Quality Assurance Project Plan

Snoqualmie River Total Maximum Daily Load Effectiveness Evaluation

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Waterbody No. WA-07-1060, WA-07-1100, and tributaries

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Approved by:	March 2, 2004
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Approved by:	March 2, 2004
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Abstract

The Washington State Department of Ecology is required under Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (EPA) regulations, to develop and implement Total Maximum Daily Loads (TMDLs) for impaired waters, and to evaluate the effectiveness of the water clean-up plan in achieving the needed improvement in water quality.

The Snoqualmie River and several tributaries are on the 1998 303(d) list of impaired water-bodies due to violations of one or more water quality criteria. The mainstem and several tributaries have parameters that exceed the water quality criteria for fecal coliform bacteria, pH, dissolved oxygen (DO), and temperature. The EPA requires states to develop and implement clean-up programs through the development of TMDLs for listed parameters and to periodically monitor progress toward compliance with TMDL targets. The TMDL is a tool for achieving improvement in water quality conditions and to eventually meet standards under the CWA for streams and lakes. In 1996, EPA Region 10 approved a Snoqualmie River and tributaries TMDL for fecal coliform bacteria, ammonia, and biochemical oxygen demand (BOD).

This Quality Assurance (QA) Project Plan describes the technical study that will monitor levels of the above mentioned and other potential pollutants in the mainstem Snoqualmie River and selected tributaries. The study will be conducted by Ecology's Environmental Assessment Program with financial assistance from the King County Department of Natural Resources and Parks.

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Project Overview

The Department of Ecology (Ecology) is evaluating the effectiveness of the Snoqualmie River Total Maximum Daily Load (TMDL), which was completed in 1994. This report summarizes the findings of the TMDL study, significant changes in permitted discharges from National Pollutant Discharge Elimination System (NPDES) permitted facilities, corrective actions taken to reduce the input of bacterial pollutants and substances that can result in dissolved oxygen (DO) depletion, and outlines Ecology's TMDL effectiveness-monitoring design in the lower Snoqualmie River basin.

The study is being funded with assistance from the King County Department of Natural Resources and Parks. Field work is scheduled to take two years to complete. Field work and data analysis will be performed primarily by Ecology staff as indicated below.

Project Organization and Schedule

The roles and responsibilities of staff involved in this project are provided below in Table 1:

Table 1. Project staff and responsibilities

Name/Address	Title	Responsibilities
David Batts Environmental Assessment Program Freshwater Monitoring Unit (360) 407-6447	Project Manager/ Principal Investigator	Responsible for overall project supervision and for final draft of Quality Assurance Project Plan (QAPP), project design, collecting and analyzing data, developing graphs and figures, and writing and editing draft and final reports.
George Onwumere Environmental Assessment Program Freshwater Monitoring Unit (360) 407-6730	Co-Principal Investigator	Responsible for initial QAPP draft, QAPP review, data collection and analysis, consultation, and reviewing draft project report.
Ralph Svrjcek Northwest Regional Office Water Quality (425) 649-7059	Co-Project Manager	Responsible for QAPP review, data collection and analysis, overall project monitoring and consultation, land-management information, and reviewing draft project report.
Cynthia Callahan Northwest Regional Office Water Quality (425) 649-7059	Co-Principal Investigator	Responsible for the equipment deployment and maintenance, field monitoring, data retrieval, evaluating and reporting data, collection and review of historical data, and reviewing draft project report.
Robert W. Plotnikoff Environmental Assessment Program Freshwater Monitoring Unit (360) 407-6687	Freshwater Monitoring Unit Supervisor	Responsible for internal review of the project QAPP and draft data summary reports as well as approving the QAPP and project budget.

Name/Address	Title	Responsibilities
Ken Dzinbal Environmental Assessment Program Environ. Monit. & Trends Section (360) 407-6687	Section Manager	Responsible for approving the project QAPP, and project reports.
Stuart Magoon Manchester Environmental Lab. (360) 871-8801	Director, Manchester Environmental Laboratory	Responsible for approving the project QAPP.
Will White/Karin Feddersen Manchester Environmental Lab. (360) 871-8860	Manchester Environmental Laboratory Staff	Responsible for sample delivery and analysis/reporting of chemical data.
Cliff Kirchmer Environmental Assessment Program (360) 407-6455	Ecology Quality Assurance Officer	Responsible for reviewing and approving the project QAPP.
Dave Garland Northwest Regional Office Water Quality (425) 649-7031	Unit Supervisor	Responsible for internal review of the project QAPP and draft data summary reports as well as approving the final QAPP.
Kevin Fitzpatrick Northwest Regional Office Water Quality (425) 649-7033	Section Manager	Responsible for internal review of the project QAPP and approval of the final QAPP.
Fran Solomon, Ph.D. King County Department of Natural Resources and Parks Water and Land Resources Division (206) 296-1924	Senior Ecologist	Responsible for reviewing draft QAPP as well as approving the final QAPP, assist with data collection and overall project monitoring and consultation, editing draft project report.

The proposed schedule for the TMDL project is as follows:

Table 2. Proposed schedule

Submit initial QAPP for internal review	June 2003
Submit initial QAPP for external review	July 2003
Submit revised QAPP for internal review	July 2003
Revised QAPP approval	August 2003
Reconnaissance survey sampling	August 2003
TMDL Effectiveness sampling	August 2003 to April 2005
Data compilation, verification, and validation	July 2005
Data review and analysis	November 2005
Draft final report	February 2006
EIM[1] entry complete	July 2006
Final report	July 2006

[1] Ecology's Environmental Information Management data base

Cost Estimate

The budget for the cost of monitoring and salaries is outlined in Table 3. This table outlines the sources and amounts of funding. Work paid for out of this budget will be performed by Ecology.

The total cost of the project is $306,600 with King County providing $150,000 and Ecology providing a combination of cash and in-kind contributions totaling $156,600.

Table 3. Budget summary

		Funding Source	
Expenditure Type	**Season**	**King County**	**Ecology**
Year 1			
Salaries		$47,000	$65,800
Laboratory Costs	Dry Wet	$25,000 $2,500	$2,500 $10,000
Transportation and Equipment		$500	--
Year 1 Subtotal		**$75,000**	**$78,300**
Year 2			
Salaries		$47,000	$65,800
Laboratory Costs	Dry Wet	$25,000 $2,500	$2,500 $10,000
Transportation and Equipment		$500	--
Year 2 Subtotal		**$75,000**	**$78,300**
Project Total Cost		**$150,000**	**$156,600**

Background and Problem Statement

The Washington State Department of Ecology (Ecology) is required, under Section 303(d) of the federal Clean Water Act (CWA) and U.S. Environmental Protection Agency's (EPA) implementing regulations, to: 1) periodically assemble the list of water-bodies that are out of compliance with the state water quality standards, 2) develop and implement Total Maximum Daily Loads (TMDLs) for these watersheds, and 3) evaluate the effectiveness of the clean-up plans and activities in achieving the needed improvements in water quality. The Snoqualmie River and several tributaries are on the 1998 303(d) list of impaired water-bodies due to violations of one or more water quality criteria.

The Environmental Assessment Program (EA Program) has been tasked with designing and conducting TMDL effectiveness 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 effectiveness evaluation project design and quality assurance project plan is described.

Overview

The Snoqualmie is a river system with good water quality and multiple aquatic resources located within 15 miles (24 km) of the Seattle-Bellevue metropolitan area. The river system is highly valued for its recreational, aesthetics, aquatic habitat, and domestic water supply uses. The Snoqualmie River Valley has been undergoing rapid changes in land use with additional waste load discharges proposed for the river (Joy 1994). As a result, Washington State Department of Ecology developed a TMDL for ammonia, biochemical oxygen demand (BOD), and fecal coliform for the basin that was approved by U.S. EPA Region 10 in 1996.

The Snoqualmie River system drains 700 square miles (mi^2), or 1813 square kilometers (km^2), in King and Snohomish Counties before meeting the Skykomish River to create the Snohomish River. Most of the basin is in King County. The study area includes the lower 44.5 miles (71.6 km) of the river from the South Fork Snoqualmie River and confluence of the two other main forks near North Bend (elevation 430 ft / 131 m), to the confluence with the Skykomish River at Monroe (elevation 15 ft / 4.6 m), as illustrated in Figures 1 and 2. Snoqualmie Falls, with a vertical height of 268 feet (81.7 m), is a predominant feature of the Snoqualmie River at river mile (RM) 40.4. The Tolt River, which drains a 101 mi^2 (262 km^2) basin, is a large tributary to the lower mainstem Snoqualmie (Joy 1994). The Tolt provides 30 percent of the drinking water for the 1.3 million people in the Seattle area. The sampling locations are depicted in Figure 2 and described in Table 4. All but one of the sampling locations are either TMDL or 303(d) listed or both. The unlisted station is on the South Fork and will be used as a baseline station.

The area above the three forks of the upper Snoqualmie at North Bend (upper basin) is mainly forested land under both private and the U.S. Forest Service managements. Residential and commercial land uses are concentrated in two areas in the upper portion of the study area: along the Interstate 90 corridor around the city of North Bend and in the city of Snoqualmie located near Snoqualmie Falls.

The lower valley, which is located below Snoqualmie Falls, is characterized by several major population centers and mixed agriculture. The population centers are the cities of Duvall and Carnation and the unincorporated towns of Fall City and Preston. Agriculture includes dairies, berry fields, pastures, and row crop fields. In addition, golf courses, wildlife reserves, and other recreational facilities are present along the middle to lower river. The slopes and upland sub-drainage areas of the lower valley have traditionally supported forestry and water supply uses, but are disproportionately being converted to residential and commercial developments along the western borders of the lower basin and around several cities. Stormwater from a number of residential developments on the western plateaus discharges into the Snoqualmie River through drainage systems or by direct pipeline.

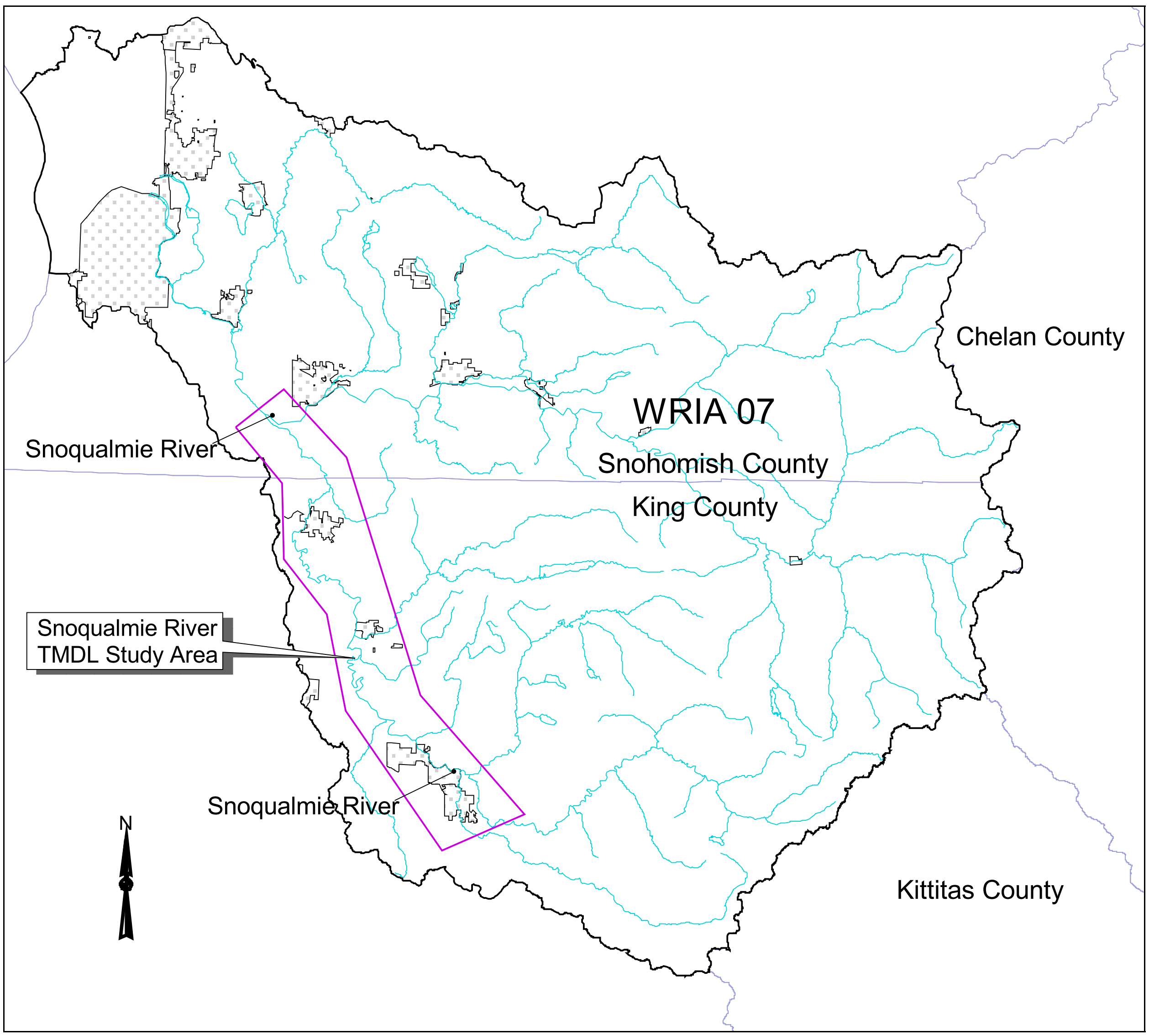

Figure 1. Snoqualmie River monitoring study area

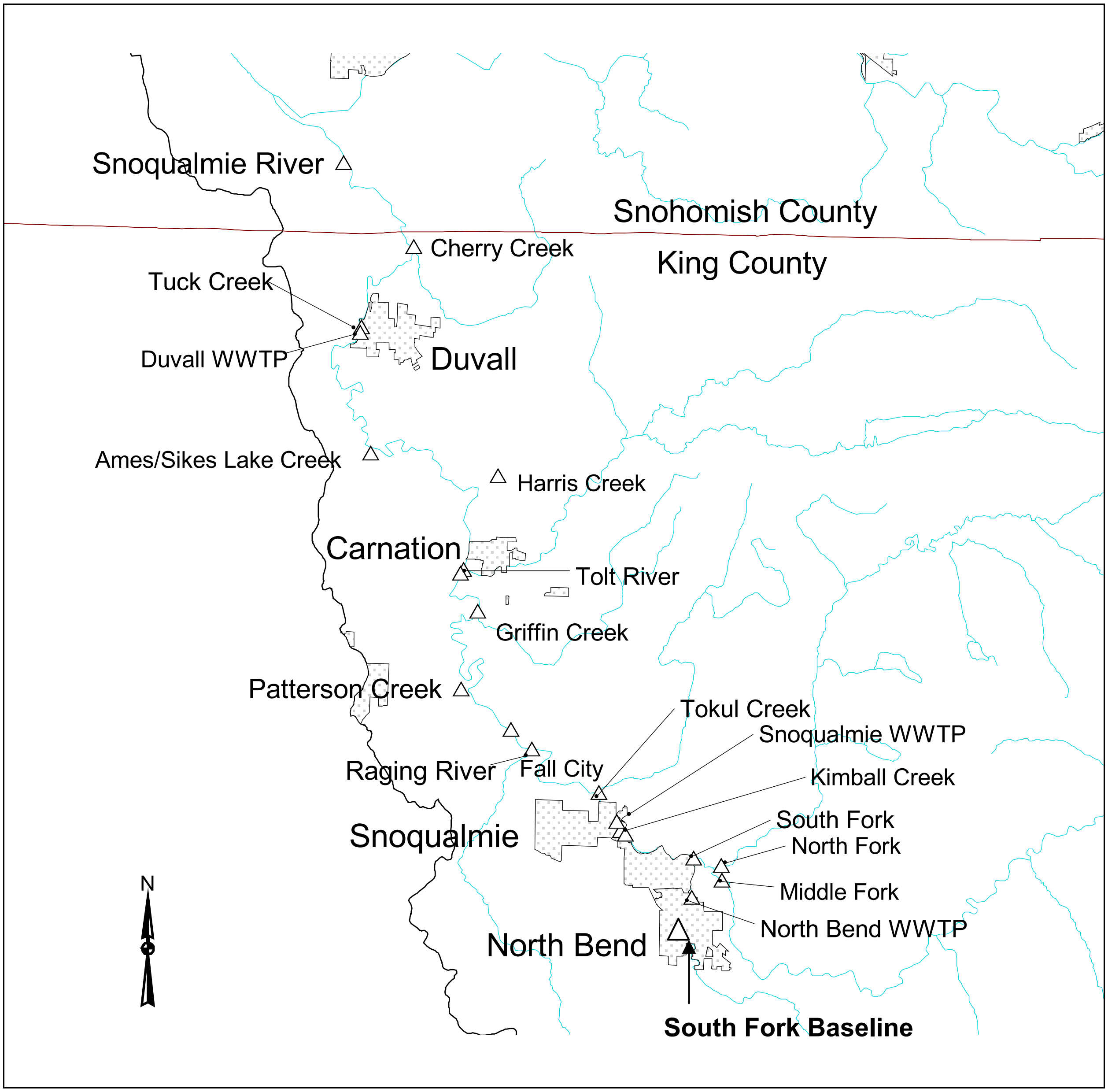

Figure 2. Snoqualmie River and tributary sampling locations

Table 4. Sampling locations

Station	River Mile	Latitude	Longitude	Waterbody Segment	Location	County
Snoqualmie River	2.7	47.803710	122.002902	WA-07-1060	25 ft Upstream of Crescent Lake Rd	Snohomish
Cherry Creek	7.5	47.770250	121.960007	WA-07-1062	At mouth from Hwy 203 bridge crossing	King
Tuck Creek	10	47.737530	121.990378	WA-07-1064	At mouth	King
Duvall WWTP	10.2	47.735100	121.991024	WA-07-1060	Duvall WWTP Outfall	King
Ames Creek Sykes Lake Drain	17.5	47.686327	121.983171	WA-07-1066	At NE 100th St bridge crossing	King
Harris Creek	22	47.678254	121.907005	WA-07-1068	At Hwy 203 bridge NE 87th St	King
Snoqualmie River	25.2	47.638457	121.928211	WA-07-1100	Between Griffin & Tolt pool end ?	King
Tolt River	24.9	47.639938	121.926393	WA-07-1070	At mouth from Dept of Wildlife boat launch	King
Griffin Creek	27.5	47.623172	121.917600	WA-07-1101	At Hwy 203 crossing	King
Patterson Creek	31.2	47.591490	121.926785	WA-07-1102	Under W Snoqualmie River Road bridge	King
Snoqualmie River downstream Fall City	35.35	47.575220	121.896700	WA-07-1100	Below Fall City	King
Raging River	36.2	47.567789	121.883890	WA-07-1104	At confluence with Snoqualmie River	King
Tokul Creek	39.6	47.550634	121.843384	WA-07-1106	At confluence with Snoqualmie River	King
Kimball Creek	41.1	47.535366	121.830138	WA-07-1108	Upstream 10 ft from Hwy 202 bridge	King
Pool above Snoqualmie Falls	40.7	47.538760	121.832290	WA-07-1100	Pool above Snoqualmie Falls	King
Snoqualmie WWTP	40.55	47.538958	121.832364	WA-07-1130	Snoqualmie WWTP Outfall	King
Snoqualmie River alternate flow site	41.2	47.533752	121.827441	WA-07-1130	Above Snoqualmie WWTP	King
Snoqualmie River	42.3	47.527100	121.810900	WA-07-1100	Below North Bend and above Snoqualmie WWTPs	King
North Bend WWTP	44.4	47.497800	121.784400	WA-07-1130	North Bend WWTP Outfall	King
South Fork Snoqualmie River	44.5	47.524763	121.786340	WA-07-1110	Snoqualmie River M444001 South Fork mouth	King
Middle Fork Snoqualmie River	45.3	47.516016	121.769289	WA-07-1140	Snoqualmie River Middle Fork near mouth	King
North Fork Snoqualmie River	44.9	47.521799	121.769707	WA-07-1150	Snoqualmie River North Fork near mouth	King
South Fork above North Bend WWTP	45.74	47.492780	121.789990	WA-07-1110	At HWY 202 bridge crossing the river just NE of I-90	King

Water quality criteria and beneficial uses for these water-body classifications are summarized in Table 5. The Snoqualmie River and its tributaries are classified Class A waters from the mouth to the west border of Twin Falls State Park at river mile (RM) 9.1 on the South Fork. The entire Middle Fork and North Fork Snoqualmie Rivers, and South Fork Snoqualmie River above RM 9.1 are Class AA waters. The South Fork Tolt River system is also Class AA, with a special condition on the South Fork of the Tolt River (a Seattle water supply) above RM 6.9 prohibiting any waste discharge.

Urban and Suburban Communities

As the communities of North Bend, Snoqualmie, Fall City, Carnation, and Duvall (Figure 2) have shifted from agricultural and logging economies, there has been a shift from rural settings to residential, commercial, and industrial land use. These changes in land use have resulted in a need for increased wastewater services and the generation of additional stormwater from impervious surfaces.

Municipal Wastewater Treatment

According to Joy (1994), there were three municipal wastewater treatment plant (WWTP) discharges. The three municipal plants discharge directly to the Snoqualmie River; although the Snoqualmie WWTP discharges only to land during the low-flow season (Callahan 2003).

As a result of the 1996 TMDL, all municipal wastewater treatment plants within the TMDL area have been issued NPDES permits with special limitations for discharges occurring during the critical low-flow period in the Snoqualmie River. Many changes have taken place since the TMDL technical work was performed.

The North Bend, Snoqualmie, and Duvall WWTPs have either undergone, completed, or are planning for expansion due to increased development. The town of Carnation has begun planning for a new WWTP to serve its growing wastewater needs. North Bend has increased in capacity and has another upgrade planned for the future. The Snoqualmie lagoon was replaced with a mechanical plant around 2000 and recently has doubled in capacity again. The Snoqualmie plant can produce Class A water for reuse on the Snoqualmie Ridge PGA golf course or discharge to the river. The city of Duvall has improved its treatment facilities over the last decade and is now preparing for another upgrade. Duvall will be constructing a membrane filter treatment facility that will produce Class A water.

The Snoqualmie TMDL provided several possible scenarios for waste load allocation under current (1991) and future conditions. Among those conditions might be the construction of wastewater treatment plants (WWTPs) to both Carnation and the Fall City area. Permits for currently existing treatment plants in North Bend, Snoqualmie, and Duvall were issued without reserve for future waste loads from future treatment plants. Carnation is currently preparing engineering reports for the construction of a new WWTP to serve both existing and future needs.

The effect of the additional wastewater capacity and future growth should be monitored closely.

Table 5. Class AA and A freshwater quality standards and characteristic uses

	Class AA (extraordinary)	Class A (excellent)
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.
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.

Municipal Stormwater

Urban stormwater runoff can carry a variety of pollutants from urban areas including bacteria from pet wastes, surface wastewater from failing septic tank systems, excess nutrients from lawns and gardens, metals, oil and grease, and other pollutants associated with activities such as car washing and sidewalk cleaning. Currently, only King County has been issued a municipal stormwater permit. Duvall is the only municipality in the basin that is on Ecology's tentative stormwater Phase II municipal stormwater permit-requirement list. Due to uncertainty regarding eligibility requirements for the Phase II permit. It is not clear at this time whether other towns in the TMDL focus area would be required to obtain a municipal stormwater permit. At this time, Ecology has not imposed any special municipal stormwater permit requirements as a result of this TMDL.

Bacteria constitute one of the pollutants of concern in stormwater that may affect this TMDL. In urban areas around Puget Sound and elsewhere across the country bacteria concentrations in stormwater range from approximately 1,000 to over 100,000 colony forming units (cfu) per 100 mL (Doran et al. 1981, Center for Watershed Protection 1999). The 1999 Center for Watershed Protection (CWP) article reported that urban stormwater mean fecal coliform concentrations in three studies varied from 15,000 to 22,000 cfu/100mL. The CWP article also indicated that nearly every individual stormwater runoff sample exceeded bacterial standards, usually by a factor of 75 to 100. The contribution of stormwater has not been determined for the Snoqualmie TMDL.

Agriculture and Livestock

The Snoqualmie TMDL considers agriculture to be a potential source of bacterial pollution and nutrients. Approximately 15 dairies were in operation at the time the TMDL was initiated. Currently, ten of these facilities are still in operation. In addition to inspecting all of these facilities, Ecology issued four dairy permits. While the existence of a permit is not necessarily an indication of pollution potential, the four permits were issued as a result of ongoing or potential water quality problems at those locations. Two of the permitted facilities (Vaness and Groeneweg farms) are still in operation. The state legislature recently transferred the dairy inspection and permitting program from Ecology to the Washington State Department of Agriculture.

King County has a livestock ordinance and works closely with the King Conservation District. Since 1990 the King Conservation District has done over 200 farm plans in the Snoqualmie Basin. Cynthia Callahan (2003) at Ecology's Northwest Regional Office issued no enforcement actions in the study area since 2000.

Miscellaneous NPDES Permitted Dischargers

At the time this TMDL was finalized, there were eight NPDES permitted wastewater discharges in the initial TMDL study area (Joy 1994). They include the three municipal WWTPs mentioned above, a log pond stormwater discharge from Lake Borst; two for a single fish hatchery; and two others that allow manure application to spray fields from one facility. The three municipal plants and the log pond discharge directly to the Snoqualmie River. The hatchery and rearing pond discharge to Tokul Creek, and the spray field permits do not allow direct discharge to surface water.

The state Department of Corrections runs a WWTP at Echo Glen Corrections Center. This discharges a relatively low flow of about 20,000 gallons per day to Icy Creek, a tributary to the Raging River (Callahan 2003). The discharge is most if not all of the flow of the creek at that point. During dry summer months, most of the effluent discharges to ground through the streambed within a few hundred feet of the outfall. The Department of Corrections is working on changing the outfall to eventually discharge directly to the Snoqualmie WWTP. There is some concern about residual bacteria under present operations (Callahan 2003, Jankowiak 2003).

In addition to the dairy, municipal stormwater, and WWTP permits mentioned earlier, there are approximately 55 active NPDES permits at this time. As of the spring of 2003, all industrial discharges from the Weyerhaeuser Mill have ceased. The facility has been inactive for a number of years with only boiler blowdown and surface water discharges entering Borst Lake. Monitoring from the stormwater pond outlet has continued and can be found with the Discharge Monitoring Reports (DMRs) for the Weyerhaeuser facility at the NWRO. There are two permitted fish hatcheries; the permit manager says there are no DMR issues that would affect water quality in the Snoqualmie (Callahan 2003).

There are twelve sand and gravel pits. One pit, Fiorito Bros. in North Bend has the potential to affect the Snoqualmie River receiving water with excess sediment discharge; an enforcement action was brought against them within the past ten years. There is also a new gravel pit going into North Bend, Grouse Ridge, which will be discharging to the Snoqualmie. Weyerhaeuser development on Snoqualmie Ridge has had a huge impact on the receiving water-body, the Snoqualmie River. They have an individual stormwater permit and are currently monitoring the receiving water-bodies. There has been a significant reduction of the trout population throughout the receiving water as a result of this project (Callahan 2003).

Other Potential Pollution Sources

Failing septic systems

County health departments deal with failing septic complaints. The city of Snoqualmie is in the middle of a water quality project only on Kimball Creek looking for sources of high fecal levels which are likely to be either farm field manure applications or septic systems. They currently have only four data points and two storm events so there is no conclusive information.

Illegal sewage dumping

There have been two documented cases of illegal septic dumping in the Snoqualmie Valley during fall of 2003; one case was near Carnation; the other case was in Duvall (King County 2003). This raises the possibility of undocumented illegal dumping occurring.

Historical information

This evaluation includes earlier work by Ecology's Environmental Assessment Program (EA Program); at that time it was named Environmental Investigations and Laboratory Services (EILS). The earlier work began with a 1989 low-flow water quality study of the Snoqualmie River (Joy et al. 1991). Some recommendations from that study were implemented with specific monitoring and follow-up investigations over the next three years (Das 1992, Hopkins 1992, Patterson and Dickes 1993). This report summarizes the findings of the past work, and outlines TMDL effectiveness monitoring design in the lower Snoqualmie River basin.

Water Quality Issues

Review of TMDL Findings

Since 1989, the Washington State Department of Ecology has conducted several water quality investigations on 44.5 mi (71.6 km) of the lower river basin to define present and potential water quality problems during the summer low-flow season. A basin-wide study of the lower Snoqualmie River was necessary to describe baseline water quality, identify current problems, and to establish TMDLs to maintain and protect a high level of water quality for existing beneficial uses.

The TMDL study began with a 1989 low-flow water quality study of the Snoqualmie River (Joy et al. 1991). Some recommendations from that study were implemented with specific monitoring and follow-up investigations over the next three years (Das, 1992, Hopkins 1992, Patterson and Dickes 1993). The TMDL also used data from two long-term Ecology and USGS stations, Ecology's additional water quality data collected from 1990 to 1992, EILS' bacterial study in swimming areas in the lower valley and a eutrophication criteria study (EarthInfo 1992, Das 1992, Hopkins 1992, Patterson and Dickes 1993, Joy 1993, STORET 1993).

According to Joy et al. (1991), most of the mainstem river exhibits high water quality during low-flow conditions. However, some mainstem reaches, the South Fork Snoqualmie River, Kimball Creek, Raging River, Patterson Creek, Ames-Sikes Creek, and Cherry Creek were either threatened or not meeting some Class A standards. Parameters which exceeded water quality standards included DO, fecal coliform bacteria, pH, and temperature.

Historical Data Evaluation

One objective of this study is to review historical data and collect additional information to determine the changes in water quality characteristics of the river. Information from the data collected from two long-term Ecology and USGS stations, Ecology's intensive surveys in 1989, Ecology's additional water quality data for at least four months from 1990 to 1992, EILS' bacterial study in swimming areas in the lower valley and a eutrophication criteria study (EarthInfo 1992, Das 1992, Hopkins 1992, Patterson and Dickes 1993, Joy 1993, STORET 1993) provided the basis for this historical evaluation. However, emphasis is limited to temperature, DO, fecal coliform, and ammonia.

Dissolved Oxygen

High water temperatures and minimum DO concentrations occurred in the months of July and August (EarthInfo 1992, STORET 1993). Naturally, these high water temperatures can create lower DO concentrations due to lesser gas solubility. On the other hand, algal primary productivity also increases in summer. Photosynthetic activity can create DO supersaturation during daylight hours, and respiration processes can cause depressed DO concentrations at night in some reaches. Similarly, reaction rates affecting oxygen demanding substances also increase with temperature, thereby affecting the DO levels. Furthermore, critical conditions for DO can occur when velocities and re-aeration rates are reduced in pool areas at lower flows. According to Joy (1994), instream temperatures and DO levels in several areas of the river basin do not meet Class A or Class AA criteria.

Several DO sensitive environments were identified from the EILS surveys and historical data sources, and they include pools on the mainstem of the Snoqualmie River at the following locations:

- The pools above Snoqualmie Falls
- Above the Tolt River, and
- On the last three miles of diked river channel.

The reasons for these conditions are slower water velocities, low re-aeration rates, high sediment oxygen demand potential, and higher temperatures. For example, the pool above Snoqualmie Falls recorded DO concentrations below 8.0 mg/L (PEI 1987, PP&L 1991), and therefore does not always meet the Class A criterion. Ecology monitoring at RM 2.7, near the confluence of the Skykomish River, recorded a mid-day DO concentration of 8.4 mg/L at a temperature of 21° C (STORET 1993).

Fecal Coliform Bacteria

Fecal coliform bacteria counts exceeding Class A and AA standards occurred at various times of the year in the Snoqualmie basin. There is less dilution during dry periods (July through September); hence direct discharges of fecal wastes to the water column can lead to violations. On the other hand, fecal wastes can be washed into water courses directly from land surfaces or through the soils during extended rainstorms or flood conditions. Joy et al. (1991) found both nonpoint and point sources contributing to the bacterial problems in the mainstem Snoqualmie River. Fecal coliform-water quality limited tributaries are Ames Creek, Cherry Creek, Kimball Creek, Patterson Creek, and Raging River. Although Das (1992) reported significant improvements in effluent disinfection at the three main sewage treatment plants, other nonpoint sources were still creating localized bacterial contamination problems (Patterson and Dickes, 1993).

Ammonia Toxicity

Critical conditions for ammonia toxicity occur near wastewater sources. According to Joy et al. (1991) and Das (1992), the highest ammonia concentrations were reported from Duvall WWTP effluent samples. These critical conditions occur during low-flow months when high pH (usually related to biomass productivity), elevated background ammonia concentrations (from the WWTP), low dilution, and high temperatures are present. Also, elevated ammonia concentrations were observed at Ames Creek in comparison to characteristically low concentrations throughout most of the Snoqualmie River system.

TMDL Conclusions

Although, the TMDL was developed for ammonia, BOD, and fecal coliform; historical water quality data in the basin had indicated potential violations of Class A standards for other parameters like pH and aesthetic values[2] (URS 1977, PEI Consultants 1987, Ecology 1988 Thornburg et al. 1991, STORET 1993). The development of ammonia limits for municipal WWTP discharges was essential to control downstream Nitrogenous BOD (NBOD) impacts, and for the prevention of un-ionized ammonia toxicity beyond the point source discharge mixing zone. Similarly, carbonaceous BOD (CBOD) limits were also needed to protect aquatic life in several critical areas of the river.

When the aeration rate is low, BOD may reduce oxygen substantially and affect aquatic life. But when the aeration rate is high, BOD may have little effect on aquatic life. These critical areas are sensitive to oxygen depletion during the low-flow period because they are regions where the river widens or pools, so aeration is low.

Pollutant allocations were also necessary for fecal coliform bacteria in order to restore and preserve the recreational uses of the river and its tributaries. Ecology focused the TMDL study on ammonia, BOD, fecal coliform bacteria, and some conventional pollutants, and only limited efforts were put toward evaluating other potential pollutants directly.

Recent Data

Ecology's ambient monitoring station reports were reviewed for recent water quality information.

Monitoring station 07D050 - Snoqualmie River near Monroe

This station has been monitored monthly from 1995 through the present. Overall water quality at this station met or exceeded expectations and is of lowest concern (based on water-year 2002 assessment). Between 1996 and 1998 there were four instances where fecal coliform bacteria exceeded the water quality criterion; in 1998 there was one instance of pH exceeding its criterion, and in 2002 there was one instance where temperature exceeded its criterion.

Monitoring station 07D130 - Snoqualmie River at Snoqualmie

This station has been monitored monthly from 1995 through the present. Overall water quality at this station met or exceeded expectations and is of lowest concern (based on water-year 2002 assessment). The water quality criterion for pH was exceeded once in 1998.

[2] For example, nutrient enrichment can cause algal blooms, which can produce toxic (no swim) conditions. Further, all biota, including plants, consume oxygen at night; and algal die-off results in further-depressed DO levels. Low DO is harmful to aquatic biota, and die-off results in aesthetic degradation.

Project Description

This QA Project Plan describes a monitoring plan to evaluate TMDL effectiveness for fecal coliform bacteria, BOD, ammonia and other selected parameters in the Snoqualmie basin. The desired outcome is to determine compliance with water quality standards or TMDL targets; to support regulation, enforcement, and maintenance of state of Washington water quality standards; and to support the systematic review and improvement of water quality.

Project Objectives

Objectives of the proposed study are as follows:

- Determine if fecal coliform bacteria, DO, and ammonia concentrations as well as BOD levels are at recommended TMDL compliance targets and points on the mainstem Snoqualmie River and its tributaries.
- Evaluate the relationship between fecal coliform and *Escherichia coli* (*E. coli*) in the Snoqualmie River mainstem and tributaries pending a decision from EPA regarding Ecology's proposed new water quality standards.
- Determine if the concentrations of other conventional parameters such as pH and temperature are meeting water quality criteria on the Snoqualmie River and its tributaries.
- Determine flow (from USGS mainstem data, and by wading tributaries and taking periodic flow measurements).
- Perform diagnostic study of nitrate/nitrite-nitrogen, chloride, fecal coliform/*E. coli* bacteria and conductivity levels around the Fall City area to provide additional information on the possibility of septic tank failures in the near-shore area.
- Determine if designated uses are supported.
- Review the effectiveness of corrective actions and preventive measures taken to improve, or protect water quality.
- Recommend any additional measures needed to return local waters to compliance with state standards.
- Identify specific pollutant sources (as resources allow).

The results of this TMDL evaluation study will allow Ecology and other basin stakeholders to engage in adaptive management of basin activities to control the level of polluting substances within the study area. Possible outcomes include:

- Recommendation to de-list waters previously determined to be polluted,
- Redirection of existing resources to control nonpoint pollution, and
- New TMDL target limits or NPDES permit limitations or other appropriate actions.

As described earlier, the primary data of interest are for the TMDL recommended parameters of indicator bacteria, DO, and ammonia. The data collected to date suggest that the water quality problems are not limited to one season or source type, but that some problems are low-flow related. Additional monitoring data are essential for better description of the spatial and temporal extent of water quality problems as well as describing current conditions. The final evaluation report will contain recommendations for de-listing parameters and comparisons of data to TMDL targets in Table 6.

Ecology Water Quality Program Policy 1-11 (Ecology, 2002) guidance on data interpretation will be followed to determine if water-bodies or contaminants can be de-listed. Statistical values such as geometric means and 90th percentiles will be derived for fecal coliform bacteria concentrations on an annual and seasonal basis depending on the availability of data. Statistical summaries that include: means, standard deviations, and coefficient of variations, will be calculated for the remaining parameters. Only data from sites within the study area that meet all quality control requirements will be used in this evaluation.

Listing or de-listing decisions and meeting TMDL target limits will be based on the most current water quality criteria during completion of the final report. DO and *E. coli* data will be compared to the recent criteria proposed that represent revised water quality standards. To meet some of the proposed DO criteria, all tributaries and mainstem reaches will be assumed to be capable of salmon rearing and serve as a migration route.

Table 6. Water quality criteria used to determine supported beneficial uses

Parameter	Criteria Category	Statistic	Criterion	Ancillary Data
Dissolved Oxygen Existing Standards[3]	Class AA Freshwater	One-day minimum	9.5 mg/L	Extraordinary Salmonid spawning and rearing
	Class A Freshwater	One-day minimum	8.0 mg/L	Excellent Salmonid spawning and rearing
	Class B Freshwater	One-day minimum	6.5 mg/L	Salmonid rearing only
Dissolved Oxygen TMDL Targets		One-day minimum	7.9 mg/L	Pool above Falls
			8.3 mg/L	Confluence with Skykomish R.
Dissolved Oxygen Final EIS Proposed December 2002 Alternative[3]		90-Day average of daily minimum (90-DAMin)	9.5 mg/L	Salmonid spawning and rearing
			8.5 mg/L	Salmonid rearing only
			7.0 mg/L	Warm water fish habitat
		One-day minimum	7.0 mg/L	Salmonid spawning and rearing
			6.0 mg/L	Salmonid rearing only
			5.5 mg/L	Warm water fish habitat
Dissolved Oxygen Final EIS No-Action and Preferred Alternative[3]	Class AA Freshwater	Existing criteria Lowest 1-day minimum	9.5 mg/L	Char. Salmon and trout spawning, core rearing, and migration
	Class A Freshwater		8.0 mg/L	Salmon and trout spawning, non-core rearing, and migration
	Class B Freshwater		6.5 mg/L	Salmon and trout rearing and migration only
	Class A Freshwater		8.0 mg/L	Non-anadromous interior redband trout
	Class B Freshwater		6.5 mg/L	Indigenous warm-water species
Dissolved Oxygen Final EIS Alternative with Lower Environmental Impact[3]		90-Day average of daily minimum (90-DAMin)	10.5 mg/L	Spawning of Salmonids (when it occurs)
			8.5 mg/L	Rearing of Salmonids (rest of year)
	This alternative would also include the one-day minimum similar to the proposed alternative to prevent unusual situations where very short-term, low dissolved oxygen levels would be harmful to aquatic life, but might not be reflected in the longer-term 90-DAMin. The 7.0 mg/L one-day minimum would be used in conjunction with, not instead of, the 90-DAmin.			
Fecal coliform Existing Standards	Class A Freshwater	Geometric Mean	100 cfu/100 mL	
		90th percentile value[4]	200 cfu/100 mL	
	Class AA Freshwater	Geometric mean	50 cfu/100 mL	
		90th percentile value[4]	100 cfu/100 mL	
Fecal coliform TMDL Targets		Geometric mean	80 cfu/100 mL	
		90th percentile value[4]	200 cfu/100 mL	
Escherichia coli Proposed Dec. 2002 Alternative Standards[3]	Freshwater primary contact	Geometric mean	100 cfu/100 mL	
		90th percentile value[4]	200 cfu/100 mL	
	Freshwater secondary contact	Geometric mean	200 cfu/100 mL	
		90th percentile value[4]	400 cfu/100 mL	
pH	Freshwater	Maximum	8.5	
		Minimum	6.5	
Ammonia[5]	Freshwater	4-day average /3 years	1.35 mg/L as N	Example: 20 deg. C; pH = 7
		1-hour average /3years	17.9 mg/L as N	Example: 20 deg. C; pH = 7
Total persulfate Nitrogen	TMDL monitoring for DO impacts; no limit			
Soluble Reactive Phosphate (Orthophosphate)	TMDL Target	Maximum	10 µg/L	

[3] (Ecology 2003)
[4] Criteria wording states that not more than 10% of the samples used to calculate the geometric mean exceed the stated value
[5] New ammonia criteria are proposed but are not presented here

Data Quality Objectives

Data quality objectives are statements of the precision, bias, and lower reporting limits necessary for the data to address project objectives. The primary indicators of data quality are precision and bias, which, together, express the data's accuracy by the relationship:

Accuracy = Bias + Precision
Precision = (±1Standard Deviation) = Relative Standard Deviation = RSD
Accuracy = Bias + 2·RSD

Precision, expressed as the standard deviation of replicate sample analyses, is a measure of data scatter due to random error, while bias is a measure of the difference between the result for a parameter and the true value due to systematic errors. Potential sources of errors include sample collection, physical and chemical instability of samples, interference effects, instrument calibration, and contamination. Random error affects the determination of bias; thus bias estimation may be problematic. Consequently, dedication to established protocols is one method used to reduce concern over sources of bias (Lombard and Kirchmer, 2001).

Some of the parameters sampled in this evaluation such as DO and pH are highly influenced by the biological component in the aquatic environment; additionally, DO is influenced by temperature, atmospheric pressure, and sampling depth. Bacteria and nutrients are subject to possible sample contamination problems. Further, bacteria are subject to die-off, yet they can accumulate and even grow in sediments, and then be re-suspended when the sediment is disturbed. Also, bacteria counts tend to be highly variable for a number of factors including low mobility through soil, presence and concentration is dependent on source (direct vs. runoff) and weather events, and bacteria are particulate and may be in the form of clumped fecal matter that does not dissolve readily.

The remaining data quality consideration is the lower reporting limits necessary for the data to address project objectives. This requires selection of procedures capable of producing accurate results at the concentrations used for decision-making (i.e., the standards, criteria, or regulatory limits). It is important that the methods used for analysis have reporting limits well below these levels, since precision near the detection limit is not good and decisions should not be based on imprecise data. An accepted rule is that for any analyte, the reporting limit should be at least 10 times lower than the reference concentration.

Table 7 summarizes the laboratory accuracy and analytical reporting limits for parameters that can reliably be used for decision-making.

Table 7. Field and laboratory measurement data quality objectives

Analysis	**Accuracy** % deviation from true value	**Precision** Relative Standard Deviation	**Bias** % deviation from true value	**Lower Reporting Limits or Range**
Field Measurements				
Water Velocity *	Zero Stability: ±0.05 ft/s; ±2% of reading + zero stability	N/A	N/A	0.05 ft/s
Stream Flow (direct measure)	N/A	7.1	N/A	No flow
pH *	± 0.2 SU	0.05 SU	0.10 SU	4 to 9
Temperature *	± 0.2 °C	N/A	N/A	1 to 40 °C
Dissolved Oxygen	15	5	5	0.1 to 15 mg/L
Conductivity	25	10	5	0.1 umhos/cm
Laboratory Analyses				
Fecal Coliform (MF)	N/A	28.3 **	N/A	1 cfu/100 mL
Escherichia coli (MF)	N/A	28.3 **	N/A	1 cfu/100 mL
Biochemical Oxygen Demand	N/A	25	N/A	2 mg/L or higher, depending on dilution required
Chloride	25	10	5	0.1 mg/L
Ammonia-nitrogen	25	10	5	0.010 mg/L
Nitrate + Nitrite-nitrogen	25	10	5	0.010 mg/L
Total persulfate nitrogen	25	10	5	0.025 mg/L
Orthophosphate	25	10	5	0.003 mg/L

RPD = Relative percent difference
RSD = Relative standard deviation

$$RPD = \frac{|x_1 - x_2|}{\bar{x}} \cdot 100$$

$$RSD = \frac{s}{\bar{x}} \cdot 100 = \frac{RPD}{\sqrt{2}}$$

* As units of measurement, not percentages

** Based on Manchester Environmental Laboratory RPD < 40% for fecal coliform and *E. coli* analysis.

Data quality objectives will vary for parameters based on their inherent variability in the natural environment. Parameters with relatively large field and laboratory variability such as fecal coliform will need to have increased numbers of duplicate samples in the field and laboratory to improve precision estimation, if funds permit. Some parameters such as DO that demonstrate strong diel changes will need accurate and nearly continuous monitoring for some periods during critical seasonal events to capture minimum and maximum fluctuations. These issues are the subject of further discussion in Sampling Design, Field Procedures, Laboratory Procedures, and Quality Control Sections.

Sampling Design

General Approach

Beyond collecting high quality individual environmental samples, it is necessary that the data be representative of actual conditions, and that they be comparable to historical data. In cases where historical data are inadequate for statistically significant comparison, it is still important for the current round of sampling to be adequate to measure against in the future. Representativeness and comparability include considerations regarding seasonality and overall time span of the study. We consider a two-year time-span the minimum required for representativeness. For this particular study, effectiveness is being measured for the low-flow season, so data will be collected during that same season for comparability. In order to address concerns that some pollution problems may also exist during the high flow season, we are adding monitoring during that period. Overall, seasonal sampling and other sampling design features will be used to evaluate critical conditions on which to determine water quality compliance for the parameters under study.

The TMDL effectiveness evaluation and Fall City diagnostic study will require field data collection and a closer analysis of any available historical data. The field survey will build on the old monitoring data and current data collected by the Environmental Assessment Program's monthly ambient monitoring study. The surveys will be conducted to address specific issues regarding TMDL compliance and potential water pollution around the Fall City area. The regular periodic monitoring part of the evaluation will be in the mainstem Snoqualmie River, the three Forks (North, Middle and South), one site each on the Raging and Tolt rivers and the following creeks: Kimball, Tokul, Patterson, Griffin, Harris, Tuck, Ames/Sikes, and Cherry. Most of these sites were chosen because they were on the U.S. EPA Snoqualmie TMDL approved in 1996, because of 303(d) listing, or based on information from the previous TMDL study (Joy 1994). The evaluation will also include focused transects in the Fall City area to attempt to narrow down the source of pollution loading in the area.

Field surveys will examine the following special monitoring issues: monthly variability in indicator bacteria (wet and dry weather monitoring), diel changes in DO at selected sites, and water quality response to storm events (wet weather monitoring). The critical period for DO is during the summer months; however, wet weather monitoring will also be conducted at some sites throughout the year based on our improved knowledge of bacterial pollution trends in Pacific Northwest watersheds. Water quality diagnostic surveys will be conducted around the Fall City area with emphasis on fecal coliform/*E. coli* bacteria, nitrate/nitrite-nitrogen, chloride, and conductivity as well as on conventional parameters.

Monitoring Schedule

Several tasks are required to meet the project objectives outlined for the mainstem Snoqualmie River, North Fork, Middle Fork, and South Fork reaches as well as the Fall City area. TMDL compliance parameters require varying degrees of monitoring and data collection, with fecal coliform bacteria monitored more frequently. The compliance sampling, Fall City area diagnostic study, and storm event monitoring in the lower Snoqualmie River basin will provide the additional data to complete the bacteria population distribution analysis and to verify that Class A criteria are being met. Where significant land use changes have occurred, or where corrective or preventive actions have been taken to reduce pollutant levels, an assessment of TMDL effectiveness will be determined by evaluating compliance with the geometric mean and 90^{th} percentile criteria. Analysis of TMDL data suggested a geometric mean of 80 cfu/100 ml was necessary to ensure that less than 10% of the samples would exceed 200 cfu/100 ml.

The plan is to collect fecal coliform/*E. coli* bacteria samples on a frequent basis from sites distributed through the Snoqualmie basin. According to the TMDL assessment(Joy 1994), Ames Creek, Cherry Creek, Kimball Creek, Patterson Creek, Raging River, and portions of the mainstem Snoqualmie River were water quality limited for fecal coliform. The study also found both nonpoint and point sources contributing to the bacterial problems in the mainstem Snoqualmie River. The indicators are used to determine recreational use compliance. Storm-event runoff bacterial quality will be monitored during wet weather synoptic surveys. These bacterial sources from tributary streams are found along the lower mainstem and will be sampled as well (Table 8) to determine recreational use compliance. Sampling sites and the analyses performed on grab samples are listed in Tables 8 and 9.

Sites will be visited weekly during the low-flow period, and approximately biweekly during the high-flow period. State holidays may affect when samples can be delivered to the laboratory, so during the winter schedules may be adjusted accordingly. We may sample consecutive weeks during the high-flow period for logistics reasons, or to capture rain events.

The Snoqualmie River basin is known to flood at times. We cannot rule out the possibility of this occurring during the defined low-flow period. During the high-flow period, flooding, freezing, or snow conditions may limit access to some or all sites at times. We will attempt to collect samples from all sites even under adverse conditions; in some cases we may be required to sample from alternate sites (e.g. further upstream on tributaries). We may miss some samples if access is not possible, or in the case of tributaries, if access is possible but flooding from the river mainstem backs up into the tributaries. If we cannot get into the basin at all because of flooding, ice, or snow, or if illness or injury prevents sampling, we will attempt to reschedule to make up the sampling event at another date within the season.

We have field instrumentation in good working condition dedicated to this project. However, we cannot rule out the possibility of equipment failure, in which case gaps may occur in the data, or data may be qualified as estimation. Failed equipment will be substituted with pool equipment if available, until the dedicated equipment is repaired.

There are no other known limitations that could affect our ability to collect samples or take field readings. The known limitations may result in data gaps, but should not affect our overall schedule.

Tables 8 and 9 show the sampling schedule, analyses performed, and sites for other parameters. However, routine monitoring may not adequately characterize the dynamic DO levels during the low-flow summer months unless continuous monitoring is used. DO levels exhibit diel changes in response to physical and chemical influences by the aquatic community. DO concentrations below 8.0 mg/L (minimum TMDL recommended target 7.9 mg/L) have been recorded in the pool above Snoqualmie Falls (PEI, 1987; PP&L, 1991), and Class A DO violations have been observed in Kimball, Patterson, and Cherry Creeks (Thornburgh, et al, 1991; Lane, et al, 1993). As a result, continuous monitoring devices will be deployed at selected locations at times to capture diel DO changes (Table 8). Limitations on the availability of continuous-recording DO equipment and limitations on available staff may limit the timing and amount of diel DO data that can be collected.

As part of the TMDL effectiveness monitoring, during the field surveys Ecology staff will measure flow at selected sites. Instantaneous stream flow measurements or gauge reading will be obtained at each site to determine flow whenever possible. A flow rating curve will be developed for sites with a staff gauge. When flows cannot be measured directly, estimation of discharge and instantaneous flow measurement will follow the Stream Hydrology Unit protocols manual (Ecology, 1999). USGS flow data may be referred to when and where it is available.

Not all parameters will be measured at all sites or at the same frequency. This is to strike a balance between available laboratory analysis funding, available staff time for sample collection and field analysis, and to focus resources where needed the most. The low-flow season is the primary period of concern with regard to the TMDL targets and 303(d) listings, so sampling frequency for all parameters is higher than sampling frequency during the high-flow season.

Of the laboratory-analyzed samples, bacteria will be collected at the highest frequency because these samples tend to have very high variability. Nutrient sampling is expected to be adequate at half the sampling frequency of bacteria during the low-flow season, and once per month during the high-flow season. Of the nutrients, ammonia will be collected at all TMDL compliance sites, and NO3-N + NO2-N, total persulfate nitrogen, and orthophosphate will be collected only at upstream baseline points and at expected sources. BOD will be sampled once per month during the dry season and once during the wet season. BOD will only be collected at sites that may be expected to have measurable contributing BOD; e.g. tributaries and WWTPs. BOD will also be collected at the baseline station to establish the level above all downstream sources. Other than that, BOD will not be collected on the Snoqualmie mainstem, because levels are expected to be below the detection limit. WWTP splits will be analyzed by Ecology for all parameters noted in tables 8 and 9 monthly during both the low and high-flow seasons, because these point-discharges are known to be potential loading sources.

Table 8. Low-flow season monitoring sites, parameters, planned tasks, and schedule; not including Fall City transects

			TMDL Parameter and frequency			303(d) or other parameter and frequency								
Station	River Mile	Waterbody Segment	Ammonia	BOD5 inhibited	Bacteria	Flow	Conductivity	Temp	pH	DO	Diel DO	NO_2NO_3	SRP	TPN
Snoqualmie River	2.7	WA-07-1060	B		W	B/U	B	W	B	B	X	B	B	B
Cherry Creek	7.5	WA-07-1062	B	M	W	B	B	W	B	B	x			
Tuck Creek	10	WA-07-1064	B	M	W	B	B	W	B	B				
Duvall WWTP	10.2	WA-07-1060	M	M	M		M	W	B	B		M	M	M
Ames/Sikes Lake Creek	17.5	WA-07-1066	B	M	W	B	B	W	B	B				
Harris Creek	22	WA-07-1068	B	M	W	B	B	W	B	B				
Tolt River	24.9	WA-07-1070	B	M	W	B/U	B	W	B	B				
Snoqualmie River	25.2	WA-07-1100	B		W	B/U	B	W	B	B	X	B	B	B
Griffin Creek	27.5	WA-07-1101	B	M	W	B	B	W	B	B				
Patterson Creek	31.2	WA-07-1102	B	M	W	B	B	W	B	B	x			
Snoqualmie River below Fall City	35.35	WA-07-1100	B		W		B							
Raging River	36.2	WA-07-1104	B	M	W	B/U	B	W	B	B				
Tokul Creek	39.6	WA-07-1106	B	M	W	B	B	W	B	B				
Snoqualmie WWTP	40.55	WA-07-1130	M	M	M		M	M	M	B		M	M	M
Pool above Snoqualmie Falls	40.7	WA-07-1130	B	M	W		B	W	B	B	X	B	B	B
Kimball Creek	41.1	WA-07-1108	B	M	W	B	B	W	B	B	x			
Snoqualmie River	42.3	WA-07-1100	B		W	B/U	B	W	B	B				
North Bend WWTP	44.4	WA-07-1130	M	M	M		M	M	M	B		M	M	M
South Fork Snoqualmie River	44.5	WA-07-1110	B		W	B/U	B	W	B	B				
North Fork Snoqualmie River	44.9	WA-07-1150	B		W	B/U	B	W	B	B		B	B	B
Middle Fork Snoqualmie River	45.3	WA-07-1140	B		W	B/U	B	W	B	B		B	B	B
South Fork above North Bend WWTP	45.74	WA-07-1110	B	M	W	B/U	B	W	B	B		B	B	B

W: Weekly sample. For flows this means either direct measurement whenever possible, but gauges and rating curves may be used
B/U: Bi-weekly when possible at or near USGS gauging stations. Once relationshipes are established, may rely on USGS for primary measure and rating curves to adjust
B: Bi-weekly
M: Monthly
X: Site of primary concern for this parameter monitor continuously as much as possible within equipment and staff constraints
x: Site of secondary concern for this parameter: monitor if possible if resources are available after primary sites are taken care of

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Table 9. High-flow season monitoring sites, parameters, planned tasks, and schedule; not including Fall City transects

			TMDL Parameter and frequency			303(d) or other parameter and frequency			Other			
Station	RM	Waterbody Segment	Ammonia	BOD5 inhibited	Bacteria	Flow	Conductivity	Temp	pH	NO2NO3	SRP	TPN
Snoqualmie River	2.7	WA-07-1060	M		13⌖	⊞	M	13⌖	M	M	M	M
Cherry Creek	7.5	WA-07-1062	M	1	13⌖	⊞	M	13⌖	M			
Tuck Creek	10	WA-07-1064	M	1	13⌖	⊞	M	13⌖	M			
Duvall WWTP	10.2	WA-07-1060	M	1	M		M	M	M	M	M	M
Ames/Sikes Lake Creek	17.5	WA-07-1066	M	1	13⌖	⊞	M	13⌖	M			
Harris Creek	22	WA-07-1068	M	1	13⌖	⊞	M	13⌖	M			
Tolt River	24.9	WA-07-1070	M	1	13⌖	⊞/U	M	13⌖	M			
Snoqualmie River	25.2	WA-07-1100	M		13⌖		M	13⌖	M	M	M	M
Griffin Creek	27.5	WA-07-1101	M	1	13⌖	⊞	M	13⌖	M			
Patterson Creek	31.2	WA-07-1102	M	1	13⌖	⊞	M	13⌖	M			
Snoqualmie River below Fall City	35.35	WA-07-1100	M		13⌖		M	13⌖	M			
Raging River	36.2	WA-07-1104	M	1	13⌖	⊞	M	13⌖	M			
Tokul Creek	39.6	WA-07-1106	M	1	13⌖	⊞/U	M	13⌖	M			
Snoqualmie WWTP	40.55	WA-07-1130	M	1	M		M	M	M	M	M	M
Pool above Snoqualmie Falls	40.7	WA-07-1100	M		13⌖	⊞	M	13⌖	M	M	M	M
Kimball Creek	41.1	WA-07-1108	M	1	13⌖	⊞	M	13⌖	M			
Snoqualmie River	42.3	WA-07-1100	M		13⌖	⊞	M	13⌖	M			
North Bend WWTP	44.4	WA-07-1130	M	1	M		M	M	M	M	M	M
South Fork Snoqualmie River	44.5	WA-07-1110	M		13⌖	⊞/U	M	13⌖	M			
North Fork Snoqualmie River	44.9	WA-07-1150	M		13⌖	⊞/U	M	13⌖	M	M	M	M
Middle Fork Snoqualmie River	45.3	WA-07-1140	M		13⌖	⊞/U	M	13⌖	M	M	M	M
South Fork above North Bend WWTP	45.74	WA-07-1110	M	1	13⌖	⊞/U	M	13⌖	M	M	M	M

⊞/U Do not expect to be able to measure flows directly -- plan on using rating curves, tape-downs, gauges, and USGS data
13⌖ Plan on 13 samples during the wet season; plan on up to 2 more samples if needed to capture rain events
M: Monthly
1: Collect one sample during the beginning of the wet-season -- ideally during the first flush

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Fall City Area Schedule

During the first year, spread over both wet and dry seasons, at least 50 samples each of bacteria, NO_3-N + NO_2-N, chloride, and conductivity will be collected. Five samples along each shore (left and right banks) = 10 samples x 5 runs. The sampling team may modify the schedule to accurately pinpoint pollution sources, if the need arises. In addition, below Fall City, there will be a regular monitoring station for bacteria on a regular basis and other parameters as indicated in Figure 2 and Table 4. Flexibility will be required with proper team consultation in locating monitoring sites as well as sample collection frequency during the second year if results indicate that pollution source identification is necessary.

Field Procedures

General

Standard Ecology Environmental Assessment Program protocols will be used for sample collection (Cusimano 1993; Ward 2001) and preservation and shipping to the Manchester Environmental Laboratory (1994). Chain-of-custody signatures will not be required during transport; samples are always within the possession of Ecology or a US EPA courier. EA Program field methods will be followed for the collection of flow, dissolved oxygen (DO), pH, temperature, and conductivity, and for the deployment of data recording equipment(Cusimano 1993; Ward 2001).

All water samples for laboratory analysis will be directly collected in pre-cleaned containers supplied by the Manchester Environmental Laboratory (MEL), except orthophosphate, which will be collected in a syringe and passed through a new 1 inch diameter, 0.45 micron filter, into a pre-cleaned container for each sample. 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 scheduled to arrive at Manchester Environmental Laboratory for analysis within 24 hours of collection. Bacteria samples delivered to the laboratory after the 24 hour holding time, they will be flagged (marked "J") for the project team to determine the usefulness of the data. Analytical methods, sample containers, volumes, preservation and holding time are listed in Table 10.

Field meter calibration will follow manufacturers' instructions. Pre- and post-checks with standards will evaluate field measurement accuracy for pH and conductivity. When the Winkler method is used for DO, at least one field replicate will be taken for each ten regular samples for quality control check purposes. A fluorescence DO probe may be used in lieu of the Winkler method, but will be calibrated against Winkler samples taken at the beginning, mid-day, and the end of each day for each two-day sampling run. Calibration data will be recorded on standard forms. A NIST-certified reference thermometer will be used for field thermometer calibration at least once per year. At the completion of the monitoring, the raw data will be adjusted for instrument bias, if present.

All sampling sites will have unique identification names. Field notes and field measurement data will be maintained – on water-resistant paper when required.

Flows

The USGS has continuous (quarter or half-hourly readings depending on site) recording gages at:

South Fork Snoqualmie River above Alice Creek near Garcia
Middle Fork Snoqualmie River near Tanner
North Fork Snoqualmie River near Snoqualmie Falls
Snoqualmie River mainstem near Snoqualmie
Snoqualmie River mainstem near Carnation
Snoqualmie River mainstem near Duvall
Raging River tributary to Snoqualmie River
Tolt River tributary to Snoqualmie River

USGS reports calculated flows for all of these except the Snoqualmie River near Duvall, for which only gauge is reported.

King County has continuous (quarter-hourly readings) recording gages at:

Griffin Creek
Harris Creek
Cherry Creek

King County reports calculated flows for these streams.

These USGS and King County sites generally do not coincide with this project's monitoring sites, but may be used to develop flow relationships between USGS or King County values and Ecology's measured values.

USGS also has a wire gauge on the Bendigo Blvd. S. bridge crossing the Snoqualmie River South Fork between Interstate 90 and the city of North Bend.

Static gauges of unknown origin are present at the following sampling sites for this project:

Snoqualmie River North Fork 428th Ave. SE bridge
Harris Creek Highway 203 overcrossing
Ames Creek / Sykes Lake Drain NE 100th St. overcrossing flood gate

Where no gauges are present, tape-downs will be measured from marked locations on bridge railings.

For each low-flow season, Ecology will measure instantaneous flows at all project sites possible during sampling runs when time allows and depth or flow do not present safety issues. This will facilitate development of flow:gauge rating curves, and will enable some correlation between

USGS and King County continuous flow values. These curves will be used to calculate flows from gauges and tapedowns when flows are not measured directly. Direct flow measurement may be extended past the low-flow periods if time and safety – including available daylight – allow.

Laboratory Procedures

Laboratory analyses of parameters of interest listed in Table 8 and Table 9 will be performed in accordance with MEL protocols (MEL, 2000). Nutrient analysis will include ammonia-nitrogen at all locations except the Fall City transects, and will include nitrate+nitrite nitrogen, total persulfate nitrogen, and orthophosphate at a few selected sites (see tables). According to the MEL manual (2000), the required reporting limits for laboratory data in Table 7 should be attainable through the analytical methods listed in Table 10. The MEL laboratory staff will consult the project manager if there are any changes in procedures over the course of the project, or if matrix difficulties are encountered.

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.

The project team will follow normal procedures for notification and scheduling. If laboratory-sample load capacities are filled, rescheduling of individual surveys may be negotiated.
All monitoring surveys will require close communication with the laboratory to ensure microbiological media and other laboratory resources are available.

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Table 10. Summary of sampling and analysis procedures for field and laboratory parameters

Analysis	Method[6] or Equipment	Estimated Range	Detection Limit	Holding Time	Preservation	Container	Estimated Samples/ Season/Site[7]	
Water Velocity	Marsh McBirney Flo-Mate 2000	0 – 6 ft/s	0.01 ft/s	N/A	N/A	N/A	Low-Flow	High-Flow
Stream gauge or tapedown	Standard gauge plates and tape measures	0 – 40 ft	N/A	N/A	N/A	N/A	13	13
Temperature	Alcohol thermometer	-10 – 40 deg C	N/A	N/A	N/A	N/A	5	0
pH	Orion Model 250B	4 – 9 [8] SU	N/A	N/A	N/A	N/A	7	7
Conductivity	Orion Model 125	1 uS/cm – 199 ms/cm in four ranges	1 uS/cm	N/A	N/A	N/A	7	7
Biochemical Oxygen Demand Inhibited (CBOD)	405.1/5210B	<3 - 30 mg/L	2 mg/L	48 Hours	Cool to 4 °C	1 gallon cubitainer	3	1
Chloride	300.0/4110D	0.1 - 200 mg/L	0.1 mg/L	28 Days	Cool to 4 °C	500 mL wide-mouth poly	See note below	
Ammonia	350.1/4500-NH3H	<0.01 - 20 mg/L	0.010 mg/L	28 Days	H_2SO_4 to pH<2, Cool to 4ºC	125 mL clear wide-mouth poly	13	13
Nitrate & Nitrite Nitrogen	353.2/4500-NO3*I	0.01 - 10 mg/L	0.010 mg/L	28 Days	H_2SO_4 to pH<2, Cool to 4ºC	125 mL clear wide-mouth poly	7	7
Total Persulfate Nitrogen	/4500-NB	0.025 - 20 mg/L	0.025 mg/L	28 Days	H_2SO_4 to pH<2, Cool to 4ºC	125 mL clear wide-mouth poly	7	7
Orthophosphate	/4500-PG	<0.005 - 0.5 mg/L	0.003 mg/L	48 Hours	Cool to 4 °C	125 mL amber wide-mouth poly	7	7
Fecal Coliform	/MF9222D	<1 - > 5000 cfu/100 mL	1 cfu/100mL	24 Hours	Cool to 4 °C	500 mL glass/poly autoclaved	13	13
Escherichia coli	1103.1/9221G1 [EC MUG]	<1 - > 5000 cfu/100 mL	1 cfu/100mL	24 Hours	Cool to 4 °C	500 mL glass/poly autoclaved	13	13

Note: Estimated number of samples from the Fall City transects for the first year is fifty each of fecal coliform, nitrate and nitrite nitrogen, and chloride.

[6] USEPA, 1983 /APHA, et al., 1998, 2000 (Standard Methods)
[7] Except Fall City transects
[8] The meter range is pH 1 – pH 14, but in practice will be three-point calibrated with nominal pH 4, 7, and 9 calibration standards.

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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. All samples will be analyzed at Manchester Environmental Laboratory (MEL) following standard quality control procedures (MEL, 2000). The laboratory's data quality objectives and quality control procedures are documented in the MEL Lab Users and Quality Assurance Manuals (MEL, 2000; MEL, 2001). The results of the laboratory quality control (QC) sample analyses should be used in determining compliance to the measurement quality objectives stated in Table 7. Variation for field sampling and analytical variation will be assessed by collecting replicate samples in addition to lab duplicates and comparing those data to data quality objectives. The laboratory QC data including check standards, replicates, spiked samples, and blanks will be appraised to determine if the measurement data quality objectives have been met.

Replicate samples will be collected at a rate indicated in Table 11. Bacteria samples tend to have high variability compared to other water quality analyses. Because of this, we will be collecting twice the usual number of field replicates for bacteria. We are not increasing the number of field duplicates at any one station during any one run; we are increasing the number of stations at which we collect field duplicates. This does not improve precision (n still = 2 for each station where we do a field duplicate); but it does mean we have a better overall estimate of variability – i.e., we will be more confident that our variability estimates are representative of the variability in the population, because we are testing it in a higher percentage of cases.

Acceptable precision for all parameters is listed in Table 7.

Table 11. Summary of field and laboratory quality control procedures

Analysis	Field Blanks	Field Replicates	Lab Check Standard	Lab Method Blank	Lab Replicates	Matrix Spikes
Field Measurements						
Velocity/Discharge	N/A	1/run	N/A	N/A	N/A	N/A
pH	N/A	1/10 samples	N/A	N/A	N/A	N/A
Temperature	N/A	1/10 samples	N/A	N/A	N/A	N/A
Dissolved Oxygen	N/A	1/10 samples	N/A	N/A	N/A	N/A
Specific Conduct.	N/A	1/10 samples	N/A	N/A	N/A	N/A
Laboratory Analysis						
Fecal Coliform (MF)	N/A	1/5 samples	N/A	1/run	1/5 samples	N/A
Escherichia coli	N/A	1/5 samples	N/A	1/run	1/5 samples	N/A
BOD	N/A	1/10 samples	1/run	1/run	N/A	N/A
Chloride	1/survey	1/10 samples	1/run	1/run	1/10 samples	1/20 samples
Ammonia-N	1/survey	1/10 samples	1/run	1/run	1/10 samples	1/20 samples
Nitrate/Nitrite-N	1/survey	1/10 samples	1/run	1/run	1/10 samples	1/20 samples
Total persulfate N	1/survey	1/10 samples	1/run	1/run	1/10 samples	1/20 samples
Orthophosphate	1/survey	1/10 samples	1/run	1/run	1/10 samples	1/20 samples

Field meters used in measuring water temperature, conductivity, and pH will be checked and calibrated against known standards at the start of each sampling day. Meter calibration will be performed in accordance with the manufacturer directions. DO meters will be calibrated by comparison to Winkler samples taken at the beginning, middle, and end of each sampling day. Field duplicate samples will be split at the laboratory to assess the variability in laboratory sample analyses.

Data Management Procedures, Audits and Reports

Laboratory Data

Procedures outlined in the Manchester Users Manual (MEL, 2000) will be followed for laboratory data reduction, review, and reporting. Laboratory staff will be responsible for internal quality control validation, and for properly transferring and reporting data to the project manager through the Laboratory Information Management System (LIMS). All water quality data will be subsequently entered into Ecology's Environmental Information Management (EIM) system. The project manager and principal investigators will review all the data for errors. Corrective measures will be taken to eliminate errors and validate the quality of the data. These data reviews will be performed on a quarterly basis and accordingly, adjustments with field or laboratory procedure or the measurement quality objectives may be made. Major changes will require notification of King County and QA Project Plan signature parties. The project manager may approve data that does not meet method quality objectives for use with appropriate qualification and consultation with the project team.

Laboratory Reports

The laboratory will report all results to the project manager within thirty days of sample delivery. The reports will include narratives, numerical results, data qualifiers, and costs.

Elevated fecal coliform densities (≥ 200 cfu/100 mL) will be reported to Ecology's Northwest Regional Office and the project manager in accordance with the EA Program's official notification procedure. All other data will be made available to the regional office for disbursement after quality control and EIM entry are completed.

Field Data

Field data will be entered into a Microsoft Excel® spreadsheet for later integration with laboratory data for data analysis and export to Ecology's LIMS data base. Data entry will be validated by an internal independent review of all entered data. Any found errors will be corrected. Data entry and validation will be performed by staff within Ecology's Environmental

Assessment Program. The project report will contain assessment of field data accuracy and completeness, and significant QA problems and corrective actions taken.

Project Report

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 will be made using Microsoft Excel® or other appropriate computer software.

Data Review, Verification, and Validation

Data Review and Verification

Manchester Environmental Laboratory (MEL) will review the QA Project Plan and all of the sample and quality control data. Reviews will be sent to the project lead in the form of case narratives and will include an assessment of MEL's performance in meeting the conditions and requirements set for in this sampling plan. Case narratives will also include a comparison of QC results with method acceptance criteria, such as precision data, surrogate and spike recoveries, laboratory control sample analysis, and procedural blanks. QC checks on instrument performance such as initial and continuing calibrations will also be noted. Results of standard reference material analysis will be reported along with certified values in the case narratives. MEL will explain flags or qualifiers assigned to sample results.

Data Validation

The project lead will examine the complete data package in detail to determine whether the procedures in the methods, SOPs, and QA Project Plan were followed.

Precision will be assessed by calculating relative percent differences (RPDs) for the following data:

- Field duplicates
- Duplicates from laboratory sample splits

Laboratory duplicates will yield estimates of precision obtained at the laboratory. Field duplicates will indicate overall variability (environmental + sampling + laboratory).

Bias will be calculated as deviations of mean% recoveries of surrogate spike and laboratory control sample analyses. Consistently low or high recoveries may indicate the data are biased in that direction. Wide ranges in recovery values may indicate data are of questionable accuracy,

but do not indicate bias in any particular direction. Matrix spike recoveries will indicate if bias is present due to matrix effects.
Completeness will be assessed through the following accounting:

- Number of samples collected compared to sampling plan
- Number of samples shipped and received at MEL and contract laboratories in good condition
- Ability of MEL and contract laboratories to produce usable results for each sample
- Acceptability of sample results by project lead

Data Quality Assessment

Data quality will be assessed to determine whether the project objectives have been met. The project lead will make this determination by examining the data and all of the associated quality control information. The project lead will be guided in this determination by the methods and procedures in this project plan. Other scientists familiar with this field may also be consulted. The project lead will continually assess field procedures and sampling conditions to assess subtle forms of bias. The project lead will review all field and laboratory data to uncover sources of bias which, if found, will be noted in the project report.

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