Quality Assurance Project Plan

Skokomish River Basin
Fecal Coliform
TMDL Attainment Monitoring

by
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Abstract

Since studies began in 1995, bacterial contamination has been found in the lower Skokomish River and its marine receiving water. Pathogenic threat is indicated by the presence of fecal coliform (FC) bacteria. Impaired or threatened beneficial uses include freshwater and marine recreation, domestic water supply, and shellfish harvest. While there have not yet been shellfish harvest restrictions, there is concern that there will be in the future. In all but one year since 1995, the state Department of Health has listed the Annas Bay commercial shellfish harvest area as threatened by FC contamination. The river and some of its tributaries exceeded state FC freshwater quality standards when the 1996 and 1998 303(d) federal Clean Water Act lists were compiled. Most streams in the lower Skokomish River basin must maintain FC levels well below Class AA freshwater criteria to protect marine waters and their beneficial uses.

The Department of Ecology began a Total Maximum Daily Load (TMDL) study in 1999 to determine the source areas of FC loading and to develop load allocations that would protect freshwater quality standards and help protect marine water quality standards. Water quality sampling was conducted with the assistance of the Skokomish Tribe from January 1999 through January 2000. The study identified percent reductions needed in FC concentration and loading at four sites. Additional sites are noted as needing to be monitored; the US EPA-approved TMDL lists eight sites for FC. The purpose of the study outlined in this Quality Assurance Project Plan is to evaluate attainment of bacteria target concentrations, percent reductions, and load allocations at the four stations identified in the TMDL study as requiring reductions. Sampling is scheduled every other week from January 2005 through November 2006 at these four sites plus one upstream reference site. This is a coordinated multi-agency, multi-program effort.

Background

The Skokomish River drains a basin of about 247 square miles (Seiders et al., 2001). The river discharges to Annas Bay in southern Hood Canal near Potlatch, Washington (Figure 1). Major sub-basins include the North Fork Skokomish River (118 square miles, including 99 square miles that are noncontributing most of the year) (Embrey and Frans, 2003), South Fork Skokomish River (104 square miles), and Vance Creek (25 square miles) (Seiders et al., 2001). The upper watershed has steep gradients, high-energy stream channels, and unstable alluvial streambeds (Embrey and Frans, 2003). The lower ten miles of the river pass through a broad floodplain, which is the primary area of residential and agricultural land use in the basin. The streams and springs in the lower valley contribute to several large wetland areas which then drain to the mainstem of the Skokomish River mostly downstream of Highway 101 at river mile (RM) 5.3. The river then discharges to the tidal estuary of Annas Bay and Hood Canal. Tidal influence to the river is thought to extend up to about RM 3.9, about 1.8 miles upstream of the Highway 106 bridge (Seiders et al., 2001).

Mainstem river flow ranges from about 200 cubic feet per second (cfs) (Seiders et al., 2001) up to the highest recorded daily flow of 30,000 cfs (Embrey and Frans, 2003). "Mean annual stream-flow for the Skokomish for 55 years of record through 1998 was 1,200 cfs, which was exceeded by annual stream-flows of 1,580, 1,500, and 1,320 ft3/s for water years 1996-98, respectively. In water year 1997, heavy rainfall on December 30, 31, and January 1 brought the river to a daily mean of 15,000 ft^3/s and over flood stage" (Embrey and Frans, 2003). The flow on March 19, 1997, was estimated to be 23,500 cfs (Embrey and Frans, 2003). The highest flow measured during any sampling event during the 1999-2000 TMDL study was 8,160 cfs (Seiders et al., 2001). The highest mean daily flows during the TMDL study were 14,100[e], 15,100, and 12,500 cfs on November 12 and December 16 and 17, 1999 (USGS, 2000).

Rainfall levels in the basin range widely from 75 inches per year near the mouth to about 230 inches per year at the crest of the Olympic Mountains near 6,000 feet elevation (Phillips, 1968). Much of the winter precipitation in the mountains accumulates as snowpack that provides runoff in the North and South forks through the spring and early summer months. The dry season runs from July into September, which is followed by a wet season in which more than 75% of the annual precipitation occurs between October and March. The US Geological Survey (USGS) attributes this pattern mostly to dam-mediated flow regulation of the North Fork Skokomish, which captures much of the snowmelt in reservoirs. The typical pattern for Puget Sound basin rivers with headwaters in the mountains includes two periods of high flows – one in fall and winter with the arrival of the rainy season, and one during spring snow-melt, with a low-flow period in late summer (August-September) (Embrey and Frans, 2003).

Weather systems moving across the basin during the wet season commonly alternate between cold and warm fronts. Snow deposited during cold fronts often melts during the passage of rainy warm fronts, thus increasing runoff and contributing to valley flooding. Numerous studies of this chronic flooding problem have been done since the 1940s and are summarized in the Mason County Skokomish River Comprehensive Flood Hazard Management Plan (KCM, 1997).

[e] Estimated

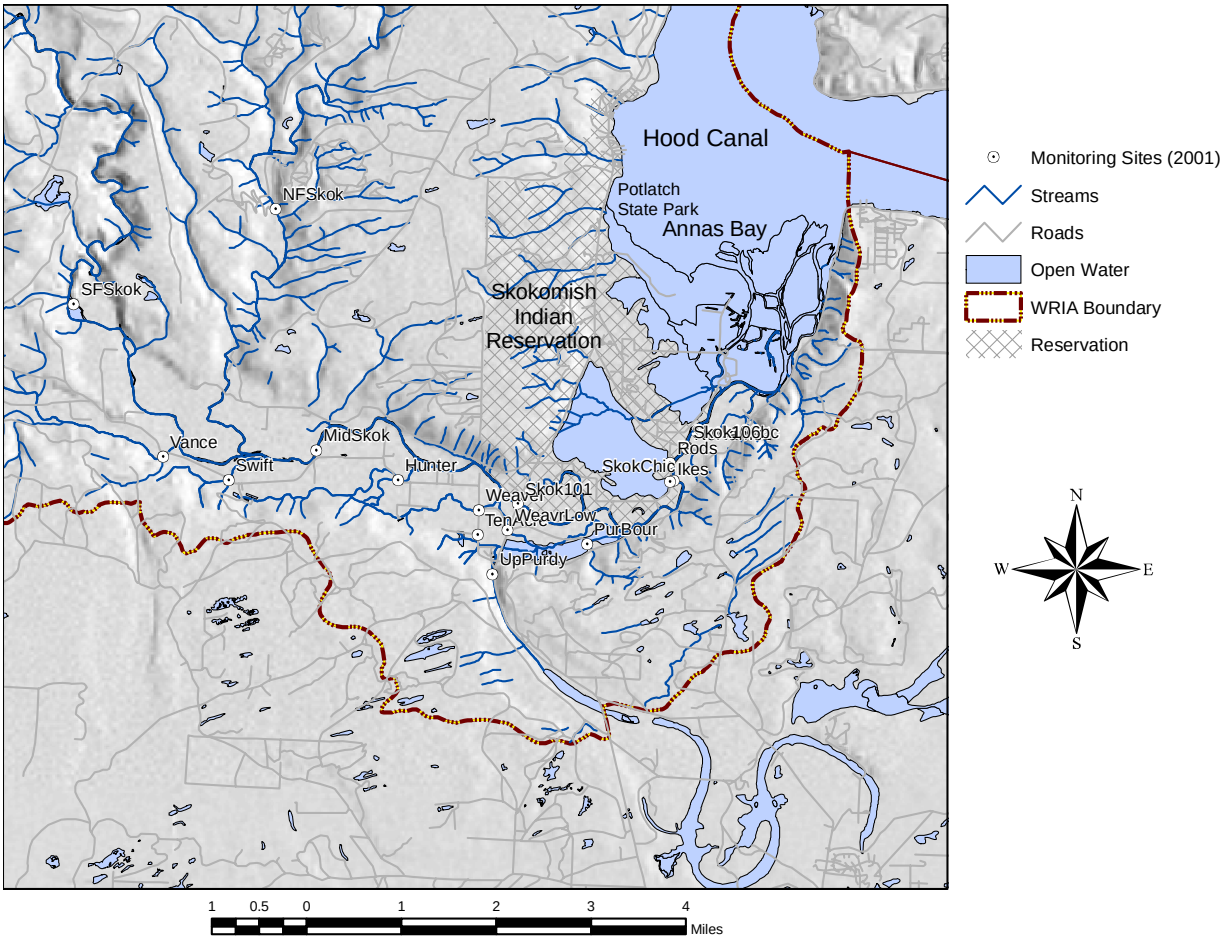

Figure 1. Sampling sites for the Skokomish River bacteria TMDL study.

Site name	Site description
SFSkok	South Fork Skokomish, 3 different sites downstream of USGS gage: RM 3.1, RM 2.7, RM 2.2
NFSkok	North Fork Skokomish, at old log road wet crossing, RM 12.5
MidSkok	Skokomish mainstem, right bank at Church Dike along W Skokomish Valley Road, RM 8.1
Skok101	Skokomish mainstem, center of Hwy 101 bridge, RM 5.3
SkokChic	Skokomish mainstem, left bank at Chico's Eddy, RM 2.5
Skok106b	Skokomish mainstem, right bank at Hwy 106 bridge, RM 2.1
Skok106c	Skokomish mainstem, center of Hwy 106 bridge, RM 2.1
Skok106	Skokomish mainstem at Hwy 106 bridge; combines data from Skok106b and Skok106c
Vance	Vance Creek, at W Skokomish Valley Road bridge
Swift	Swift Creek, (aka Vanice Creek on USGS map) at W Skokomish Valley Road bridge
Hunter	Hunter Creek, at W Skokomish Valley Road bridge
UpPurdy	Purdy Creek, at upstream of all hatchery intake structures
TenAcre	TenAcre Creek, at culvert under sideroad off of W Skokomish Valley Road
Weaver	Weaver Creek, at W Skokomish Valley Road bridge
WeavrLow	Weaver Creek, at W Bourgault Rd bridge
PurBour	Purdy Creek, at bridge on E Bourgault Road
Ikes	Ikes Creek, small creek draining wetlands, at bridge on Skokomish River Road
Rods	Rods Creek, small creek draining wetlands, at bridge on Skokomish River Road
NoName1	unnamed creek joins mainstem near site Skok106b; at logjam 30 yards up from mouth

Human activities have altered the natural hydrologic regime in the entire Skokomish basin. Forestry practices, road building, dikes, levies, and other land use practices have also caused an unnatural filling of the lower river channel with aggregate to over five times background levels. The effect has been an increase in the frequency and intensity of flood events, higher basin groundwater levels, and subsequent septic system failures (Barreca, 1998). Hydroelectric power generation diverts about 90 percent of the North Fork's flow and 45 percent of the mainstem Skokomish flow (KCM, 1997). This is achieved through Cushman Dam No. 1 creating a 4,000 surface-acre (453,000 acre-feet) lake, and diversion dam Cushman Dam No. 2, about two miles downstream, creating 70 surface-acre (8,000 acre-feet) Lake Kokanee. All flow but 30 cubic feet per second (cfs) is directed through a spillway to a power generating facility which then discharges directly to Hood Canal at Potlatch; flow in the lower North Fork Skokomish River is limited to the non-impounded 30 cfs, drainage of adjacent slopes, and rare releases or spills from the lower dam (EPA, 2004; Golder, 2002).

The Skokomish River basin is sparsely populated, rural in nature, and free of urban areas. The Skokomish Indian Reservation is located at the mouth of the basin. Land-use and many other regulations within the Reservation are under the jurisdiction of the Skokomish Tribe. Some of the land use is residential. Commercial and noncommercial agricultural activities occur in the lower river valley and include cattle and other livestock culture, hay and Christmas tree production, and some vegetable cropping. Silviculture within National Forest Service and privately owned lands dominate the upper basins. The upper reaches of the Skokomish River lie within The Olympic National Park. The North Fork basin includes the impoundment Lake Cushman, noted above. The shores of Lake Cushman have some residential development, and the lake is used for recreation (Seiders et al., 2001).

The varied resources of the lower Skokomish River area are shared by many groups. The Annas Bay estuary area contains a rich shellfish resource that is used by Tribal, commercial, and recreational harvesters. Recreational shellfish beds are located within, and to the south of, Potlatch State Park. Potlatch State Park is also a center of primary contact recreation, being used by swimmers and scuba divers. The mainstem Skokomish River and lower Vance Creek are also used by swimmers and waders during the summer months. The lower Skokomish River valley provides important habitat to a variety of terrestrial wildlife such as elk, deer, beaver, and waterfowl. The wildlife, shellfish, and fin-fish are important cultural and economic resources for the Tribe (Seiders et al., 2001).

The Skokomish River system provides valuable habitat for important species of fish such as chinook, coho, and chum salmon; steelhead; and various trout (Williams et al., 1975). Chinook salmon and summer chum in this basin are listed as threatened species under the Endangered Species Act (ESA). Bull trout reside in the South and North forks of the Skokomish River and are listed as threatened under the ESA (Seiders et al., 2001).

Three fish-rearing facilities comprise the only point sources of pollution in the study area. The first of these facilities was built in the 1940s, and all are located along the southern valley wall where nearby springs provide an ideal water supply for fish-rearing operations. Pollutant discharges from these facilities are managed under the Upland Fin-Fish Hatching and Rearing National Pollutant Discharge Elimination System Waste Discharge General Permit (Seiders et al., 2001). Pollutants monitored under this permit generally relate to settleable and suspended

solids; fecal coliform bacteria are not included since it has been documented that such operations are not a source of FC bacteria (Kendra, 1989).

Sources of FC pollution in the project area include humans, domestic animals, and wild animals. The domestic livestock population in the lower valley is estimated to include about 500 cattle, and a smaller number of horses, llamas, goats, and chickens (MCD, 2001). Estimates of wild animal populations (e.g. elk, deer, beaver, waterfowl, and other warm-blooded animals) were not obtained.

The Skokomish River mainstem, as well as its tributaries, are Class AA waterbodies. The associated water quality standard for fecal coliform bacteria is a geometric mean value (GMV) of 50 colony-forming units per 100 milliliters of water (cfu/100mL), with no more than ten percent of the samples used to calculate the GMV exceeding 100 cfu/100mL. However, since the Skokomish River empties into Annas Bay, the bacteria concentrations in the river affect water quality in the Bay. The TMDL study calculated target concentrations and loads based on protection of shellfish harvests in Annas Bay (Seiders et al., 2001).

Problem Statement

303(d) listing for fecal coliform bacteria

The 1998 303(d) list included eight sites in five waterbody segments in the Skokomish River watershed for fecal coliform bacteria: Hunter Creek, Purdy Creek (2 listings), Ten Acre Creek, Weaver Creek, and the Skokomish River (3 listings).

Ecology initiated a TMDL study in 1999 (Seiders et al., 2001). Water quality sampling, with the assistance of the Skokomish Tribe, was conducted from January 1999 through January 2000. The *Skokomish River Basin Fecal Coliform Bacteria Total Maximum Daily Load Study* was subsequently issued in April 2001. The report recommended Hunter Creek for de-listing, but it was included in the approved EPA TMDL. Based on the TMDL study recommendation, it is likely that Hunter will be de-listed during the current round of public review of the draft Water Quality Assessment, including the Section 303(d) List for 2002/2004, available for public review from November 3 - December 17, 2004 (Ecology, 2004). Other fecal coliform (FC) listings were confirmed. FC reductions recommended in the TMDL report were based on protection of shellfish harvest in Annas Bay, at the mouth of the river, making them more stringent than the Class AA freshwater standard that would otherwise apply.

Sites targeted for fecal coliform concentration and load reductions

The TMDL study indicated fecal coliform concentrations and loads needed to be reduced at the four sites indicated below (Table 1) (Seiders et al., 2001). Reductions were not determined at five other sites, and the remaining sites were designated as requiring no change from the study period. The TMDL study assumed that the target levels at the Skokomish River at Highway 101 should be met if upstream sites met or bettered their allocated loads. Purdy Creek at mouth is assumed to meet water quality standards if Purdy Creek at E. Bourgault Rd. meets target FC levels. These assumptions are not being tested. The TMDL study did not measure nonpoint

pollution between the Highway 106 bridge and the mouth of the Skokomish River at Annas Bay. The Skokomish River at the Bobby Allens site was not evaluated because of difficult access (Seiders, 2004), and is noted as needing monitoring to see if the site at least meets FC target values for the Skokomish River at Highway 106 (Seiders et al., 2001). This site location is approximately 1.1 mile north of the junction of State Hwy. 106 and Purdy Cutoff Rd., on the right bank of the Skokomish River (Kirby, 2004).

Table 1. Sampling locations for TMDL attainment monitoring

Sample site	TMDL ID	Latitude N	Longitude W
Hwy 106 bridge at center*	Skok106c	47.319608	123.138539
Purdy Creek	PurBour	47.304238	123.159728
Weaver Creek	WeavrLow	47.308621	123.184393
Ten Acre Creek	TenAcre	47.303506	123.183914
Middle Skokomish **	MidSkok	47.317164	123.221303

* Furthest downstream point of attainment ** Reference site
Latitude and Longitude are NAD27 coordinate system.

US EPA approved the Skokomish bacteria TMDL in the fall of 2001 (EPA, 2001). The TMDL lists five stream segments with waterbody ID numbers and eight locations within these five segments. The eight locations appeared on the 1998 303(d) list. Excessive sediment runoff and flooding are listed as concerns for evaluation by Ecology, but there is no requirement stipulated for assessment. As already noted, Hunter Creek has already been recommended for de-listing. There remain three other sites that are not included in the requested scope of work, but are on the 303(d) list and are listed on EPA's TMDL Approval: Purdy Creek at mouth, Skokomish River at Highway 101, and Skokomish River at Bobby Allens. Purdy Creek at mouth and the Skokomish River at Highway 101 must meet the class AA water quality standard, and monitoring is needed to see if the Skokomish River at Bobby Allens at least meets the target GMV for the Skokomish River at Highway 106, which is 18.5 MPN/100mL, and a 90th percentile not to exceed 67.7 MPN/100mL (Seiders et al., 2001).

Dissolved Oxygen

Ecology also monitored dissolved oxygen (DO) in study area streams because anecdotal evidence suggested that DO levels were below state water quality standards, and could potentially be limiting for salmon and other fish. During the study period, eight stream segments (seven streams) were found where DO did not meet the Class AA water quality standard criterion of 9.5 mg/L during one or more sampling events. DO was low at one site (TenAcre) every time it was sampled. Causes for depressed DO levels were not investigated during the TMDL study. Possible contributors to low DO include groundwater, wetlands, agricultural activities, and fish hatchery operations.

Flooding

The increasing frequency and intensity of flooding of the Skokomish River Valley is a recognized problem for many reasons including effect on water quality. The flooding problem is

being addressed through a variety of other local, state, and federal mechanisms and is not the subject of this TMDL effort. While it is recognized that flood events can affect water quality, non-flood related FC pollution requires attention. The TMDL study was designed to characterize the FC problem throughout a one-year period, which included a range of hydrologic conditions.

Follow-up work

Water cleanup planning began in the spring of 2002 (Hempleman, 2004a), and the Detailed Implementation Plan was completed in February 2003 (Hempleman, 2003). Implementation of watershed efforts began during the TMDL study. The primary water quality issue identified in the watershed was the need for agricultural best management practices (Hempleman, 2004a). Since the beginning of the TMDL study, a number of watershed improvement actions have been taken; these are detailed in the *Skokomish River Detailed Implementation Plan for Fecal Coliform Bacteria* (Hempleman, 2003).

Mason County has submitted a grant application to address, among other things, monitoring for the 303(d) listings in the Skokomish valley that are not being addressed by the TMDL attainment monitoring specified in this Quality Assurance Project Plan (Hempleman, 2004c).

The Skokomish Tribe has continued to monitor TMDL sampling sites, including Bobby Allens, since the TMDL study was conducted (Hempleman 2004b). Preliminary analysis of data from the points targeted for load reductions indicated the possibility that the watershed might have attained target reductions (Zentner, 2003) based on 2002-2003 measurements. However, target reductions do not appear to have been met at the four target reduction sites or at the Bobby Allens site during the most recent year (fall 2003 – fall 2004; n = 9 to 14 depending on site) except possibly at Weaver Creek. Of most significance to the downstream shellfish areas, target reductions were not met for either the target geometric mean value or 90th percentile value at the downstream river mainstem site at the Highway 106 bridge (analysis by this author)[1].

Project Description

General

The purpose of the current study is to evaluate attainment of the percent reductions and load allocations at four stations identified for bacteria concentration and load reductions in the *Skokomish River Basin Fecal Coliform Bacteria Total Maximum Daily Load Study* (Seiders et al., 2001). Because data collected during this study will be used by Ecology and Mason Conservation District to drive cleanup efforts during the monitoring period, no conclusions may be drawn as to whether targets were attained prior to this study. The study will evaluate whether the targets have been achieved in the presence of a monitoring program with a data feedback loop.

[1] Percentiles calculated using Microsoft Excel® and Systat® Weighted Average 2 percentile methods, and the NSSP (2003) percentile equation. All sites exceeded the target 90th percentile value using all methods, except for Weaver, which exceeded using Systat, but not Excel or the NSSP formula. The Weaver GMV was 16.5 – just below the target value of 17.5.

This is a coordinated multi-agency, multi program project, involving US EPA, the Washington state Department of Ecology (Ecology), Mason Conservation District (Mason CD), and Mason County. US EPA approved the TMDL and is funding Ecology's work on this project through a clean water act Section 319 grant. Ecology is funding Mason CD's work and Mason County's lab analysis though a Centennial Clean Water Fund grant. Mason CD will be doing primary field sampling and monitoring, with quality checks by Ecology doing some concomitant sampling. Ecology is defining the scope of the project, providing technical training and support to Mason CD, and doing the data analysis and final report. Ecology's Water Quality Program, Southwest Regional Office is coordinating the overall effort. Details of roles and responsibilities appear in the *Organization, Schedule, and Budget* section below.

Water quality samples will be collected at the sampling points given in Table 1. Spatial location of these sites is shown in Figure 2. An additional site is set at the MidSkok site, as a reference for downstream sites. Sampling will occur every other week, starting January 2005 and continuing through November 2006.

This is one of several monitoring projects in the Skokomish watershed. The Skokomish Tribe, Washington State Department of Health (DOH), Mason County, Mason CD, and Ecology have all conducted water quality monitoring at one time or another.

Establishing comparability of Mason CD data

Primary monitoring will be conducted by Mason Conservation District (Mason CD), via funding from a Centennial Clean Water grant issued by the Department of Ecology (Ecology). Concomitant secondary monitoring will be conducted at a lower frequency by the Environmental Assessment Program (EA Program) of the Department of Ecology, via EPA section 319 funding. Mason CD and Ecology samples will be collected at the same time, and gauges will be read at the same time. Flows will be measured as close together in time and location as possible. Samples collected by Mason CD will be delivered to the Mason County Water Quality Laboratory (Mason County Laboratory[1]) and analyzed for fecal coliform using the most probable number (MPN) method. Samples collected by Ecology will be sent to Manchester Environmental Laboratory for MPN analysis. Both parties will attempt sample delivery within the same time frame (i.e. same day, within six hours; or next day, within 24 hours); deviations will be noted when analyzing the data sets for bias.

Mason CD and Ecology data will be assessed for comparability to each other. Comparison criteria are: bacteria 95% confidence intervals overlap for each paired instance[2], flows no more than 10% RPD, and stream level no more than 3% RPD. For the entire data set at each site, root mean square coefficient of variation (RMSCV) expressed as percent should not exceed 50%[3]. Only FC MPN values greater than 10/100mL will be used for estimating precision within the

[1] Ecology's Laboratory Accreditation web site uses the title "Mason County Water Quality Lab". Laboratory staff refers to it as "Mason County Laboratory". For brevity, the latter term will be used throughout this report.
[2] The FDA table will be used by the laboratories for reading MPN tubes, but it does not list confidence limits. Standard Methods Table 9221.IV will be used solely for determination of confidence limits around the closest available value at a particular tube series in the FDA table.
[3] Consistent with Seiders et al. (2001)

complete data set[1]. When differences occur outside the bounds of acceptable variability, and results are not at or near the lower reporting limit, all parties will work toward discovering why the discrepancy exists, and will address any problems that are found. In cases where parameter values differ, and the cause of the difference can be identified, data that are considered to be more reliable will be used. In cases where parameter values differ, and the cause of the difference cannot be identified, the arithmetic mean of the values may be used; or the higher value may be used to be more protective. If a consistent unidirectional difference is found between the data sets, the relationship will be determined using regression, and adjustment may be used for analysis. Any adjustments that are made, including but not limited to averaging, value determination by regression, and data selection, must be reported.

Field specifics

Mason CD will install static gauges where possible and not already present, and where not possible or impractical, will use tape-down measurements from fixed points on bridges to record changes in stream height. Mason CD will also measure flow directly whenever safe by means of a portable in-stream flow-meter and wading-rod, and following the USGS stream-flow protocol. Depending on time and staff availability, Ecology's Stream Hydrology Unit may measure flow at some point during the high-flow period at the Highway 101 bridge, and if possible at the Highway 106 bridge. Flow-rating curves will be developed between gauges or tape-downs and measured flows. Further, flow relationships may be established between tributaries, and flow data from the USGS gauging station at the Highway 101 bridge may be correlated to project stream flows in order to estimate flows when they cannot be otherwise measured. Data will be provided to Ecology's headquarters Water Quality Program staff for entry into EIM.

Report and use of data

Freshwater Monitoring staff from Ecology's Environmental Assessment Program will produce a report after monitoring has been completed, to assess the data for attainment of the TMDL target reductions and with water quality standards. Because data collected during this study will be used by Ecology and Mason Conservation District to drive cleanup efforts during the monitoring period, no conclusions may be drawn as to whether targets were attained prior to this study. The study will evaluate whether the targets have been achieved in the presence of a monitoring program with a data feedback loop.

Data from other monitoring programs may be used by Ecology in concert with data from this study to guide cleanup efforts during and after this study. A portion of the workgroup which developed the Detailed Implementation Plan for this TMDL will continue to oversee implementation activities, and make adjustments to the focus of those activities as needed until the TMDL allocations are achieved.

[1] Consistent with Seiders et al. (2001)

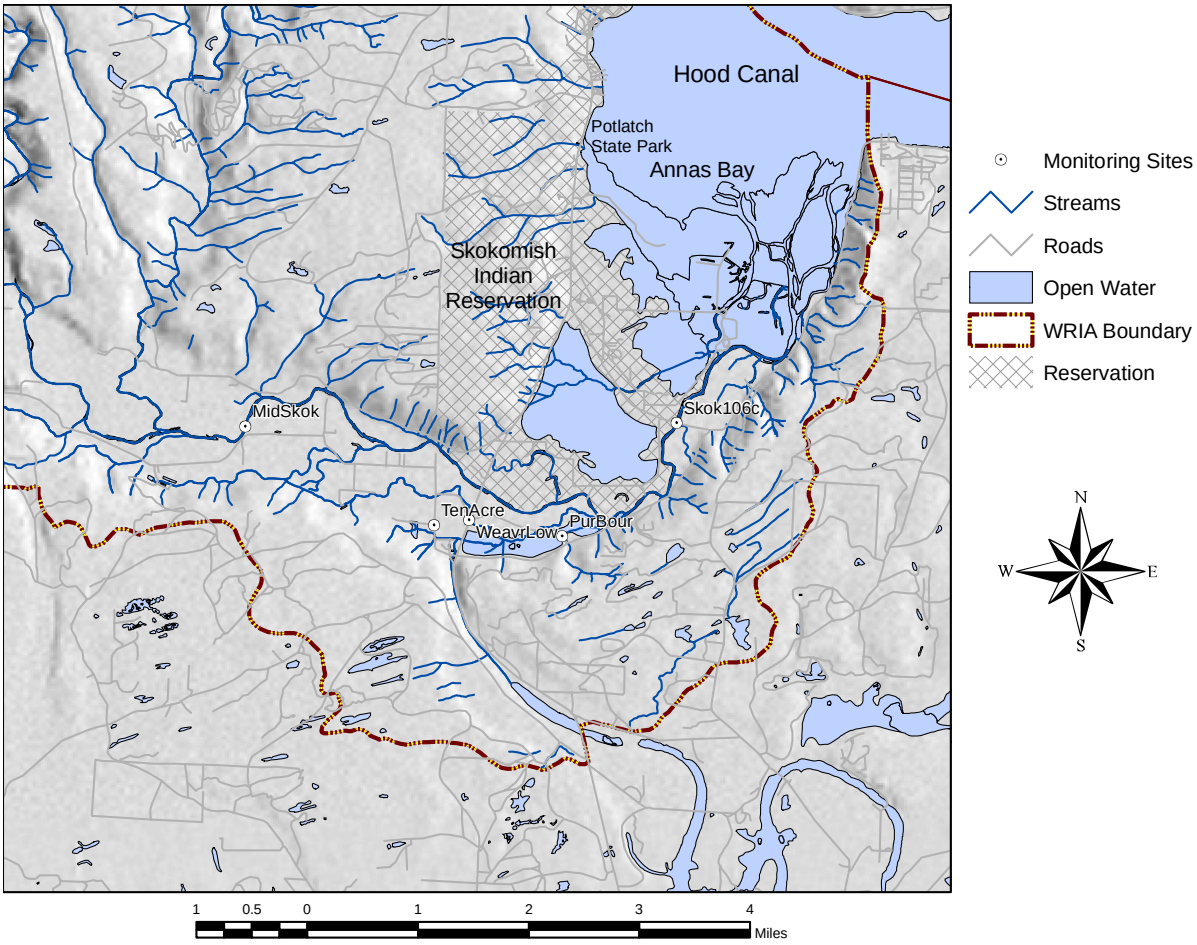

Figure 2. Skokomish River TMDL target fecal coliform reduction sites.

Water quality objectives

This study addresses fecal coliform concerns identified at four sites in the *Skokomish Basin Fecal Coliform TMDL study* (Seiders et al., 2001). Loads were calculated to protect shellfish harvesting in Annas Bay, assuming no FC inputs between the lowest sampling station on the river and where the river discharges into Annas Bay. Target concentrations, 90th percentiles, and load allocations are indicated in Table 2 below. 90th percentile values were calculated according to NSSP (2003).

Table 2. Recommended TMDL allocations

Monitoring Site	Study GMV	Study 90th Percentile	Target GMV	Target 90th Percentile	Target Percent Reduction	Target FC Load Allocation (/day)
Hwy 106 bridge	32.8	120.3	18.5	67.7	-44%	7.52E+11
Weaver Creek	55.0	314.6	17.5	100.0	-68%	5.86E+10
Ten Acre Creek	34.1	133.2	25.6	100.0	-25%	8.23E+09
Purdy Creek	54.3	146.6	25.7	69.4	-53%	1.16E+11

After reductions are achieved, Ecology, in accordance with its compliance monitoring strategy, will conduct follow-up monitoring on a five-year cycle to assure continued compliance with water quality standards and TMDL targets.

Constraints

This is a multi-agency, multi-program effort spanning over two years from initial scoping through final reporting. As documented in the 319-funded National Monitoring Program Totten-Eld report (Batts and Seiders, 2003), coordination of these kinds of projects presents challenges, because of the different goals of the different parties involved, and because of changes in program policies and staffs over time. For example, changes in funding at any layer may complicate the whole study e.g. if Mason County Laboratory were to close down part way through the project, or if project EIM data management resources are reduced. If data are not found to be comparable between the primary and concomitant sampling, Ecology may need to allocate more resources than budgeted to ensure reliable data.

Direct measurement of flow by wading is unsafe and unreasonable on the lower mainstem of the river during all but the lowest flow periods during dry years. Field staff should never consider lower mainstem flow measurement by wading except during the lowest flow periods. The upper mainstem may be safe to wade during low flows, but should not be waded if there is any doubt about safety. Tributaries are also likely to be too deep and/or swift at times for direct wading flow measurement. The overriding rule is that any time an individual feels at all unsafe, direct flow measurement by wading should not be done.

Sampling will need to be timed at the Highway 106 bridge to avoid high-tide influence on water depth relative to flow. That may affect time of day for other sampling. Samples will need to be collected early in the week to guarantee delivery to the analytical laboratories with enough time for analysis before the weekends.

Sampling may need to be cancelled or rescheduled because of inclement weather or flooding, creating hazardous driving or monitoring conditions, or because of illness or other unavailability of monitoring staffers. To do so regularly could impart bias in the final data. Runs may also need to be rescheduled for missed samples because of temporary road or bridge closures. Equipment failure in the field may cause loss of constituent monitoring at a few stations. Ideally, backup equipment will be available in the sampling vehicle or at a not too distant location to minimize this problem. Unlike weather, however, these occurrences, presumably, are random relative to water quality and will not affect long-term data analyses, except for potentially reducing the sample size.

If climate conditions turn out not to be typical of historical conditions, that may affect conclusions that can be drawn from the data. Further, hydrologic factors may affect the comparability of the data sets from the TMDL study and this attainment study.

Organization, Schedule, and Budget

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Additional Name Unknown (field assistant)

***Field sampling and monitoring and data collection*:** *Samples are to be delivered to the Mason County Laboratory for analysis. Field and laboratory data are to be compiled, evaluated for completeness and quality assurance, and delivered to Ecology's Water Quality Program, Southwest Regional Office (WQP-SWRO). Data will be submitted in electronic computer file format to:*

Clay Keown (360) 407-407-6533 ckeo461@ecy.wa.gov
with Cc to:
Christine Hempleman (360) 407-6329 chem461@ecy.wa.gov
and David Batts (360) 407-6447 dbat461@ecy.wa.gov

Photocopies of all paper data records including field notes and laboratory reports will be submitted to:

David Batts
Environmental Assessment Program
Washington State Department of Ecology
PO Box 47710
Olympia, WA 98504-7710
(360) 407-6447 dbat461@ecy.wa.gov

Mason County Department of Health Services
Mason County Laboratory
Mason County Building 3
PO Box 1666, Shelton, WA 98584

Carol Spaulding
Water Lab Manager
(360) 427-9670 ext. 580

Mason County Laboratory wil analyze samples collected by Mason Conservation District. Sample analysis will be by multiple-tube fermentation most probable number

(MPN) method, Standard Methods 20th edition [MPN 9221 E2]. Lab splits will be done with field duplicate samples. Analytical results including QA data will be sent to Mason Conservation District. This laboratory must maintain accreditation status for the measured parameter and matrix during the course of the study.

Washington State Department of Ecology
PO Box 47600
Olympia, WA 98504

David Batts
Freshwater Monitoring Unit
Environmental Assessment Program
(360) 407-6447
dbat461@ecy.wa.gov

Ecology's Environmental Assessment Program, Freshwater Monitoring Unit, will provide the project Quality Assurance Project Plan (QA Project Plan), provide technical assistance including monitoring training, will periodically perform concomitant sampling and monitoring to evaluate the quality of Mason CD's sampling and monitoring, and will produce the final TMDL attainment report for Ecology's SWRO.

Christine Hempleman
TMDL coordinator
Water Cleanup Unit
Water Quality Program
Southwest Regional Office
(360) 407-6329
chem461@ecy.wa.gov

Ecology's Water Quality Program, Southwest Regional Office, Water Cleanup Unit, TMDL coordinator will coordinate efforts between Mason Conservation District, Ecology's SWRO Water Quality Program, Water Cleanup Unit, and Ecology's Environmental Assessment Program, Freshwater Monitoring Unit.

Clay Keown
EIM data coordinator
Water Quality Program
(360) 407-407-6533
ckeo461@ecy.wa.gov

Ecology's Water Quality Program will provide necessary electronic data entry file forms to Mason CD and to Ecology's Environmental Assessment Program (EA Program), will instruct Mason CD as to data entry requirements, will receive electronic data from Mason CD and Ecology's EA Program for this project, will validate and verify data from MCD, and will enter these data into Ecology's EIM data base.

Stuart Magoon
Director
Manchester Environmental Laboratory
7411 Beach Drive E.
Port Orchard, Washington 98366
(360) 871-8801
smag461@ecy.wa.gov

Manchester EnvironmentalLaboratory will analyze project samples collected by Ecology. Sample analysis will be by multiple-tube fermentation most probable number (MPN) method, Standard Methods 20th edition [MPN 9221 E2]. Lab splits will be done with field duplicate samples. Analytical results including QA data will be sent to Ecology's EA program and Cc'd to Ecology's Water Quality Program, SWRO. This laboratory must maintain accreditation status for the measured parameter and matrix during the course of the study.

Schedule

Field activities

Fecal coliform sampling by Mason CD will occur every other week, starting at the beginning of January 2005, and continuing through November 2006. If sampling is prevented by flooding, but can be done the following off-week, the schedule may be adjusted accordingly; the reason for the shift in schedule should be recorded in the field notes. If sampling is cancelled because of sustained flooding, that will be noted, and sampling will resume as soon as possible once the flood has subsided. Gauges and/or tape-down measurements from bridges will be recorded upon each visit. Flows will be measured whenever possible and safe.

Concomitant sampling by Ecology should occur for each of the first four sampling events. Depending on comparability, concomitant sampling may be reduced to once a month. After the first six months, depending on comparability, concomitant sampling may be reduced to four events per year (quarterly). Ecology will do concomitant flow sampling at at-least one site during the first two sampling events, where it is possible to measure flows, or more sites if time and access allow, and will evaluate the necessary frequency of future concomitant flow measurement depending on comparability from the first event. Evaluation of comparability is discussed below under *Data Quality Objectives*, Table 3, and under subsection *Comparability*

Field data entry

Field notes will be entered in final written form on waterproof paper at the time the data are observed. Incorrect entries should be stricken through with a single line, and the corrected record should be placed on a new line. Data will be transferred to electronic form as soon as practical upon returning from the field.

Reporting field data and laboratory data

Submittal of electronic data and photocopies of field and laboratory data sheets will be submitted by Mason CD to Ecology quarterly, within 30 days following each quarter or the last sampling month. The electronic data will need to have been reviewed by Mason CD and found to completely agree with the original field and laboratory records. The first quarter starts January 1, 2005. The last sampling month is November 2006.

Analysis and reporting

Data analysis will commence following completion of monitoring and receipt of all data which have undergone quality assurance scrutiny. A final report will be completed within six months of receipt of all quality assured data. Assuming that all quality assured data will have been received by Ecology by December 31, 2006, the final project report should be produced by June 30, 2007.

Budget

Sampling duration	January 2005 through November 2006			
Mason CD lab and field work costs				
Projected number of sampling events	26 per year x 1.83 years	48		
Sites per sampling event		5		
Samples per sampling event (includes one field duplicate)		6		
Analyses per sampling event (includes one lab-split for quality assurance)		7		
Cost per analysis		$ 20		
			$ 6,720	Total Lab Cost
Labor cost per field run		$ 341	$ 16,368	Total Field Labor Cost
			$ 23,088	Total Lab and Field Costs
Ecology lab and field work costs				
Projected number of sampling events		15	(up to)	
Sites per sampling event		5	(up to)	
Samples per sampling event (includes one field duplicate)		6	(up to)	
Analyses per sampling event (includes one lab-split for quality assurance)		7	(up to)	
Cost per analysis		$ 39		
			$ 4,095	Total Lab Cost
EA Program				
Quality Assurance Project Plan				
Technical assistance to Mason CD				
Training Mason CD				
Concomitant sampling		0.35 FTE		
Data entry, QA, and analysis				
Final report				
WQ Program				
MCD Data coordination, QA and EIM data submittal		0.1 FTE		

Contingency lab cost for Ecology: If concomitant sampling is not comparable between CD data and Ecology data, and full sampling is needed by Ecology, the total laboratory cost for Ecology will be $13,104; and a higher FTE allocation will be needed for the additional field work.

Data Quality Objectives

Laboratory data reduction, review, and reporting will follow procedures outlined in the Manchester Environmental Laboratory (MEL) Lab Users Manual (MEL, 2003). These will be followed by Ecology, and should be followed by the Mason County Laboratory.

Bias

Adherence with established protocols should eliminate most sources of bias (Lombard and Kirchmer, 2001).

Precision

Relative percent difference (RPD) will be used for field duplicates, laboratory splits, and comparison between Mason CD (MCD) and Ecology (ECY) laboratory and field measurements. The levels of precision for this project are noted in Table 3.

Table 3. Measurement Quality Objectives

Parameter	Accuracy Deviation from True Value	Precision	Lower Reporting Limit
Fecal coliform Field duplicates and Lab splits	N/A	Raw (untransformed) data Each event; 95% CI from Standard Methods Table 9221.IV[1] Entire data set; 30% RMSCV[2]	1.8 MPN/100ml
Fecal coliform MCD-ECY comparisons	No difference between complete data sets ($\alpha = 0.05$)[3]	Raw (untransformed) data Each event; 95% CI from Standard Methods Table 9221.IV[4] Entire data set; 50% RMSCV[5]	1.8 MPN/100ml
Flow Field replicates and MCD-ECY comparisons	Single point reading Zero Stability: ±0.05 ft/s; ±2% of reading ± zero stability	Integrated stream-flow Relative Percent Difference Between Duplicate Samples 10%	0.05 ft/s
Gauge Field replicates and MCD-ECY comparisons	±0.01 ft	Relative Percent Difference Between Duplicate Samples 3%	N/A

[1] The FDA table will be used by the laboratories for reading MPN tubes, but it does not list confidence limits. Standard Methods Table 9221.IV will be used solely for determination of confidence limits around the closest available value at a particular tube series in the FDA table. Overlapping confidence intervals = acceptable precision.
[2] Root mean square coefficient of variation; consistent with Seiders et al. (2001) and Shannahan et al. (2004)
[3] If a consistent unidirectional difference is established, the relationship will be determined using regression, and adjustment may be considered for analysis. If adjustment is made, it must be reported.
[4] The FDA table will be used by the laboratories for reading MPN tubes, but it does not list confidence limits. Standard Methods Table 9221.IV will be used solely for determination of confidence limits around the closest available value at a particular tube series in the FDA table. Overlapping confidence intervals = acceptable precision.
[5] Root mean square coefficient of variation; consistent with Seiders et al. (2001)

Representativeness

Sampling design should provide samples that represent a range of water quality conditions. Employing consistent and standard sampling procedures will ensure individual samples are representative of the water conditions at the times and places they are taken. The time of day sites are visited will be determined by the logistics of getting all sampling done for each run in one day. No effort will be made to sample a particular location at the same time of day for repeat visits. It would be ideal to randomize the order in which sites are visited in order to reduce potential time-of-day bias at each site. However, this may be impractical for getting all sampling done in one day, and time of sampling may be constrained if tidal influence is a factor at any site (e.g. the Highway 106 bridge). Reverse flow in creeks, which represents backflow from the Skokomish River during flooding, will not be sampled. Case-by case judgment will be needed to determine whether out-of-bank floodplain sampling is representative of the main flow when the main part of the flow cannot be reached safely. If a sample is collected under this condition, a field note will be made to that effect. Any time a sample is not collected, a field note will be made for the reason.

Comparability

TMDL study and TMDL attainment comparability

Loading targets defined in the TMDL study (Seiders et al., 2001) were based on the most probable number (MPN) analytical method for bacteria. MPN is also used by the Washington State Department of Health (DOH) Shellfish Program in the marine receiving water. The MPN laboratory analytical method will be used in this study.

All samples will generally be collected on Monday or Tuesday, in order to get the samples to the laboratories in time for analysis before weekends. On weeks when Mason CD and Ecology are doing concomitant sampling, the preferred collection day is Monday, since Manchester Laboratory prefers sample delivery no later than Tuesday for MPN analysis. Delivery is preferred by 2:30 p.m. for same-day analysis setup. Accommodations can be made at Manchester Environmental Laboratory for later sampling if necessary.

The selected sites are a subset of sites sampled for the 2001 TMDL report.

Comparability between Mason CD and Ecology samples and monitoring

Comparability will be determined by the precision targets noted in Table 3. In cases where lab-split or field-duplicate results for both Mason CD and Ecology meet precision targets, comparison of Mason CD results with Ecology results should also meet precision targets. If they do not, judgment will need to be made as to which data are more reliable on a case-by-case basis; and an effort will be made to determine where the problem lies, and what corrective action to take. In cases where lab-split or field-duplicate results for either Mason CD or Ecology exceed precision targets, the project lead may judge RPD exceedences between Mason CD and Ecology not to be indicative of a problem, depending on the relative degrees of differences and how close

the values are to lower reporting limits. This is discussed in more detail above under *Project Description*, subheading *Establishing comparability of Mason CD data*.

Sampling Process Design (Experimental Design)

The intent of this study is to collect fecal coliform data at a high enough frequency and a long enough time span to perform the following analyses and obtain a reasonable level of confidence in the results:

- Measure percent change from conditions described in the 2001 TMDL report
- Measure statistical significance of percent change
- Measure whether target fecal coliform loading levels have been achieved
- Measure the statistical confidence level for target attainment
- Determine whether sites meet state water quality criteria

The sampling frequency and length of study are needed to generate enough data for statistical inference. Sample size is a compromise between budget limitations and statistical power analysis (see Appendix B). With the design sample size, if the target reductions are just met, the levels of significance will likely fall below the generally accepted value of α = 0.05, and be more in the neighborhood of 0.15, except for TenAcre, which will be more in the neighborhood of 0.35. This means there is likely to be between a 15% and 35% chance of declaring attainment when it has not occurred, depending on the site. However, if improvements exceed targets, the chance of making an error will be reduced. It is hoped that representative climatic conditions will be encountered during at least part of the study. As already noted under *Constraints*, if climate conditions turn out not to be typical of historical conditions, that may affect conclusions that can be drawn from the data, and hydrologic factors may affect the comparability of the data sets from the TMDL study and this attainment study. Data will be analyzed on moving average and seasonal bases in addition to annual and total composites compared to the TMDL data.

Laboratory Procedures

Laboratory analyses for fecal coliform bacteria will be performed in accordance with MEL (2003) protocols. Analytical method MPN 9221 E2 (*Standard Methods 20th edition*) will be used for this study with the following exceptions:

1. Holding temperature is to be between zero and four degrees C (per MEL).
2. Holding time is not to exceed 24 hours (per MEL)
3. The FDA MPN chart will be used, not the Standard Methods chart

Both laboratories will run a lab-split on each delivered field duplicate sample.

Field Procedures

Safety

No sample, gauge reading, or flow measurement is required any time field personnel feel that driving conditions, site access, or sampling conditions are unsafe for that site and parameter. Flow is the parameter that is expected most frequently to be unsafe to obtain; but ice, snow, flooding, or high wind may make it unsafe to access any or all sites at one time or another.

Sampling

Field sampling and measurement protocols will follow those described in *Sampling Protocols for River and Stream Water Quality Monitoring* (Ward et al., 2001) and *Field Sampling and Measurement Protocols for the Watershed Assessments Section* (Cusimano, 1993). Bacteria grab samples will be collected directly into pre-cleaned containers supplied by the laboratory and described in MEL (2003). Samples will be collected from the stream thalweg (center of flow) whenever possible. This may be achieved by in-stream wading, wading with a grab-pole to extend reach, or using a sampling-bucket to hold the sample container, lowered from a bridge by rope. Direct collection is preferred over bridge sampling whenever given a choice. Samples will be collected at approximately six inches below the surface of the water, with the sampler standing downstream from the collection point. Caution must be exercised not to stir up sediment in slow streams.

Each bacteria sample will be labeled, transferred to a cooler as soon as possible, placed in crushed or cube ice, and kept at greater than 0°C and no more than 4°C until the sample cases are opened by the laboratory. All samples will be received at the laboratory no later than 24 hours after collection.

Composite samples should be avoided except when absolutely necessary. If a sample is composited, sterile technique must be used, and the field notes must indicate that a composite has been made. The fact that the sample is a composite must be indicated in the appropriate EIM data base field.

Sampling should be timed to avoid tidal influence at the Highway 106 bridge. Reverse flow in creeks, which represents backflow from the Skokomish River during flooding, will not be sampled. Case-by case judgment will be needed to determine whether out-of-bank floodplain sampling is representative of the main flow when the main part of the flow cannot be reached safely.

Measurement

Flow

With the exception measurement of stream-flow using a meter during high flows, all parties will in general use sampling and measurement protocols described in *Field Sampling and Measurement Protocols for the Watershed Assessments Section* (Cusimano, 1993). Equipment has evolved some since this document was published. The following modifications and clarifications apply to this monitoring effort.

Wading

Only obtain direct flows by wading when safe. When using a digital readout meter, be sure the meter is set for ft/s before each reading. Use the flow integration setting (not the R/C setting), and set the time span for 20 seconds for smooth laminar flows. For more turbulent or otherwise uneven conditions where the readings do not stabilize in 20 seconds, set the integration time to 30 to 40 seconds as needed for stability. If relative percent difference between replicate total streamflow readings exceeds 10% for a particular site, increase integration time by 20 seconds on subsequent site visits at that location.

With the exception of very narrow streams, where horizontal distance between measurements is less than 0.1 ft., a minimum of 21 cross-sectional readings should be taken at each stream in order to obtain at least 20 segments. The number of reading-points at which measurements are taken should be between 21 and 30. An attempt should be made to space the readings so that no one segment will represent more than 10% of the overall stream-flow (5% is ideal) The operator should stand as far back and to the side as practical and possible from the wading rod, in order to not interfere with the flow of water at the measurement point.

Flow is to be measured at 0.6 depth when depths are below two feet, and at 0.2 and 0.8 depth when depths are equal to or greater than two feet. These two velocities are averaged to represent average vertical velocity. Velocity should decrease closer to bottom because of friction. If velocity at 0.8 depth is greater than velocity at 0.2 depth or if velocity at 0.2 depth is twice the velocity at 0.8 depth then the velocity profile is considered abnormal and the three-point method must be used. In this case, velocity is measured at 0.2, 0.6, and 0.8 depth; the 0.2 and 0.8 depth values are averaged, and this average value is averaged with the 0.6 depth value (arithmetic means).

High flows

When stream flows are too high to measure flows directly, Ecology and Mason CD field workers may use the high flow "float method" described in *Field Sampling and Measurement Protocols for the Watershed Assessments Section* (Cusimano, 1993). Oranges, not sample bottles, should be used for floats. Ecology's Stream Hydrology Unit will use its own protocols for meter-measurement of high stream-flow data on the Skokomish River at Highway 101 and Highway 106.

Field records

General

Field notes will be entered in tabular form on waterproof paper. Each sheet will include project name, date, name(s) of sampler(s), name(s) of recorder(s), project area (e.g. Skokomish Basin), WRIA, matrix type (e.g. water, sediment), source type (e.g. stream, lake), monitoring type (e.g. ambient, project monitoring). Not more than one date should be present on a sheet. Each record will include time, site ID, station name, sample ID, parameter(s), value(s), and comment(s). As part of its technical assistance, Ecology's Environmental Assessment Program, Freshwater Monitoring Unit, will provide templates for field data-entry forms including flow data-entry forms.

If a sample is collected under an unusual or extreme circumstance, e.g. during flooding, a field note will be made to that effect. Any time a sample is not collected, a field note will be made for the reason.

When an error is made in recording data, a single line is to be drawn through the record, and the correct data should be entered on the next line or in other adjacent available space. Do not erase or write over errors. If necessary, start or continue on a new sheet.

Flows

Flow records should include the model and serial number of the meter used. Flow integration time should be recorded, as should any comments regarding unusual flow readings (e.g. 'behind rock'). Stream flow is calculated by integration of stream cross-section segment flow data, and by use of flow:gauge or interbasin flow:flow rating curves. Flow rating curves are developed over the course of each sampling year, so calculated flows may only be available at the end of each year of monitoring. For flows calculated by regression, both the r^2 value and the regression equation will be reported.. For directly measured flows, in addition to integrated flow, both the number of segments measured, and the number of segments meeting minimum criteria (flow >= 0.05 ft/s and depth >= 0.18 ft) are to be reported.

Whenever a stream is out of bank, or whenever the Skokomish river is designated as at or above flood stage (16 feet), a note to that effect will be made in the field log.

Data qualifiers

Field notes must indicate when a composite has been made. The fact that the sample is a composite must be indicated in the appropriate EIM data base field; composites are not expected to be needed in this study. Any field estimate gets a qualifier code of "j" (lower case). This includes but is not limited to tape-downs under windy conditions, gauges that are difficult to read because of high or turbulent flow, and flows that do not meet the required number of segments (20) meeting minimum criteria (flow >= 0.05 ft/s and depth >= 0.18 ft). The comment field should include a note explaining the cause for the qualifier.

Quality Control Procedures

Field quality control

Site selection for all field duplicates will be random. Locations should be well identified, photographed, and written descriptions provided.

Bacteria

Total variability for field sampling and laboratory analysis of bacteria will be assessed by collecting duplicate samples at the rate of 20% of regular samples collected. This amounts to one field duplicate per run in this study. Duplicates will be collected as close together in time as practical. Field duplicates and lab splits whose 95% confidence intervals overlap will meet the single-event precision target. The FDA table will be used by the laboratories for reading most probable number (MPN) method tubes, but it does not list confidence limits. Standard Methods Table 9221.IV will be used solely for determination of confidence limits around the closest available value at a particular tube series in the FDA table. Acceptable precision for the total set of each agency's duplicate pairs will be percent root mean square of the coefficient of variation (RMSCV%) equal to or less than 30%[1]. For comparison of Ecology - Mason CD pairs, the precision target is RMSCV% equal to or less than 50%[2].

For MPN analysis, the same size bottle may be used for both regular samples and QA samples.

In general, follow directions in the field protocol manuals. Use the utmost care when handling bacteria sampling bottles to avoid sample contamination. Extra bottles should be brought on each run in case one or more bottles lose sterility during handling. Examples include dropping a cork or cap on the ground, touching the stream bed with the mouth of the bottle, or bridge debris falling in a bottle. Hand contamination, e.g. of a bottle lip or cap, must not occur. If in doubt, use another bottle. Always collect upstream from your body when sampling. If sediment has been stirred up during the first try and the water is moving slowly, gently move upstream beyond the sediment plume for the next attempt. If using a bridge sampler or grab pole to hold bacteria bottles, rinse it with de-ionized water before using it at a station.

Each bacteria sample will be labeled, transferred to a cooler as soon as possible, placed in crushed or cube ice, and kept between 0°C and 4°C until the sample cases are opened by the laboratory. Maximum holding time is 24 hours.

Flow

The flow meter will be factory calibrated at least once per year. The meter will be checked for single-point, zero-flow calibration prior to each sampling run, according to the manufacturers' instructions. One complete stream cross-section flow series (total stream-flow) should be duplicated per run, and the integrated flow calculated. Whenever possible, the duplicate should

[1] Consistent with Seiders et al. (2001) and Shannahan et al. (2004)
[2] Consistent with Seiders et al. (2001)

be done by a different person than the person who did the first series. A relative percent difference (RPD) no greater than 10% between integrated flows is considered to be acceptable. All flows including quality checks will be reported. When duplicate flows exceed 10% RPD, the flow will be qualified with a "j", and the comment field will note the RPD value. Both initial and duplicate values will be reported.

Gauge and/or Tape-down

Stream level is evaluated by recording gauge or tape-down measurement from a fixed point on a bridge. Locations should be well marked, photographed, and written descriptions provided. One field duplicate should be done per run. The duplicate should be read by the other field staff, rather than read twice by the same person. Both initial and duplicate values will be reported.

Laboratory quality control

Routine laboratory quality control procedures will be used. Both laboratories will run a lab-split on each delivered field duplicate sample. As noted above under Laboratory Procedures, laboratory analyses for fecal coliform bacteria will be performed in accordance with MEL (2003) protocols. Analytical method MPN 9221 E2 (Standard Methods 20th edition) will be used for this study with the following exceptions:

1. Holding temperature is to be between zero and four degrees C (per MEL).
2. Holding time is not to exceed 24 hours (per MEL)
3. The FDA MPN chart will be used, not the Standard Methods chart

Both Manchester Environmental Laboratory and The Mason County Water Lab are accredited by the Department of Ecology's Laboratory Accreditation Section to perform the specified analysis on non-potable water. Both are certified to participate in audits and interlaboratory studies by Ecology. The performance and system audits for both laboratories have verified the adequacy of the laboratory standard operating procedures, which include preventive maintenance and error reduction procedures.

Historical bacteria values have ranged from 1 < MPN < 1200, although this high end is an extreme value. Most samples have ranged from 1 < MPN < 300. Both labs are asked to do a sufficient number of dilutions to cover the larger range, in order to minimize the number of results reported at or above the reported value, and consequently "J" qualified.

Data Management Procedures

Field data will be recorded at the time of sampling, and maintained throughout the project to be eventually archived in project files. Details are noted above under Field Procedures / Field Records. Field data will be entered into spreadsheets for input into the Environmental Information Management (EIM) data repository.

Mason County Laboratory will submit project data and reports to Mason Conservation District. Reports should include an explanation of data qualifiers. As data are collected, compiled, and validated by Mason CD, the data will be delivered to Ecology's Water Quality Program, with a Cc to Ecology's project lead.

Data generated by Manchester Environmental Laboratory will be managed by the Laboratory Information Mangangement System (LIMS) and sent to the Ecology project lead in both electronic and hard copy formats. Reports should include an explanation of data qualifiers.

Mason CD field data will be recorded in a field notebook, using waterproof paper. All the data will be verified by Mason CD; i.e. reviewed for errors like missing decimal points and values that appear out of bounds because of ambiguous handwriting. The data will then be transferred into an electronic form provided by Ecology. A printout of the data will be checked by Mason CD against the field notebook for accuracy. Electronic data will then be forwarded to Ecology's Southwest Regional Office. The electronic data will be Cc'd to Ecology's Environmental Assessment Program, and copies of field data sheets and laboratory reports will be sent to Ecology's Environmental Assessment Program. Mason CD will keep copies of all original data and reports for a period of no less than seven years.

Ecology's Water Quality Program staff will enter received compiled electronic data into Ecology's EIM data base.

Ecology's field data will be handled in the same manner, except it will not be routed through Ecology's Water Quality Program.

After comparison of the analytical data to project measurement quality objectives, the reported results will be input into the EIM system. Data will be entered into spreadsheets for evaluation and presentation in graphical formats.

Audits and Reports

Mason County Department of Health Services Water Laboratory will submit laboratory reports, quality assurance (QA) worksheets, and chain-of-custody records to Mason Conservation District (Mason CD). Any problems with the analyses, corrective actions taken, or changes to the referenced method will be reported by the laboratory to Mason CD.

Manchester Environmental Laboratory will submit laboratory reports, QA worksheets, and chain-of-custody records to Ecology's Environmental Assessment Program (EA Program), Freshwater Monitoring Unit (FMU). Any problems and associated corrective actions will be reported by the laboratory to the FMU.

Documentation from both labs should include any quality control results associated with the data in order to evaluate the accuracy of the data and to verify that the quality objectives were met.

For both laboratories, results below the lower reporting limit of 1.8 MPN will be qualified with a "U". If either holding time or temperature is exceeded, a notation to that effect will be included in the laboratory report. Notation will be made for cause of any rejected analyses. Chain of custody records will be maintained by both laboratories.

Mason CD will submit copies of all laboratory reports, QA worksheets, and chain of custody records to Ecology's EA Program, FMU. Mason CD will also submit copies of all field data sheets and field data QA worksheets to Ecology's EA Program FMU.

Specific QA information that will be noted in the reports includes the following:

- Changes in monitoring, i.e., divergence from the QA project plan
- Results of performance and/or system audits
- Significant QA problems and recommended solutions
- Data quality assessment in terms of precision, accuracy, representativeness, completeness, comparability, and reporting limits
- Sample estimates and rejections
- Discussion of whether the QA objectives were met, and the resulting impact on decision making
- Limitation on use of the measurement data

Data Verification, Validation, and Review

Verification

Data verification involves examining the data for errors, omissions, and compliance with quality control (QC) acceptance criteria. Once measurement results have been recorded, they are verified to ensure that:

- Data are consistent, correct, and complete, with no errors or omissions
- Results for QC samples accompany the sample results
- Established criteria for QC results were met
- Data qualifiers are properly assigned where necessary
- Data specified in Sampling Process Design were obtained
- Methods and protocols specified in the QA Project Plan were followed

Qualified and experienced laboratory staff will examine lab results for errors, omissions, and compliance with QC acceptance criteria. Findings will be documented in each case narrative. Mason County Laboratory and Manchester Environmental Laboratory are responsible for verifying their respective analytical results. Analytical data generated by both labs will be reviewed and verified by comparison with acceptance criteria according to the data review procedures outlined in the Lab User's Manual (Ecology, 2003). Results that do not meet quality assurance requirements will be labeled with appropriate qualifiers, and an explanation will be provided in a quality assurance memorandum attached to the data package.

Field results should also be verified, whenever possible before leaving the site where the measurements are made. The field lead is responsible for checking to be sure that field data entries are complete, and to check for errors; e.g. flow-meter set to m/s instead of ft/s or decimal point missing from an entry. The field lead should be on the lookout for any entries that do not seem consistent with expected values; verification measurements may need to be made. Field duplicate measurements that can be easily repeated (e.g. gauge) should be checked against each other. Measurements that differ by more than the acceptable error limit should be repeated by both individuals, and the new values recorded and evaluated. If the difference is not a result of reading error, but is a result of rapidly changing conditions; e.g. a rapidly rising or falling stream, or a great deal of turbulence, a note should be made to that effect, and both values should be recorded for potential averaging.

Validation

Data validation will follow verification. Validation is parameter-specific, and involves a detailed examination of the data package, using professional judgment to determine whether the method quality objectives (MQOs) have been met. The project lead will examine the complete data package in detail to determine whether the procedures in the methods and procedures specified in this QA Project Plan were followed. Validation will entail evaluation of relative percent differences between field duplicates, lab splits, and comparisons between Mason CD and

Ecology field and laboratory results. Acceptable precision is outlined in Table 3. Bias is unknown, and will be addressed in the context of the sampling regimen.
Laboratory duplicates will yield estimates laboratory precision. Field duplicates will indicate overall variability (environmental + sampling + laboratory) in the case of bacteria or (environment + instrumentation + sampling) in the case of flow and stream gauge. Concomitant sampling between Mason CD and Ecology will indicate overall variability (environmental + sampling + between laboratory).

Review

It is vital that results be transferred accurately at each stage, including checking data that will be entered into the EIM system for accuracy. Ecology's Water Quality Program is responsible for entering Mason CD's field and lab results into Ecology's EIM data base. The individual tasked with that data entry is responsible for reviewing the data to be sure it is complete, consistent, and correct. Ecology's Skokomish project lead is responsible for reviewing Ecology's data prior to entry into EIM.

Data Quality (Usability) Assessment

Assessment

The data will be used to determine whether total maximum daily load (TMDL) targets have been met in the presence of a monitoring program with a data feedback loop. 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.

The project lead will review the laboratorys' data packages and data verification reports. The project lead will check these data and reports for completeness and reasonableness. Based on these assessments, the data will be accepted, accepted with appropriate qualifications, or rejected and re-analysis considered.

If measurement quality objectives have been met for all sampling episodes, the data will be considered acceptable for use except as qualified during the data review and validation process. The project lead will conduct a preliminary data review, which will consist of use of graphs to look for obvious data outliers.

Use

The data will be used to determine whether total maximum daily load (TMDL) targets have been met. This includes target geometric mean (GMV) and 90th percentile values, required percent changes, and target load allocations. GMV and percentile values will be calculated on moving average, seasonal, and annual bases. In order to be consistent with 90th percentile calculations used for the Skokomish TMDL development, the NSSP (2003) formula will be used. This is referred to as the "estimated ninetieth percentile", and is calculated using the following equation:

$$\text{Estimated } 90^{th} \text{ percentile} = 10^{\left(\bar{x}_{\log} + 1.28 \cdot S_{\log}\right)}$$

where

$S_{\log}$ = standard deviation of base 10 logarithms of raw values

$\bar{x}_{\log}$ = mean of base 10 logarithms of raw values

The value 1.28 is obtained from the standard normal distribution

Log values may but are not required to be rounded to three decimal places

There are a number of methods that are used for calculating percentiles, and they can yield different results; choice of the NSSP method is for consistency, not to set a precedent. The data will also be evaluated using the "*no more than 10% samples exceeding*" …. criterion in the fecal coliform standard (WAC 173- 201A). The more protective of these two methods will be used to

determine attainment of TMDL targets, in addition to the geometric mean requirement. Percent change will be calculated for annual and total composite data. Significance of percent change will be evaluated using univariate statistical methods; data will be evaluated for assumptions needed for parametric tests, and will be transformed if necessary. If assumptions are not met for parametric tests, a non-parametric method may be used. The commonly accepted significance level is $P \leq \alpha = 0.05$. Graphs including notched box-plots indicating 95% confidence intervals will be used to display data visually. A project report will be produced including data summary, findings, conclusions, and recommendations.

Continuous loading may be evaluated using one or more of the following: Beale's Ratio estimator, the method developed by Cohn et al. (1992), modified and described by Pelletier and Seiders (2000) and Ahmed and Sullivan (2004), or another estimator. Use or rejection of a tested estimator will be based on quality of comparison of predicted versus observed loads. The rationale for choice of estimator will be reported.

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Appendixes

Appendix A.

US EPA TMDL approval for the Skokomish River Basin

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
1200 Sixth Avenue
Seattle, WA 98101

OCT 16 2001

Reply To

Attn Of: OW-134

Megan White
Manager, Water Quality Program
Washington Department of Ecology
P.O. Box 47600
Olympia, Washington 98504-7600

Re: Approval of TMDL for the Skokomish River Basin

Dear Ms. White:

The U.S. Environmental Protection Agency (EPA) is pleased to approve the Skokomish River Basin Total Maximum Daily Load (TMDL) for fecal coliform in state waters submitted by the Department of Ecology on June 22, 2001, with the exception of those waters which are within Indian Country, as defined at 18 USC section 1151. There are five listed stream segments within this TMDL. Each of these segments was listed on the 1996 303(d) list. Each of these waterbodies was also listed on the 1998 303(d) list with the exception of Skokomish River at Rocky Beach, Skokomish River at Chico Eddy and Weaver Creek at E. Bourgault Road.

Waterbody	***Waterbody ID#***	***TMDL Parameter***
Skokomish River at Hwy. 106, Skokomish River at 101, Skokomish River at Bobby Allen's	WA-16-1010	Fecal coliform
Purdy Creek at E. Bourgault Road; Purdy Creek at mouth	WA-16-1013	Fecal Coliform
Weaver Creek at Skokomish Valley Rd.	WA-16-1014	Fecal Coliform
Ten Acre Creek at Campbell Lane	WA-16-1015	Fecal Coliform
Hunter Creek at West Skokomish Valley Road	WA-16-1016	Fecal Coliform

By EPA's approval, these TMDLs are now incorporated into the State Water Quality Management Plan under Section 303(e) of the Clean Water Act.

During the public comment period held last spring, concerns were raised by members of the public about excessive sediment runoff and flooding impacts. We note that the Skokomish River segments are not currently listed for sediments. EPA encourages Ecology to evaluate whether sediment loading is a problem in the Skokomish system that warrants further assessment.

We appreciate the commitment and hard work that went into the development of these TMDLs. If you have any questions or comments, please feel free to contact me at (206) 553-1261 or Martha Turvey of my staff at (206) 553-1261.

Sincerely,

Randall F. Smith
Director
Office of Water

Enclosure

cc: Jeannette Barreca, SWRO, Ecology
Kelly Susewind, SWRO, Ecology
Darrel Anderson, SWRO, Ecology

EPA Region 10 TMDL Review Checklist

State/Tribe: Washington
§303(d) Segment(s): Skokomish River, Purdy Creek, Weaver Creek, Ten Acre Creek, Hunter Creek
Pollutant(s): Fecal Coliform

Date of Submittal: June 22, 2001
Date Received by EPA: June 28, 2001
EPA Reviewer: Martha Turvey

Review Element	Required	Approved *(check if yes)*	Recommendations/Comments
Submittal Letter	**Yes**	Yes	None
Scope of TMDL	**Yes**	Yes	None
Applicable Water Quality Standards & Numeric Targets*	**Yes**	Yes	See attached memorandum
Loading Capacity*	**Yes**	Yes	See attached checklist
Wasteload Allocations (WLAs)*	**Yes**	Yes	See attached checklist
Load Allocations (LAs)*	**Yes**	Yes	See attached checklist
Margin of Safety (MOS)*	**Yes**	Yes	See atttached checklist
Seasonal Variation*	**Yes**	Yes	See attached checklist
Monitoring Plan for TMDLs under adaptive management	**Optional**	Yes	See attached checklist
Implementation Plans	**Optional**	Yes	See attached checklist
Reasonable Assurances	**If WLAs depend on LAs**		See attached checklist
Public Participation*	**Yes**	Yes	See attached checklist
Other Comments	**As necessary**		None

* These elements are required by statute and implementing regulations.

✔ Submittal Letter

Washington Department of Ecology submitted a final TMDL under 303(d) of the Clean Water Act for EPA to review and approve on June 28, 2001.

✔ Scope of TMDL

The TMDL addresses 5 water body segments identified in the 6/22/01 letter from Megan White, Ecology; which drain to Annas Bay in southern Hood Canal with the exception of those waters which are within Indian country, as defined as 18 USC section 1151. The segments are listed under Segments in the attached memorandum. Page 4-7 of the TMDL describes the land use features of the Skokomish River Basin and the pollutant sources. The Skokomish River Basin is primarily rural and low density residential whose upper reaches are within the Olympic National Park. The Annas Bay estuary contains shellfish beds that is used by a variety of harvesters. The Skokomish River system provides habitat for chinook, coho, chum salmon, steelhead and various trout. Chinook, summer chum and bull trout are listed as threatened under the Endangered Species Act. Sources of Fecal Coliform are determined to be from human, domestic animals and wildlife.

Total Maximum Daily Load (TMDL)

Skokomish River Basin Fecal Coliform Bacteria TMDL

April 2001

TMDL AT A GLANCE:

Basin:	***Skokomish River Basin***
Watershed Identifier:	***WA-16-1010,WA-16-1013,WA-16-1014, WA-16-1015, WA-16-1016***
Pollutants:	***Fecal Coliform Bacteria***
Key Resources:	***Chinook Salmon, Steelhead Trout, Coho Salmon, Chum Salmon***
Uses Affected:	***Shellfish Harvesting, Primary and Secondary Contact Recreation***
Sources Considered:	***NPS - Livestock Grazing, Human Recreational use, Wildlife***

Water Body	Pollutants Addressed
Skokomish River at Hwy 106	*Fecal Coliform Bacteria*
Skokomish River at Hwy 101	*Fecal Coliform Bacteria*
Skokomish River at Bobby Allen's	*Fecal Coliform Bacteria*
Purdy Creek at E. Bourgault Road	*Fecal Coliform Bacteria*
Purdy Creek at mouth	*Fecal Coliform Bacteria*
Weaver Creek at Skokomish Valley Road	*Fecal Coliform Bacteria*
Ten Acre Creek at Campbell Lane	*Fecal Coliform Bacteria*
Hunter Creek at West Skokomish Valley Road	*Fecal Coliform Bacteria*

✔ Applicable Water Quality Standards & Numeric Targets

See attached memorandum

✔ Loading Capacity

The Loading Capacity (LC) is presented in Table 2, page 9 of the Skokomish River Basin Fecal Coliform TMDL (Water Cleanup Plan), Submittal Report, June 2001.
The LC is described as the maximum daily FC load that the Skokomish River at Highway 106 could deliver to Hood Canal without causing a violation of marine water quality standards and is estimated to be 7.52 x 10 FC/Day. The approach used is described on page 25, of the TMDL, which was the same used to develop the Lower Skagit River TMDL Water Quality Study. It is based on the average salinity values found in the river and the average background FC concentrations found in the receiving waters. Accordingly, a Skokomish River GMV (geometric mean value) of 21.5 FC/100 ml, and 90th percentile of 67.7 FC/100 ml, would result in a FC GMV of 14/100 ml and a 90th percentile of 43/100ml when mixed with Hood Canal water to a salinity of 10 ppt. This would meet both marine and Class AA fresh water quality standards. The values represent a 34% and 44% reduction in the GMV and 90th percentile respectively.

My review has concluded that the LC of the TMDL is established at a level which if fully attained would lead to the attainment of the WQ criteria.

✔ Load Allocations (LAs)

The fecal coliform (FC) were derived after reviewing five different scenarios. These scenarios are described in Appendix D. The recommended load allocation is presented in Table 8 on page 32 of the TMDL. Load allocations for listed segments are significant, with a FC load along the lower mainstem corridor needing to be reduced by 66% in order for the Skokomish River at Hwy. 106 to meet its target value.
Non-303(d)- listed streams were given FC values in order to consider the effects on listed segments. The allocation scheme considered Skokomish Reservation land as well as non-Reservation land in its calculations. A separate allocation would need to be developed for each jurisdiction along the lower mainstem
Load allocations did not include wildlife contributions because it was beyond the scope of this study. In the future, if the wildlife contribution is determined to be significant, wildlife would be considered a natural source and given its own load allocation. This would result in a smaller load allocation to human related sources.

My review has concluded that the attainment of the load allocation will attain the Load Capacity and thus the Water Quality Standard consistent with the Clean Water Act requirements.

Wasteload Allocations: There are currently no point sources of FC or regulated stormwater discharges in the basin, please see page 2, Problem Description, Skokomish River Basin FC Bacteria TMDL Study, April 2001. No wasteload allocation is required.

✔ Margin of Safety (MOS)

The margin of safety is discussed on page 10, Skokomish River Basin Fecal Coliform TMDL Submittal Report. The conservative assumptions that were identified include the following:

* The mass balance calculation for fecal Coliform (FC) from the Skokomish River to Annas Bay uses simple dilution and disregards FC die-off in the marine waters.

* To do the mass balance calculation for FC, they used the arithmetic mean instead of the geometric mean. The arithmetic mean is not biased low and therefore provides a better margin of safety.

* They will use a rollback method which assumes a variance of the pre-management data set will be equivalent to the variance of the post-management data set. After pollution management efforts have been implemented, the frequency of high FC values will be less and thus reduce the variance and the 90th percentile of the post- management condition.

* Only Ecology data was used instead of combining Ecology and Skokomish Tribal data, because it provides greater protection.

* The North Fork Skokomish FC load is an overestimate because it is based on a higher flow (River mile 10.10) than that found at the actual sample site (River mile 12.5). Several tributaries enter the stream between the sample site and the point of flow measurement.

My review has concluded that the analysis adequately incorporates a margin of safety to account for uncertainty.

✔ Seasonal Variation

Seasonality was examined reviewing data plots by month over a wide range of time (see pages 19-22, Skokomish River Basin FCB TMDL Study, April 2001). The data suggested that the lowest fecal coliform (FC) levels occur during March and April. Various averaging periods were examined for sensitivity to violations of water quality standards (WAC 173-201A-060(3)). The averaging period for the TMDL analyses was chosen to be the 10 months from May to February which is as sensitive to water quality standards as shorter averaging periods and excludes the two months when fecal coliform concentrations are lowest. This TMDL applies to the entire year.

My review concludes that the analyses adequately incorporates the seasonal variation.

✔ Monitoring Plan

Ecology will apply an adaptive management approach to the basin TMDL strategy. They will annually evaluate monitoring results from Washington State Department of Health's Commercial Shellfish Growing Area Report for Annas Bay, from Ecology's Skokomish River monthly monitoring station and from the Skokomish Tribe's stream monitoring program. Ecology will determine if fecal coliform water quality standards are being met in non-reservation waters. If water quality objectives are not being met the load allocations may need to be adjusted. Also, the Department of Health will initiate a shellfish growing area downgrade which will trigger state, local, tribal agencies and other entities to develop strategies to improve water quality. Please see page 18 of the Skokomish River Basin FC TMDL Submittal Report.

My review has concluded that this is an acceptable approach to apply adaptive management strategies.

✔ Implementation Plans

Ecology submitted a Summary Implementation Strategy (SIS) discussed in the Skokomish River Basin FC TMDL Submittal report, June 2001 and presented in a separate document as a draft for public review dated April 2001. The SIS describes the activities conducted to date and the process by which a Detailed Implementation Plan (DIP) will be developed. The DIP is scheduled to be completed one year following the approval of the TMDL. According to Ecology records of the Public Meeting, ten citizens have volunteered to help develop the DIP. Ecology estimates that it will take five years for implementation efforts to reach the goals of the TMDL.

My review has concluded that this is an acceptable approach to development of a implementation plan.

✔ Reasonable Assurance

Since there are no point source discharges into the portion of the Skokomish River Basin covered by this TMDL, reasonable assurance is not required.

✔ Public Participation

Ecology's public involvement in the basin has been extensive. Please see Appendix A of the TMDL for a outline of the history. A public comment period was conducted from April 23 to May 23, 2001, for the draft TMDL. A public meeting was held on April 25, 2001, at the Hood Canal School in Potlach, WA. The responses to comments received were included in the Skokomish River Basin Fecal Coliform TMDL (Water Cleanup Plan), Submittal Report, June 2001. For more detail please see this section in the attached memorandum.

My review concludes that the public participation and documentation requirements (40 CFR Part 25) have been satisfied.

✔ Other Comments

Each of the required elements and assumptions of this TMDL are adequately identified and explained . The TMDL provides a clear basis to conclude that the allocations will achieve water quality standards and that information gathered in follow-up monitoring and studies will be used to further refine the TMDL.

Appendix B.

Number of samples required: statistical power analysis

Analysis is for target concentrations and loadings, where (concentration · flow) = loading. For meeting water quality standards, the maximum acceptable pollution concentration is fixed by the regulatory standard. Allowable loading is flow-dependent. For shellfish protection, allowable concentration is based on maximum acceptable loading in order to meet marine water-quality standards in the receiving water. One element of uncertainty in the total maximum daily load is a result of uncertainty in flow during the load determination phase.

Before / after analysis

We are interested in both percent change and the degree of significance of any change. The null hypothesis in each instance is that target percent reductions in concentration and loading have not been achieved. That would mean observed differences between the values measured for the TMDL and post-TMDL monitoring values are not statistically significant; i.e., the observed differences are no greater than might be explained by random variability alone. The alternative hypothesis in each instance is that one or more of the target pollution levels have been achieved or bettered. Sample-design needs to consider the probabilities and consequences of errors in comparing post-treatment concentration and loading to pre-treatment values. A type I error occurs when the null hypothesis is rejected, but should have been retained. In this case that would mean the target percent reduction in concentration or loading appears to have been attained (null hypothesis is rejected), but the observed difference is actually a result of random variability rather than real differences (null hypothesis should have been retained). Another term for this is "false positive"; i.e., change appears to have occurred, but it has not. In this case, there is a risk of declaring improved water quality when it has not actually occurred. A type II error occurs when the null hypothesis is accepted, but should have been rejected. In this case, a declaration of no significant improvement is made, when there really is one. Another term for this is "false negative". The risk in this case is that we may continue to spend money cleaning up a watershed that does not need it, diverting funds from other projects.

Post-TMDL comparison to target values

The null hypothesis in each case is that the post-TMDL concentration and loading is equal to or less than (no greater than) the TMDL target values. The alternative hypothesis in each case is that post-TMDL concentration or loading, or both, are greater than TMDL target values.

Error and sample size

Alpha (α) is the probability of type I error, and is called the level of significance; the lower the level of α, the lower the probability of making a type I error. Beta (β) is the probability of making a type II error. 1-β is the probability of rejecting the null hypothesis correctly, and is referred to as statistical *power*. An acceptable α level is pre-defined for a statistical hypothesis test; if the p-value of the test is equal to or less than the α value, the null hypothesis is rejected. The value $\alpha = 0.05$ is generally considered to be an acceptable level, but there is nothing absolute about this. If a p-value exceeds α; e.g. if a target 35% decrease in pollution appears to have been met, and the statistical test p-value is 0.07, we may declare that the reduction was not significant at the $\alpha = 0.05$ level, but that the specified percent change occurred with a 7% chance of a type I error in the determination. We cannot know what β is, and usually do not specify it;

but at any given sample size, α and β are inversely related, so specifying a smaller α level increases the probability of a type II (β) error; both types of error are reduced by increasing sample size (Zar, 1999).

If we consider follow-up monitoring compared to fixed values, sample sizes can be smaller than when we consider monitoring the differences between pre- and post-treatment periods. For monitoring between pre- and post-treatment periods, ideally sample sizes should be the same during both periods. When they are not, an upward adjustment needs to be made in the post-treatment sample size to compensate for the difference in sample sizes. Sample sizes are often restricted by budget limitations, and this is no exception. Statistical power analysis after Zar (1999) is used to determine the minimum number of samples required depending on risk of type I and type II errors; this includes adjusting for unequal sample sizes.

The data used for power analysis are from the Skokomish River TMDL study (Seiders et al., 2001). These include pre-treatment and target loading values, and the raw data from which original sample sizes, means, and variability were determined. Because the TMDL analysis was based on geometric mean values (GMV) for bacteria, this power analysis uses log loading values. Results are shown for both before-after design and for attainment of fixed values. As discussed earlier, use of the before/after analysis should yield the most rigorous results because of uncertainty in the original flow measurements.

If loading or concentrations are reduced beyond target values, fewer samples are required to demonstrate change in the respective parameters at any given significance level. Alternatively, given the number of samples obtained, the greater the improvement beyond the target level, or the lower the variability, the higher the significance. Sample size is a compromise between budget limitations and statistical power. If target reductions are just met, significance levels will not be as good as if target reductions are exceeded. If before/after analysis is used, project sample size is maintained, and Weaver just meets target reductions, error probability should be well within acceptable bounds. Under the same circumstances, error probability will be considerably higher at PurBour, Skok(106c), and particularly TenAcre (Table B-1). For these three sites there is likely to be between a 15% and 35% chance of declaring attainment when it has not occurred, depending on site. However, if improvements exceed targets, the chances of making decision errors will be reduced. For attainment of fixed values, the probabilities of error are lessened (Table B-2).

Table B-1. Samples needed for loading-attainment monitoring assuming uncertainty in target values. Comparison between before/after mean log (loading) values.

	PurBour	Skok	TenAcre	Weaver
α=.05 β=.05				
n for equal sample sizes (not applicable)	53	71	351	37
n_2 for follow-up sampling given n_1 for pre-sampling	N/A	N/A	N/A	N/A
α=.05 β=.1				
n for equal sample sizes (not applicable)	42	57	278	30
n_2 for follow-up sampling given n_1 for pre-sampling	N/A	N/A	N/A	N/A
α=.1 β=.1				
n for equal sample sizes (not applicable)	32	44	214	23
n_2 for follow-up sampling given n_1 for pre-sampling	N/A	N/A	N/A	**276**
α=.1 β=.15				
n for equal sample sizes (not applicable)	27	36	175	19
n_2 for follow-up sampling given n_1 for pre-sampling	**86**	N/A	N/A	**46**
α=.15 β=.15				
n for equal sample sizes (not applicable)	22	29	140	15
n_2 for follow-up sampling given n_1 for pre-sampling	**35**	435	N/A	**20**
α=.15 β=.2				
n for equal sample sizes (not applicable)		24	115	
n_2 for follow-up sampling given n_1 for pre-sampling		**60**	N/A	
α=.2 β=.2				
n for equal sample sizes (not applicable)		19	93	
n_2 for follow-up sampling given n_1 for pre-sampling		**26**	N/A	
α=.3 β=.3				
n for equal sample sizes (not applicable)			37	
n_2 for follow-up sampling given n_1 for pre-sampling			N/A	
α=.35 β=.35				
n for equal sample sizes (not applicable)			20	
n_2 for follow-up sampling given n_1 for pre-sampling			**60**	
α=.37 β=.37				
n for equal sample sizes (not applicable)			15	
n_2 for follow-up sampling given n_1 for pre-sampling			**20**	

The target number of samples to be collected is 26 the first year and 22 the second year, for a total of 48 sampling events per site. Bold numbers bracket this sample-number target. N/A means the adjustment formula resulted in a negative value, so it is not applicable.

Table B-2. Samples needed for loading attainment monitoring if there were no uncertainties in target values. Comparison to a fixed log (loading) value.

		PurBour	Skok	TenAcre	Weaver
α=.05	β= .05	27	37	182	19
α=.05	β=.1			140	
α=.1	β=.1			108	
α=.1	β=.15			88	
α=.15	β=.15			71	
α=.15	β=.2			58	
α=.2	β=.2			47	
α=.2	β=.25			40	