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Gibbons Creek Fecal Coliform Total Maximum Daily Load Assessment

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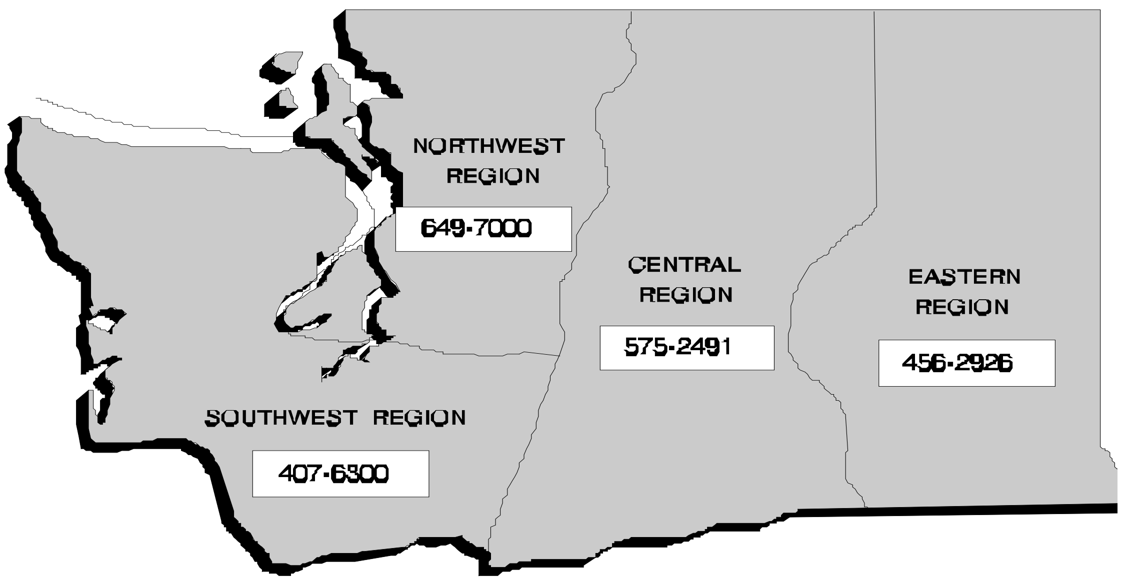

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Gibbons Creek Fecal Coliform
Total Maximum Daily Load Assessment

by
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Abstract

The Washington State Department of Ecology conducted a fecal coliform total maximum daily load assessment of Gibbons Creek in Clark County from September 1994 to January 1995. The intent of the study was to establish a nonpoint source loading capacity for fecal coliform bacteria, recommend load allocations for control of sources throughout the basin, and identify specific problem areas for follow-up action or continued study. Six sampling sites (two mainstem, two Campen Creek, and two unnamed tributaries) were sampled three times. Study findings indicated that all sites violated at least one of the two parts of the water quality criteria for fecal coliform, while Campen Creek was in violation of both parts of the criteria. Load allocations, equal to the water quality criteria, are recommended for the mainstem Gibbons Creek and Campen Creek. Recommendations are made for additional fecal coliform source identification and monitoring throughout the Gibbons Creek watershed.

Acknowledgments

Thanks are extended to Nora Jewett and David Giglio of Ecology for helping to collect field data and water samples for this study. Also, a special thanks to David Giglio for creating many of the figures used in this report.

Introduction

Regulatory Background and Purpose

The Washington State Department of Ecology (Ecology) Environmental Investigations and Laboratory Services Program, Watershed Assessments Section conducted a total maximum daily load (TMDL) assessment for the Gibbons Creek watershed located in Clark County. The federal Clean Water Act, section 303(d) specifies that waterbodies be listed where state water quality standards are not met, and that a TMDL be developed. TMDLs define the pollution loading limits required to meet water quality standards throughout the watershed.

Gibbons Creek is currently on the 303(d) list as a water quality limited waterbody for fecal coliform (FC) bacteria based on Ecology Ambient Monitoring Program data (Ehinger, 1993). Pollution within the watershed is from nonpoint sources. This report recommends a phased TMDL for Gibbons Creek and pollution control measures that will reduce FC levels to those needed to meet water quality standards.

Project Goals and Objectives

The goal of this project was to establish a phased TMDL for Gibbons Creek watershed. The project objectives, as stated in the Quality Assurance Project Plan (Erickson, 1994), were:

A. Identify potential sources of FC pollution in the Gibbons Creek watershed.

B. Measure FC levels and other general chemistry parameters during dry and wet weather at six sites within the watershed.

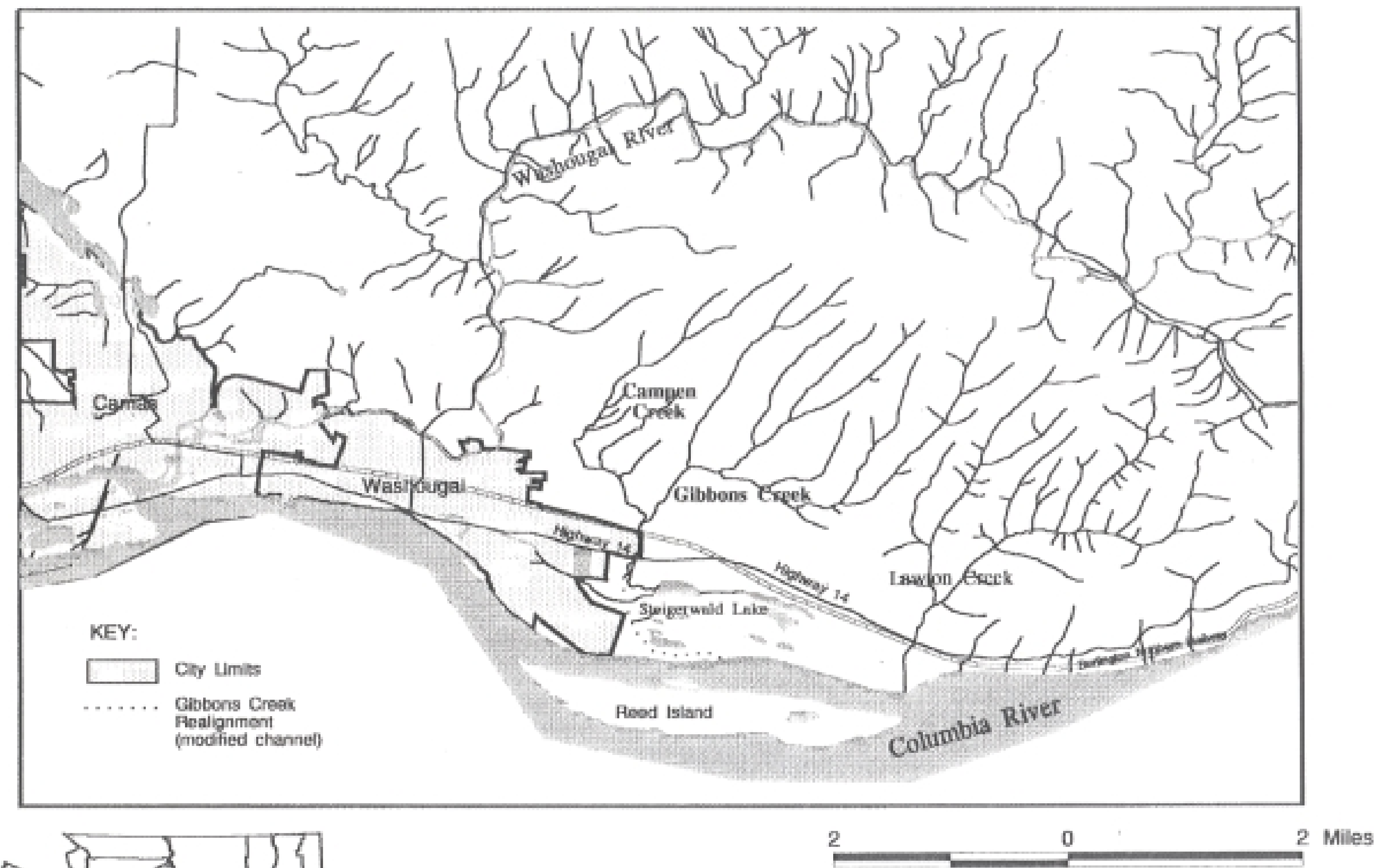
C. Determine FC load allocations for Gibbons Creek and Campen Creek (the main tributary to Gibbons Creek).

D. Recommend pollution control measures that will reduce FC levels to the identified load allocations.

Basin Overview

Setting and Land Use

Gibbons Creek is located in eastern Clark County and flows into the Columbia River just east of the town of Washougal (Figure 1). In the upper watershed, the creek and its tributaries flow through relatively steep, incised valleys as the water travels down the northern slope of the Columbia River Gorge. The gradient lessens considerably as the creek reaches the floor of the valley, near the Evergreen Highway crossing.



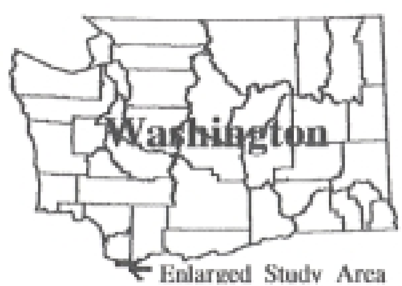


Figure 1. Reference Location Map

Prior to 1992, Gibbons Creek flowed westerly for the lower mile before discharging into the Columbia River. The lower creek channel was then modified, and now drains nearly due south from the highway crossing, through the Steigerwald Lake Wildlife Refuge, to the Columbia River. For most of this lower mile, the creek flows through an artificial, elevated channel before discharging into the Columbia River through a fish ladder structure. Because this portion of the channel is elevated (built on a dike), the surrounding land does not drain into Gibbons Creek, but instead drains into the old remnant channel. Therefore no land south of Highway 14, including the wildlife refuge and industrial park, contributes runoff into Gibbons Creek. Water quality in the remnant channel was the subject of a separate but concurrent investigation by Ecology (Erickson and Tooley, 1996).

Land use in the watershed consists largely of rural residential development with small farms, gardens, and/or animal-keeping operations along the slopes of the Columbia River Valley. The eastern fringe of the town of Washougal extends into the western portion of the watershed, including community subdivisions, schools, a borrow pit, and a golf course, all within the Campen Creek drainage area. New residential construction was occurring in the Campen Creek subbasin during the study period. Most of the study area is unincorporated with residences having on-site disposal systems (septic systems). There are no known point source dischargers within the Gibbons Creek subbasin.

Waterbody Classification, Beneficial Uses, and Water Quality Criteria

Gibbons Creek is classified as Class A (excellent) for water quality standards (WAC 173-201A). Water quality of this class shall meet or exceed the requirements for all or substantially all of the following characteristic uses:

- domestic, industrial, and agricultural water supply;
- stock watering;
- salmonid and other fish migration, rearing, spawning, and harvesting;

clam, oyster, and mussel rearing, spawning, and harvesting;

- wildlife habitat;
- primary contact recreation, sport fishing, boating, and aesthetic enjoyment.

United States Fish and Wildlife Service (USFWS) staff at the Ridgefield National Wildlife Refuge have identified native runs of cut throat and rainbow trout, steelhead, and coho salmon which utilize Gibbons Creek south of Highway 14 for spawning and early rearing of salmonids (Figure 1). USFWS is uncertain how far anadromous fish migrate upstream beyond Evergreen Highway because of culverting within the watershed which pose obstructions for these fish (USFWS, 1996).

An indication of surface water use in the basin is reflected in the 29 recorded water right certificates that may be active. These water rights consist of 17 permits for springs, primarily for single household/domestic use (i.e., drinking water); the remainder are direct creek withdrawals. Of these 12 permitted creek withdrawals, ten are used for irrigation purposes located in Campen (four) and Gibbons (six) Creek. The remaining two permitted withdrawals are for single household/domestic use in the upper reaches of Gibbons Creek.

The state water quality standards for Class A freshwaters state that “fecal coliform organism levels shall both not exceed a geometric mean value of 100 colonies/100 mL, and not have more than 10 percent of all samples obtained for calculating the geometric mean value exceeding 200 colonies/100 mL.” Water quality criteria for other conventional parameters are given in Appendix A.

Problem Description

Historical Water Quality Data

Prior to this study, the only water quality data available were those measured by the Ecology Ambient Monitoring Program. These data were collected monthly from October 1991 to September 1992 at the Evergreen Highway crossing. Water quality parameters measured include temperature, dissolved oxygen (DO), pH, FC, total suspended solids (TSS), turbidity, total and soluble reactive phosphorus, nitrate, and ammonia (NH_3). Ehinger (1993) summarized findings as follows:

> “The maximum temperature recorded was approximately 16^o C. Dissolved oxygen and pH were unremarkable. Fecal coliform counts were high with ten of the twelve samples exceeding 100 colonies/100 mL. Total suspended solids and turbidity were variable. Total phosphorus and soluble reactive phosphorus were somewhat higher than either the Lewis River or the Washougal River, but not particularly high on an absolute scale. Nitrate concentration exceeded 1.5 mg/L in November and was rather high all year.
>
> The high nitrate concentration and elevated total phosphorus concentration (in comparison with the Lewis and Washougal Rivers) may indicate a point or nonpoint source of nutrients to the stream. Ammonia concentration was unremarkable.”

Ehinger’s study found FC concentrations ranging from 37 to 910 colonies/100 mL (Table 1). The geometric mean of all measurements was 230 colonies/100 mL and 50 percent of the samples exceeded 200 colonies/100 mL; therefore, both parts of the water quality standard were violated. These data were the basis for Gibbons Creek’s inclusion on the 303(d) list (Ecology, 1994a).

Table 1. Fecal Coliform Concentrations Found in Gibbons Creek during October 1991 through September 1992 (Ehinger, 1993)

Year	Month	Fecal Coliform Concentration (# colonies/100 mL)
1991	October	450
	November	150
	December	37
1992	January	480
	February	140
	March	69
	April	360
	May	910
	June	730
	July	190
	August	140
	September	310
Geometric Mean:		**230**

Fecal Coliform Sources

The 1987 Water Quality Plan for Clark County (Intergovernmental Resource Center, 1987) states: "The water quality of Gibbons Creek is likely to be affected by septic system effluent in the upper reaches of the drainage basin, and agricultural runoff in the lower reaches." However, since that plan was written, additional residential development has taken place. Suspected sources of elevated FC levels include failing septic systems and agricultural run-off from small farms and animal-keeping operations.

Water Quality Investigation

Methods

Sampling Design

Two mainstem Gibbons Creek sites, two Campen Creek sites, and two unnamed tributaries to Gibbons Creek were sampled as described in Table 2 and shown in Figure 2.

Three water quality surveys were conducted at the above six sites. The first survey was conducted in late summer on September 8, 1994. The second and third surveys were conducted during winter on November 9, 1994, and January 17, 1995.

Table 2. Description of Sampling Locations for Gibbons Creek Fecal Coliform Total Maximum Daily Load Study

Station ID	Description	Latitude	Longitude	Township	Range	Section
GC1	**Gibbons Creek** - below confluence with Campen Creek at Evergreen Highway crossing	45°34'29"	122°18'51"	1N	4E	16
GC2	**Campen Creek** - mouth, above confluence with Gibbons Creek	45°34'40"	122°18'52"	1N	4E	16
GC3	**Campen Creek** - upstream site at Bailey Road crossing	45°35'07"	122°19'32"	1N	4E	9
GC4	**Unnamed Tributary** #1 - mouth, above confluence with Gibbons Creek	45°35'00"	122°18'21"	1N	4E	10
GC5	**Unnamed Tributary** #2 - mouth, above confluence with Gibbons Creek	45°34'58"	122°17'55"	1N	4E	10
GC6	At confluence of Gibbons Creek and two unnamed tributaries (uppermost Gibbons Creek site)	45°34'43"	122°16'45"	1N	4E	11

Thirteen water quality parameters were measured at each site during each survey: FC, pH, conductivity, temperature, DO, turbidity, TSS, NH_3, nitrite+nitrate (NO_3+NO_2), total persulfate nitrogen (TPN), orthophosphate (OP), total phosphate (TP), and chloride (CL).
In addition, streamflow was measured at each of the sites during each survey (Table 3).

Quality Assurance/Quality Control Procedures

Quality assurance protocols for field sampling followed those listed in WAS guidance manuals (Ecology, 1993; Cusimano, 1994). Duplicate samples for general chemistry parameters were collected at station GC1 during each survey. Since this study focused on FC, duplicate bacteria samples were collected at each site. Data reduction, review, and reporting procedures followed those outlined in the Manchester Laboratory Users Manual (Ecology, 1994b).

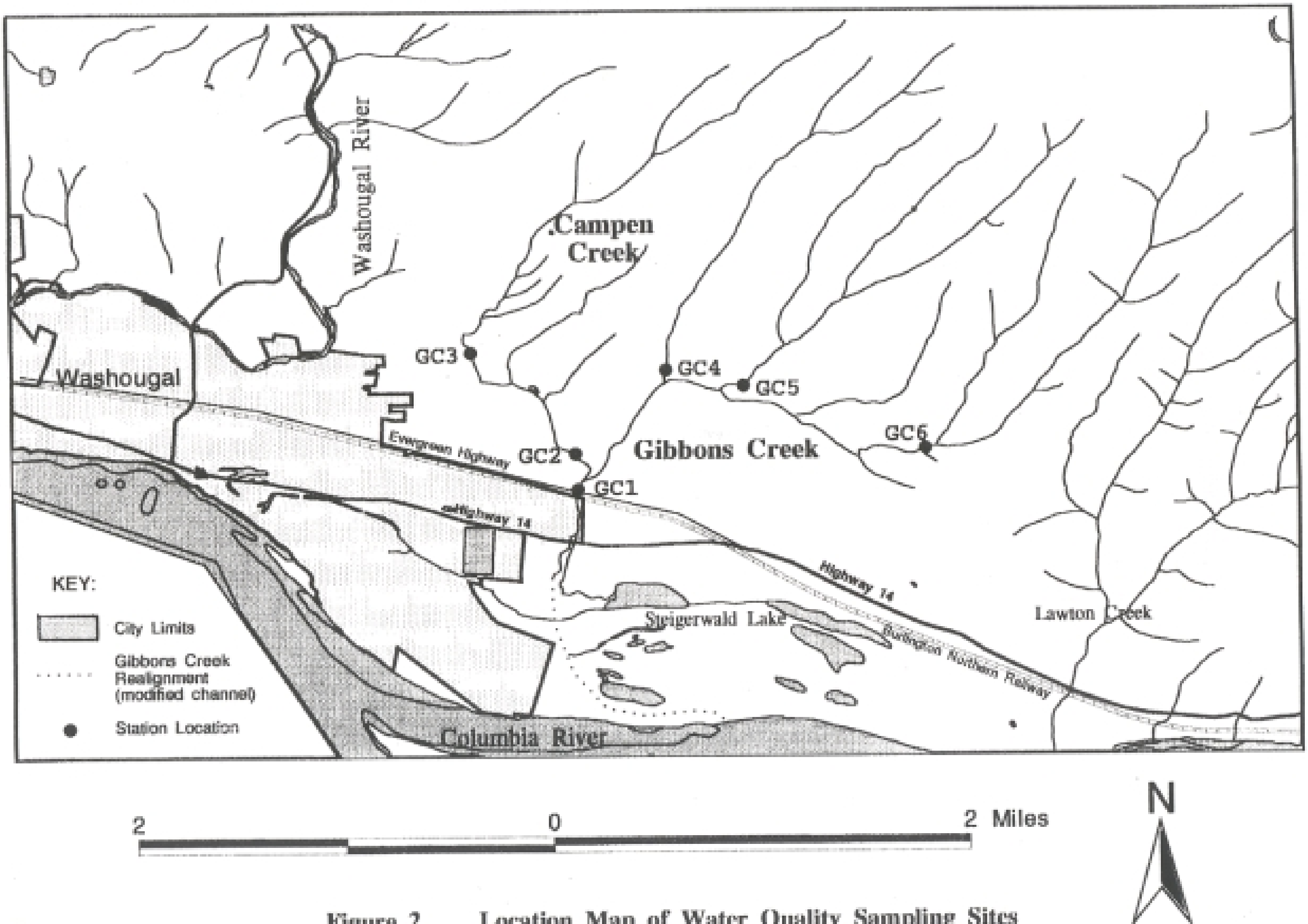


Figure 2. Location Map of Water Quality Sampling Sites

Table 3. Summary of Field and Laboratory Measurements, Target Detection Limits, and Methods

Parameter	**Precision Limit** (for field measurement and turbidity) or **Detection Limit** (all others)	**Method**[1]
Field Measurements:		
Velocity (for discharge)	± 0.05 fps	Current Meter
pH	± 0.1 SU	Field Meter/electrode
Temperature	± 0.2 °C	Thermometer
Dissolved Oxygen	± 0.06 mg/L	Winkler Titration
Specific Conductance	± 20 umhos	Field Meter/cond. bridge
Laboratory Measurements:		
Fecal Coliform Bacteria	1 col/100mL	SM 18 MF 9222D
Turbidity	± 1 NTU	EPA 180.1
Total Suspended Solids	1 mg/L	EPA 160.2
Ammonia Nitrogen	0.01 mg/L	EPA 350.1
Nitrate and Nitrite Nitrogen	0.01 mg/L	EPA 353.2
Total Persulfate Nitrogen	0.01 mg/L	SM 4500 NO_3-F
Orthophosphate	0.01 mg/L	EPA 365.3
Total Phosphorus	0.01 mg/L	EPA 365.3
Chloride	0.01 mg/L	EPA 300.0

[1]References: (APHA, 1989; USEPA, 1983)

Results and Discussion

Quality Assurance/Quality Control Assessment

A quality assurance evaluation showed that the data collected were of good quality and adequate for the use intended. To assess overall variability of field and analytical data collected, the coefficient of variation (standard deviation divided by the mean, expressed as percent) was calculated for all pairs of replicate samples (Table 4). The mean coefficient of variation (CV) for all parameters other than FC, ranged from 0% (pH, DO, NH_3, NO_3+NO_2 and CL) to 10% (TSS). Comparison of the mean CV for FC replicates at each station location showed greater variability, ranging from 4% (GC1) to 50% (GC4). As explained by Coots (1994), "Fecal coliform bacteria from nonpoint sources tend to be more inherently variable than other water quality data. This is because bacterial populations have a patchy distribution in the environment and are intermittently discharged."

Table 4. Coefficient of Variation for Replicate Samples

Coefficient of Variation (Survey)	pH (std units)	Cond (umhos/cm)	Temp (°C)	DO (mg/L)	FC (col/100 mL)	Turb (NTU)	TSS (mg/L)	NH3 (mg/L)	NO3+NO2 (mg/L)	TPN (mg/L)	OP (mg/L)	TP (mg/L)	CL (mg/L)
CV(1)	0.3	1.5	1.0	1.1	6.4	.4	0.0	0.0	0.0	7.6	5.2	2.8	0.0
CV(2)	-	-	-	0.0	53.7	5.2	28.3	0.0	0.5	8.2	0.0	1.3	0.0
CV(3)	0.6	1.8	0.0	0.0	29.2	3.7	2.9	0.0	0.0	2.8	0.0	0.0	0.0
CV(mean)	0.5	1.6	0.5	0.4	29.8	3.4	10.4	0.0	0.2	6.2	1.8	1.4	0.0

- No Data Obtained

As illustrated in Figure 3, when bacteria densities are near the lower detection limit of 1 colony/100 mL, a higher CV is obtained. The overall mean CV of the FC replicates for the study was 30%. When the replicate FC results are separated by mean densities of <100 colonies/100 mL and ≥100 colonies/mL, the mean CV's are 43% and 13%, respectively (Table 5). Based on CV values from similar studies, variability of general chemistry parameters and FC data was considered acceptable.

Table 5. Coefficient of Variation for Fecal Coliform Replicate Samples

Fecal Coliform Mean Densities	**Mean CV**	**(N=)**
< 100 colonies/100 mL	**43**	**20**
≥ 100 colonies/100 mL	**13**	**16**
MEAN TOTAL $CV_{(all\ sites)}$	**30**	**36**

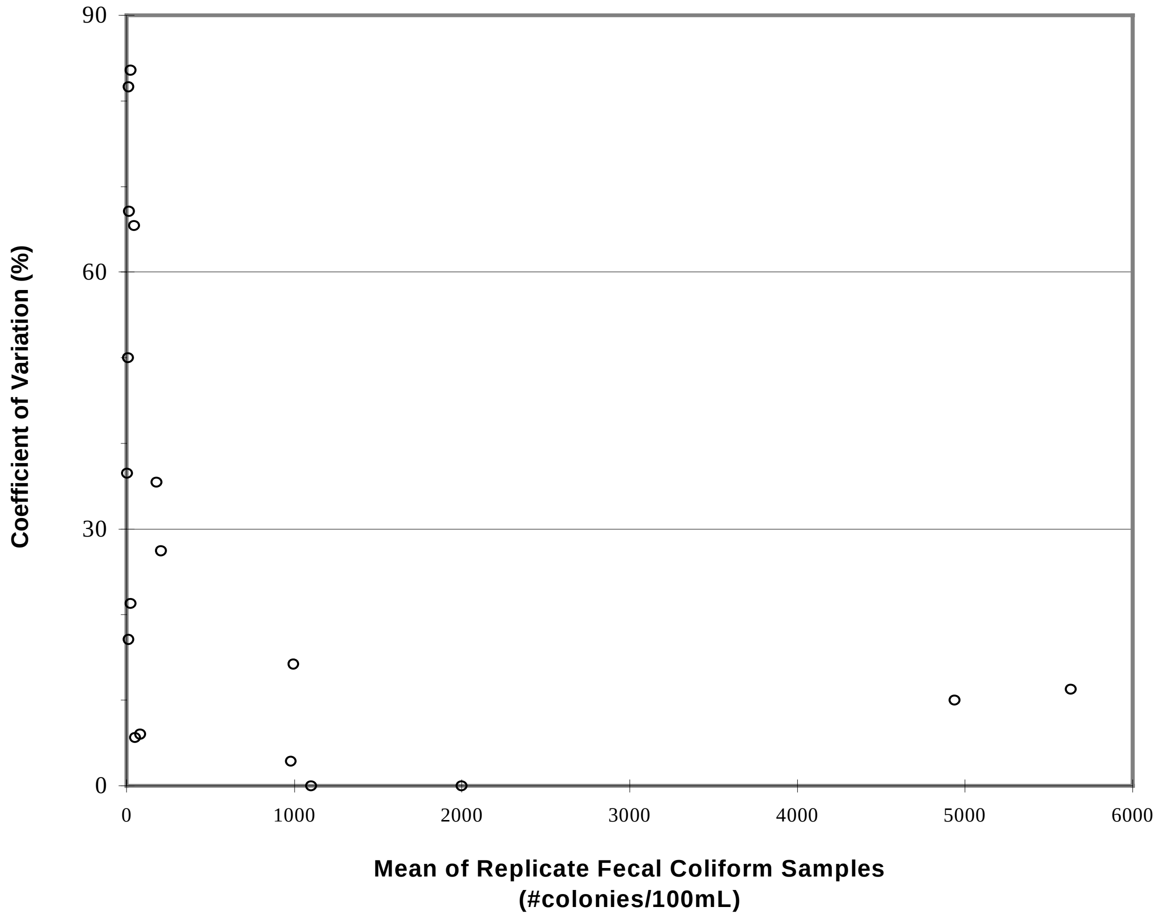


Figure 3. Coefficient of Variation for Fecal Coliform Field Replicate Samples

Water Quality Results

The results of the water quality surveys are presented in Appendix B.

Sampling dates represented a variety of weather conditions. Limited flow data for Gibbons Creek obtained by the U.S. Fish and Wildlife Service (USFWS, 1994) near the Highway 14 crossing from 1987 through 1993 are illustrated in Figure 4. The antecedent precipitation and streamflow for each sampling event are summarized in Table 6. Figure 5 shows measured streamflow at each sampling location and corresponding precipitation at the nearby city of Washougal wastewater treatment plant over the study period.

Table 6. Antecedent Precipitation (inches) and Streamflow (cfs) for Sampling Events

Survey Number	Date	Precipitation*	Station GC1	Station GC2	Station GC3	Station GC4	Station GC5	Station GC6
1	9/8/94	0.04	3.5	0.9	1.1	1.2	0.7	0.6
2	11/9/94	1.19	35	8.3	5.5	5.4	6.1	6.1
3	1/17/94	0.00	58	15	10	10	11	-

***** Precipitation (inches) at City of Washougal Wastewater Treatment Plant in 24 hours preceding sampling date

- No data obtained

Approximately 0.32 inch of rain fell on the first sampling date. Antecedent precipitation was 0.04 inches for the previous 24 hours, and averaged 0.12 inches/day in September preceding Survey 1. However, July and August were generally dry with total monthly rainfalls of 0.16 inches and 0.29 inches, respectively (City of Washougal Wastewater Treatment Plant, 1995).

Precipitation prior to Surveys 2 and 3 was generally rainy. As indicated in Table 6, the lowest flow rates were observed during the summer survey (September 8, 1994), while the highest flow rates were observed during the last winter survey (January 17, 1995).

The streamflows measured during the three surveys (3.5, 35, and 58 cfs for September, November, and December, respectively) were close to the historical mean monthly flows (3.9, 35, and 54 cfs). Therefore, the flow rates observed during the study period are probably representative of those respective months.

Fecal Coliform Bacteria -- Highest FC concentrations were found during Survey 1, in late summer (Table 7). Station GC2 at Campen Creek consistently had the greatest FC concentrations in relation to other station locations.

The much lower FC concentrations in November and January compared to September suggest that the diluting effect of higher streamflow is more than compensating for any additional rainfall washoff of FC sources. This would be consistent with continuous and steady FC sources, independent of rainfall, such as failing septic tanks, or may represent a situation where FC sources have been depleted (washed off) by previous rainfall events.

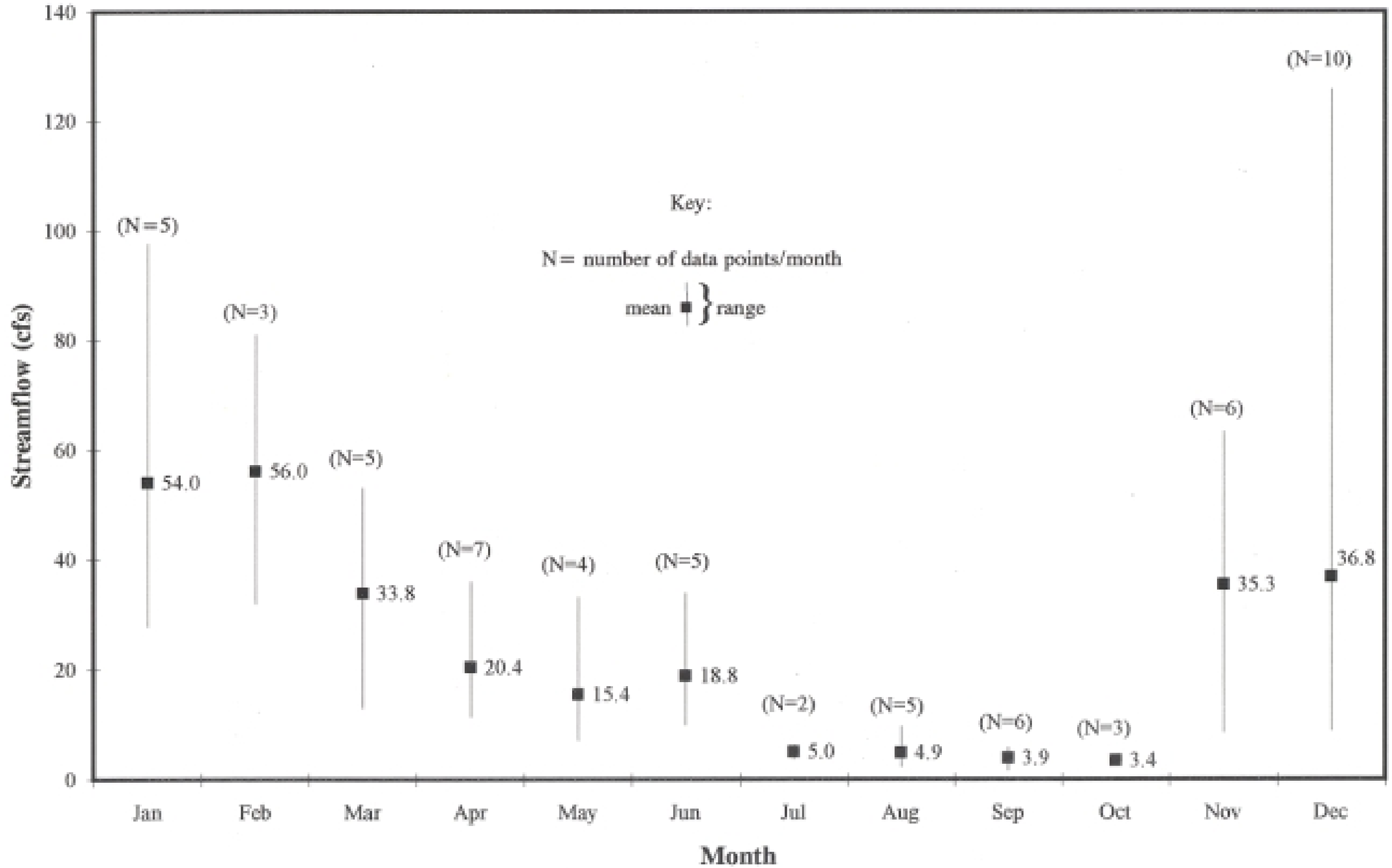


Figure 4. Gibbons Creek Flows near Highway 14, 1987 - 1993 (USFWS, 1994)

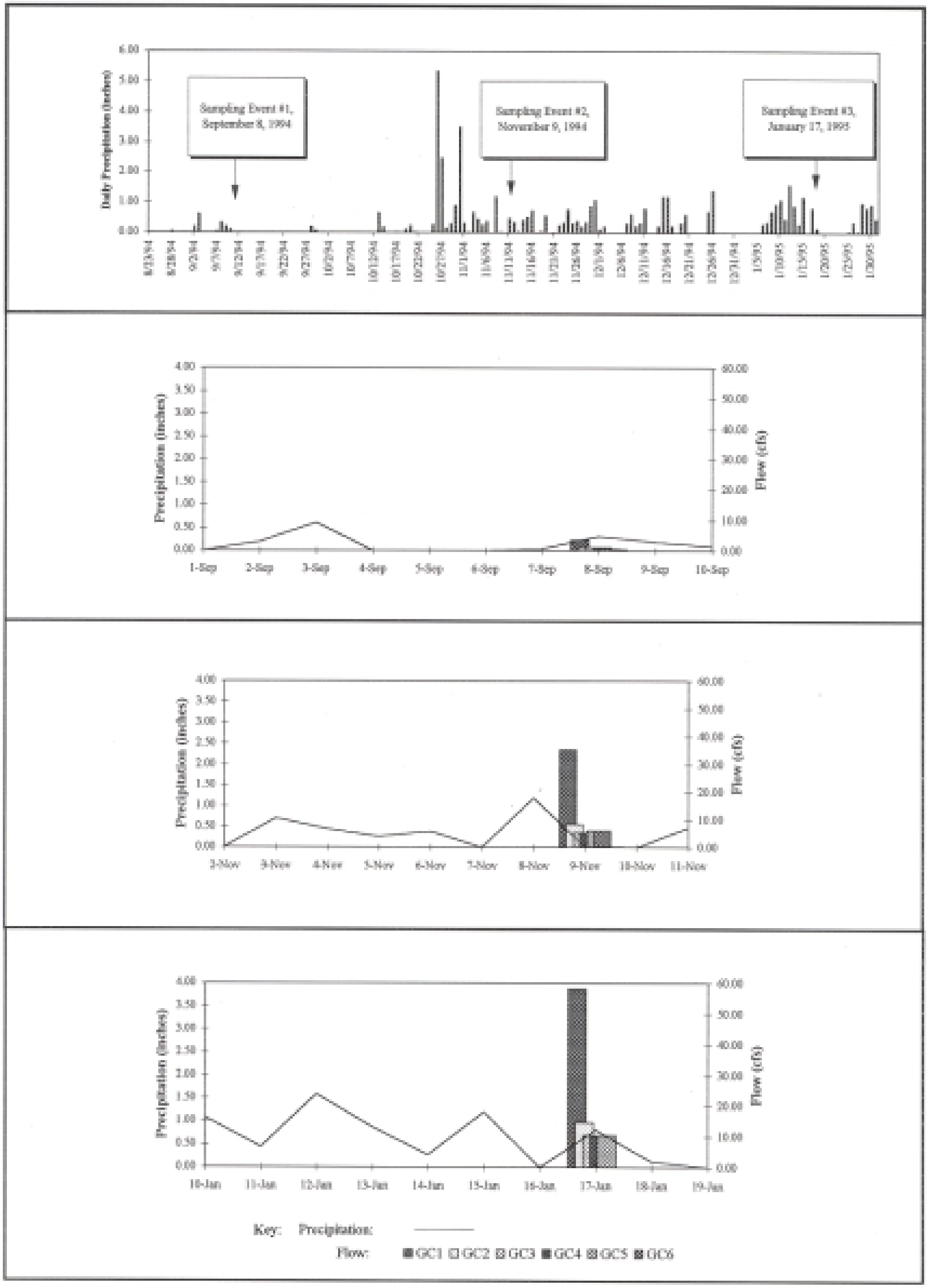


Figure 5. Precipitation and Flow Data for Gibbons Creek

Table 7. Fecal Coliform Geometric Means (#colonies/100 mL) Found in Gibbons Creek

STATION ID	Survey 1	Survey 2	Survey 3	ALL SURVEYS
GC1	2,000	82	50	200
GC2	5,600	180	210	590
GC3	4,900	45	23	170
GC4	1,100	12	16	60
GC5	980	10	12	49
GC6	990	25	4	46
ALL STATIONS	2,000	35	24	120

An analysis of FC loading into the mainstem of Gibbons Creek from Campen Creek and the other tributaries was conducted using the following expressions:

(1) $FC_Z = [(FC_{GC1} * Flow_{GC1}) - (FC_{GC2} * Flow_{GC2})]/Flow_Z$

where FC = fecal coliform concentration (colonies/100 mL),
Z represents Gibbons Creek above confluence with Campen Creek, and
$Flow_z$ was calculated as the difference of $Flow_{GC1}$ and $Flow_{GC2}$

(2) FC Loading (col/sec) = Flow (cfs) * FC (col/100 mL) * 284.7

where 284.7 is the conversion factor used for calculating FC loading (Kittrell, 1969)

The intent of this simplified analysis was to examine the relative contribution of FC loading into station GC1 and did not address the effect of bacterial decay, deposition and resuspension. It should be noted that FC samples in Campen Creek were collected approximately two hours apart during each survey and may not be representing the same set of conditions, especially during Survey 1 when sampling coincided with a rainfall event.

As shown in Table 8, the area draining into Campen Creek is contributing the greatest proportion of FC load to the watershed in relation to the other tributaries. FC relative load from Campen Creek during the study period ranged from 51% (Survey 2) to roughly 100% (Survey 3).

Table 8. Fecal Coliform Loading (col/sec) in Gibbons Creek (x 10,000)

Station ID	Survey 1	Survey 2	Survey 3
GC1	200	82	83
GC2	140	42	86
GC3	150	7.0	6.8
GC4	38	1.8	4.6
GC5	20	1.7	3.6
GC6	17	4.3	*
Z	56	40	-5.8

* = no flow data obtained
Z = station representing Gibbons Creek above the confluence with Campen Creek

The pattern of FC loading along Campen Creek was different in the late summer than in the winter. In September, the upstream loading was roughly 100% of the downstream loading, whereas in November and January, the upstream loading was only 17% and 8% of the downstream loading, respectively. This indicates that the land draining to the reach between stations is contributing a proportionately larger share of FC in the winter than in the summer.

General Chemistry Parameters --Appendix B shows the results of pH, conductivity, temperature, DO, turbidity, TSS, CL, and nutrient measurements. In most instances, the data show a general correlation between streamflow and the level of the parameter measured at each station location. Conductivity, temperature, turbidity, TSS, NH_3, OP, and TP were measured at their highest levels during the summer survey, and DO, NO_3+NO_2, TPN, and CL were observed at their highest in the winter. Throughout the watershed, pH levels were relatively constant during the study period with an overall standard deviation of only 0.2 standard unit.

The geographic area with the greatest water quality problems is the Campen Creek basin:

- The maximum temperature and minimum DO levels were identified at GC3 and GC2, respectively. At station GC3, the maximum temperature of 18.5 ^{o}C was recorded while DO levels measured 8.5 mg/L. At station GC2 the minimum DO level of 8.1 mg/L was measured at a stream temperature of 15.5 ^{o}C.
- The greatest level of turbidity and TSS within the watershed was observed at station GC3 (400 NTU and 222 mg/L, respectively). Turbidity and TSS levels measured at station GC3 exceeded levels measured at the downstream station GC2 by over 2,200% and 1,300%, respectively.
- The highest levels of NH_3 were also found at GC2 (0.047 mg/L) and GC3 (0.045 mg/L) during Survey 1. Freshwater acute and chronic ammonia criteria were not violated at either location; however, levels should generally not exceed 0.02 mg/L for the protection of freshwater aquatic life (Cusimano, 1994).
- The greatest total phosphorus concentrations were detected at GC2 (0.13 mg/L) and GC3 (0.506 mg/L) during Survey 1, which exceeded the 0.10 mg/L level which may stimulate algal growth in flowing water (Dwyer, 1979).

Potential sources of nutrients include urban runoff from new and existing residential development. Elevated ammonia and phosphorus levels detected in Campen Creek during Survey 1 may be due to contaminants attached to solids that are washed into receiving water as evidenced by increased TSS levels seen at GC3. The high values of turbidity and TSS at GC3 relative to other sites are indicative of loading sources further upstream and may be due, in part, to sample timing showing the effects of channel erosion from a rising hydrograph, or runoff of nearstream fines. However, construction activity in the upper basin above GC3 observed during this survey suggests the possibility of erosion from new construction sites.

At station GC6, NO_3+NO_2 and TPN were measured at their highest concentration during Survey 2 (1.54 mg/L) and Survey 3 (1.62 mg/L), respectively. Waters draining from agriculture areas and failing septic systems upstream of GC6 may be a potential source for the levels detected.

Water Quality Standards Violations

The Washington State water quality standards (Chapter 173-201A WAC) for FC state that, for Class A freshwaters, "organism levels shall both not exceed a geometric mean value of 100 colonies/100 mL, and not have more than 10 percent of all samples obtained for calculating the geometric mean value exceeding 200 colonies/100 mL."

- Stations GC1, GC2, and GC3 exceeded both parts of the criterion, and
- All sites exceeded the second part of the criterion during the study period (Figure 6).

Surface water temperature criteria in Washington State specify that Class A freshwater shall not exceed 18.0^{o}C due to human activities. In addition, water quality regulations state that, "When natural conditions exceed 18.0 ^{o}C (freshwater), no temperature increases will be allowed which will raise the receiving water temperature by greater than 0.3 ^{o}C." Also, "Incremental temperature increases resulting from nonpoint source activities shall not exceed 2.8 ^{o}C."

- The maximum temperature recorded at GC3 on September 8, 1994, was 18.5^{o}C, however, it is not known whether this temperature was due to human activities or is a natural condition. However, lower temperatures in other parts of the basin imply it is caused by human activities, such as removal of riparian shade canopy.

Turbidity criteria for Class A fresh surface water specify that, "Turbidity shall not exceed 5 NTU over background turbidity when the background turbidity is 50 NTU or less, or have more than a 10 percent increase in turbidity when the background turbidity is more than 50 NTU."
The maximum turbidity level recorded at GC3 on September 8, 1994, was 400 NTU. Although an upstream value is not available, the fact that the value greatly exceeds all other values measured in the basin implies that the criterion was violated.

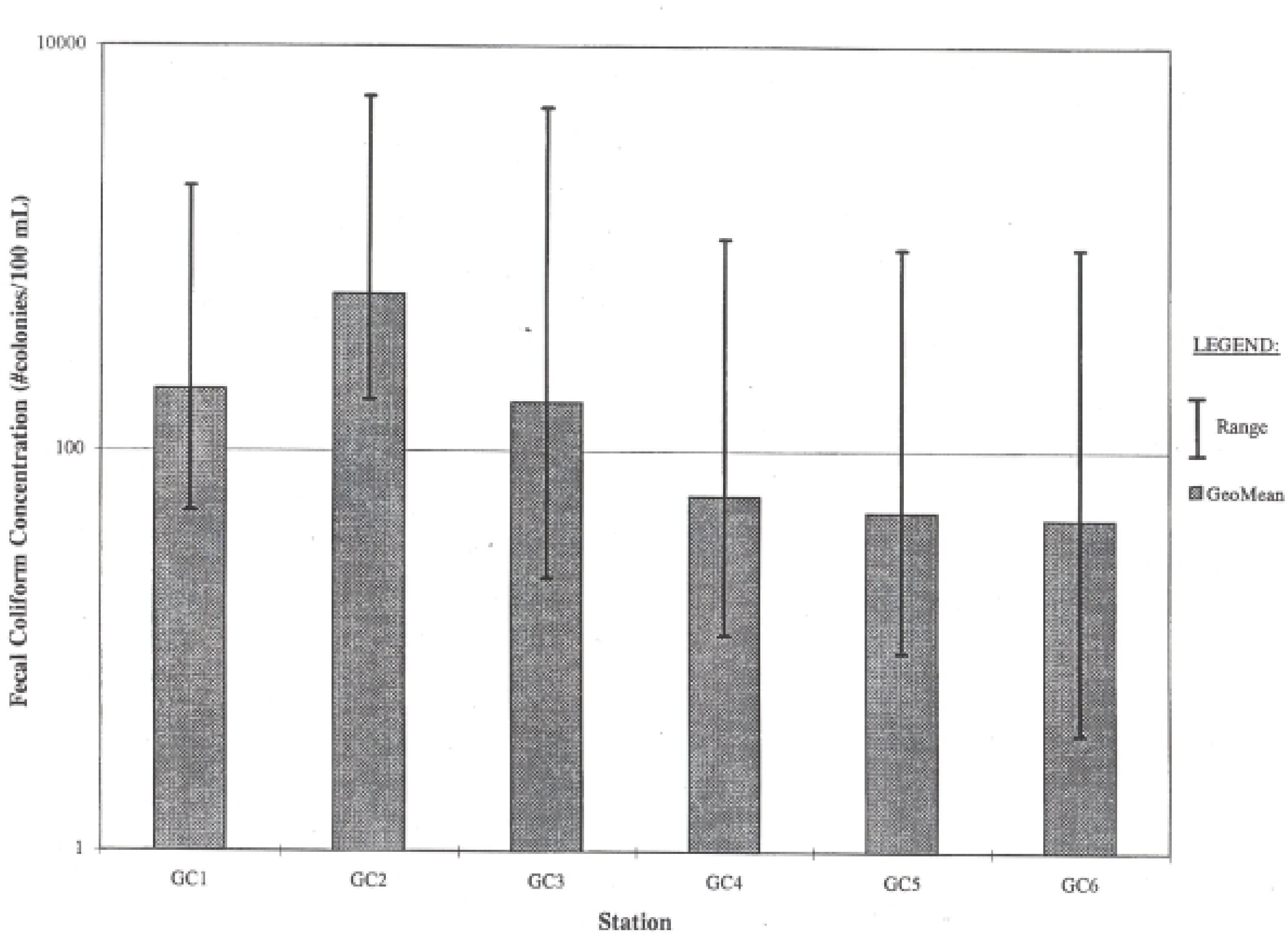


Figure 6. Fecal Coliform Geometric Mean Values Found at Each Study Site

TMDL Allocations

Load Allocations

A phased approach is recommended for the Gibbons Creek TMDL, as is appropriate for basins with largely nonpoint source contributions. With a phased approach, load allocations (LAs) are defined, control measures are implemented, and the basin continues to be monitored to assess the effectiveness of the nonpoint source controls. If water quality targets are not met, additional nonpoint management techniques need to be implemented.

The study results indicate two general problems:

(1) high FC levels throughout the basin in the late summer, and
(2) consistently high FC levels in Campen Creek.

The CWA specifies that TMDLs can be expressed in terms of either mass per time (i.e., load), toxicity, **or other appropriate measure** (emphasis added) (40 CFR 130.2(i)). It is recommended that a Load Allocation for FC be set for the mainstem Gibbons Creek at GC1 and Campen Creek at GC2 to meet the water quality criterion:

- The geometric mean of all samples at each site is not to exceed 100 colonies/100 mL, and
- No more than 10 percent of all samples may exceed 200 colonies/100 mL.

For purposes of calculating the percent reduction of FC concentrations needed at GC1, data collected from the ambient monitoring program were pooled with data collected during this study. The pooled data shows a significant seasonal pattern, with generally higher fecal coliform concentrations in the summer than the winter. The histogram in Figure 7 shows two distinctly different seasonal log-normal distributions of FC concentrations (Summer: April through October, and Winter: November through March). Although these seasons were selected based on fecal coliform concentrations, they are consistent with the streamflow pattern of Gibbons Creek, with relatively low average monthly streamflows in the summer months and high flows in the winter months.

Because of the seasonality of the data, percent reductions were calculated by season (Table 9). In the winter, essentially no reductions are necessary. In the summer, however, a 78 percent reduction in fecal coliform concentrations is needed to meet the TMDL load allocation.

In Campen Creek, the first part of the water quality criterion was violated throughout the study period and there was insufficient data for determining seasonality. Therefore the percent reduction needed, 83 percent, was based on surveys from all dates (Table 9).

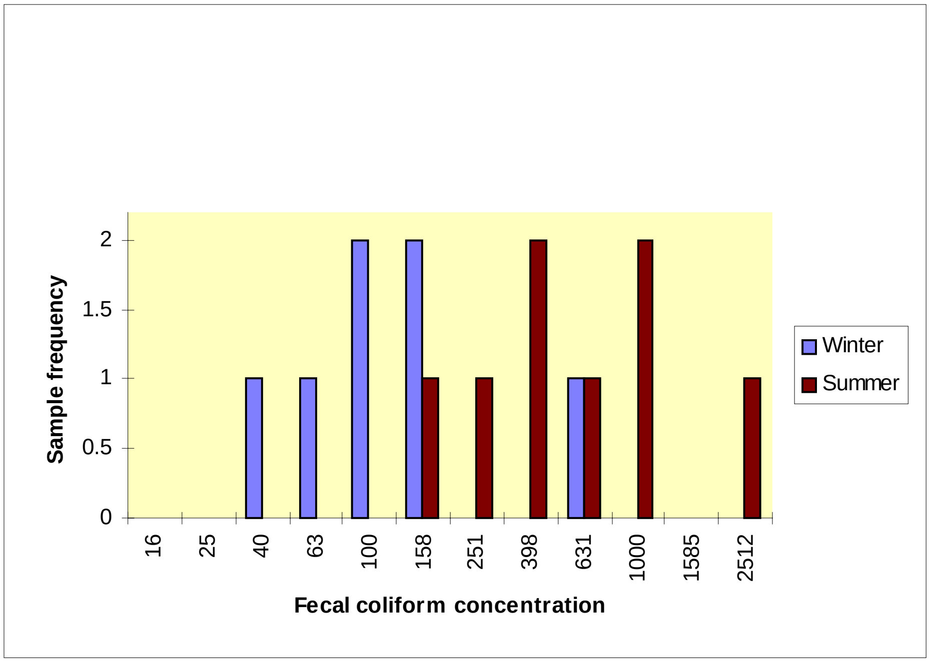


Figure 7. Comparison of Winter and Summer Fecal Coliform Distributions in Gibbons Creek at GC1

The LAs proposed are intended to bring the water quality of Gibbons Creek into compliance with FC standards. However, it is not certain whether the LAs would be protective enough to meet the second criterion of the FC standard, especially in winter. Use of a phased TMDL approach will allow reconsideration of water quality management goals after evaluating the effectiveness of the LAs.

Implementation

The LAs for FC described above may be achieved by source control and delivery reduction through farm plans, implementation of "best management practices" (BMPs) for agricultural and storm water control, and repair of failing septic systems. Initial priorities for the basin should focus on additional monitoring and source identification for summer and winter. Seasonal sources may be identified through land-use analysis, such as an inventory of farm animals, the types of animal waste systems utilized, and a survey of operating septic systems within the basin. Control measures could then target summer sources of FC throughout the basin, and winter sources in Campen Creek.

Table 9. Fecal Coliform Geometric Means and Recommended Percent Fecal Coliform Reductions for Gibbons Creek

Station ID	Geometric Mean (#colonies/100 mL)			Load Allocation (#colonies/100 mL)	Percent Reduction Needed		
	summer	winter	year-round		summer	winter	year-round
GC1	453	101	-	100	78	1	-
GC2	-	-	590	100	-	-	83

Effectiveness can vary for different agricultural BMPs applied to any given area depending on maintenance and on such site-specific variables as soil type, topography, precipitation characteristic, type of animal housing and waste storage facilities, method of waste collection and disposal, and seasonal variations. Table 10 shows literature values of effectiveness estimates for selected management practices to control bacterial losses from confined livestock (EPA, 1993). BMPs also have a variety of technical levels and costs that range from the simple, like fencing stream corridors from animal access, to the complex, like installing engineered waste retention basins (Coots, 1994). The Clark County Conservation District has the technical knowledge to do site evaluations and recommend implementation of known effective measures to meet LA goals.

Table 10. Estimated Effectiveness of Selected Best Management Practices (EPA, 1993)

Management Category	Management Practice	Fecal Coliform Reduction (%)
Confined livestock control measure	Animal waste system[a]	85
	Filter strips[b]	55
	Containment structures[c]	90

[a] = Includes methods for collecting, storing, and disposing of runoff and process-generated wastewater.
[b] = Includes all practices that reduce contaminant losses using vegetative control measures.
[c] = Includes such practices as waste storage ponds, waste storage structures, and waste treatment lagoons.

Although LAs for turbidity and TSS are not defined in this TMDL assessment, erosion and sediment control measures should be implemented, primarily, to prevent degradation of wildlife habitat and beneficial use of the watershed. Adverse impacts from eroded sediment associated with agricultural practices and construction activity may be reduced by implementing effective BMP strategies. Climate, topography, soils, drainage patterns, and vegetation will affect how erosion and sediment should be controlled for a particular source site. Table 11 shows literature values of effectiveness estimates for selected control strategies and management practices. The most desirable BMP strategy to implement initially are erosion controls which reduce the amount of sediment transported off-site, thereby reducing the need for sediment controls. When erosion controls are used in conjunction with sediment controls, the size of control structures and associated maintenance may be reduced, decreasing the overall treatment costs (EPA, 1993).

Performing regular inspections of septic systems to determine whether they are failing, and proper operation and maintenance of these systems to prevent them from failing may be the most cost-effective way of achieving pollutant reductions (EPA, 1993). Septic tanks, especially in Campen Creek upstream of station GC3, should be inspected to determine whether they are a significant source of FC.

Conclusions and Recommendations

Conclusions

Both parts of the water quality criterion for FC were exceeded in Campen Creek, (1) the geometric mean of all samples at each site is not to exceed 100 colonies/100mL, and (2) no more than 10 percent of all samples may exceed 200 colonies/100 mL. The second part was exceeded throughout the Gibbons Creek watershed. Study results indicate that the primary FC loading problem is occurring throughout the basin in summer and also in Campen Creek year-round. The water quality criteria for temperature and turbidity were likely violated in Campen Creek.

Potential nonpoint sources of FC identified within the study area include agricultural run-off from small farms and animal-keeping operations, and failing septic systems. Potential sources of nutrients include the FC sources and urban run-off from expanding residential development identified within the study area. Potential sources of turbidity and TSS include agricultural practices, construction activity, and suburban run-off.

Table 11. Estimated Effectiveness of Selected Best Management Practices (BMP) Erosion and Sediment Control

Source Type	BMP Strategy	Management Practice	Practice Example(s)	Sediment (% relative gross effectiveness)	Total Suspended Solids (Avg % removal)
Agricultural Practices	Sediment Control	Diversion systems[1]	grade stabilization structures	35	*
			sediment retention pond	35	60 - 70[c]
			water and sediment control basins	35	60 - 70[c]
			terraces	35 - 85[a]	55 - 70[b]
Construction Activity	Erosion Control	Structural control	perimeter controls	*	85
			mulching and seeding	65	90
		Non-structural control	minimizing the area of bare soil exposed at one time (phased grading)	35	85
			planning and designing the development within the natural constraints of the site	*	85
	Sediment Control	Structural control	sediment basin and traps	35	60 - 70[c]
			filter fabric, or silt fences	35	70
		Non-structural control	providing for stream crossing areas for natural and man-made areas	35	*
			stabilizing cut-and-fill slopes caused by construction activities	35	*

1 Includes all practices that reduce contaminant losses using vegetative control measures.

a Specifies relative gross effectiveness range for both diversion systems and terrace systems

b Specifies average observed range of % removal of TSS as reduction in erosion dependent on land slope:

Land Slope	Reduction in Erosion
1 - 12%	70%
12 - 18%	60%
18 - 24%	55%

No data found or not applicable

c Specifies average % removal of TSS with design constrains:
sediment trap = 60% average effectiveness removal with max. drainage area = 5 acres
sediment basin = 70% average effectiveness removal with min. drainage area = 5 acres, max. drainage area= 100 acres

Recommendations

A phased TMDL is recommended for the Gibbons Creek watershed. It is recommended that a LA for FC be set for the mainstem Gibbons Creek at GC1 and Campen Creek at GC2 to meet the water quality criterion:

- The geometric mean of all samples at each site is not to exceed 100 colonies/100 mL, and
- No more than 10 percent of all samples may exceed 200 colonies/100 mL.

Additional work is needed to identify the sources of elevated FC levels within the basin, including:

- an inventory of farm animals;
- an assessment of animal waste systems and identification of farms that are likely to be contributing excess levels of FC to Campen Creek, particularly between stations GC2 and GC3;
- a septic survey to identify failing septic tanks, especially in Campen Creek upstream of station GC3; and
- a land-use analysis of the entire basin to identify other potential sources of FC.

It is recommended that initial work be focused on summer problems, because FC concentrations were highest in the summer basin-wide, and this is the time of year that contact recreation is most likely to occur (e.g., children wading in the stream and irrigation applied to fields, lawns, and gardens).

It is unlikely that Gibbons Creek water is used for drinking water. However, two water rights exist for domestic use (above sampling sites 4 and 6). It should be verified that these water right holders are not using creek water for drinking water. The fecal coliform levels found in this study far exceed the Washington State Health Department criteria for drinking water (one to four organisms/100 mL, depending on frequency of sampling).

Monitoring is recommended in two areas:

- Monitoring of Campen Creek in summer and possibly winter to assist in identifying the sources of FC, and to monitor improvements in water quality as pollution controls are implemented, and
- Monitoring of the upper Gibbons Creek watershed in summer to better determine the source and extent of FC problems.

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Appendix A
Chapter 173-201A WAC

Class A (Excellent) Freshwater Quality Standards and Characteristic Uses

Appendix A. Class A (excellent) Freshwater Quality Standards and Characteristic Uses (WAC 173-201A)

General Characteristic: Shall meet or exceed the requirements for all or substantially all uses.

Characteristic Uses: Shall include, but not be limited to, the following: domestic, industrial, and agricultural water supply; stock watering; salmonid and other fish, clam, oyster, mussel, crustacean and other shellfish (crabs, shrimp, crayfish, scallops, etc.) rearing, spawning and harvesting; salmonid and other fish migration; wildlife habitat; primary contact recreation, sport fishing, boating, and aesthetic enjoyment; and commerce and navigation.

<u>**Water Quality Criteria**</u>

Fecal Coliform: Organism levels shall both not exceed a geometric mean value of 100 colonies/100 mL, and not have more than 10 percent of all samples obtained for calculating the geometric mean value exceeding 200 colonies/100 mL.

Dissolved oxygen: Shall exceed 8.0 mg/L.

Temperature: Shall not exceed 18.0 ^{o}C due to human activities. When natural conditions exceed 18.0 ^{o}C, no temperature increases will be allowed which will raise the receiving water temperature by greater than 0.3 ^{o}C. Incremental temperature increases resulting from nonpoint source activities shall not exceed 2.8 ^{o}C.

pH: Shall be within the range of 6.5 to 8.5 with a human-caused variation within a range of less than 0.5 units.

Ammonia: Ammonia criteria for chronic (4-day average) and acute (1-hour average) are dependent on pH and temperature.

Turbidity: Shall not exceed 5 NTU over background turbidity when the background turbidity is 50 NTU or less, or have more than a 10 percent increase in turbidity when the background turbidity is more than 50 NTU.

Toxic, radioactive, or deleterious material: Concentrations shall be below those which have the potential either singularly or cumulatively to adversely affect characteristic water uses, cause acute or chronic conditions to the most sensitive biota dependent upon those waters, or adversely affect public health, as determined by the department.

Aesthetic values: Shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste.

Appendix B

Water Quality Sampling Results
for Gibbons Creek Fecal Coliform TMDL Study

Appendix B. Gibbons Creek Fecal Coliform TMDL Study - Water Quality Sampling Results

Analytical Raw Data

Station ID	Date (m/d/yr)	Flow Time	Flow (CFS)	Sample Time	GENERAL CHEMISTRY PARAMETERS (units)													
					pH (std. units)	Cond. (umhos/cm)	Temp. (°C)	DO (mg/L)	FC (col./100 mL)		Turb. (NTU)	TSS (mg/L)	NH3 (mg/L)	NO3+NO2 (mg/L)	TPN (mg/L)	OP (mg/L)	TP (mg/L)	CL (mg/L)
GC1	9/8/94	13:00	3.5	12:11	7.5	74	14.0	10.00	2000	J	10	15	< 0.010	0.287	0.372	0.042	0.078	1.8
	9/8/94			12:11	7.5	73	14.2	9.85	2000	J	9.8	15	< 0.010	0.287	0.414	0.039	0.075	1.8
	11/9/94		35.3	12:15	7.7	55	9.1	11.05	79	X	7.0	4	< 0.010	1.38	1.26	0.011	0.027	2.1
	11/9/94			12:15				11.05	86	X	6.5	6	< 0.010	1.37	1.42	0.011	0.027	2.1
	1/17/95	11:40	58.1	11:00	6.8	39	7.2	12.00	52		9.4	12	< 0.010	1.20	1.23	< 0.010	< 0.010	1.9
	1/17/95			11:00	6.9	40	7.2	12.00	48		9.9	13	< 0.010	1.20	1.28	< 0.010	< 0.010	1.9
GC2	9/8/94	13:20	0.9	13:20	7.4	87	15.5	8.05	5200	J	18	16	0.047	0.423	0.918	0.053	0.130	2.0
	9/8/94								6100	J								
	11/9/94	13:00	8.3	13:15	7.3	60	9.1	10.60	230	X	7.0	4	< 0.010	1.27	1.36	0.015	0.043	2.5
	11/9/94								140	X, S								
	1/17/95	12:40	14.6	12:25	7.1	49	7.4	11.70	250		27	32	< 0.010	0.958	1.15	< 0.010	0.027	2.1
	1/17/95								170									
GC3	9/8/94	15:08	1.1	15:09	7.4	53	18.5	8.50	5300		400	222	0.045	0.243	0.610	0.061	0.506	1.4
	9/8/94								4600									
	11/9/94	15:10	5.5	15:15	7.4	56	9.9	10.95	71	X, S	7.2	12	< 0.010	1.42	1.41	0.013	0.046	2.4
	11/9/94								29	X								
	1/17/95	14:50	10.4	14:40	7.2	46	7.3	11.80	27		10	11	< 0.010	1.11	1.10	< 0.010	< 0.010	2.0
	1/17/95								20									

FC QUALIFIERS:

J = estimated value; X = high background count; S = spreader (motile) colonies on the plate

Appendix B. Gibbons Creek Fecal Coliform TMDL Study - Water Quality Sampling Results

Analytical Raw Data (con't)

Station ID	Date (m/d/yr)	Flow Time	Flow (CFS)	Sample Time	pH (std. units)	Cond. (umhos/cm)	Temp. (°C)	DO (mg/L)	FC (col./100 mL)		Turb. (NTU)	TSS (mg/L)	NH3 (mg/L)	NO3+NO2 (mg/L)	TPN (mg/L)	OP (mg/L)	TP (mg/L)	CL (mg/L)
					GENERAL CHEMISTRY PARAMETERS (units)													
GC4	9/8/94	13:40	1.2	14:00	7.6	65	13.7	9.95	1100		33	48	0.012	0.335	0.510	0.040	0.104	2.1
	9/8/94								1100									
	11/9/94	13:30	5.4	13:45	7.4	45	9.3	11.20	21		6.1	4	< 0.010	0.971	0.888	0.013	0.016	1.9
	11/9/94								7									
	1/17/95	13:10	10.0	13:00	7.4	37	7.1	11.95	25		8.5	7	< 0.010	0.840	0.858	< 0.010	< 0.010	1.7
	1/17/95								10									
GC5	9/8/94	14:18	0.7	14:20	7.6	71	13.8	9.85	960		18	26	< 0.010	0.317	0.468	0.048	0.107	2.0
	9/8/94	-							1000									
	11/9/94	14:00	6.1	14:15	7.5	44	9.3	11.00	7		6.4	6	< 0.010	1.49	1.51	0.012	0.028	1.9
	11/9/94								14									
	1/17/95	13:30	10.5	13:20	7.3	36	7.0	12.00	11		14	20	< 0.010	1.20	1.24	< 0.010	< 0.010	1.7
	1/17/95								14									
GC6	9/8/94	15:49	0.6	15:24	7.6	45	13.8	9.70	1100		9.1	13	< 0.010	0.376	0.511	0.017	0.045	1.9
	9/8/94								900									
	11/9/94		6.1	14:45	7.5	36	9.4	11.00	43		5.3	4	< 0.010	1.54	1.60	< 0.010	0.016	2.0
	11/9/94								14									
	1/17/95			14:10	7.3	30	7.3	11.75	3	S	13	12	< 0.010	1.46	1.62	< 0.010	< 0.010	1.6
	1/17/95								5									

FC QUALIFIERS:

J = estimated value; X = high background count; S = spreader (motile) colonies on the plate