# QUALITY ASSURANCE PLAN

**for the**

# TILLAMOOK BAY NATIONAL ESTUARY PROJECT

## RIVER WATER QUALITY MONITORING PROJECT

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## I. BACKGROUND AND PROJECT OBJECTIVES

Tillamook Bay has a long history of bacterial pollution problems (Blair and Michener 1962, Jackson and Glendening 1982, Musselman 1986, Oregon Department of Environmental Quality 1994) and of programs to address those problems. In the early 1980's, the Oregon Department of Environmental Quality (Oregon DEQ) had a federal grant under section 208 of the Clean Water Act, which created the Rural Clean Water Program (RCWP), to identify bacterial sources to the bay and to develop a fecal coliform management plan for the watershed. The Agricultural Stabilization and Conservation Service received federal funding through the RCWP to provide cost sharing for farmers to adopt better management practices and to construct the facilities to do so. Despite progress in these efforts to restore water quality, both fresh and saline waters in the Tillamook Basin often don't meet water quality standards.

Through the RCWP during the 1980's, major bacterial sources were identified and various measures taken to decrease bacterial pollution. The RCWP provided over $6 million in cost-share money to improve manure management facilities on dairy farms. Many wastewater treatment plants and septic systems were also upgraded during this time period. While these efforts resulted in improved management practices in the region (Arnold et al. 1989, Dorsey-Kramer 1995), bacterial contamination still causes water quality violations in Tillamook area rivers and streams, and elevated levels in Tillamook Bay during and after storm events.

Water quality bacteria standards for recreational contact and shellfish growing waters differ; but standards in both fresh water and the bay have long been violated in the Tillamook Watershed (Jackson and Glendening 1982). The bacteria standard for recreational contact applies to both fresh and saline waters and is intended to protect people in contact with water such as swimmers. The shellfish standard is much more stringent, as it is designed to protect people from pathogens which might be consumed with raw shellfish.

Bacterial problems often close harvesting in Tillamook Bay, which has been one of Oregon's leading producers of shellfish, particularly oysters. Oregon has adopted the water quality standards for bacterial and other pathogens in estuarine water set by the federal Food and Drug Administration (FDA) for interstate commerce (U.S. Dept. of Health and Human Services 1995). Bacterial concentrations in the bay have historically been high during the wet seasons of the year: fall, winter, and early spring. Due to the bay's unpredictable water quality, the proximity of five wastewater treatment plants to the bay, and many nonpoint sources of bacteria and viruses, oyster culture is allowed only in specified areas of the bay, and harvesting is allowed only under certain conditions, as identified in the shellfish management plan for Tillamook Bay (Oregon Department of Agriculture 1991).

Bacterial concentration is an important water quality parameter identified as a priority problem by the National Estuary Project. However, Tillamook Basin waters also have other water quality problems. Temperatures in the lower reaches of some of the rivers exceed water quality standards and may affect salmonid habitat in those reaches during part of the year. Nutrient levels are currently low to moderate in the Tillamook Basin. These are of concern, nevertheless, since estuarine eutrophication is an increasing problem nationwide (National Oceanic and Atmospheric Administration 1996). The causes of many of these problems are related. Nutrients accompany human and animal wastes, as do bacteria, so controlling bacteria will likely affect nutrient loads as well. Stream temperature is related to the loss of shade, the loss of riparian habitat and possibly thermal pollution from wastewater treatment plant effluents. Buffer strips along streams both improve riparian habitat and decrease overland runoff of nutrients and bacteria. Therefore, the National Estuary Project is addressing these problems concurrently.

Section 303(d) of the federal Clean Water Act requires the Oregon DEQ to list water quality impaired water bodies for the entire state. A water body is "water quality impaired" when it violates the State's water quality standards, either numeric or narrative. In the Tillamook Bay area, only fecal coliform and water temperature are sufficiently documented as a basis for listing water bodies. Fecal coliform levels commonly exceed the recreational contact standard in the streams and rivers and exceed both the recreational standard and the shellfish harvest standard in the bay. Freshwater values occasionally exceed 12,000 cfu/100 mls and estuarine values exceed 1,600 cfu/100 mls. The Tillamook River is listed for water contact recreation (fecal coliform) from the mouth to headwaters, and also conditionally listed as a water body of concern for temperature, sediment, nutrients, and habitat modification (Oregon 303d list). Portions of the Miami, Kilchis, Trask, and Wilson Rivers are also listed for temperature.

High water temperatures in Tillamook Bay Basin violate water quality standards. During the summer of 1995, the water temperature standard applicable to the Tillamook Bay Basin was exceeded in both the Trask and Wilson River basins. The seven-day running average maximum temperature reached 70.8$^{o}$F in the lower Trask River, and 69.5$^{o}$F in the lower Wilson River, leading to the inclusion of these lower river reaches on the 1996 303(d) list of water quality impaired waters[1]. However, the 1988 Nonpoint Source Assessment identified temperature as a concern in the Tillamook River and temperature measurements from grab samples collected in the recent monitoring study (Sullivan et al. 1998a) reached near 70EF in the Tillamook River, so it should be evaluated further.

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[1] The temperature monitor deployed in the lower Tillamook River was stolen, so similar data are not available for the Tillamook River

Several stream reaches in the Tillamook Basin were evaluated as being "of concern" for aquatic habitat, flow modification, and sediment. This evaluation was based on data from state and federal agencies, described in the 1988 Oregon statewide Assessment of Nonpoint Sources of Water Pollution (Oregon DEQ 1988). Quantitative data are needed to describe the extent of the problems. The DEQ listed these waters as water quality impaired (the 303(d) list), but classified them as needing more information.

The Oregon Departments of Agriculture and Environmental Quality are charged with developing management plans for all of the water bodies on the 303(d) list. The Department of Agriculture has established priorities for management plan development, and has included the Tillamook Watershed in Tier I of that list. The watershed is also in Tier 1 for ODEQ's development of total maximum daily load (TMDL) allocations.

The Tillamook Bay National Estuary Project (TBNEP) was initiated to develop a comprehensive conservation management plan for Tillamook Bay. The project has identified bacterial contamination and sedimentation as two of the priority problem areas under consideration. Recent research has also indicated that temperature, and to a lesser extent, nutrient concentrations, are important water quality parameters that need to be monitored.

The purpose of this monitoring project is to continue water quality monitoring on four of the major river systems that flow into Tillamook Bay. Concentrations of nutrients (TKN, $NO_3^-$, $NH_4^+$, total P), total suspended solids (TSS), and fecal coliform bacteria (FCB) will be investigated by conducting a bi-monthly monitoring program for nutrients and a storm-based monitoring program for TSS and FCB. The monitoring will continue for one year. This research is intended to provide continued detailed information on current water quality conditions at the primary monitoring site in the lower reaches of each of the rivers throughout an annual cycle, and to quantify seasonal and episodic variability in that water quality. The research will also provide quantitative estimates (first approximation) of bacterial and sediment loads from each of the rivers to the bay throughout a one-year period. The data collected within this project will be added to the TBNEP water quality database. It will be analyzed, together with recently acquired monitoring data and temperature data to be collected by the Tillamook Bay Watershed Council.

## II. RECENT AND ONGOING MONITORING EFFORTS

From November 1996 to March 1998, E&S Environmental Chemistry, Inc., under contract to TBNEP, conducted a water quality monitoring effort throughout the basin. It included regular monitoring for fecal coliform bacteria (FCB), total suspended solids (TSS), nutrients, and temperature in each of the five rivers that flow into Tillamook Bay. In addition, intensive storm sampling (especially for bacteria) was conducted during six rainstorm events.

The purpose of this project was to provide critical information needed to design a rigorous water quality monitoring program and to assist in preparing the Comprehensive Conservation and Management Plan (CCMP) for the watershed. Results of this study were reported in two companion reports to TBNEP (Sullivan et al. 1998a, b). The first report presented the annual overview results and general watershed characterization. The second report presented the results of the storm sampling and the loading estimates. Additional storm sampling has been conducted during the fall of 1998.

**General Watershed Characterization**

Fecal Coliform Bacteria

The Tillamook River has consistently had the highest FCB concentrations (Figure 1), with the Kilchis River having the lowest. TSS concentrations were highest in the Trask and Wilson Rivers, corresponding to the rivers with the largest watersheds and highest flows. Conversely, TSS concentrations were lowest in the Tillamook River, which has the smallest watershed area and lowest flows of the five rivers. Inorganic nitrogen concentrations were similar among sites and low relative to values observed in other parts of Oregon (e.g., Wentz et al. 1998). Total phosphorus concentrations were highest in the Wilson River and the lowest in the Tillamook River, but again were not particularly high relative to other sites in western Oregon (Wentz et al. 1998), although frequently higher than the 0.1 mg/L maximum value recommended by U.S. EPA (1986) as a goal for prevention of nuisance plant growth in streams.

Fecal coliform bacteria concentrations were variable from river to river, ranging from 0 to 3700 cfu/100 ml at the downriver primary sites. The range for the secondary sites representing the forest/agriculture interfaces was much narrower, from 0 to 500 cfu/100 ml.

Seasonal differences in FCB concentrations were observed at all of the primary sites. At the Tillamook and Trask River primary sites, which were sampled most intensively of the five rivers, the highest bacterial concentrations were observed during the storm event of early October, 1997. Many samples were measured during that storm in excess of 500 cfu/100 ml. High bacterial concentrations (>500 cfu/100 ml) also were recorded for the Tillamook, Trask, and Wilson Rivers during small summer rainstorms and during one winter storm in the Wilson River. High values were also recorded in the Kilchis and Miami Rivers during summer and fall storms, as compared with other seasons, but the concentration in those rivers seldom exceed 500 cfu/100 ml.

In all cases, small summer storm events caused greater increases in FCB concentration than larger more intense storms in the winter and spring months. This suggests that the antecedent moisture conditions and/or length of the dry period preceding the storm may play significant roles in

controlling fecal coliform contributions from the watersheds to the rivers and/or that dilution of FCB sources occurs during the larger storm events.

Measured concentrations of FCB at the forest/agriculture interfaces were always less than 500 cfu/100 ml and only 2 out of 42 samples had fecal coliform concentrations higher that 100 cfu/100 ml (both on the Trask River). On a number of sampling occasions, paired samples were collected within a few hours or less of each other at a primary site and its respective forest/agriculture interface on the various rivers. Concentrations were generally higher at the primary sites as compared to the respective forest/agriculture interface site. In many cases, the concentration of FCB was dramatically higher at the downstream primary site.

Temperature

Water temperatures at the time of sample collection generally ranged between about 8E and 18°C to 20EC at the primary site on each of the rivers. Peak temperatures were observed in August in all of the rivers, and reached fairly high values in the Tillamook, Trask and Wilson Rivers. Measured August temperature in each was near 20EC, considered to be in the range of stressful to lethal temperature conditions for salmonids. The Oregon DEQ also conducted temperature monitoring in each of the river basins during the summers of 1997 and 1998. Routine monitoring data would be useful to document the temporal and spatial duration of high temperature that occurs in these rivers.

Nutrients

Total inorganic nitrogen concentrations (TIN; $NO_3$-N + $NH_4$-N) were generally near 1 mg/L (± 0.2 mg/L) in all rivers (Figure 3). Limited data from the forest/agriculture interface sites showed similar patterns. Paired sample analyses between the primary and forest/agriculture interface sites showed there was relatively little contribution of TIN to the rivers from the lower agricultural portions of the watershed. Concentrations of TIN were reduced during summer and higher during winter. This was likely due to greater biological demand for N in the aquatic and terrestrial systems during summer months.

Total phosphorus (TP) concentrations in all of the rivers were typically less than about 0.1 to 0.2 mg/L, except during storms when the concentrations sometimes exceeded 0.5 mg/L (Figure 4). Total phosphorus at the forest/agriculture interfaces exhibited similar patterns although concentrations were often slightly lower than at the primary sites. The rivers with largest watersheds (Trask and Wilson), during periods of the highest flows, tended to have the highest TP concentrations and the river with the lowest flows and smallest watershed (Tillamook) had the lowest TP concentrations.

**Storm Sampling**

There were several objectives to the storm sampling efforts reported by Sullivan et al. 1998b. This component of the study was designed to investigate and quantify episodic variability in the concentrations of FCB, TSS, and nutrients during storm events that occur during the rainy season in the Tillamook watershed (about October to March). An additional objective was to estimate the storm-based loading of each of these parameters to the bay in an effort to differentiate among the five rivers regarding their relative contributions of various pollutants to Tillamook Bay.

Prior to and during the course of the general monitoring efforts, it became increasingly clear that FCB contamination was a widespread problem throughout the basin, with highest concentration in the Tillamook River, and highest loads in the Trask and Wilson Rivers. The source of this FCB was expected to be variable, with the primary contributions presumed to include dairy operations, septic systems, sewer treatment plants, and urban land use. The storm monitoring effort was expanded in the fall of 1997 to include intensive sampling during two storms at about 30 sites on the Tillamook and Trask Rivers by E&S. One fall and one winter storm were selected for this component of the study. The principal objective of the intensive storm monitoring was to quantify the major contributing areas of bacterial loads along these river systems in order to allow evaluation of land use/bacterial load interactions. An additional objective was to evaluate differences in storm-driven pulses of bacteria at various locations in the watersheds of these two rivers.

Storms were selected throughout the study by the expected duration and intensity of rainfall subsequent to a variety of antecedent moisture conditions. The storms were selected in an effort to represent storms of different intensity and differing hydrological response. Four routine storms were sampled at the primary sites close to the mouth of each river. Routine storms were sampled for FCB, TSS, nutrients, and conductivity. Two storms were sampled more intensively for FCB on the Tillamook and Trask rivers by E&S and on the Wilson River by the Tillamook County Creamery Association (TCCA). The highest concentrations of FCB were reached during the storms well before the time of peak river discharge, and often during the period of most intensive rainfall.

Subbasins that drained into each sampling site were delineated and digitized into a GIS coverage. Using this coverage, in conjunction with estimated precipitation throughout the watershed, correction factors were calculated for each site so that river discharge data could be corrected for contributing area and for differential rainfall amounts according to elevation of the sub-basin. River flow was then calculated at each sampling site on each river, from the correction factors and the measured discharge at the gauging station. From these corrected flow values, FCB loads (cfu/sec) were calculated by multiplying the FCB concentration (cfu/100 ml) by the instantaneous flow (ml/sec). This resulted in load estimates associated with individual sub-basins for the Tillamook and Trask River watersheds during different time periods (12 hour time slices)

during each of the intensively sampled storm events. Loads associated with each time slice were ranked according to the amount of loading that occurred from each river segment. Scores were then assigned to each sub-basin or river segment across all time slices based upon the number of times that segment ranked the highest in loading, second highest in loading, and so on. This analysis resulted in the identification of the stream segments and their associated subbasins that most frequently contributed the largest loads of FCB to the rivers during these two storms. Analogous analyses have also recently been conducted for the Wilson River using data collected by TCCA (Bischoff and Sullivan, in review).

Watershed factors thought to influence loading of FCB to surface waters were also quantified using coverages produced by Alsea Geospatial (Corvallis, OR) for the TBNEP from aerial photographs of the lowland areas (<500 ft elevation). The coverages included information about land use and hydrology, including the locations of drainage ditches. Land use or development type was then quantified from these coverages for each subbasin that drained into a particular sampling site, including area used for pastureland, rural residential housing, urban development, agriculture, and area of riparian zone.

Centroids were produced for the development types designated as farm building clusters and rural residential building clusters. Each represented a discrete cluster of residential homes or farm buildings. The total number of centroids and type for each sub-basin were then quantified.

Total storm loads for FCB were calculated for each discrete storm event sampled (Table 1). This was accomplished by calculating the area under the curve for the hydrograph of each storm, in discrete segments corresponding to the available FCB measurements. For each segment, the FCB measurement taken at the beginning of the time segment was averaged with the FCB concentration measured at the end of the time segment. This average was then multiplied by the cumulative discharge during the time segment. Discharge estimates were generated using the trapezoidal rule to calculate water volume between sampling points.

Annual loads were estimated two different ways for bacteria (Table 1). The first approach entailed multiplying the flow-weighted annual average of all samples collected at each primary site by the cumulative flow during the 1997 water year. The second approach involved assignment of a discrete load to each storm that occurred in the 1997 water year, based on the storm-based estimates generated for the storms sampled throughout this study. Storm loads were assigned on the basis of season, storm size, and antecedent flow conditions. Discrete storm load estimates were then summed to produce an estimated annual load. Results of these storm-based load calculations, as expected, were lower than the estimates based on flow-weighted average concentration of FCB on all sampling occasions. The estimates differed by only about 50% for the Trask River (3,189 x $10^{12}$ cfu versus 2,031 x $10^{12}$ cfu), but about 100% for the Tillamook River (1,623 x $10^{12}$ cfu versus

Table 1. Results of storm discharge and fecal coliform bacteria load calculations at the Wilson River primary monitoring site for the intensive storms monitored with four or more samples during this study.

| Data Collected by | Storm Dates | Cumulative Precip. (in) | Peak River Discharge (cfs x $10^3$) | Peak FCB Concentration (cfu/100 ml) | Cumulative Storm Discharge and FCB Loads | |
|---|---|---|---|---|---|---|
| | | | | | Water Volume ($m^3$ x $10^6$) | Total FCB Load (cfu x $10^{12}$) |
| E&S | 12/4/96- 12/8/96 | 5.2 | 10.4 | 596 | 57.4 | 59.9 |
| E&S | 1/16/97- 1/21/97 | 5.5 | 4.6 | 2720 | 33.1 | 174 |
| TCCA | 9/30/97- 10/8/97 | 6.5 | 8.8 | 5800 | 50.4 | 353.0 |
| E&S | 2/09/98- 2/18/98 | 5.4 | 5.1 | 220 | 54.9 | 42.9 |
| TCCA | 2/27/98- 3/08/98 | 4.3 | 3.7 | 60 | 47.2 | 9.2 |

793 x $10^{12}$ cfu). Estimated annual loads for TSS, total inorganic nitrogen (TIN) and total phosphorus (TP) were generated in a manner analogous to the first approach used for bacteria. All of these load estimates should be viewed as first approximations. More rigorous quantification of storm-based, and especially annual, loads would require additional monitoring data and the application of one or more non-point source pollution models.

The results of the storm monitoring indicate that some of the higher concentrations of FCB were measured in the lower portions of the watersheds. However, because the purpose of the recent monitoring program was to provide a general characterization of water quality in the Tillamook Basin, most of the monitoring sites were located along the main river channels. Consequently, it is difficult to attribute some of the water quality problems to specific land uses based on these data. In addition to the problems associated with spatial uncertainty, there are concerns that measured FCB concentrations may not necessarily reflect immediate contributions from adjacent land uses. For example, Stephenson and Rychert (1982) measured *E. coli* concentrations in stream sediments up to 760 times greater than values measured in the overlying water. *E. coli* was resuspended from the sediments during a rainstorm event, causing concentrations in downstream waters to be derived largely from the resuspended sediment rather than watershed contributions. Research is currently in progress to address this issue in the Tillamook River (J. Moore, pers. comm.).

A summary of the recent water quality monitoring results for the Tillamook Basin is presented in Table 2.

Table 2. Flow-weighted average concentration of water quality parameters measured during the course of this study at the primary site on each of the five rivers (n is in parentheses).

| | Flow Weighted Average Concentration | | | | |
|---|---|---|---|---|---|
| Parameter | Tillamook | Trask | Wilson | Kilchis | Miami |
| FCB (cfu/100ml) | 523(41) | 169(26) | 158(34) | 38(32) | 133(32) |
| $NH_4$-N (mg/L) | 0.02(20) | 0.02(18) | 0.02(19) | 0.02(20) | 0.02(20) |
| $NO_3$-N (mg/L) | 0.78(21) | 0.82(19) | 0.59(20) | 0.73(21) | 0.93(21) |
| Conductivity (FS/cm) | 56(32) | 66(13) | 50(27) | 44(24) | 52(22) |
| pH | 6.6(15) | 7.0(22) | 7.0(14) | 6.9(15) | 6.9(15) |
| TSS (mg/L) | 38(24) | 137(19) | 253(23) | 86(24) | 60(24) |
| TKN (mg/L) | 0.31(21) | 0.25(19) | 0.22(20) | 0.24(21) | 0.27(21) |
| TP (mg/L) | 0.11(21) | 0.25(4) | 0.52(19) | 0.22(20) | 0.15(21) |
| Ca (mg/L) | 3.1(4) | 7.2(4) | 7.8(4) | 4.3(4) | 3.97(4) |
| Mg (mg/L) | 1.5(4) | 4.3(4) | 7.4(4) | 2.8(4) | 2.1(4) |
| Na (mg/L) | 4.0(4) | 3.9(4) | 3.4(4) | 2.9(4) | 3.6(4) |
| K (mg/L) | 0.614(4) | 0.32(4) | 0.47(4) | 0.20(4) | 0.27(4) |
| $SO_4$-S (mg/L) | 0.62(4) | 0.61(4) | 0.49(4) | 0.29(4) | 0.35(4) |
| Cl (mg/L) | 6.5(4) | 3.2(4) | 2.7(4) | 3.3(4) | 5.0(4) |

## III. SAMPLING SITES AND MONITORING SCHEDULE

In consultation with TBNEP staff, one sampling site was selected at the downstream end of each of the subject rivers (Kilchis, Trask, Wilson, Tillamook). Sites were selected with an aim to avoid tidal prism influence. There are numerous major stream crossings that provide opportunities for sampling. These and other sites were examined in the field and a final selection of sites was made in consultation with TBNEP staff (Figure 4). On-site conductivity measurements are taken to ensure that baywater contamination of samples does not occur. The Trask and Wilson River sites will be monitored for nutrients. River water samples will be collected and analyzed for total phosphorus, total Kjeldahl nitrogen (TKN), nitrate, and ammonium. The Wilson, Trask, and Kilchis Rivers will be sampled for TSS, and the Tillamook, Trask, and Wilson Rivers will be sampled for FCB. An effort will be made to schedule winter nutrient sampling to coincide with relatively high-flow periods, especially conditions of rising hydrographs, and summer nutrient sampling trips to coincide with relatively low-flow periods.

Primary sampling sites are situated at major downstream river crossings expected to have minimal near-by point source contribution. Bridge crossings and docks were selected for primary sites in order to help insure sample collection at depth (~ 0.5 m) in the mid-channel areas of each river. In addition, there was concern that some potential sampling locations may be inaccessible due to flooding during some high flow periods. The Tillamook River is sampled at the Burton Bridge crossing (River Mile 4 from the mouth) in order to avoid probable tidal influence at the lowest bridge location on the river. The Wilson River is sampled at Sollie Smith Bridge (River Mile 3.8) which avoids the influence of a point source (Tillamook Creamery) and a dangerous sampling location at the Highway 101 bridge crossing. The Trask River is sampled at the 5$^{th}$ Street dock (River Mile 1.4). The Kilchis River is sampled at Alder Bridge (River Mile 1.5).

Routine sampling for nutrients will occur bi-monthly for a period of twelve months. Sample times will be noted so that tidal influences and river flows can be linked to measurements in the rivers.

Six storm events will be monitored for TSS during the fall and winter. During each storm event, 6-8 samples will be collected from TSS monitoring sites. Eight storm events will be monitored for FCB, two during each season.

## IV. SAMPLING METHODS

At the sampling sites, water samples are collected by submerging a weighted Nalgene bottle directly into the river to a depth of 0.5 m and retrieving it by rope. FCB samples are collected directly into sterile 125 ml bottles. Sample bottles are filled and placed in coolers on ice and transported to the Oregon State University Central Analytical Laboratory in Corvallis for chemical analyses and the Kilchis Analytical Laboratory in Bay City for bacterial analyses. Duplicate samples are submitted as routine samples to the laboratories as checks on analytical quality. *In situ* measurements are collected for temperature and conductivity. Storm-based samples are distributed over the rising and falling limbs of the hydrographs of the rivers, with an effort to sample most intensively during the rising limb of the hydrograph. When sampling during periods of relatively low river flows, samples will be collected close to low tide when necessary to avoid baywater influence on the sample. During high flow periods, flushing will be sufficiently great as to minimize this problem. In all cases, on-site conductivity measurements will be used to provide instantaneous evaluation of potential saltwater influence. Collection of baywater samples will be avoided by waiting for a change in tidal cycle.

## V. QUALITY CONTROL

The overall quality assurance objectives for the project are to implement quality control requirements for laboratory analysis that will provide data that can be used to achieve the program objectives, and to follow procedures that will provide data of known quality in terms of precision, accuracy, completeness, representativeness, and comparability.

Levels of data quality are defined by EPA (*Data Quality Objectives for Remedial Response Activities*, Volume 1- Development Process, EPA 540/G-87/003A (OSWER) (Directive 9335.0-7B), March 1987). Levels I through V cover the range from non-quantitative field screening tests (Level I) to specially developed non-standard methods following rigorous QA/QC protocols and documentation (Level V). The water quality monitoring program will use Level II analysis for field measurement and Level III for laboratory analysis.

Level III protocols provide internal quality control with calibration runs, surrogate standards, and matrix spike duplicates as appropriate. External quality control is employed in the form of replicate samples and field blanks. Level II protocols provide quantitative information using field instrumentation. The quality of the data generated can depend on the sophistication of the instrument, the use of calibration standards, and the training of the operator.

More than 10% of the samples analyzed will be allocated to QA/QC, and these will include field duplicates and blanks. QA/QC samples will be used to quantify sampling and analytical variability and analytical detection limits.

### Parameters

Temperature and conductivity are measured in the field. Samples are stored on ice in coolers and transported to the laboratories for additional analysis. The analytes to be measured in the laboratory are:

| | |
|---|---|
| Total Suspended Solids (TSS) | Ammonium ($NH_4$) |
| Total Phosphorus (TP) | Nitrate ($NO_3^-$) |
| Total Kjeldahl Nitrogen (TKN) | Fecal Coliform Bacteria |

### Sample Collection and Field Processing

Glass and Plasticware Preparation

All plasticware and aliquot bottles are Nalgene® high density polyethylene (HDPE). New bottles will be used for nutrients. These are soaked in deionized water (DIW) prior to use. The TSS aliquots will be collected with previously used Nalgene® bottles that have been rinsed. Bacteria samples are collected into new sterile bottles (125 ml) or sterilized sample bottles (using an autoclave).

Sample Collection

Samples will be collected from near mid-stream in mid-water column on the upstream side of a bridge or dock. The sample bottle and sample collection device are rinsed twice prior to collection of the sample. The number of samples collected on each sample occasion will vary depending on the number and type of aliquots required for a given situation.

**Analytical Methodologies**

Fecal Coliform Bacteria

The Kilchis Dairy Herd Service (KDHS) provides the sample collection crew with unmarked, clean sterile nalgene (or similar) screw top bottles. The sampling crew attaches a label at the time of sample collection. This label contains a three-letter code to identify the river, then a three-letter or number code to identify the sampling location, followed by a two-number code to identify sample number. As an example, TRA-101-02 would be a sample from the Trask River collected at the Highway 101 Bridge and this would be the second sample collected on this date at this site.

QA samples of bacterial analyses include several different types, each of which provides information regarding one or more sources of uncertainty. These include:

- blank - sample of deionized water
- blind duplicate - duplicate aliquot of same river sample provided to analytical laboratory with fictitious sample identification information
- known duplicate - duplicate aliquot of same river sample known to analytical laboratory
- replicate - sample collected from same site immediately following collection of a routine sample
- split - sample divided into two aliquots sent to two different analytical laboratories

On the E&S Environmental Chemistry, Inc. chain of custody record form there is information to determine sample name, date, time of day, bottles, test requested, and comments. An example chain of custody form is shown in Figure 5.

When the samples are delivered to the laboratory (KDHS), a second chain of custody form is started for use in the lab. On this is noted the name of who collected the samples and the date and time the samples were delivered to the laboratory. The person who receives the samples signs them in and records the date and time. This form also identifies the project name and number and contains the sample date and number.

The laboratory also utilizes a worksheet which shows who collected, analyzed, and counted the plates and the three dates for these activities. On the worksheet, there is a sample number,

identifying number, volume of sample water filtered, plate count, and calculated cfu/100 ml. Information from these worksheets is transferred to a results form. This shows the sample identification and the resulting plate count. This form is reviewed and the reviewer signature is noted. The calculations are rechecked by E&S staff prior to entering the data into the database.

Within the laboratory, the equipment is maintained and monitored to public health certification standards. Fecal coliform are determined using the membrane filter technique described in Standard Methods for the Examination of Water and Wastewater.

Sample Preparation for Nutrients and Major Ion Chemistry

Samples for specific conductance are not filtered. Aliquots for anions and cations are filtered through 0.45 µ Millipore or GFC filters. Samples are filtered using vacuum filtration with a Nalgene® filter apparatus and collection flask. Filters are rinsed first with at least 50 ml deionized water, then at least 10 ml of sample. These rinses also serve to rinse the collection flask.

Sample Preservation

The cation aliquots are acidified with nitric acid to give a sample acid concentration of 1.25% (v/v) and a pH < 2. Sulfuric acid is used in $NH_4^+$ aliquots for the same acid concentration. All samples and aliquots are refrigerated until processing or analysis.

Sample Identification Codes

Samples are labeled uniquely with site identifier and date in the field. An additional lab number is added to the alloquot.

The data quality objectives are presented in Table 3.

Laboratory Blank Samples

Laboratory blank samples are made for each analyte requiring sample preparation. These samples indicate control of contamination during sample preparation. The laboratory blank is made from reagent grade water and is prepared in the same manner as a sample. A single laboratory blank is generated for each sample preparation batch. For samples not requiring preparation, a laboratory blank is used to monitor background changes in measurement systems. These are made from reagent grade water and treated in an identical fashion to samples prepared for these tests. The laboratory and reagent blank DQO is expected to be less than twice the analytical detection limit.

| Table 3. Chemical methods and detection limits proposed for analysis of samples. | | | |
|---|---|---|---|
| Parameter | Method[a] | Detection Limit[b] | Reporting Unit |
| Nitrogen, $NO_2$ _ $NO_3$ as N | Ion chromatography | 0.05 | mg/L |
| Nitrogen, $NH_4$ as N | Perstorp (SM4500) | 0.01 | mg/L |
| Nitrogen, Kjeldahl as N | BD-40 auto. phenate | 0.05 | mg/L |
| Phosphorus, total as P | Digest./ascorbic acid | 0.002 | mg/L |
| Solids, total suspended (TSS) | Gravimetric 103C | 2 | mg/L |
| Fecal coliform bacteria | SM9221 (ALPHA 9221E) | NA | MPN/100 mL |

[a] Alternate methods may be necessary due to the composition or matrix or some samples

[b] Actual detection limit may be higher or lower due to sample mix.

Precision

Precision is a measure of mutual agreement characteristic of independent measurements resulting from repeated application of the process under specified conditions (Taylor 1987). The coefficient of variation (CV), or percent relative standard deviation (RSD), is used to estimate precision:

$$CV = (s/x)*100$$

where s = sample standard deviation

x = arithmetic mean

Precision can be partitioned in several ways: analytical precision refers to precision of the analysis performed by laboratory instruments; it is estimated by laboratory replicates. Analytical precision can be estimated for within-batch precision if laboratory replicates are measured within the same analytical batch, or for among-batch precision if laboratory replicates are measured in different batches. A batch is a set of samples analyzed with the same calibration curve.

Accuracy

Accuracy is the degree of agreement of a measured value with the true or expected value of the quantity of concern (Taylor, 1987). Accuracy is expressed as the percent difference from the reference value

$$(X-T)/T)*100$$

where

X = measured value

T = reference value.

Accuracy will be estimated for the analytical system, for both within- and among-batch.

Bias

Bias is a systematic error inherent in a method or caused by some artifact of the measurement system (Taylor, 1987). Bias is estimated by interlaboratory comparisons of performance evaluation samples among laboratories. Bias among the core analytes can be determined by computation of percent recovery of spiked samples. Additional information on bias at low levels is provided by analysis of blank samples. Methods of collection, preservation, transportation, and storage of the samples have been designed following established procedures to reduce most sources of bias.

Completeness

Completeness is defined as the percentage of reportable analyses out of the total number of possible analyses. The laboratory completeness objective for samples received intact from the field is expected to be 95% to 100%.

Comparability

Comparability of data collected during this program to other data is provided by specifying standard procedures for sample collection and analysis, and by using defined standard methods for laboratory analyses. Quality assurance objectives are outlined in Table 4.

Sample Custody and Documentation Procedures

Sample bottles are labeled with indelible ink. Sample identification includes the year, month, day and station code in the form "ymmddss" where "y" is the last digit of the year, "mm" is the number of the month, "dd" is the day of the month, and "ss" is the station code. This information will be recorded on a multi part chain of custody record along with information about the desired analyses and the identity of the sample collector. A field log book will be kept in which station codes, date and time of sampling, and all field data will be recorded. Notes on any unusual conditions at the sample sites or any circumstances that may have caused deviation from normal procedures will also be recorded in the field data book. An example of the custody form is included as Figure 5.

Table 4. Quality Assurance Objectives for the TBNEP Watershed Water Quality Monitoring Program.

| Constituent | Method | Target Detection Limit | Precision | Accuracy | Completeness |
|---|---|---|---|---|---|
| Suspended solids | EPA 160.2 | NA | 20% RPD[1] | 75-125%[2] | 95% |
| Ammonia | EPA 350.1 | 0.01 mg/L | 20% RPD | 75-125% | 95% |
| $NO_3$+$NO_2$ | PA 353.2 | 0.01 mg/L | 20% RPD | 75-125% | 95% |
| Kjeldahl nitrogen | EPA 351.1 | 0.01 mg/L | 20% RPD | 75-125% | 95% |
| Total phosphorus | EPA 365.1 | 0.01 mg/L | 20% RPD | 75-125% | 95% |
| Fecal coliform | APHA 9221E | 1/100 ml | NA | NA | 95% |

[1]RPD = relative percent difference
[2]Acceptable range of percent spike recovery.

Document control procedures will include the following:

Records will be clear, comprehensive, and written in indelible ink

Corrections to data sheets and logbooks will be made by drawing a single line through the error and initialing and dating the correction

Before release of data, records will be cross checked for consistency between sample tags, custody records, bench sheets, personal and instrument logs, and other relevant data

Documents will be archived in the project records according to the contract requirements

Data Reduction, Validation, and Reporting

Laboratory data reduction and validation will be performed according to standard Quality Assurance plans. Data will be reported as hard copy delivered by the laboratory to the contractor, E&S Environmental Chemistry. Field data will be recorded in a field notebook, examined for internal consistency, and reported. All data will be entered into a computer database in a format compatible with Excel for Windows version 4.0a.

Prior to data analysis and interpretation, all data entered into the database will be validated using automated statistical procedures developed by E&S Environmental Chemistry for the SAS statistical package. Tests available include evaluation of blanks, duplicate samples, split samples, checks for time series anomalies, outlier analysis, and principal component analysis.

Interim results will be supplied in quarterly reports delivered in March, June, and September, and one final report delivered (in draft form) December 1, 1999. Bimonthly reports will contain the following elements:

A narrative summary of activity

Data from all measurements and analyses performed during the period

A discussion of any problems encountered or modifications made to the established protocols

Corrective Actions

If a review of laboratory or field procedures detects unacceptable conditions or data, the Contractor's project manager will be responsible for developing and initiating corrective action. Corrective action may included the following:

Re-analyzing the samples, if quantity and holding-time criteria permit

Resampling and analyzing

Evaluating and amending sampling and analytical procedures

Accepting data and acknowledging a level of uncertainty or inaccuracy by flagging the data and providing an explanation for its qualification

Documentation of corrective action steps will include problem identification, investigation, action taken to eliminate the problem, monitoring of the effectiveness of the corrective action, and verification that the problem is eliminated.

## DESCRIPTION OF LABORATORIES

### Central Analytical Laboratory

The Central Analytical Laboratory at Oregon State University is an analytical service laboratory which serves the university community as well as other governmental agencies. It supports the university in its research and extension missions in agriculture and related environmental issues. The laboratory concentrates its efforts in the area of soil, plant tissue, and water analysis with the emphasis on the analysis of nutrients.

Staff:

| | |
|---|---|
| 1.0 FTE | Dean Hanson, Laboratory Director/Analytical Chemist |
| 1.0 FTE | James Wernz, Spectroscopist/Methods development |
| 1.6 FTE | Barbara Koepsell, Ellen Bush, Laboratory Technicians |
| 0.5 FTE | Nancy Kyle, Computer Specialist/QA-QC Officer |

Major instrumentation includes:

- Perkins-Elmer Optima 3000 DV ICP Optical Emissions Spectrometer
- Perkin-Elmer Model 4000 Atomic Absorption Spectrometer
- Perkin-Elmer Model 5000 Atomic Absorption Spectrometer
- LECO Model CNS-2000 Carbon/Nitrogen/Sulfur Analyzer
- Perstorp Model 3500 Continuous Flow Analyzer
- Alpkem Model 300 Continuous Flow Analyzer
- Tecator Aquatec Flow Injection Analyzer
- CEM Corp MDS-2000 Microwave Digestion System

The laboratory has been involved in nutrient analysis of soils and plant tissue since the early 1950's. The Central Analytical Laboratory, as it exists today, is the result of merging the Soil Testing Laboratory and the Plant Analysis Laboratory/Horticulture into one facility. Water quality analysis was added in the 1980's. The laboratory has worked closely with researchers, instrument manufacturers, and other laboratories in order to develop procedures to give consistent low level nutrient analysis necessary for water quality work. Recent projects involving water quality analysis include the Willamette River Basin Water Quality Study and the Tualatin Basin Monitoring Program (Oregon Department of Forestry).

Quality of the analysis is maintained by a QA/QC program which may vary depending on the needs of the research. Minimum requirements for the laboratory include:

- Maintaining instrument log books including identification of samples run, calibration information, instrumentation settings, maintenance performed, and other observations which may affect the quality of the results.
- Calibration of instruments is performed with each set of samples analyzed with no more than 35 samples between recalibrations.
- An independent check standard or check sample is run with each calibration.
- A minimum of two blanks, one duplicate, and one spiked sample is analyzed with each sample set.

In addition to the above laboratory QA/QC program, the laboratory also participates in the Interlaboratory Quality Control Sample Split for the Tualatin Basin. Other participants of this program are Clackamas County, Multnomah County, Oregon Graduate Institute, City of Portland, Unified Sewage Agency, Department of Environmental Quality, and United States Geology Survey. The Central Analytical Laboratory has taken pride in being among the best laboratories in the program as rated by accuracy of a known sample, recovery of spiked unknowns, precision of blind triplicate analysis, and bias from the mean value of unknowns.

Chain of custody of samples is maintained by a log-in system that assigns a number unique to the sample set and sample. This number is marked on each sample and a preprinted label is applied to the log sheet when the sample enters the laboratory. This number is used for any subsequent analysis identification. All sample logs and data are kept on a computer system which is backed up daily by the network administrator and weekly by our computer specialist. Hard copies are also kept to ensure no loss of data or chain of custody.

**Kilchis Analytical Laboratory**

The Kilchis Analytical Laboratory is located in Bay City, Oregon and provides bacterial analysis laboratory services. The laboratory is directed by Dr. Mark Wustenberg and Judy Wustenberg and is certified for coliform bacteria presence/absence determinations for drinking water. The laboratory staff work closely with the local dairy industry and are involved in educational efforts concerning herd management and implementation of Best Management Practices.

**Data Analysis**

Routine Review of the Data

Examination of monitoring data at a late date within a monitoring program often reveals analytical problems that could have been addressed earlier at considerable savings to the program. In some cases, analytes might not be measured with sufficient precision consistent with the intended use of the data. As a consequence, data collected during the period of most rapid change in key variables may be unusable for trends analysis. By instituting routine analytical reviews and measures of internal consistency and external quality control samples (e.g. blanks, spikes, splits), aberrant analytical results can be identified and corrected immediately. Samples can be re-analyzed before they are discarded and when necessary adjustments can be made in monitoring protocols. Once a pattern has been established for a given body of water in a long term monitoring program, specific flags can sometimes be written in the QA/QC algorithms to identify samples for re-analysis that fall outside prescribed ranges. If monitoring data are not reviewed on a routine basis, there is considerable risk that a major problem will go undetected, and this can compromise the utility of the resulting data for its intended purpose.

For bacteria, we wish to quantify changes that occur in bacterial concentrations and loads. It is best to attempt to do that using several approaches, in anticipation of a high degree of temporal variability. These will include analyzing for trends in bacterial fluxes associated with specific storm types, flow-weighted storm average concentrations, and total storm loads.

Flow-weighted storm average bacteria concentrations will be calculated for each river during each storm. This calculation gives an indication of the average bacterial concentration, but the times of high flow count more towards that average than do the times of low flow.

The principal way in which data will be analyzed for trends in storm fluxes of bacteria is by first classifying all monitored storms by type and season and then testing for trends within each type and within each season. Results of bacterial concentrations and loads will be compared from year to year by evaluating results obtained for each storm type for which a sufficient number of storms are successfully monitored ($ 10). We propose the following as a strawman storm classification system. Within each season and combination of seasons, individual cells in an 8-cell matrix will be used as the basis for classifying storm events. This matrix will be based on two possible values for each of three parameter choices:

rainfall intensity - high or moderate

total storm size - large or moderate

length of precipitation-"free" (< 1" [25 mm]) period prior to storm - long or short

There will be eight possible storm types within each season. An effort will be made to constrain the number of storms actually sampled to only a few of these types. This should be done by attempting to sample mostly large storms of high rainfall intensity. For this analysis, we propose the following preliminary criteria, which are subject to modification after additional storms have been studied. Rainfall intensity will be classified as high if the rainfall at Tillamook exceeds 0.15 in/hr (6 mm/hr) during eight or more hours during the course of the storm. Total storm size will be classified as large if total precipitation exceeds 4". Length of precipitation-"free" period will be classified as long if it is greater than one week. These parameter criteria are based on examination of recent data, but are subject to change.

Thus, each storm that is monitored will be classified into one of the cells (e.g., high intensity - large storm size - long precipitation-free period represents one cell). Results for individual cells will be compared within a given season or combination of seasons from year to year. Some cells may have data (one or more storms sampled) for a given season each year. Other cells will contain data only for some years during the period of monitoring. Each cell type will provide the potential for quantifying reductions in bacterial loads for particular kinds of storms. Available storm monitoring data are presented in Table 5 within the context of the proposed matrix. To date, storms have been monitored within five of the proposed cells.

Thus, the proposed routine monitoring data will be analyzed for trends in bacterial concentrations and loads using multiple approaches. The monitoring data are expected to contain considerable "noise." The use of multiple approaches and stratification by season and by storm type will help assure that we will be able to be document any significant changes that occur.

Table 5. Classification of storms monitored to date, with indication of flow-weighted storm average FCB concentrations and total storm FCB loads.

| Storm Class[a] | Fall Storms | | Winter Storms | | Spring Storms | |
|---|---|---|---|---|---|---|
| | Ave FCB[c] | Load[c] | Ave FCB[b] | Load[c] | Ave FCB[b] | Load[c] |
| **Tillamook River** | | | | | | |
| IH, SL, PL | | | 531 | 21.7 | | |
| IH, SL, PS | 1497 | 108.0 | 323 | 26.3 | | |
| IH, SM, PL | | | | | | |
| IH, SM, PS | | | | | | |
| IM, SL, PL | | | | | 166 | 14.9 |
| IM, SL, PS | | | 221 | 15.4 | | |
| IM, SM, PL | | | | | | |
| IM, SM, PS | | | | | | |
| **Trask River** | | | | | | |
| IH, SL, PL | | | 358 | 66.6 | | |
| IH, SL, PS | 931 | 225.0 | 157 | 46.1 | | |
| IH, SM, PL | | | | | | |
| IH, SM, PS | | | | | | |
| IM, SL, PL | | | | | 149 | 33.7 |
| IM, SL, PS | | | 227[d] | 88.8[d] | | |
| IM, SM, PL | | | | | | |
| IM, SM, PS | | | | | | |
| **Wilson River** | | | | | | |
| IH, SL, PL | | | 674 | 174.0 | | |
| IH, SL, PS | 874 | 353.0 | 151 | 59.9 | | |
| IH, SM, PL | | | | | | |
| IH, SM, PS | | | | | | |
| IM, SL, PL | | | | | 43 | 9.2 |
| IM, SL, PS | | | 105 | 42.9 | | |
| IM, SM, PL | | | | | | |
| IM, SM, PS | | | | | | |

[a] Storm classes are designated as follows:
Intensity: high or moderate (IH, IM)
Size: large or moderate (SL, SM)
Precipitation "free" period: long or short (PL, PS)

[b] Flow-weighted storm average FCB concentration (cfu/100 ml)

[c] Total FCB storm load (cfu x $10^{12}$)

[d] Primary site for Trask River was not available for sampling during the early February storm in 1998, so data were collected from 5th Street dock instead. Limited comparisons suggest that FCB concentrations tend to be higher at 5th Street dock.

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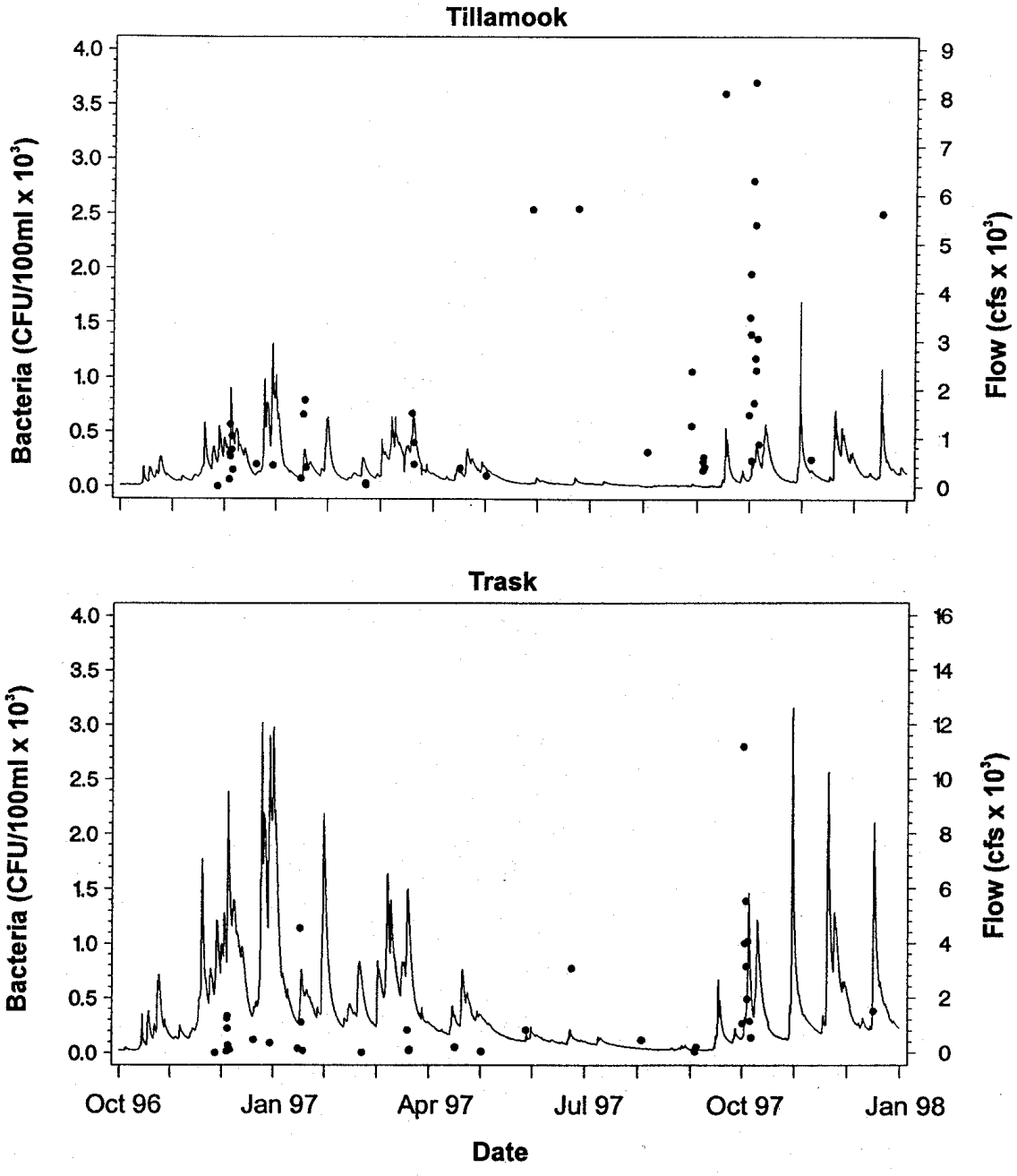



Figure 1. Concentration of FCB (cfu/100 ml x $10^3$) and river flow (cfs x $10^3$) at the primary monitoring site on each river.

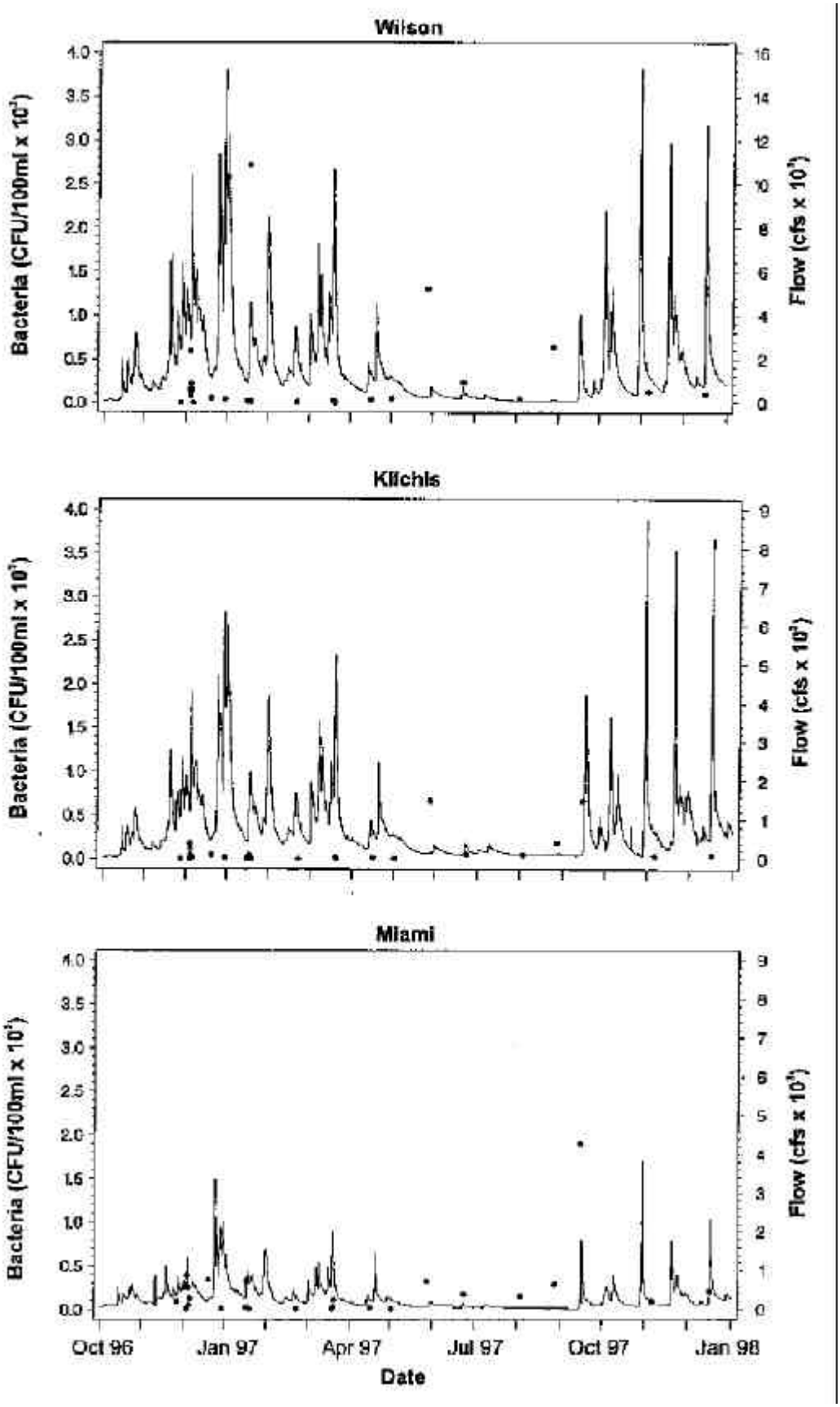



Figure 1. Continued.

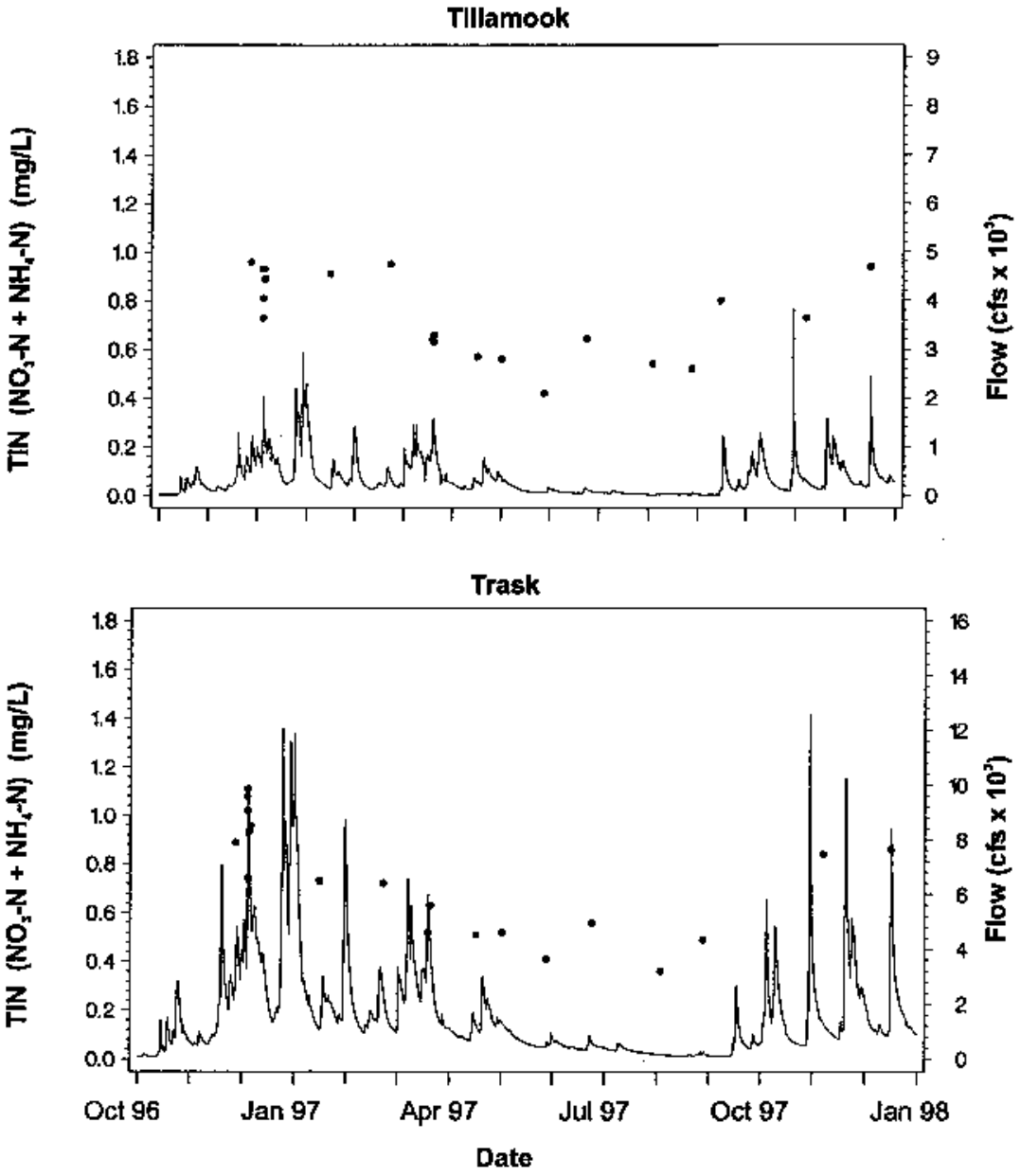



Figure 2. Concentration of inorganic N (mg/L) and river flow (cfs x $10^3$) at the primary monitoring site on each river.

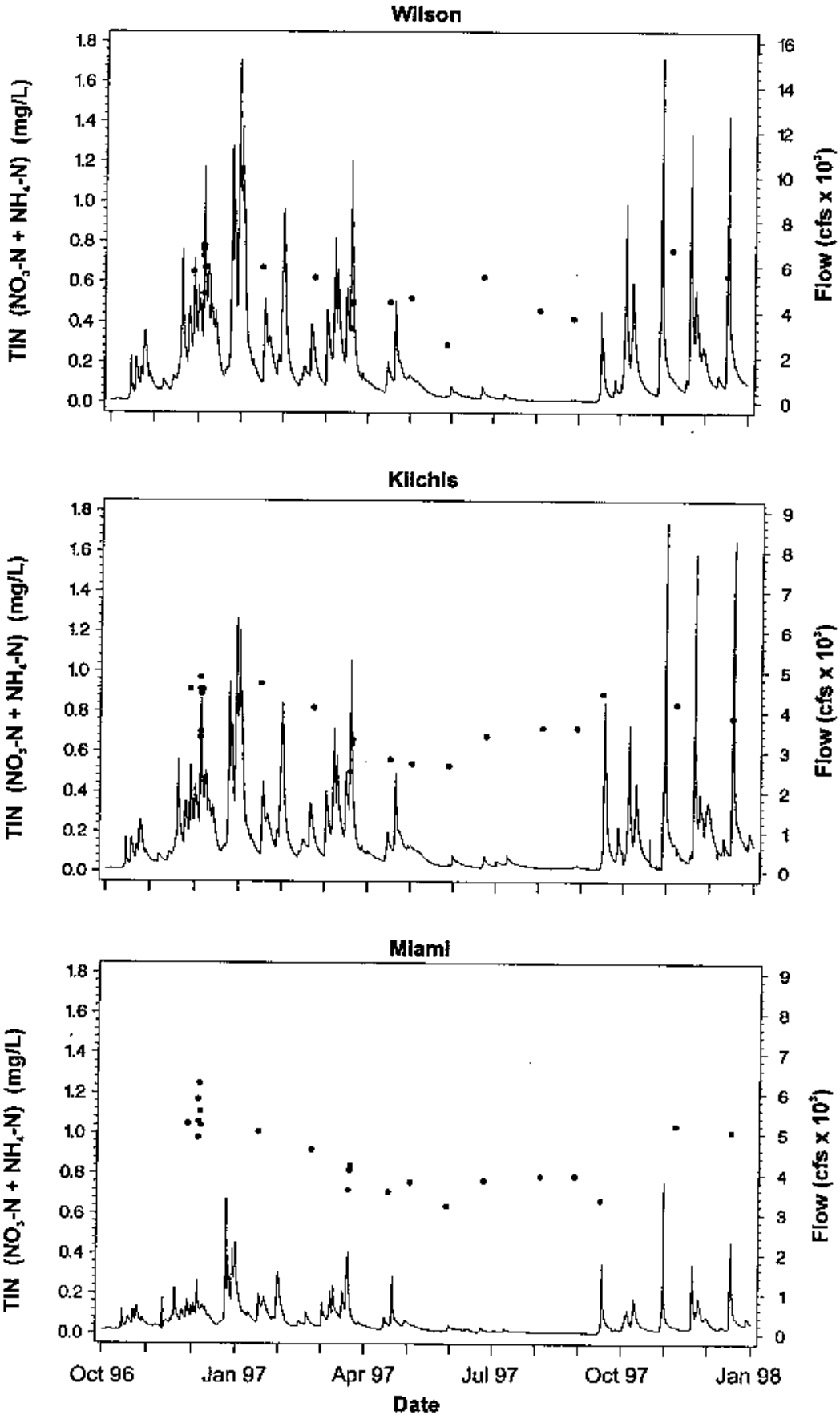



Figure 2. Continued.

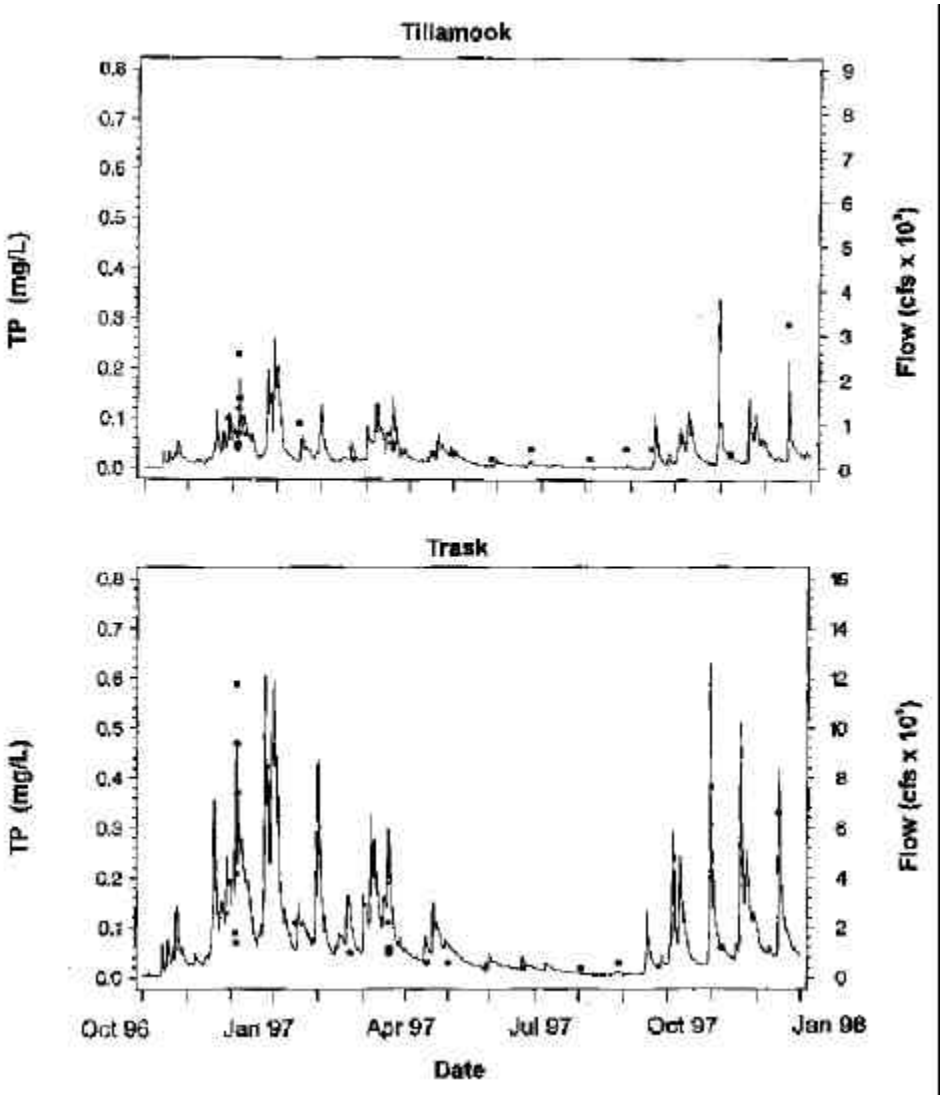



Figure 3. Concentration of total phosphorus (TP; mg/L) and river flow (cfs x $10^3$) at the primary monitoring site on each river.

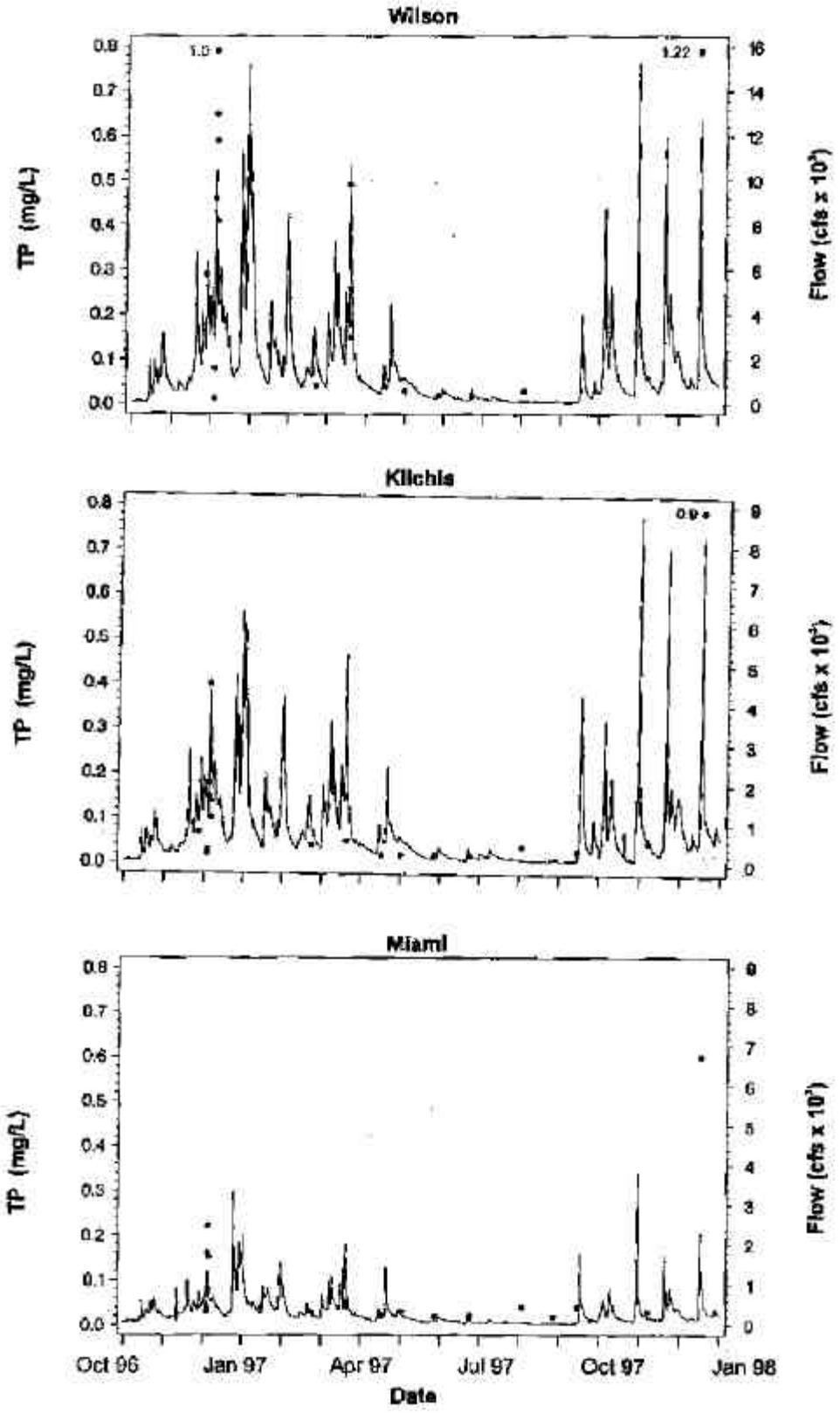



Figure 3. Continued.

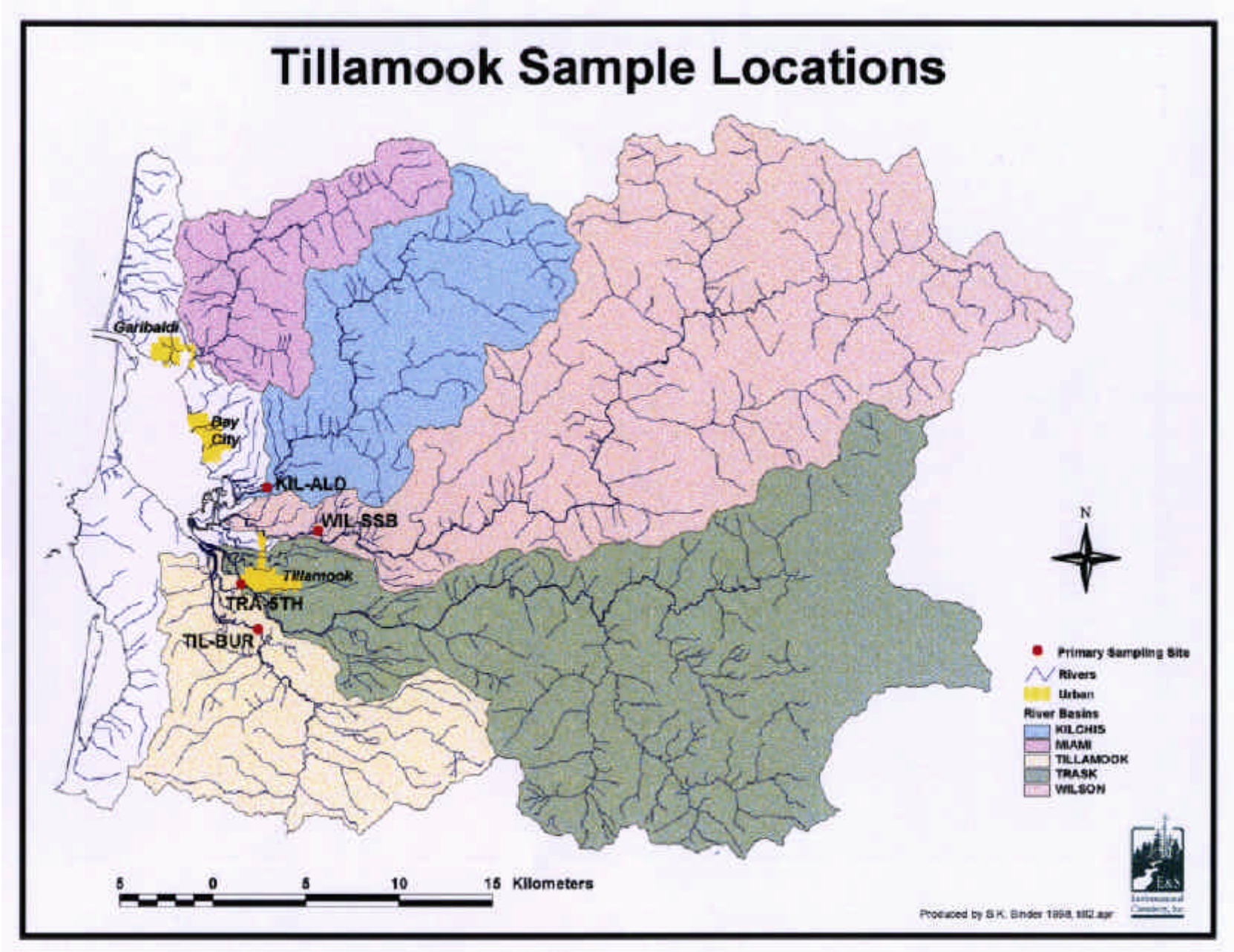
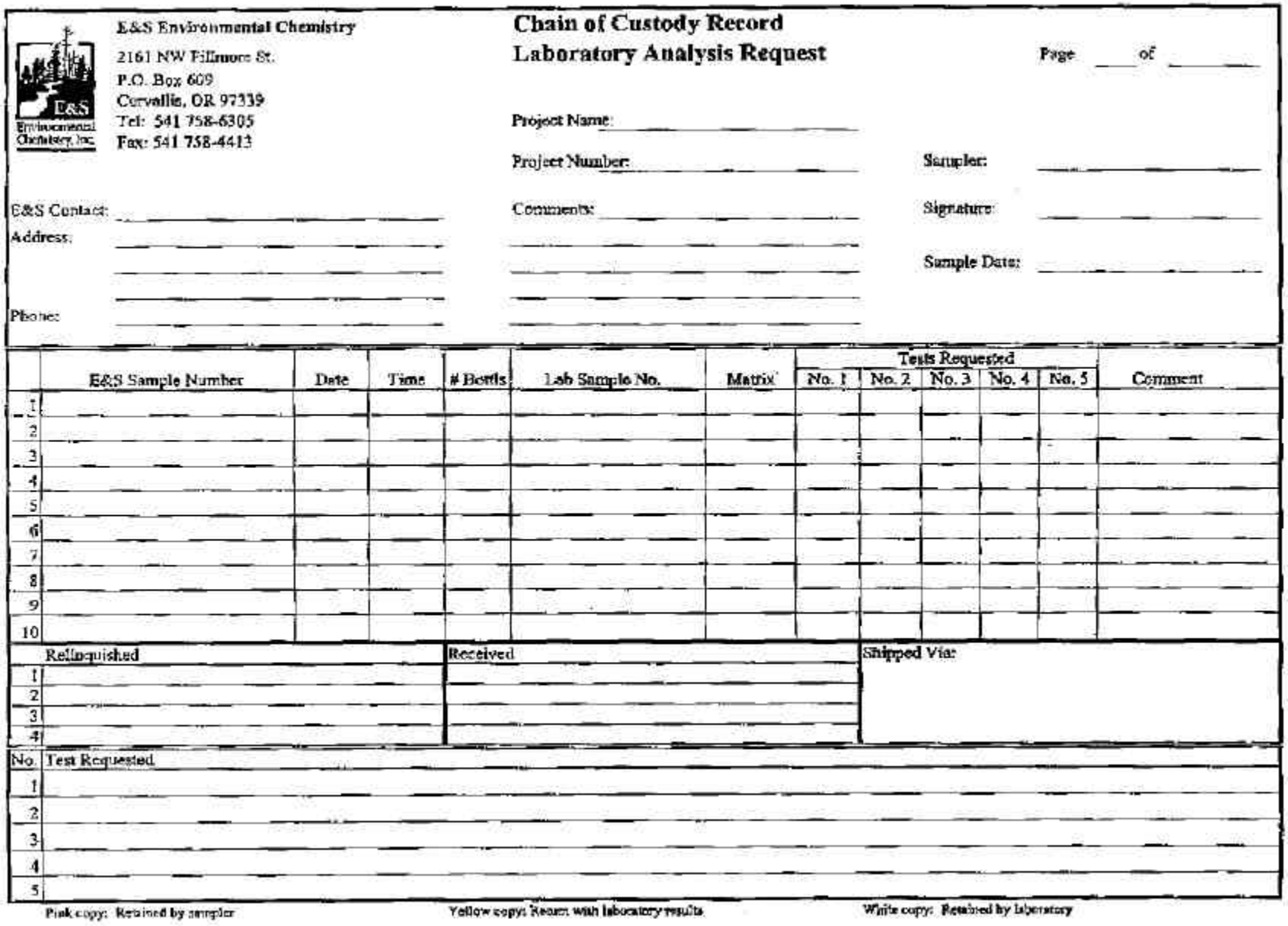



Figure 4. Sampling sites for continued monitoring.



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**Chain of Custody Record**
**Laboratory Analysis Request**

Page ____ of ____

Project Name:
Project Number:
Comments:
Sampler:
Signature:
Sample Date:

E&S Contact:
Address:
Phone:

| | E&S Sample Number | Date | Time | # Bottls | Lab Sample No. | Matrix | Tests Requested No. 1 | No. 2 | No. 3 | No. 4 | No. 5 | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | |

| | Relinquished | Received | Shipped Via: |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |

| No. | Test Requested |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |

Pink copy: Retained by sampler  Yellow copy: Return with laboratory results  White copy: Retained by laboratory

Figure 5. Example chain of custody form.