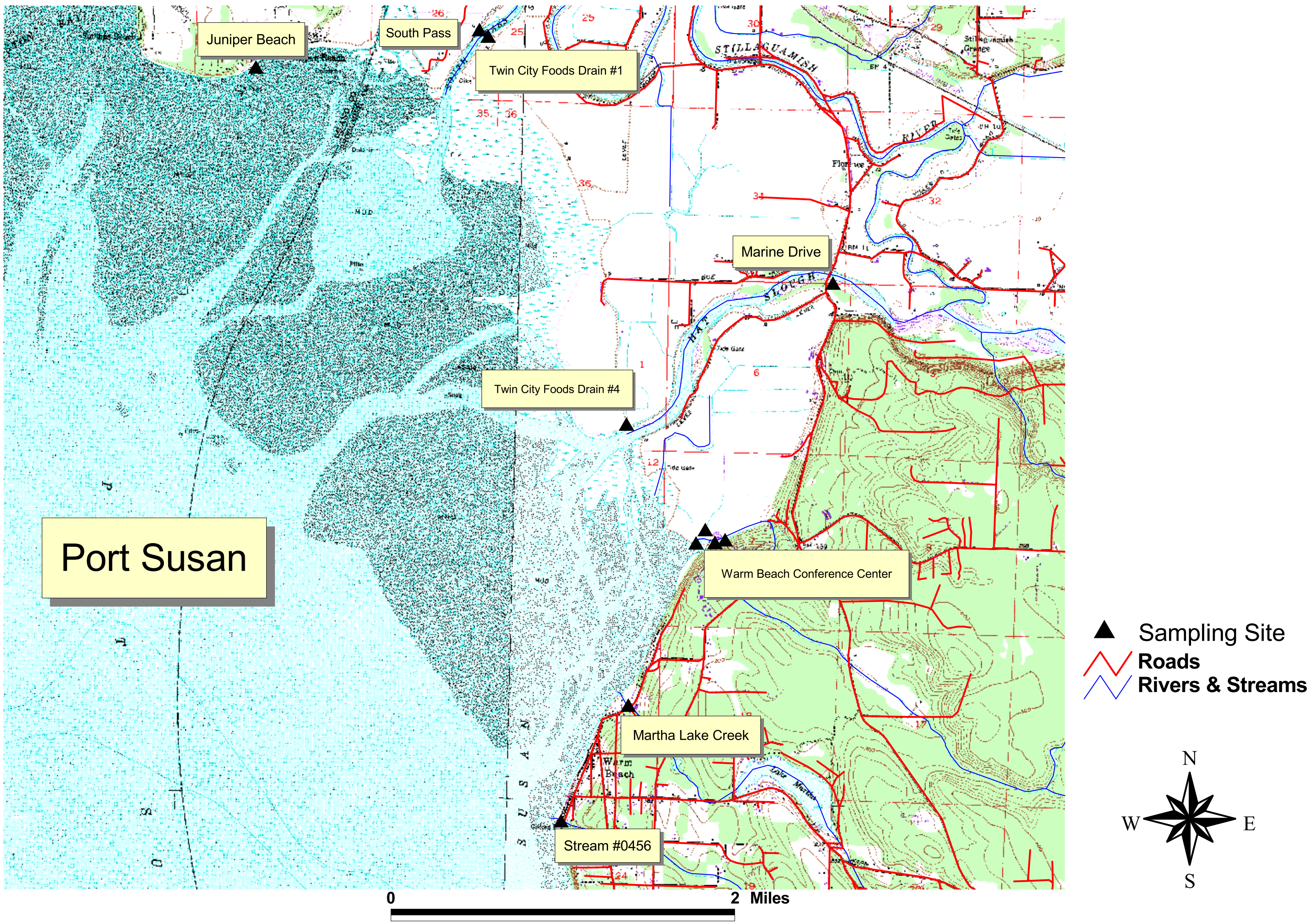

Figure 7

Table 13. Ecology sites to be sampled monthly (Feb. 2001 – Nov. 2001) while the Stillaguamish Tribe samples sites in Port Susan.

Site	ID Number	Latitude	Longitude	No. of Samples
Juniper Beach	05TJUNIP	48°13'40"N	122°24'32"W	10
South Pass	05TSOUTH	48°13'51"N	122°22'52"W	10
Twin City Foods Drain #1	05TTCF1	48°13'50"N	122°22'47"W	10
Twin City Foods Drain #4	05TTCF4	48°11'54"N	122°21'39"W	10
Hat Slough at Marine Dr.	05TMARIN	48°12'39"N	122°20'09"W	10
Warm Beach Creek	05TWARUP	48°11'20"N	122°20'55"W	10
Warm Beach WWTP&drain	05TWAREF	48°11'19"N	122°20'55"W	10
Warm Beach ag drain	05TWARTG	48°11'20"N	122°21'04"W	10
Warm Beach pump	05TWARSL	48°11'18"N	122°21'05"W	10
Martha Lake Creek	05TMARTH	48°10'29"N	122°21'36"W	10
Unnamed Creek #0456	05TUNID	48°09'53"N	122°22'05"W	10

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Methods

Flows

The USGS has gages at the South Fork Stillaguamish and the North Fork Stillaguamish River. The South Fork gage measures only stage height. Ecology maintains the wire weight gage at Interstate 5, and Snohomish County is planning to repair the gage there in 2001. The Stillaguamish Flood District has installed a tide gage at the head end of the Old Stillaguamish River Channel. Ecology Stream Hydrology Unit installed continuously recording gages at Armstrong Creek at the Stillaguamish fish hatchery. A suitable Portage Creek site is still being sought. Data will be collected from August 2000 through November 2001. Instantaneous flows will be measured at tributary sites when samples are taken by measuring velocities in sixteen or more divisions of a cross-section (WAS, 1993).

Field Procedures

Standard Ecology protocols will be used for sample collection, preservation, and shipping to the Manchester Environmental Laboratory (Manchester Environmental Laboratory, 1994). Chain-of-custody signatures will not be required during sample transport; samples are always within the possession of Ecology or Greyhound Line employees. EAP field methods will be followed for the collection of flow, dissolved oxygen, pH, temperature, and specific conductance, and for the deployment of data recording equipment (WAS, 1993). All sampling sites will have unique identification numbers. Field notes and field measurement data will be maintained in ink on water-resistant paper.

Field meter calibration will follow EAP protocols (WAS, 1993) under manufacturer's instructions. Calibration data will be recorded in the field notebooks. All water samples for laboratory analysis will be directly collected in pre-cleaned containers supplied by the Manchester Environmental Laboratory (MEL), except ortho-phosphorus and dissolved organic carbon, which will be collected in a syringe and filtered into a pre-cleaned container. The syringe will be rinsed with ambient water at each sampling site three times before filtering. Samples will be stored in the dark, on ice, and shipped to the MEL. Samples will be available at MEL for analysis within 30 hours of collection. When possible, bacteria and chlorophyll samples will be delivered for analysis within 24-hours of collection to avoid holding time violations.

Metals samples are prone to contamination and require special precaution. USEPA protocols (Method 1669) for sampling ambient water trace metals using two people will be followed for sample collection and handling (USEPA, 1995). Metals samples will be collected directly into pre-cleaned Teflon bottles. One site (OC 3) may require the use of a bottle holding device used by the Ecology ambient monitoring team to collect samples. Dissolved metals samples will be filtered in the field through a pre-cleaned 0.45 um Nalgene filter unit (#450-0045, type S). Bottles and filters will be obtained from Manchester Environmental Laboratory, cleaned as described by Kammin et al. (1995), and sealed in plastic bags until ready for use. Field staff collecting and filtering samples will wear non-talc nitrile gloves. A glove box constructed of a PVC frame and polyethylene cover will be used to protect samples during filtering when dust or rain could enter the filtering chamber. Samples will be acidified in the field to ≤ pH 2 using high-purity nitric acid. Samples will be placed in double-plastic bags and stored on ice for transport to the laboratory. Samples will then be held at least two days before being analyzed.

Laboratory Procedures

Laboratory analyses of other chemical parameters of interest listed in Table 14 will be performed in accordance with MEL protocols (2000). Nutrient analyses will include inorganic (nitrate & nitrite, ammonia) and total (persulfate) forms of nitrogen, and orthophosphate and total phosphorus. According to the Manchester Laboratory manual (2000), the required reporting limits for laboratory data in Table 8 should be attainable through the analytical methods listed in Table 14. The MEL laboratory staff will consult the project manager if any changes in procedures over the course of project are recommended, or if matrix difficulties are encountered.

Table 14. Recommended methods for field measurements and laboratory analyses (except metals) of water samples for the Stillaguamish River Basin TMDL evaluation.

Analysis	Method[1]	Estimated Range	Estimated Number of Samples
Field Measurements			
Velocity	WAS, 1993	0 – 9 ft/sec.	NA
pH	150.1/4500H	6.0 – 9.0 s.u.	> 500
Temperature	/2550B	0 – 30 ° C	> 500
Dissolved Oxygen	360.2/4500-OC	0 – 15 mg/L	> 500
Specific Conductivity	/2510	10 - >24,000 umhos/cm	> 500
Salinity	/2520B	0 – 23 ppt.	> 100
Laboratory Analyses			
Fecal Coliform (MPN)	/9221E	<3 - > 1000 MPN/100 mL	150
Fecal Coliform (MF)	/9222D	<1 - > 5000 cfu/100 mL	220
Enterococcus	/9330C	<1 - > 500 cfu/100 mL	280
Biochemical oxygen demand	405.1/5210B	<3 – 30 mg/L	80
Chlorophyll a	/10200H(3)	0.05 – 100 ug/L	100
Total organic carbon	415.1/5310B	1 – 20 mg/L	180
Dissolved organic carbon	415.1/5310B	1 – 20 mg/L	60
Total Suspended Solids	160.2/2540D	1 – 5000 mg/L	320
Turbidity	180.1/2130B	0.5 – 1000 NTU	50
Chloride	300/4110D	0.1 – 200 mg/L	250
Total Persulfate Nitrogen	Valderrama, 1981	0.025 – 20 mg/L	300
Ammonia Nitrogen	350.1/4500-NH3D	<0.01 – 20 mg/L	300
Nitrate & Nitrite Nitrogen	353.2/4500-NO3F	0.01 – 10 mg/L	300
Orthophosphate P	365.3/4500PF	<0.005 – 0.5 mg/L	300
Total Phosphorus	365.3/4500PF	0.01 – 10 mg/L	300
Hardness	130.2/2340C	1 – 200 mg/L as $CaCO_3$	60

[1] USEPA, 1983 /APHA, et al., 1998 (Standard Methods)

Sample quantities and processing procedures should not overwhelm the laboratory capacity. The project manager will follow normal procedures for notification and scheduling. If laboratory sample load capacities are in doubt, rescheduling of individual surveys may be negotiated. Storm-event surveys will require close communication with the laboratory to ensure microbiological media and other laboratory resources are available.

Primary productivity is determined using Standard Methods 10300D-4 (2), the free-water diurnal curve method. Reaeration rates applied to the curve method will be estimated from channel depth and water velocity characteristics during the period when dissolved oxygen measurements are recorded.

Periphyton biomass samples will be collected by scraping material from a measured surface area on representative rocks. Three samples will be collected at each site. The material will then be analyzed for chlorophyll a and ash-free dry weight.

The evaluation of metals samples to criteria requires low level analyses from whole and filtered samples, some of which may come from estuarine influence. Seawater can raise the detection limit of some metals by a factor 5 to 20. The ICP/MS detection limits are listed for arsenic, copper, lead, and nickel and compared to respective criteria in Table 15. Mercury analysis limits by cold vapor atomic adsorption are also compared to criteria in Table 15. The seawater influence may make some comparisons to criteria difficult for samples at or near the detection limit. Arsenic and mercury results may be especially difficult to compare to human health criteria. The most sensitive technique for arsenic detection does not get as low as the human health criteria; mercury results from cold vapor analysis of estuarine samples may also create some criteria evaluation difficulties.

Table 15. Metals analysis detection limits using ICP/MS and cold vapor AA (see text) compared to water quality criteria.

Metal	Detection Limit (ug/L)	Chronic WQ Criteria		Human Health Criteria	
		Fresh[1]	Marine	Water + Organisms	Organisms only
Arsenic	0.2	190	36	0.018	0.14
Copper	0.05 – 0.1	2.8	3.1		
Nickel	0.05 – 0.1	31.6	8.2	610	4600
Lead	0.02 –0.1	0.3	8.1		
Mercury	0.002	0.012	0.025	0.14	0.15

1 Calculated for a hardness of 15 mg/L

The ICP/MS method (EPA Method 200.8) is recommended to measure arsenic, copper, nickel, and lead. The cold vapor AA method (EPA Method 245.7) will be used to measure mercury. Most metal detection limits (Table 15) will be suitable for comparison to the water quality criteria (Table 7). The exceptions may be comparing arsenic results to human health criteria. If samples collected in the Old Stillaguamish Channel or at Marine Drive exhibit saline characteristics, then reductive co-precipitation will be required. This could raise detection limits by a factor of 5 to 20, but should not compromise data objectives (Manchester Environmental Laboratory, 1994).

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Quality Control Procedures

Quality control procedures used during field sampling and laboratory analysis will provide estimates of the accuracy of the monitoring data. The number of field and laboratory quality control procedures are indicated in Table 16. Field blanks and field replicate results will be compared to laboratory blank and replicate results to estimate some sources of sampling precision and bias. Manchester Laboratory's published quality control performance standards in general chemistry are less rigorous than those stated in Table 8. Past performance by the lab in similar TMDL studies has usually been within the accuracy requirements in Table 8.

Metals sampling technique was previously described in the *Methods* section. Systematic errors are especially prevalent in low-level metals sampling. Additional samples for field filter and transport blanks will be submitted to reduce these types of errors. Matrix blank analyses will be requested for two rounds of samples. A field replicate will be collected for one site during each sampling event. Matrix spike samples will be performed on two samples from one survey event. Standard reference materials and laboratory control samples will be analyzed with each sampling event set.

Arlington and Stanwood effluent sampling may require sample splitting and interlaboratory comparisons. At least two effluent samples from these point sources will be split if the municipalities choose qualified independent laboratories.

Table 16. Summary of field and laboratory quality control procedures for the Stillaguamish River and Port Susan TMDL project.

Analysis	Field Blanks	Field Replicates	Lab Check Standard	Lab Method Blank	Lab Replicate	Matrix Spikes
Field Measurements						
Velocity/ Discharge	N/A	1/run	N/A	N/A	N/A	N/A
pH	N/A	1/run	N/A	N/A	N/A	N/A
Temperature	N/A	1/run	N/A	N/A	N/A	N/A
Dissolved Oxygen	N/A	1/5 samples	N/A	N/A	N/A	N/A
Specific Conductivity	N/A	1/run	N/A	N/A	N/A	N/A
Laboratory Analyses						
Fecal Coliform (MF)	N/A	1/5 samples	N/A	1/run	1/run	N/A
Fecal coliform (MPN)	N/A	1/5 samples	N/A	1/run	1/run	N/A
Biochemical oxygen demand	N/A	1/run	1/run	1/run	N/A	N/A
Chlorophyll a	N/A	1/10 samples	N/A	N/A	1/10 samples	N/A
Total organic carbon	N/A	1/10 samples	1/run	1/run	1/10 samples	1/20 samples
Enterococcus	N/A	1/5 samples	N/A	1/run	1/run	N/A
Total Suspended Solids	N/A	1/10 samples		1/run	1/10 samples	N/A
Turbidity	N/A	1/10 samples	1/run	1/run	1/10 samples	N/A
Chloride	1/survey	1/10 samples	1/run	1/run	1/10 samples	1/20 samples
Total Persulfate Nitrogen	1/survey	1/10 samples	1/run	1/run	1/10 samples	1/20 samples
Ammonia Nitrogen	1/survey	1/10 samples	1/run	1/run	1/10 samples	1/20 samples
Nitrate & Nitrite Nitrogen	1/survey	1/10 samples	1/run	1/run	1/10 samples	1/20 samples
Orthophosphate P	1/survey	1/10 samples	1/run	1/run	1/10 samples	1/20 samples
Total Phosphorus	1/survey	1/10 samples	1/run	1/run	1/10 samples	1/20 samples
Arsenic	2 Filter, 2 transfer/ survey	1/run	1/run	1/run	1 set duplicate/run	1 set duplicate/run
Copper	2 Filter, 2 transfer/ survey	1/run	1/run	1/run	1 set duplicate/run	1 set duplicate/run
Nickel	2 Filter, 2 transfer/ survey	1/run	1/run	1/run	1 set duplicate/run	1 set duplicate/run
Lead	2 Filter, 2 transfer/ survey	1/run	1/run	1/run	1 set duplicate/run	1 set duplicate/run
Mercury	2 Filter, 2 transfer/ survey	1/run	1/run	1/run	1 set duplicate/run	1 set duplicate/run

Data Assessment Procedures and Reporting

Laboratory data reduction, review, and reporting will follow procedures outlined in MEL's Users Manual (MEL 1994). All water quality data will be entered into Ecology's Environmental Information Management (EIM) system. Data will be verified and 100% of the data entry will be reviewed for errors.

Elevated fecal coliform densities (> 200 cfu/100 mL) will be reported to the NWRO in accordance with the official notification procedure. All other data will be made available to the NWRO for disbursement after quality control and EIM are completed.

Data analysis will include evaluation of data distribution characteristics and, if necessary, appropriate distribution transformations. Estimation of univariate statistical parameters and graphical presentation of the data (box plots, time series, regressions) will be made using EXCEL or WQHYDRO (Aroner, 1994) computer software.

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Appendix 1
Water Quality Standards

Table 1. Class AA (extraordinary) and Class A (excellent) fresh water quality standards and characteristic uses.

	Class AA	**Class A**
General Characteristic:	Shall markedly and uniformly exceed the requirements for all, or substantially all uses.	Shall meet or exceed the requirements for all, or substantially all uses.
Characteristic Uses:	Shall include, but not be limited to, the following: domestic industrial, and agricultural water supply; stock watering; salmonid and other fish migration, rearing, spawning, and harvesting; wildlife habitat; primary contact recreation, sport fishing, boating, and aesthetic enjoyment; and commerce and navigation.	Same as AA.
Water Quality Criteria:		
Fecal Coliform:	Shall not exceed a geometric mean value of 50 organisms/100 mL, with not more than 10% of samples exceeding 100 organisms/100 mL.	Shall not exceed a geometric mean value of 100 organisms/100 mL, with not more than 10% of samples exceeding 200 organisms/100 mL.
Dissolved Oxygen:	Shall exceed 9.5 mg/L.	Shall exceed 8.0 mg/L.
Total Dissolved Gas:	Shall not exceed 110% saturation.	Same as AA.
Temperature:	Shall not exceed 16.0°C due to human activities. When conditions exceed 16.0°C, no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3°C. Increases from non-point sources shall not exceed 2.8°C.	Shall not exceed 18.0°C due to human activities. When conditions exceed 18.0°C, no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3°C . Increases from non-point sources shall not exceed 2.8°C.
pH:	Shall be within the range of 6.5 to 8.5 with a man-caused variation with a range of less than 0.2 units	Shall be within the range of 6.5 to 8.5 with a man-caused variation with a range of less than 0.5 units.
Turbidity:	Shall not exceed 5 NTU over background turbidity when the background turbidity is 50 NTU or less, or have more than a 10% increase in turbidity when the background is more than 50 NTU.	Same as AA.
Toxic, Radioactive, or Deleterious Material:	Shall be below concentrations which have the potential singularly or cumulatively to adversely affect characteristic uses, cause acute or chronic conditions to the most sensitive aquatic biota, or adversely affect public health.	Same as AA.
Aesthetic Values:	Shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste.	Same as AA.

Table 2. Class A marine water quality standards and characteristic uses.

	Class A
General Characteristic:	Shall meet or exceed the requirements for all, or substantially all uses.
Characteristic Uses:	Shall include, but not be limited to, the following: domestic industrial, and agricultural water supply; stock watering; salmonid and other fish and shellfish migration, rearing, spawning, and harvesting; wildlife habitat; primary contact recreation, sport fishing, boating, and aesthetic enjoyment; and commerce and navigation.
Water Quality Criteria:	
Fecal Coliform:	Shall not exceed a geometric mean value of 14 colonies/100 mL, with not more than 10% of samples exceeding 43 colonies/100 mL.
Dissolved Oxygen:	Shall exceed 6.0 mg/L. When natural conditions, such as upwelling, occur, causing the dissolved oxygen to be depressed near or below 6.0 mg/L, natural dissolved oxygen levels may be degraded by up to 0.2 mg/L by human caused activities.
Total Dissolved Gas:	Shall not exceed 110% saturation.
Temperature:	Shall not exceed 16.0°C due to human activities. When conditions exceed 16.0°C, no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3°C. Increases from non-point sources shall not exceed 2.8°C.
pH:	Shall be within the range of 7.0 to 8.5 with a man-caused variation with a range of less than 0.2 units
Turbidity:	Shall not exceed 5 NTU over background turbidity when the background turbidity is 50 NTU or less, or have more than a 10% increase in turbidity when the background is more than 50 NTU.
Toxic, Radioactive, or Deleterious Material:	Shall be below concentrations which have the potential singularly or cumulatively to adversely affect characteristic uses, cause acute or chronic conditions to the most sensitive aquatic biota, or adversely affect public health.
Aesthetic Values:	Shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste.

Appendix 2

Criteria for Information Used in 303(d) Listing and De-listing

Guidelines applicable to the Stillaguamish River and Port Susan TMDL evaluation as summarized from Department of Ecology Water Quality Program Policy 1-11, June 1997 revision.

Data received must meet one of the following criteria:

- For water measurements of temperature, dissolved oxygen, pH, turbidity and total dissolved gas in 10% or more of the measurements and a minimum of at least two measurements are beyond the numeric state surface water quality criteria within the most recent five-year period that data has been collected.
- For water samples of toxic pollutants, a minimum of at least two samples exceed the numeric state water quality criteria or the national toxic rule criteria (40 CFR Part 131) and must be sampled: within the same waterbody segment and within the most recent three-year period that data has been collected.

Data will be interpreted according to the following policies:

- Measurements of instantaneous concentrations are assumed to represent the averaging periods specified in the state surface water quality standards for acute and chronic criteria.
- Sample data that are below detection limits will not be used with criteria that are also below such detection limits.
- Nondetected analytes will not be used as a basis for listing.
- Sample data collected below the quantitation limit, but above the detection limit, will be used with criteria that are below the detection limit.
- Sample data collected between the quantitation limit and the detection limit will not be used with criteria that are also between the quantitation limit and the detection limit unless replicate samples confirm the result.
- Sample data of fecal coliform from freshwater will require a minimum of 5 samples collected within a 30-day period to calculate the geometric mean. Sample data of fecal coliform from marine waters will require a minimum of 30 from a systematic random sampling survey or 15 samples from a storm event sampling survey to calculate the geometric mean. If sample sizes are less than that specified, data from two single samples can be used with the criterion for 10% of samples used in calculating the geometric mean (e.g. 100 cfu/100mL for Class A freshwaters or 43 cfu/100mL for Class A marine waters) to list a water segment.
- Data collected over ten years old will not be used for listing unless specific information is identified and/or rationale can be posed that shows these older data likely represent current conditions.

Waterbody segments can be excluded from the proposed list for any one of the following:

- New information showing that water quality standards are being met. This may include more recent or more accurate data; more sophisticated analysis using a calibrated model; identification of flaws in the original assessment; or changes in standards, guidance, or policy. New data showing standards are now being met should at a minimum be collected at about the same time of year or during the most critical period for the parameter and at the same frequency as the monitoring that was used as a basis to list the water.